TEST REPORT

DIN VDE V 0124-100

Test requirements for generation units to be connected and operated parallel with the low voltage distribution networks

Report reference number .....:	**PVDE200320N032**
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Testing laboratory name.....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
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Address .....:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China
Test specification	
Standard.....:	VDE AR-N 4105:2018-11 DIN VDE V 0124-100:2020-06
Test Report Form No.....:	DIN VDE V 0124-100 VER.2
TRF Originator.....:	Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Master TRF .....:	Dated 2020-08-06
Test item description .....:	**Hybrid Inverter**
Trademark .....:	SOFAR SOLAR
Model / Type.....:	HYD 3000-ES, HYD 3600-ES, HYD 4000-ES, HYD 4600-ES

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Ratings .....:	**HYD 4600-ES**	**HYD 4000-ES**	**HYD 3600-ES**	**HYD 3000-ES**
Input DC voltage [V] .....:	Max. 600Vd.c.			
MPP DC voltage range [V] .....:	90 – 580Vd.c.			
Input DC current [A].....:	Max. 2 x 12,0A			
Output AC voltage [V].....:	230Va.c., 50Hz			
Normal Output AC current [A] .....:	20,0	17,3	15,6	13,0
Max. Output AC current [A] .....:	Max.21,0	Max.18,2	Max.16,0	Max. 13,7
Initial short-current AC current I_{k}''[A].:	Max. 33,0A			
Normal Output power [VA] .....:	4600	4000	3680	3000
Output DC voltage range [V] .....: [Battery charge].....:	42-58Vdc			
Input DC current [A].....: [Battery charge].....:	Max.65A			
Output DC current [A].....: [Battery discharge].....:	Max. 70A			
Charge and discharge power[VA] ....:	Max. 3000			
Output AC voltage [V].....:	230Vac, 50Hz			
Output AC current [A] .....:	Max.13,2			
Output power [VA] .....:	3000			

Testing Location.....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address .....:	No. 96, Guantai Road (Houjie Section), Houjie Town, Dongguan City, Guangdong Province, 523942, People's Republic of China
Tested by (name, function and signature) .....:	Jack Shi
Approved by (name, function and signature) .....:	James Huang
Manufacturer's name .....:	**Shenzhen SOFARSOLAR Co., Ltd.**
Factory address.....:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China
Factory's name .....:	**Dongguan SOFAR SOLAR Co.,Ltd**
Factory address.....:	1F - 6F, Building E, No. 1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City

Document History			
Date	**Internal reference**	**Modification / Change / Status**	**Revision**
2020-10-30	Jack Shi	Initial report was written	0
Supplementary information:			

Test items particulars	
Equipment mobility ..... :	Permanent connection
Operating condition ..... :	Continuous
Class of equipment..... :	Class I
Protection against ingress of water .. :	IP65 according to EN 60529
Mass of equipment [kg] ..... :	Approx. 20,5kg
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 ..... :	2020-03-20
Date(s) of performance of test ..... :	2020-03-20 to 2020-09-14

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 VDE-AR-N 4105 / DIN VDE V 0124-100. This report must not be reproduced in part or in full without the written approval of the issuing testing laboratory.

”(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.

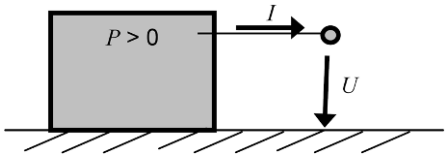
- “P_{rE}” for the rated active power:

  P_{rE} = Un x I_r x cos φn (single-Phase); P_{rE} = √ 3 Un x I_r x cos φn (three-Phase)
- “P_{ref}” for the momentary power
- “ΔP_{E60}” in [%] = ($P_{Setpoint}$ - P_{E60}) / P_{rE}
- “ΔQ_{E60}” in [%] = ($Q_{expected}$ - Q_{E60}) / P_{Emax}
- “(c)” for over-excited
- “(i)” for under-excited

Active and reactive power:

The regarded system of the voltage and current vectors is the load view (Figure 2):

- 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.

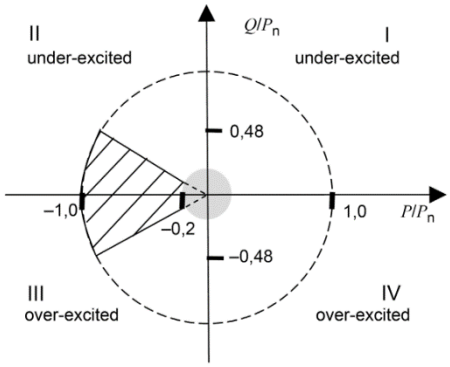


Figure 2

This Test Report consists of the following documents:

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End of Test Report.....197

Copy of marking plate

SOFAR SOLAR

Hybrid Inverter

Model No:	HYD 3000-ES
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	13.7A
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	3000VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25-+60°C
Protective Class	Class I

Manufacturer : Shenzhen SOFAR SOLAR Co.,Ltd.
Address : 401, Building 4, AnTongDa Industrial Park,
District 68, XingDong Community,XinAn Street,
BaoAn District, Shenzhen, China
SAA 183423
VDE0126-1-1,VDE-AR-N4105,G98,EN50438,
AS4777,UTE C15-712-1

SOFAR SOLAR

Hybrid Inverter

Model No:	HYD 3600-ES
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	16A
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	3680VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25-+60°C
Protective Class	Class I

Manufacturer : Shenzhen SOFAR SOLAR Co.,Ltd.
Address : 401 , Building 4, An TongDa Industrial Park,
District 68, Xing Dong Community,XinAn Street,
BaoAn District, Shenzhen , China
SAA 183423
VDE0126-1-1,VDE-AR-N4105,G98,EN50438,
AS4777,UTE C15-712-1

SOFAR SOLAR

Hybrid Inverter

Model No:	HYD4000-ES
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	18.2A
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	4000VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25-+60℃
Protective Class	Class I

Manufacturer : Shenzhen SOFAR SOLAR Co.,Ltd.
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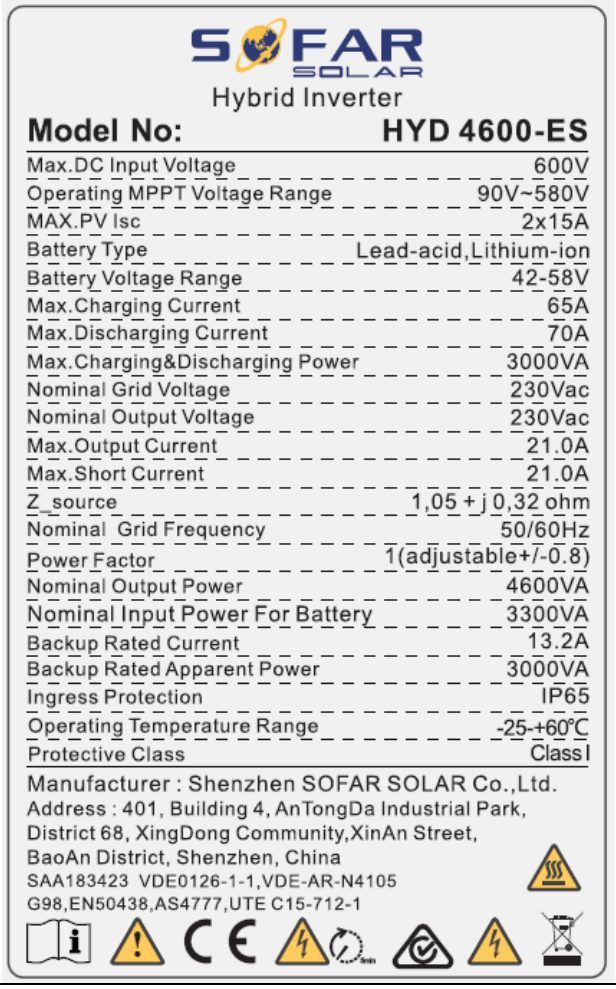
AS4777,UTE C15-712-1



SOFAR SOLAR

Hybrid Inverter

Model No:	HYD 4600-ES
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	21.0A
Max.Short Current	21.0A
Z_source	1,05 + j 0,32 ohm
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	4600VA
Nominal Input Power For Battery	3300VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25-+60℃
Protective Class	ClassI

Manufacturer : Shenzhen SOFAR SOLAR Co.,Ltd.
Address : 401, Building 4, AnTongDa Industrial Park,
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SAA183423 VDE0126-1-1,VDE-AR-N4105
G98,EN50438,AS4777,UTE C15-712-1

General product information:

HYD 3000/3600/4000/4600/5000/6000-ES

User Manual

2018-10-13

Version V1.1

8. Technical Data

Model	HYD 3000-ES	HYD 3600-ES	HYD 4000-ES	*HYD 4600-ES	HYD 5000-ES	HYD 6000-ES
Battery Parameters						
Battery Type	Lead-acid, Lithium-ion					
Nominal battery voltage	48V					
Battery voltage range	42 - 58V					
Min discharge voltage	Lithium:(according to BMS), General 46.0V					
	Lead acid: 44.0V					
Max charge voltage	Lithium-ion:(according to BMS), Max 58V					
	Lead acid: 58V					
Battery capacity	50-2000Ah					
Recommended storage capacity	9.6 kWh					
Max charge current	65A					
Charge current range	0 - 65A programmable					
Charge curve	3 - stage adaptive with maintenance					
Max discharge current	70A programmable					
Battery protection	Over voltage protection / Over current protection / Over temperature protection					
Depth of discharge	Lithium: 0 - 90% DOD adjustable					
	Lead acid: 0 - 50% DOD adjustable					
PV parameters						
Recommended Max.PV input power	3990Wp	4790Wp	5320Wp	6120Wp	6650Wp	7980Wp
Max DC input power	3500W	4000W	4400W	5000W	5500W	6600W
Max DC power for single MPPT	2000W (160-520V)	2400W (180-520V)	2600W (200-520V)	2800W (230-520V)	3000W (250-520V)	3500W (300-520V)
The max DC input voltage	600V					

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Start-up DC voltage	120V					
Nominal DC Voltage	360V					
MPPT operating voltage range	90-580V					
Full load DC voltage range	160-520V	180-520V	200-520V	230-520V	250-520V	300-520V
MPPT number	2					
The max DC input current	12A/12A					
The max DC input short current	15A/15A					
AC parameters						
Max output power	3000W	3680W	4000W	4600W	5000W	6000W
Max output current	13.7A	16A	18.2A	21.0A	22.8A	27.3A
Nominal grid voltage & frequency	220V，230V，240V， 44 - 55Hz or 54 - 66Hz					
AC voltage range	180 - 276V (according to local authority requirements)					
THD	<3%					
Power factor	1default (+ / - 0.8 adjustable)					
Inrush current	0.8A / 1us					
Max output fault current	100A / 1us					
System parameters						
Max efficiency	Charge: 94.6% / discharge 94.6%					
Standby losses	< 10W (PV SPS)					
Topology	High frequency isolation(for bat)					
Ingress protection ratings	IP 65					
Safety protection	Anti-islanding, RCMU, ground fault monitoring					
Communication	Wi-Fi/GPRS/Ethernet(optional), RS485, SD,CAN2.0					
Certification	EN 61000-6-2, EN 61000-6-3, EN 61000-3-2, EN 61000-3-3, EN 61000-3-11, EN 61000-3-12 IEC62109-1/2, IEC62040-1, IEC62116, IEC61727, IEC-61683,					

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	IEC60068(1,2,14,30) AS/NZS 4777, VDE V 0124-100, V 0126-1-1, VDE-AR-N 4105, CEI 0-21, EN50438/EN50549, G83/G59/G98/G99, UTE C15-712-1, UNE 206 007-1
Environmental data	
Ambient temperature range	-25℃ to +60℃(Derating above +45℃)
Relative humidity range	0% - 100% (no condensing)
Protective class	Class I
Max operating altitude	2000m
Current transformer connection	Hard wired
General data	
Noise	<25dB
Weight	20.5kg
Cooling	Natural convection
Dimensions (W*H*D)	566 x 394 x 173 mm
Display	LCD display
Warranty	5 years or more
EPS (Emergency Power Supply) data	
EPS rated power	3000VA
EPS nominal voltage/frequency	230V, 50/60Hz
EPS rated current	13.2A
THD	<3%
Switch time	10mS default

The models marked with " * " should be available only for some designated countries.

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Block diagram of the utility interactive inverter:

The Hybrid inverter converts DC voltage into AC voltage.
The Hybrid inverter converts provide input by photovoltaic modules and batteries.
The Hybrid inverter is a single-phase type and only one machine is allowed on each line conductor.
The Hybrid inverter no provided the functional of clause 5.7 $P_{AV,E}$-Control and shall be testing and evaluated in end system If it's necessary.
The input and output are protected by varistors to Earth. The unit is providing EMC filtering at the PV input and output toward mains. The unit does not provide galvanic separation from input to output (transformerless). The output is switched off redundantly by the high power switching bridge and two relays. This assures that the opening of the output circuit will also operate in case of a single error.

The internal control is redundant built. It consists of Microcontroller Main DSP (U4) and slave DSP (U22).
The Main DSP (U4) 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 slave DSP (U22) is measures the grid voltage, grid frequency and residual current, also can switch off the relays independently, and communicate with Main DSP (U4) each other.
The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the Main DSP(U4). The Main DSP(U4) 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.

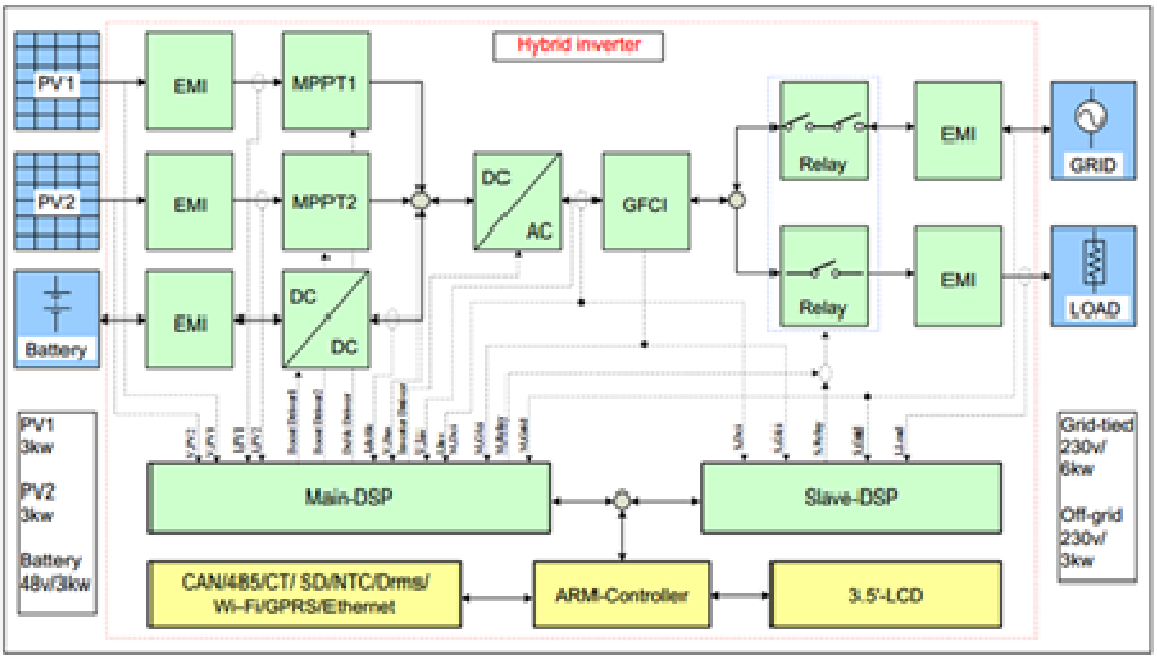


Figure 1 – Block diagram

Differences of the models in the series:

The models HYD 3000-ES, HYD 3600-ES, HYD 4000-ES and HYD 5000-ES are completely identical hardware and software and output power derated by software, except for the following table.

	HYD 4600-ES	HYD 4000-ES	HYD 3600-ES	HYD 3000-ES
(R332,R334,R336)	(0Ω, NC, 0Ω)	(NC, 0Ω, NC)		
Bus capcitance	8 pcs	6pcs		
INV inductor	0,75mH	1,035mH		
R190	30kΩ	40,2kΩ		
(R123,R132)	(1,5kΩ, 1,5kΩ)	(499Ω, 499Ω)		

The product was tested on:

Hardware version: V1.0

Software version: V2.00

All tests were performed on EUT of HYD 4600-ES. Tests of the EUT of HYD 4600-ES applicable for the models HYD 3000-ES, HYD 3600-ES and HYD 4000-ES were performed on the concerned models and a statement is given at the relevant test.

Description of the remote control in a typical installation:
N/A
Description of the connection to the ripple control receiver:
N/A

Test Results

DIN VDE V 0124-100			
Clause	**Requirement – Test**	**Result – Remark**	**Verdict**
5.2	Evidence of permissible network perturbations		**P**
5.3	Evidence of symmetry behaviour of inverters		**N/A**
5.4	Evidence of the behaviour of the generating unit on the network		**P**
5.5	NS-protection		**P**
5.6	Connecting conditions and synchronization		**P**
5.7	Evidence of $P_{AV,E}$-Control		**N/A**
5.8	Evidence dynamic grid support		**P**
5.9	Test of Ancillary Unit		**N/A**

DIN VDE V 0124-100			
Clause	**Requirement – Test**	**Result – Remark**	**Verdict**
5.2	**Evidence of permissible network perturbations**		
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 a)	Test Harmonics DIN EN 61000-3-2 (≤16 A per Phase)		**P**
5.2.4.1 a)	Test Harmonics DIN EN 61000-3-12 (≥16 A and ≤75 A per Phase)		**P**
5.2.4.1 b)	Test Harmonics and interharmonics DIN EN 61000-4-7 (≥75 A per Phase)		**P**
5.2.5	Commutation		**N/A**
5.2.6	Feed in of DC current		**P**

5.2.1	General	P

The electrical installations of the customer system shall be planned, constructed and operated so that reactions to the network operator's network and to the systems of other customers are permanently reduced to a permissible minimum. Should interfering reactions on the network operator's network occur nonetheless, the customer shall apply measures to his system that are to be coordinated with the network operator. The network operator is entitled to disconnect the power generation system concerned from the network until the deficiencies are corrected.

System perturbations are defined as:

- Rapid voltage changes

- Flicker

- Harmonics, interharmonics and higher frequencies (up to 9 kHz)

5.2.2	Rapid voltage changes	P

The purpose of the test is to determine k_i and k_{imax}.

The following three cases must be tested (where applicable).

- Switch-on for any capacity
- Unfavourable case when switching the generator step
- Switch-on for nominal capacity

Note: For PV-plants the inverter is the generator

- Switch-off for nominal capacity (no emergency shutdown, but operative shutdown)

If the manufacturer knows more critical cases (e.g. different cos φ parameters) then these additional have to be tested

Test conditions:

Frequency: 50 Hz ± 0,5%

THD of the voltage supply: ≤ 3 %

Voltage rise of the PGU at 100 P_{Emax} %: ≤ 3 %

HYD 4600-ES

Switch-on for any capacity (10% PEmax)

Phase	L1			L2			L3		
Single period effective values of the current [A]	0,599	0,535	0,597	/	/	/	/	/	/
Single period effective values of the voltage [V]	230,12	230,21	230,23	/	/	/	/	/	/
k_i value [1]	0,030	0,028	0,030	/	/	/	/	/	/
k_{imax} value [1]	0,030								

Unfavourable case when switching the generator step (not necessary for electronic inverter)

Phase	L1			L2			L3		
Single period effective values of the current [A]	/	/	/	/	/	/	/	/	/
Single period effective values of the voltage [V]	/	/	/	/	/	/	/	/	/
k_i value [1]	/	/	/	/	/	/	/	/	/
k_{imax} value [1]	/								

Switch-on for nominal capacity

Phase	L1			L2			L3		
Single period effective values of the current [A]	0,620	0,578	0,575	/	/	/	/	/	/
Single period effective values of the voltage [V]	230,25	230,18	230,27	/	/	/	/	/	/
k_i value [1]	0,031	0,029	0,020	/	/	/	/	/	/
k_{imax} value [1]	0,031								

5.2.2	Rapid voltage changes								P
Switch-off for nominal capacity									
Phase	**L1**			**L2**			**L3**		
Single period effective values of the current [A]	11,171	10,110	12,216	/	/	/	/	/	/
Single period effective values of the voltage [V]	230,55	230,39	230,44	/	/	/	/	/	/
k_i value [1]	0,559	0,506	0,611	/	/	/	/	/	/
k_{imax} value [1]	0,611								

Grid Frequency [Hz]	50,0
Grid voltage [V]	230,0
Rated current I_r [A]	20,0
Highest k_{imax} value for all switching operations [1]	1

Note:

Limits:

k_{imax} = 1,2 for synchronous generators with fine synchronization, converter; (electronic inverter)

k_{imax} = 4 for asynchronous generators, which are switched on at 95% to 105% of their synchronous speed, if no further details are available regarding the type of current limitation. With regard to short-term compensation processes, the condition mentioned below for very short voltage changes must also be observed.

k_{imax} = 8 for asynchronous generators that are powered up by the network if I_a is unknown.

(I_a = starting current)

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

5.2.3	**Flicker** 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 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)

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 to DIN EN 61000-3-3 (VDE 0838-3) or DIN EN 61000-3-11 (VDE 0838-11) for generator units ≤ 75 A

Grid impedance DIN EN 61000-3-3 (VDE 0838-3) [Ω]:	R_A = 0,24Ω jX_A = 0,15Ω / R_N = 0,16Ω jX_N = 0,10Ω (Rn and jXn only for single-phase units used!)
Grid impedance DIN EN 61000-3-11 (VDE 0838-11) [Ω]:	R_A = 0,15Ω jX_A= 0,15Ω / R_N = 0,01Ω jX_N= 0,01Ω (Rn and jXn only for single-phase units used!)
Output voltage of the impedance network [V]	230Vac

Flicker to:	Result:		
	P_{lt}	P_{st}	dc%
DIN EN 61000-3-3/-11(HYD 3000-ES)	0,07	0,07	0,07
DIN EN 61000-3-3/-11(HYD 3600-ES)	0,07	0,07	0,11
DIN EN 61000-3-3/-11(HYD 4000-ES)	0,07	0,07	0,12
DIN EN 61000-3-3/-11(HYD 4600-ES)	0,07	0,09	0,44

Assessment criterion:

Long-term flicker strength Plt to DIN EN 61000-3-3 (VDE 0838-3) or DIN EN 61000-3-11 must be ≤ 0,5.

Determination of the flicker coefficient:

$$c_{\psi k} = P_{st} \times (S_k / P_n)$$

where S_k is the short-circuit power of the network standby element (during the determination of the appropriate P_{st} values)

The value for the network standby element must be determined separately with measurements for rated currents > 75 A.

Flicker for rated currents ≤75A to DIN EN 61000-3-3 (VDE 0838-3) / DIN EN 61000-3-11 (VDE 0838-11)

Grid impedance angle ψ_k	32° / 45°
Flicker coefficient c(ψ_k) (HYD 3000-ES)	3,634
Flicker coefficient c(ψ_k) (HYD 3600-ES)	3,634
Flicker coefficient c(ψ_k) (HYD 4000-ES)	3,634
Flicker coefficient c(ψ_k) (HYD 4600-ES)	4,673

Assessment criterion:

Long-term flicker strength: P_{lt}≤0,5

5.2.3	**Flicker** 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 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)		
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 %		

5.2.4.1 a)	Test Harmonics DIN EN 61000-3-2 (≤16 A per Phase)	P

HYD 3000-ES

Phase	L1	L2	L3
Power Level	100%	100%	100%
AC Power [kW]	3,038	N/A	N/A
AC Voltage [V]	231,36	N/A	N/A
AC Current [A]	13,137	N/A	N/A
Frequency [Hz]	50,00	N/A	N/A
THD [%]	0,832	N/A	N/A

Harmonic	Current Magnitude (A)	% of Funda-mental	Current Magnitude (A)	% of Funda-mental	Current Magnitude (A)	% of Funda-mental	Harmonic Current Limits (A)
1st	13,137	100,720	N/A	N/A	N/A	N/A	--
2nd	0,010	0,075	N/A	N/A	N/A	N/A	1,080
3rd	0,095	0,725	N/A	N/A	N/A	N/A	2,300
4th	0,002	0,014	N/A	N/A	N/A	N/A	0,430
5th	0,035	0,269	N/A	N/A	N/A	N/A	1,140
6th	0,002	0,015	N/A	N/A	N/A	N/A	0,300
7th	0,016	0,121	N/A	N/A	N/A	N/A	0,770
8th	0,002	0,014	N/A	N/A	N/A	N/A	0,263
9th	0,007	0,057	N/A	N/A	N/A	N/A	0,400
10th	0,002	0,014	N/A	N/A	N/A	N/A	0,184
11th	0,002	0,018	N/A	N/A	N/A	N/A	0,330
12th	0,002	0,013	N/A	N/A	N/A	N/A	0,153
13th	0,003	0,023	N/A	N/A	N/A	N/A	0,210
14th	0,002	0,013	N/A	N/A	N/A	N/A	0,131
15th	0,004	0,034	N/A	N/A	N/A	N/A	0,150
16th	0,002	0,012	N/A	N/A	N/A	N/A	0,115
17th	0,006	0,050	N/A	N/A	N/A	N/A	0,132
18th	0,001	0,011	N/A	N/A	N/A	N/A	0,102
19th	0,007	0,052	N/A	N/A	N/A	N/A	0,188
20th	0,001	0,010	N/A	N/A	N/A	N/A	0,092
21th	0,008	0,063	N/A	N/A	N/A	N/A	0,107
22th	0,001	0,010	N/A	N/A	N/A	N/A	0,084
23th	0,009	0,067	N/A	N/A	N/A	N/A	0,098
24th	0,001	0,010	N/A	N/A	N/A	N/A	0,077
25th	0,008	0,064	N/A	N/A	N/A	N/A	0,090
26th	0,001	0,010	N/A	N/A	N/A	N/A	0,071
27th	0,009	0,068	N/A	N/A	N/A	N/A	0,080

5.2.4.1 a)	Test Harmonics DIN EN 61000-3-2 (≤16 A per Phase)						P
HYD 3000-ES							
28th	0,001	0,010	N/A	N/A	N/A	N/A	0,066
29th	0,008	0,065	N/A	N/A	N/A	N/A	0,078
30th	0,001	0,009	N/A	N/A	N/A	N/A	0,061
31th	0,008	0,064	N/A	N/A	N/A	N/A	0,073
32th	0,001	0,009	N/A	N/A	N/A	N/A	0,057
33th	0,009	0,068	N/A	N/A	N/A	N/A	0,068
34th	0,001	0,008	N/A	N/A	N/A	N/A	0,054
35th	0,008	0,064	N/A	N/A	N/A	N/A	0,064
36th	0,001	0,010	N/A	N/A	N/A	N/A	0,051
37th	0,008	0,064	N/A	N/A	N/A	N/A	0,061
38th	0,001	0,008	N/A	N/A	N/A	N/A	0,048
39th	0,008	0,063	N/A	N/A	N/A	N/A	0,058
40th	0,001	0,009	N/A	N/A	N/A	N/A	0,046
41th	0,008	0,058	N/A	N/A	N/A	N/A	N/A
42th	0,001	0,010	N/A	N/A	N/A	N/A	N/A
43th	0,008	0,061	N/A	N/A	N/A	N/A	N/A
44th	0,002	0,013	N/A	N/A	N/A	N/A	N/A
45th	0,008	0,058	N/A	N/A	N/A	N/A	N/A
46th	0,005	0,040	N/A	N/A	N/A	N/A	N/A
47th	0,007	0,052	N/A	N/A	N/A	N/A	N/A
48th	0,005	0,039	N/A	N/A	N/A	N/A	N/A
49th	0,007	0,051	N/A	N/A	N/A	N/A	N/A
50th	0,004	0,029	N/A	N/A	N/A	N/A	N/A

PV-curve simulated according to	/
Voltage of defined MPP [V]	380
Current of defined MPP [A]	8,050
FFU of PV curve [1]	1
Impedance [Ω]	
Line	R_A = 0,24 jX_A = 0,15
Neutral	R_N = 0,16 jX_N = 0,10
Note:	

HYD 3600-ES							
Phase	**L1**		**L2**		**L3**		
Power Level	**100%**		**100%**		**100%**		
AC Power [kW]	3,696		N/A		N/A		
AC Voltage [V]	231,36		N/A		N/A		
AC Current [A]	15,976		N/A		N/A		
Frequency [Hz]	50,00		N/A		N/A		
THD [%]	0,827		N/A		N/A		
Harmonic	**Current Magnitude (A)**	**% of Funda-mental**	**Current Magnitude (A)**	**% of Funda-mental**	**Current Magnitude (A)**	**% of Funda-mental**	**Harmonic Current Limits (A)**
1st	15,976	--	N/A	N/A	N/A	N/A	--
2nd	0,010	0,063	N/A	N/A	N/A	N/A	1,080
3rd	0,115	0,720	N/A	N/A	N/A	N/A	2,300
4th	0,002	0,013	N/A	N/A	N/A	N/A	0,430
5th	0,043	0,269	N/A	N/A	N/A	N/A	1,140
6th	0,002	0,013	N/A	N/A	N/A	N/A	0,300
7th	0,019	0,119	N/A	N/A	N/A	N/A	0,770
8th	0,002	0,013	N/A	N/A	N/A	N/A	0,263
9th	0,009	0,056	N/A	N/A	N/A	N/A	0,400
10th	0,002	0,013	N/A	N/A	N/A	N/A	0,184
11th	0,003	0,019	N/A	N/A	N/A	N/A	0,330
12th	0,002	0,013	N/A	N/A	N/A	N/A	0,153
13th	0,004	0,025	N/A	N/A	N/A	N/A	0,210
14th	0,002	0,013	N/A	N/A	N/A	N/A	0,131
15th	0,006	0,038	N/A	N/A	N/A	N/A	0,150
16th	0,002	0,013	N/A	N/A	N/A	N/A	0,115
17th	0,008	0,050	N/A	N/A	N/A	N/A	0,132
18th	0,002	0,013	N/A	N/A	N/A	N/A	0,102
19th	0,009	0,056	N/A	N/A	N/A	N/A	0,188
20th	0,002	0,013	N/A	N/A	N/A	N/A	0,092
21th	0,010	0,063	N/A	N/A	N/A	N/A	0,107
22th	0,002	0,013	N/A	N/A	N/A	N/A	0,084
23th	0,011	0,069	N/A	N/A	N/A	N/A	0,098
24th	0,002	0,013	N/A	N/A	N/A	N/A	0,077
25th	0,010	0,063	N/A	N/A	N/A	N/A	0,090
26th	0,002	0,013	N/A	N/A	N/A	N/A	0,071
27th	0,011	0,069	N/A	N/A	N/A	N/A	0,080
28th	0,002	0,013	N/A	N/A	N/A	N/A	0,066

HYD 3600-ES							
29th	0,010	0,063	N/A	N/A	N/A	N/A	0,078
30th	0,001	0,006	N/A	N/A	N/A	N/A	0,061
31th	0,010	0,063	N/A	N/A	N/A	N/A	0,073
32th	0,001	0,006	N/A	N/A	N/A	N/A	0,057
33th	0,011	0,069	N/A	N/A	N/A	N/A	0,068
34th	0,001	0,006	N/A	N/A	N/A	N/A	0,054
35th	0,010	0,063	N/A	N/A	N/A	N/A	0,064
36th	0,001	0,006	N/A	N/A	N/A	N/A	0,051
37th	0,010	0,063	N/A	N/A	N/A	N/A	0,061
38th	0,001	0,006	N/A	N/A	N/A	N/A	0,048
39th	0,010	0,063	N/A	N/A	N/A	N/A	0,058
40th	0,001	0,006	N/A	N/A	N/A	N/A	0,046
41th	0,009	0,056	N/A	N/A	N/A	N/A	N/A
42th	0,002	0,013	N/A	N/A	N/A	N/A	N/A
43th	0,010	0,063	N/A	N/A	N/A	N/A	N/A
44th	0,002	0,013	N/A	N/A	N/A	N/A	N/A
45th	0,009	0,056	N/A	N/A	N/A	N/A	N/A
46th	0,006	0,038	N/A	N/A	N/A	N/A	N/A
47th	0,008	0,050	N/A	N/A	N/A	N/A	N/A
48th	0,006	0,038	N/A	N/A	N/A	N/A	N/A
49th	0,008	0,050	N/A	N/A	N/A	N/A	N/A
50th	0,005	0,031	N/A	N/A	N/A	N/A	N/A

PV-curve simulated according to	/
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	9,737
FFU of PV curve [1]	1
Impedance [Ω]	
Line	R_A = 0,24 jX_A = 0,15
Neutral	R_N = 0,16 jX_N = 0,10
Note:	

5.2.4.1 a)	Test Harmonics DIN EN 61000-3-12 (≥16 A and ≤75 A per Phase)	P

HYD 4600-ES

Phase 1

Power Level	33%	66%	100%
AC Power [kW]	1,529	3,054	4,594
AC Voltage [V]	230,49	230,37	231,60
AC Current [A]	6,771	13,175	19,907
Frequency [Hz]	50,00		
THD [%]	2,162	1,618	0,820
PWHD	3,033	2,880	1,509

Harmonic	Current Magnitude (A)	% of Funda-mental	Current Magnitude (A)	% of Funda-mental	Current Magnitude (A)	% of Funda-mental	Harmonic Current Limits (%)
1st	6,737	--	13,338	--	20,149	--	-
2nd	0,008	0,119	0,017	0,127	0,011	0,055	8,00
3rd	0,122	1,811	0,162	1,215	0,144	0,715	N/A
4th	0,008	0,119	0,012	0,090	0,003	0,015	4,00
5th	0,046	0,683	0,074	0,555	0,054	0,268	10,70
6th	0,004	0,059	0,006	0,045	0,002	0,010	2,67
7th	0,027	0,401	0,028	0,210	0,023	0,114	7,20
8th	0,004	0,059	0,005	0,037	0,002	0,010	2,00
9th	0,026	0,386	0,037	0,277	0,011	0,055	N/A
10th	0,004	0,059	0,005	0,037	0,003	0,015	1,60
11th	0,023	0,341	0,050	0,375	0,003	0,015	3,10
12th	0,005	0,074	0,005	0,037	0,002	0,010	1,33
13th	0,017	0,252	0,045	0,337	0,005	0,025	2,00
14th	0,004	0,059	0,004	0,030	0,002	0,010	N/A
15th	0,017	0,252	0,046	0,345	0,008	0,040	N/A
16th	0,003	0,045	0,005	0,037	0,002	0,010	N/A
17th	0,015	0,223	0,042	0,315	0,011	0,055	N/A
18th	0,005	0,074	0,004	0,030	0,002	0,010	N/A
19th	0,016	0,237	0,034	0,255	0,011	0,055	N/A
20th	0,003	0,045	0,003	0,022	0,002	0,010	N/A
21th	0,013	0,193	0,030	0,225	0,013	0,065	N/A
22th	0,003	0,045	0,005	0,037	0,002	0,010	N/A
23th	0,011	0,163	0,026	0,195	0,014	0,069	N/A
24th	0,004	0,059	0,002	0,015	0,002	0,010	N/A
25th	0,013	0,193	0,018	0,135	0,013	0,065	N/A
26th	0,003	0,045	0,003	0,022	0,002	0,010	N/A

5.2.4.1 a)	Test Harmonics DIN EN 61000-3-12 (≥16 A and ≤75 A per Phase)						P
HYD 4600-ES							
27th	0,009	0,134	0,012	0,090	0,013	0,065	N/A
28th	0,003	0,045	0,004	0,030	0,002	0,010	N/A
29th	0,007	0,104	0,012	0,090	0,013	0,065	N/A
30th	0,002	0,030	0,005	0,037	0,002	0,010	N/A
31th	0,006	0,089	0,008	0,060	0,013	0,065	N/A
32th	0,003	0,045	0,002	0,015	0,002	0,010	N/A
33th	0,008	0,119	0,005	0,037	0,013	0,065	N/A
34th	0,002	0,030	0,002	0,015	0,002	0,010	N/A
35th	0,006	0,089	0,004	0,030	0,013	0,065	N/A
36th	0,001	0,015	0,001	0,007	0,002	0,010	N/A
37th	0,006	0,089	0,005	0,037	0,013	0,065	N/A
38th	0,001	0,015	0,002	0,015	0,001	0,005	N/A
39th	0,005	0,074	0,005	0,037	0,013	0,065	N/A
40th	0,001	0,015	0,001	0,007	0,002	0,010	N/A
41th	0,006	0,089	0,004	0,030	0,011	0,055	N/A
42th	0,001	0,015	0,002	0,015	0,002	0,010	N/A
43th	0,004	0,059	0,005	0,037	0,012	0,060	N/A
44th	0,001	0,015	0,001	0,007	0,002	0,010	N/A
45th	0,005	0,074	0,004	0,030	0,011	0,055	N/A
46th	0,001	0,015	0,001	0,007	0,008	0,040	N/A
47th	0,004	0,059	0,004	0,030	0,010	0,050	N/A
48th	0,001	0,015	0,001	0,007	0,008	0,040	N/A
49th	0,004	0,059	0,004	0,030	0,010	0,050	N/A
50th	0,001	0,015	0,001	0,007	0,006	0,030	N/A

PV-curve simulated according to	
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	12,368A
FFU of PV curve [1]	1
Impedance [Ω]	
Line	R_A = 0,15 jX_A= 0,15
Neutral	R_N = 0,01 jX_N= 0,01
Note:	

5.2.4.1 a)	Test Harmonics DIN EN 61000-3-12 (≥16 A and ≤75 A per Phase)						P
HYD 4000-ES							
Phase 1							
Power Level	**33%**		**66%**		**100%**		
AC Power [W]	1,320		2,677		4,037		
AC Voltage [V]	230,57		231,21		231,36		
AC Current [A]	5,747		11,584		17,454		
Frequency [Hz]	50,00						
THD [%]	2,442		1,682		0,828		
PWHD	3,106		2,851		1,510		
Harmonic	**Current Magnitude (A)**	**% of Funda-mental**	**Current Magnitude (A)**	**% of Funda-mental**	**Current Magnitude (A)**	**% of Funda-mental**	**Harmonic Current Limits (%)**
1st	5,686	--	11,494	--	17,496	--	-
2nd	0,008	0,141	0,013	0,113	0,013	0,074	8,00
3rd	0,117	2,058	0,148	1,288	0,126	0,720	N/A
4th	0,007	0,123	0,010	0,087	0,002	0,011	4,00
5th	0,048	0,844	0,064	0,557	0,047	0,269	10,70
6th	0,004	0,070	0,006	0,052	0,003	0,017	2,67
7th	0,030	0,528	0,024	0,209	0,021	0,120	7,20
8th	0,004	0,070	0,004	0,035	0,002	0,011	2,00
9th	0,024	0,422	0,035	0,305	0,010	0,057	N/A
10th	0,004	0,070	0,005	0,044	0,002	0,011	1,60
11th	0,018	0,317	0,045	0,392	0,003	0,017	3,10
12th	0,005	0,088	0,005	0,044	0,002	0,011	1,33
13th	0,011	0,193	0,041	0,357	0,004	0,023	2,00
14th	0,004	0,070	0,005	0,044	0,002	0,011	N/A
15th	0,011	0,193	0,038	0,331	0,006	0,034	N/A
16th	0,003	0,053	0,006	0,052	0,002	0,011	N/A
17th	0,010	0,176	0,035	0,305	0,009	0,051	N/A
18th	0,004	0,070	0,004	0,035	0,002	0,011	N/A
19th	0,010	0,176	0,030	0,261	0,009	0,051	N/A
20th	0,004	0,070	0,003	0,026	0,002	0,011	N/A
21th	0,009	0,158	0,025	0,218	0,011	0,063	N/A
22th	0,002	0,035	0,005	0,044	0,002	0,011	N/A
23th	0,007	0,123	0,022	0,191	0,012	0,069	N/A
24th	0,004	0,070	0,003	0,026	0,002	0,011	N/A
25th	0,011	0,193	0,017	0,148	0,011	0,063	N/A
26th	0,003	0,053	0,004	0,035	0,002	0,011	N/A

5.2.4.1 a)	Test Harmonics DIN EN 61000-3-12 (≥16 A and ≤75 A per Phase)						P
HYD 4000-ES							
27th	0,008	0,141	0,011	0,096	0,012	0,069	N/A
28th	0,003	0,053	0,002	0,017	0,002	0,011	N/A
29th	0,008	0,141	0,008	0,070	0,011	0,063	N/A
30th	0,002	0,035	0,005	0,044	0,002	0,011	N/A
31th	0,007	0,123	0,007	0,061	0,011	0,063	N/A
32th	0,003	0,053	0,003	0,026	0,002	0,011	N/A
33th	0,008	0,141	0,004	0,035	0,012	0,069	N/A
34th	0,002	0,035	0,001	0,009	0,001	0,006	N/A
35th	0,008	0,141	0,003	0,026	0,011	0,063	N/A
36th	0,001	0,018	0,001	0,009	0,002	0,011	N/A
37th	0,007	0,123	0,004	0,035	0,011	0,063	N/A
38th	0,001	0,018	0,002	0,017	0,001	0,006	N/A
39th	0,006	0,106	0,004	0,035	0,011	0,063	N/A
40th	0,001	0,018	0,001	0,009	0,002	0,011	N/A
41th	0,006	0,106	0,004	0,035	0,010	0,057	N/A
42th	0,001	0,018	0,001	0,009	0,002	0,011	N/A
43th	0,004	0,070	0,004	0,035	0,010	0,057	N/A
44th	0,001	0,018	0,002	0,017	0,002	0,011	N/A
45th	0,004	0,070	0,004	0,035	0,010	0,057	N/A
46th	0,001	0,018	0,001	0,009	0,007	0,040	N/A
47th	0,004	0,070	0,003	0,026	0,009	0,051	N/A
48th	0,001	0,018	0,001	0,009	0,007	0,040	N/A
49th	0,004	0,070	0,004	0,035	0,009	0,051	N/A
50th	0,001	0,018	0,001	0,009	0,005	0,029	N/A

PV-curve simulated according to	
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	10,711
FFU of PV curve [1]	1
Impedance [Ω]	
Line	R_A = 0,15 jX_A= 0,15
Neutral	R_N = 0,01 jX_N= 0,01
Note:	

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)											P
HYD 3000-ES												
Harmonics												
P/ P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
Order	I_h [%]											
1	2,677	9,981	19,999	29,744	40,058	50,254	60,535	70,705	80,800	90,785	100,720	--
2	0,025	0,017	0,021	0,026	0,032	0,035	0,038	0,041	0,055	0,069	0,075	--
3	0,452	0,561	0,589	0,608	0,614	0,626	0,643	0,655	0,663	0,688	0,725	--
4	0,017	0,007	0,009	0,010	0,013	0,014	0,013	0,012	0,012	0,012	0,014	--
5	0,257	0,294	0,284	0,282	0,288	0,286	0,279	0,279	0,280	0,279	0,269	--
6	0,011	0,009	0,010	0,011	0,011	0,013	0,014	0,013	0,015	0,016	0,015	--
7	0,171	0,168	0,146	0,148	0,146	0,145	0,140	0,135	0,130	0,126	0,121	--
8	0,009	0,009	0,010	0,012	0,011	0,013	0,014	0,014	0,014	0,013	0,014	--
9	0,121	0,101	0,096	0,093	0,088	0,083	0,077	0,073	0,069	0,065	0,057	--
10	0,008	0,008	0,010	0,011	0,011	0,013	0,014	0,014	0,013	0,013	0,014	--
11	0,066	0,063	0,067	0,048	0,040	0,036	0,030	0,027	0,023	0,020	0,018	--
12	0,006	0,008	0,010	0,010	0,010	0,012	0,013	0,013	0,013	0,013	0,013	--
13	0,067	0,049	0,045	0,022	0,025	0,026	0,024	0,021	0,019	0,018	0,023	--
14	0,007	0,006	0,007	0,009	0,010	0,011	0,012	0,013	0,012	0,012	0,013	--
15	0,041	0,043	0,028	0,024	0,024	0,030	0,034	0,033	0,032	0,029	0,034	--
16	0,006	0,006	0,007	0,009	0,009	0,010	0,011	0,011	0,011	0,011	0,012	--
17	0,043	0,046	0,032	0,030	0,036	0,048	0,051	0,049	0,048	0,046	0,050	--
18	0,005	0,006	0,006	0,008	0,008	0,009	0,010	0,010	0,011	0,011	0,011	--
19	0,044	0,041	0,030	0,031	0,044	0,054	0,058	0,058	0,056	0,051	0,052	--
20	0,005	0,005	0,006	0,007	0,007	0,009	0,009	0,010	0,010	0,009	0,010	--
21	0,044	0,043	0,031	0,034	0,046	0,059	0,066	0,065	0,063	0,061	0,063	--
22	0,005	0,006	0,006	0,006	0,007	0,008	0,008	0,008	0,008	0,010	0,010	--
23	0,052	0,046	0,035	0,039	0,051	0,068	0,074	0,073	0,070	0,066	0,067	--
24	0,005	0,005	0,005	0,006	0,007	0,008	0,007	0,008	0,009	0,010	0,010	--
25	0,052	0,044	0,035	0,039	0,052	0,069	0,074	0,073	0,071	0,066	0,064	--
26	0,007	0,005	0,005	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,010	--
27	0,059	0,045	0,036	0,041	0,056	0,071	0,076	0,076	0,073	0,067	0,068	--
28	0,006	0,005	0,005	0,006	0,007	0,007	0,008	0,008	0,007	0,009	0,010	--
29	0,058	0,041	0,034	0,041	0,056	0,070	0,076	0,074	0,071	0,067	0,065	--
30	0,007	0,005	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,008	0,009	--
31	0,064	0,045	0,038	0,045	0,061	0,075	0,080	0,078	0,075	0,069	0,064	--
32	0,008	0,005	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,008	0,009	--
33	0,070	0,047	0,041	0,048	0,065	0,080	0,085	0,083	0,079	0,072	0,068	--

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)										P
HYD 3000-ES											
Harmonics											
P/ P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
34	0,009	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,008	--
35	0,067	0,043	0,039	0,047	0,065	0,081	0,085	0,081	0,077	0,069	0,064	--
36	0,009	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,010	--
37	0,069	0,043	0,038	0,047	0,066	0,082	0,086	0,082	0,078	0,070	0,064	--
38	0,009	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,008	--
39	0,070	0,044	0,041	0,051	0,070	0,088	0,093	0,087	0,084	0,073	0,063	--
40	0,010	0,006	0,006	0,007	0,007	0,007	0,007	0,008	0,008	0,008	0,009	--
41	0,063	0,038	0,036	0,048	0,068	0,086	0,089	0,084	0,076	0,064	0,058	--
42	0,012	0,006	0,007	0,007	0,008	0,008	0,008	0,009	0,009	0,010	0,010	--
43	0,063	0,040	0,037	0,051	0,072	0,089	0,092	0,089	0,078	0,070	0,061	--
44	0,012	0,008	0,009	0,009	0,010	0,010	0,010	0,012	0,012	0,012	0,013	--
45	0,061	0,042	0,041	0,056	0,076	0,096	0,097	0,092	0,081	0,071	0,058	--
46	0,058	0,049	0,014	0,010	0,027	0,037	0,044	0,044	0,043	0,041	0,040	--
47	0,055	0,037	0,037	0,053	0,074	0,092	0,091	0,086	0,079	0,064	0,052	--
48	0,062	0,049	0,014	0,009	0,027	0,037	0,044	0,043	0,042	0,040	0,039	--
49	0,048	0,036	0,036	0,053	0,072	0,090	0,091	0,085	0,078	0,059	0,051	--
50	0,048	0,049	0,012	0,019	0,031	0,028	0,026	0,027	0,026	0,027	0,029	--
THC [%]	0,629	0,697	0,7	0,721	0,749	0,783	0,8	0,803	0,801	0,81	0,832	--
THDU40 [%]	0,162	0,15	0,132	0,146	0,171	0,195	0,207	0,217	0,218	0,222	0,235	--

5.2.4.1 b)	Interharmonics											P
HYD 3000-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [Hz]	I_h [%]											
75	0,212	0,029	0,045	0,039	0,039	0,042	0,044	0,046	0,049	0,052	0,059	--
125	0,071	0,013	0,016	0,015	0,015	0,017	0,016	0,016	0,016	0,017	0,019	--
175	0,078	0,011	0,013	0,013	0,012	0,014	0,014	0,013	0,014	0,015	0,016	--
225	0,075	0,013	0,014	0,013	0,013	0,014	0,014	0,013	0,014	0,014	0,015	--
275	0,041	0,012	0,013	0,016	0,016	0,017	0,017	0,016	0,016	0,016	0,017	--
325	0,055	0,012	0,013	0,014	0,014	0,015	0,016	0,015	0,015	0,015	0,015	--
375	0,050	0,013	0,014	0,014	0,015	0,015	0,017	0,015	0,015	0,016	0,015	--
425	0,034	0,011	0,013	0,015	0,016	0,016	0,018	0,017	0,017	0,017	0,017	--
475	0,025	0,011	0,012	0,013	0,014	0,015	0,017	0,015	0,016	0,015	0,016	--
525	0,021	0,010	0,011	0,012	0,013	0,015	0,016	0,015	0,015	0,015	0,015	--
575	0,015	0,009	0,010	0,012	0,013	0,014	0,015	0,014	0,016	0,015	0,015	--
625	0,009	0,009	0,009	0,010	0,012	0,013	0,014	0,013	0,014	0,014	0,014	--
675	0,007	0,008	0,009	0,010	0,011	0,012	0,014	0,013	0,014	0,014	0,014	--
725	0,007	0,008	0,008	0,009	0,010	0,011	0,012	0,012	0,013	0,013	0,013	--
775	0,007	0,007	0,008	0,009	0,009	0,010	0,012	0,012	0,012	0,013	0,013	--
825	0,007	0,007	0,008	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,013	--
875	0,008	0,007	0,007	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,012	--
925	0,008	0,007	0,007	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,012	--
975	0,006	0,006	0,007	0,007	0,008	0,009	0,010	0,010	0,011	0,012	0,012	--
1025	0,007	0,007	0,007	0,007	0,008	0,009	0,010	0,010	0,011	0,012	0,012	--
1075	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	0,011	0,012	--
1125	0,006	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1175	0,006	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,011	0,011	--
1225	0,007	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,010	0,011	--
1275	0,007	0,006	0,006	0,006	0,007	0,007	0,008	0,009	0,009	0,010	0,011	--
1325	0,008	0,007	0,007	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1375	0,007	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,010	0,011	--
1425	0,008	0,007	0,007	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1475	0,007	0,006	0,005	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1525	0,008	0,005	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1575	0,008	0,005	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	--
1625	0,008	0,006	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	--
1675	0,008	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	--
1725	0,008	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,010	--
1775	0,009	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,010	--
1825	0,009	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,009	--
1875	0,009	0,006	0,005	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,009	--
1925	0,010	0,006	0,005	0,006	0,007	0,007	0,008	0,008	0,008	0,009	0,009	--
1975	0,010	0,006	0,005	0,006	0,006	0,007	0,008	0,007	0,008	0,008	0,009	--

5.2.4.1 b)	Higher Frequencies											P
HYD 3000-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [kHz]	I_h [%]											
2,1	0,094	0,058	0,055	0,073	0,101	0,126	0,130	0,124	0,112	0,098	0,088	--
2,3	0,107	0,079	0,078	0,094	0,119	0,143	0,142	0,136	0,124	0,108	0,092	--
2,5	0,105	0,088	0,087	0,098	0,117	0,138	0,138	0,129	0,121	0,098	0,089	--
2,7	0,053	0,049	0,050	0,072	0,093	0,112	0,108	0,100	0,092	0,076	0,059	--
2,9	0,032	0,035	0,036	0,054	0,069	0,083	0,079	0,071	0,065	0,056	0,045	--
3,1	0,026	0,028	0,031	0,042	0,053	0,059	0,057	0,052	0,046	0,039	0,035	--
3,3	0,020	0,021	0,023	0,031	0,037	0,042	0,038	0,034	0,032	0,028	0,028	--
3,5	0,015	0,016	0,017	0,023	0,027	0,029	0,027	0,024	0,022	0,021	0,022	--
3,7	0,017	0,017	0,018	0,022	0,024	0,025	0,023	0,021	0,021	0,020	0,021	--
3,9	0,013	0,013	0,014	0,017	0,018	0,019	0,017	0,016	0,016	0,016	0,018	--
4,1	0,012	0,012	0,013	0,015	0,016	0,016	0,015	0,015	0,015	0,016	0,017	--
4,3	0,013	0,013	0,013	0,014	0,015	0,015	0,015	0,015	0,015	0,016	0,017	--
4,5	0,013	0,013	0,014	0,014	0,015	0,015	0,015	0,015	0,016	0,016	0,018	--
4,7	0,040	0,042	0,042	0,042	0,042	0,043	0,043	0,043	0,044	0,044	0,045	--
4,9	0,016	0,016	0,017	0,017	0,018	0,018	0,018	0,019	0,020	0,020	0,021	--
5,1	0,016	0,016	0,017	0,017	0,018	0,018	0,018	0,019	0,019	0,020	0,021	--
5,3	0,012	0,013	0,013	0,014	0,014	0,014	0,014	0,015	0,015	0,016	0,017	--
5,5	0,010	0,010	0,010	0,011	0,011	0,011	0,011	0,012	0,012	0,013	0,014	--
5,7	0,009	0,009	0,009	0,009	0,009	0,009	0,010	0,010	0,010	0,011	0,012	--
5,9	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,008	0,008	0,008	0,009	--
6,1	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,009	0,009	0,009	0,009	--
6,3	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,007	--
6,5	0,006	0,006	0,006	0,005	0,005	0,006	0,006	0,006	0,006	0,006	0,006	--
6,7	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
6,9	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,1	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	--
7,3	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,5	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,7	0,004	0,004	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,004	0,004	--
7,9	0,004	0,004	0,004	0,004	0,004	0,005	0,005	0,005	0,004	0,004	0,004	--
8,1	0,004	0,004	0,004	0,004	0,004	0,005	0,004	0,004	0,004	0,004	0,004	--
8,3	0,004	0,004	0,004	0,004	0,004	0,005	0,005	0,004	0,004	0,004	0,004	--
8,5	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,7	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,9	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	

5.2.4.1 b)	Higher Frequencies	P
HYD 3000-ES		
PV-curve simulated according to	/	
Voltage of defined MPP [V]	**380**	
Current of defined MPP [A]	**8,050**	
FFU of PV curve [1]	**1**	
Impedance [Ω]		
Line	R_A = 0,15 jX_A= 0,15	
Neutral	R_N = 0,01 jX_N= 0,01	

Note:

The normalization current is 13,0A.

The harmonics, interharmonics and higher frequencies are maximum values of all three phases.

The currents of the interharmonics 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.

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)											P
HYD 3600-ES												
Harmonics												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
Order	I_h [%]											
1	2,570	10,221	20,235	30,162	40,554	50,966	61,287	71,577	81,835	91,956	102,069	--
2	0,024	0,015	0,019	0,026	0,032	0,035	0,041	0,041	0,049	0,058	0,063	--
3	0,472	0,574	0,608	0,621	0,625	0,638	0,654	0,663	0,676	0,697	0,736	--
4	0,017	0,008	0,009	0,009	0,012	0,012	0,013	0,011	0,012	0,013	0,014	--
5	0,262	0,298	0,287	0,283	0,288	0,286	0,282	0,281	0,283	0,283	0,273	--
6	0,017	0,009	0,009	0,010	0,011	0,012	0,013	0,012	0,013	0,013	0,012	--
7	0,179	0,171	0,148	0,147	0,147	0,145	0,141	0,135	0,130	0,126	0,120	--
8	0,015	0,010	0,010	0,011	0,012	0,014	0,015	0,013	0,014	0,014	0,012	--
9	0,119	0,103	0,096	0,094	0,088	0,082	0,079	0,072	0,066	0,063	0,056	--
10	0,017	0,009	0,010	0,011	0,011	0,013	0,014	0,013	0,013	0,013	0,015	--
11	0,078	0,064	0,073	0,049	0,041	0,035	0,032	0,026	0,021	0,019	0,016	--
12	0,015	0,008	0,010	0,009	0,010	0,012	0,013	0,013	0,013	0,013	0,013	--
13	0,070	0,053	0,048	0,023	0,025	0,027	0,024	0,021	0,019	0,018	0,022	--
14	0,014	0,007	0,008	0,008	0,010	0,011	0,012	0,012	0,013	0,013	0,012	--
15	0,044	0,044	0,027	0,024	0,025	0,031	0,035	0,035	0,033	0,031	0,036	--
16	0,013	0,007	0,007	0,008	0,009	0,010	0,011	0,010	0,011	0,011	0,011	--
17	0,048	0,045	0,034	0,031	0,037	0,049	0,053	0,051	0,049	0,048	0,053	--
18	0,012	0,006	0,006	0,007	0,008	0,009	0,010	0,010	0,010	0,011	0,010	--
19	0,043	0,042	0,031	0,031	0,045	0,056	0,059	0,059	0,058	0,054	0,055	--
20	0,011	0,006	0,006	0,007	0,007	0,009	0,009	0,010	0,010	0,010	0,010	--
21	0,048	0,043	0,031	0,034	0,046	0,060	0,067	0,067	0,065	0,063	0,065	--
22	0,011	0,006	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	0,010	--
23	0,052	0,046	0,036	0,039	0,052	0,069	0,075	0,073	0,071	0,067	0,068	--
24	0,011	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	0,010	--
25	0,056	0,044	0,035	0,040	0,053	0,070	0,074	0,073	0,071	0,067	0,065	--
26	0,011	0,005	0,006	0,006	0,007	0,007	0,008	0,008	0,008	0,008	0,010	--
27	0,060	0,045	0,037	0,042	0,057	0,072	0,077	0,077	0,074	0,067	0,067	--
28	0,011	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,008	0,009	0,010	--
29	0,061	0,042	0,035	0,041	0,057	0,071	0,077	0,075	0,072	0,067	0,065	--
30	0,012	0,005	0,006	0,005	0,006	0,007	0,007	0,007	0,008	0,008	0,009	--
31	0,068	0,046	0,039	0,045	0,061	0,076	0,081	0,079	0,076	0,070	0,065	--
32	0,012	0,005	0,006	0,005	0,006	0,007	0,007	0,008	0,008	0,008	0,009	--
33	0,071	0,048	0,042	0,048	0,065	0,082	0,086	0,084	0,079	0,072	0,069	--

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)										P
HYD 3600-ES											
Harmonics											
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
34	0,013	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	--
35	0,071	0,044	0,040	0,047	0,065	0,082	0,086	0,082	0,077	0,070	0,065	--
36	0,013	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,009	--
37	0,071	0,043	0,039	0,048	0,066	0,084	0,087	0,082	0,079	0,071	0,066	--
38	0,014	0,006	0,006	0,006	0,007	0,007	0,007	0,007	0,008	0,008	0,008	--
39	0,072	0,045	0,043	0,052	0,071	0,089	0,093	0,088	0,084	0,073	0,064	--
40	0,015	0,006	0,007	0,006	0,007	0,008	0,007	0,008	0,008	0,009	0,009	--
41	0,066	0,039	0,037	0,048	0,069	0,088	0,090	0,085	0,078	0,065	0,059	--
42	0,017	0,006	0,007	0,006	0,007	0,008	0,008	0,009	0,010	0,010	0,010	--
43	0,065	0,040	0,038	0,052	0,072	0,091	0,093	0,090	0,078	0,070	0,061	--
44	0,017	0,008	0,010	0,009	0,010	0,010	0,010	0,011	0,013	0,013	0,013	--
45	0,065	0,042	0,042	0,056	0,077	0,097	0,097	0,092	0,081	0,071	0,059	--
46	0,060	0,049	0,011	0,010	0,031	0,039	0,045	0,044	0,044	0,042	0,041	--
47	0,057	0,038	0,037	0,053	0,074	0,094	0,092	0,087	0,079	0,064	0,052	--
48	0,063	0,050	0,011	0,009	0,030	0,039	0,044	0,043	0,042	0,041	0,039	--
49	0,051	0,036	0,037	0,054	0,073	0,091	0,091	0,086	0,079	0,060	0,052	--
50	0,044	0,043	0,015	0,023	0,032	0,029	0,027	0,027	0,027	0,028	0,029	--
THC [%]	0,654	0,711	0,719	0,733	0,76	0,795	0,812	0,812	0,814	0,82	0,844	--
THDU40 [%]	0,188	0,181	0,161	0,169	0,194	0,211	0,223	0,231	0,228	0,225	0,237	--

5.2.4.1 b)	Interharmonics											P
HYD 3600-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [Hz]	I_h [%]											
75	0,205	0,031	0,034	0,035	0,037	0,046	0,066	0,048	0,058	0,058	0,059	--
125	0,081	0,014	0,015	0,015	0,016	0,017	0,021	0,016	0,018	0,019	0,019	--
175	0,104	0,011	0,012	0,012	0,014	0,014	0,017	0,014	0,015	0,015	0,016	--
225	0,095	0,012	0,013	0,013	0,014	0,014	0,017	0,013	0,014	0,015	0,015	--
275	0,048	0,015	0,015	0,016	0,016	0,017	0,019	0,016	0,017	0,017	0,017	--
325	0,041	0,012	0,013	0,014	0,015	0,016	0,018	0,015	0,016	0,015	0,016	--
375	0,042	0,013	0,014	0,014	0,015	0,016	0,018	0,015	0,016	0,016	0,016	--
425	0,034	0,012	0,013	0,014	0,015	0,016	0,019	0,016	0,018	0,016	0,017	--
475	0,032	0,011	0,012	0,013	0,014	0,015	0,018	0,015	0,017	0,016	0,016	--
525	0,031	0,011	0,012	0,013	0,014	0,015	0,017	0,015	0,016	0,016	0,016	--
575	0,029	0,010	0,011	0,011	0,012	0,014	0,016	0,014	0,016	0,015	0,015	--
625	0,026	0,009	0,010	0,011	0,012	0,013	0,015	0,014	0,015	0,014	0,015	--
675	0,023	0,009	0,009	0,010	0,011	0,013	0,015	0,013	0,014	0,014	0,014	--
725	0,022	0,008	0,009	0,009	0,010	0,011	0,013	0,012	0,013	0,013	0,014	--
775	0,020	0,008	0,008	0,009	0,010	0,011	0,012	0,012	0,013	0,013	0,013	--
825	0,019	0,007	0,008	0,008	0,009	0,011	0,012	0,011	0,012	0,012	0,013	--
875	0,019	0,007	0,007	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,012	--
925	0,018	0,007	0,008	0,008	0,009	0,010	0,012	0,011	0,012	0,012	0,013	--
975	0,017	0,006	0,007	0,007	0,008	0,009	0,011	0,010	0,011	0,011	0,012	--
1025	0,017	0,007	0,007	0,007	0,008	0,009	0,011	0,010	0,011	0,012	0,012	--
1075	0,016	0,006	0,006	0,007	0,007	0,009	0,010	0,009	0,011	0,011	0,012	--
1125	0,016	0,006	0,006	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1175	0,015	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,011	0,011	--
1225	0,015	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,010	0,011	--
1275	0,015	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,010	0,011	--
1325	0,016	0,007	0,007	0,007	0,008	0,008	0,010	0,009	0,010	0,011	0,012	--
1375	0,015	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,011	--
1425	0,016	0,007	0,007	0,007	0,008	0,008	0,009	0,009	0,010	0,011	0,012	--
1475	0,015	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,010	--
1525	0,015	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1575	0,015	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1625	0,015	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1675	0,016	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	--
1725	0,016	0,006	0,006	0,006	0,006	0,007	0,008	0,007	0,008	0,009	0,010	--
1775	0,016	0,006	0,006	0,006	0,006	0,007	0,008	0,007	0,008	0,009	0,010	--
1825	0,016	0,006	0,006	0,006	0,006	0,007	0,008	0,007	0,008	0,009	0,009	--
1875	0,016	0,006	0,006	0,006	0,006	0,007	0,008	0,007	0,008	0,009	0,009	--
1925	0,017	0,006	0,005	0,007	0,007	0,008	0,008	0,008	0,009	0,009	0,010	--
1975	0,018	0,006	0,004	0,006	0,006	0,007	0,008	0,007	0,008	0,009	0,009	--

5.2.4.1 b)	Higher Frequencies											P
HYD 3600-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [kHz]	I_h [%]											
2,1	0,105	0,059	0,056	0,073	0,102	0,128	0,131	0,125	0,113	0,099	0,089	--
2,3	0,118	0,079	0,080	0,095	0,120	0,145	0,144	0,137	0,125	0,109	0,093	--
2,5	0,112	0,086	0,085	0,099	0,119	0,141	0,139	0,130	0,122	0,099	0,090	--
2,7	0,064	0,050	0,052	0,072	0,094	0,114	0,109	0,101	0,093	0,076	0,060	--
2,9	0,042	0,036	0,037	0,054	0,069	0,083	0,080	0,071	0,066	0,056	0,046	--
3,1	0,032	0,030	0,032	0,043	0,053	0,060	0,057	0,052	0,046	0,039	0,036	--
3,3	0,024	0,022	0,024	0,031	0,038	0,042	0,039	0,034	0,032	0,028	0,028	--
3,5	0,019	0,016	0,018	0,023	0,027	0,029	0,027	0,024	0,022	0,021	0,022	--
3,7	0,019	0,017	0,019	0,022	0,024	0,025	0,023	0,021	0,021	0,020	0,022	--
3,9	0,015	0,013	0,014	0,017	0,018	0,019	0,017	0,016	0,016	0,016	0,018	--
4,1	0,014	0,013	0,014	0,015	0,016	0,016	0,016	0,015	0,015	0,016	0,018	--
4,3	0,014	0,013	0,014	0,015	0,015	0,015	0,015	0,015	0,015	0,016	0,017	--
4,5	0,014	0,014	0,014	0,015	0,015	0,015	0,015	0,015	0,016	0,017	0,018	--
4,7	0,041	0,042	0,042	0,042	0,043	0,043	0,044	0,043	0,045	0,045	0,045	--
4,9	0,016	0,017	0,017	0,017	0,017	0,018	0,018	0,019	0,020	0,020	0,021	--
5,1	0,017	0,017	0,017	0,017	0,017	0,018	0,018	0,019	0,020	0,020	0,021	--
5,3	0,014	0,013	0,014	0,014	0,014	0,014	0,014	0,015	0,016	0,017	0,018	--
5,5	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,012	0,012	0,013	0,014	--
5,7	0,010	0,009	0,010	0,009	0,009	0,010	0,010	0,010	0,011	0,011	0,012	--
5,9	0,008	0,007	0,007	0,007	0,007	0,007	0,007	0,008	0,008	0,009	0,009	--
6,1	0,009	0,008	0,008	0,008	0,008	0,008	0,008	0,009	0,009	0,009	0,010	--
6,3	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,007	0,007	--
6,5	0,006	0,006	0,006	0,006	0,005	0,006	0,006	0,006	0,006	0,006	0,006	--
6,7	0,006	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,006	0,006	0,005	--
6,9	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,1	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	--
7,3	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,5	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,7	0,005	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,005	0,004	0,004	--
7,9	0,005	0,004	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,004	0,004	--
8,1	0,005	0,004	0,004	0,004	0,004	0,005	0,005	0,004	0,004	0,004	0,004	--
8,3	0,005	0,004	0,004	0,004	0,005	0,005	0,005	0,004	0,004	0,004	0,004	--
8,5	0,004	0,004	0,004	0,004	0,004	0,005	0,005	0,004	0,004	0,004	0,004	--
8,7	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,9	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--

5.2.4.1 b)	Higher Frequencies	P
HYD 3600-ES		
PV-curve simulated according to	/	
Voltage of defined MPP [V]	380Vdc	
Current of defined MPP [A]	9,737	
FFU of PV curve [1]	1	
Impedance [Ω]		
Line	R_A = 0,15 jX_A= 0,15	
Neutral	R_N = 0,01 jX_N= 0,01	

Note:

The normalization current is 15,6A.

The harmonics, interharmonics and higher frequencies are maximum values of all three phases.

The currents of the interharmonics 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.

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)											P
HYD 4000-ES												
Harmonics												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
Order	I_h [%]											
1	2,566	10,152	19,949	29,731	40,074	50,240	60,583	70,696	80,781	90,718	100,607	--
2	0,024	0,015	0,019	0,026	0,031	0,036	0,040	0,043	0,054	0,068	0,075	--
3	0,467	0,573	0,600	0,609	0,615	0,629	0,645	0,654	0,664	0,686	0,726	--
4	0,017	0,008	0,008	0,010	0,014	0,014	0,012	0,012	0,012	0,012	0,013	--
5	0,258	0,294	0,284	0,282	0,288	0,286	0,280	0,282	0,282	0,278	0,267	--
6	0,016	0,009	0,010	0,010	0,011	0,013	0,012	0,013	0,016	0,019	0,019	--
7	0,174	0,169	0,148	0,147	0,147	0,144	0,141	0,136	0,131	0,128	0,122	--
8	0,013	0,010	0,010	0,011	0,011	0,014	0,014	0,014	0,014	0,013	0,014	--
9	0,120	0,101	0,096	0,094	0,087	0,083	0,078	0,075	0,071	0,065	0,057	--
10	0,014	0,009	0,010	0,011	0,011	0,013	0,014	0,014	0,013	0,013	0,014	--
11	0,076	0,064	0,073	0,048	0,041	0,035	0,032	0,028	0,023	0,022	0,019	--
12	0,012	0,008	0,009	0,010	0,011	0,012	0,013	0,013	0,013	0,013	0,014	--
13	0,067	0,053	0,046	0,023	0,024	0,027	0,024	0,021	0,020	0,018	0,022	--
14	0,012	0,007	0,008	0,009	0,010	0,011	0,012	0,012	0,012	0,011	0,012	--
15	0,045	0,042	0,028	0,024	0,025	0,030	0,034	0,034	0,032	0,029	0,034	--
16	0,010	0,007	0,007	0,009	0,009	0,010	0,011	0,010	0,011	0,011	0,011	--
17	0,047	0,046	0,034	0,031	0,036	0,047	0,051	0,049	0,049	0,047	0,051	--
18	0,009	0,006	0,007	0,008	0,008	0,009	0,010	0,010	0,010	0,010	0,011	--
19	0,043	0,043	0,031	0,031	0,044	0,054	0,058	0,058	0,056	0,052	0,051	--
20	0,009	0,006	0,007	0,007	0,008	0,009	0,010	0,010	0,010	0,010	0,010	--
21	0,047	0,042	0,031	0,034	0,046	0,059	0,066	0,065	0,063	0,059	0,062	--
22	0,009	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,008	0,011	0,011	--
23	0,051	0,046	0,036	0,039	0,051	0,068	0,075	0,073	0,071	0,066	0,066	--
24	0,009	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	0,010	--
25	0,055	0,044	0,035	0,039	0,052	0,069	0,075	0,073	0,071	0,066	0,063	--
26	0,010	0,005	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,009	0,011	--
27	0,060	0,045	0,036	0,042	0,056	0,071	0,077	0,076	0,073	0,067	0,068	--
28	0,009	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,008	0,009	0,010	--
29	0,060	0,042	0,034	0,040	0,056	0,070	0,077	0,074	0,072	0,067	0,065	--
30	0,010	0,005	0,006	0,006	0,007	0,008	0,007	0,008	0,008	0,008	0,009	--
31	0,067	0,046	0,039	0,045	0,061	0,075	0,081	0,079	0,076	0,068	0,064	--
32	0,010	0,005	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,008	0,009	--
33	0,070	0,048	0,042	0,048	0,065	0,080	0,086	0,083	0,079	0,071	0,068	--

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)											P
HYD 4000-ES												
Harmonics												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
34	0,011	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,009	--
35	0,070	0,044	0,040	0,047	0,065	0,081	0,085	0,081	0,078	0,069	0,064	--
36	0,011	0,006	0,006	0,006	0,007	0,008	0,007	0,008	0,008	0,008	0,010	--
37	0,069	0,043	0,039	0,047	0,065	0,082	0,087	0,082	0,079	0,070	0,064	--
38	0,012	0,006	0,007	0,006	0,007	0,008	0,007	0,008	0,008	0,009	0,009	--
39	0,071	0,045	0,042	0,051	0,070	0,088	0,093	0,087	0,084	0,073	0,063	--
40	0,013	0,006	0,007	0,006	0,007	0,008	0,007	0,008	0,009	0,009	0,010	--
41	0,064	0,039	0,037	0,048	0,068	0,086	0,089	0,084	0,077	0,065	0,058	--
42	0,015	0,007	0,008	0,007	0,008	0,008	0,008	0,009	0,010	0,011	0,010	--
43	0,064	0,040	0,038	0,051	0,072	0,089	0,093	0,089	0,079	0,069	0,060	--
44	0,015	0,008	0,009	0,008	0,010	0,010	0,010	0,012	0,013	0,013	0,013	--
45	0,063	0,042	0,041	0,056	0,076	0,095	0,097	0,092	0,081	0,071	0,058	--
46	0,058	0,048	0,014	0,018	0,026	0,036	0,044	0,043	0,043	0,041	0,040	--
47	0,056	0,038	0,037	0,053	0,074	0,092	0,092	0,087	0,079	0,064	0,051	--
48	0,062	0,049	0,014	0,018	0,025	0,036	0,043	0,042	0,041	0,040	0,039	--
49	0,050	0,036	0,037	0,053	0,072	0,090	0,092	0,085	0,079	0,059	0,051	--
50	0,041	0,041	0,009	0,011	0,030	0,027	0,026	0,025	0,026	0,027	0,029	--
THC [%]	0,644	0,708	0,711	0,722	0,75	0,785	0,803	0,804	0,804	0,809	0,833	--
THDU40 [%]	0,171	0,168	0,156	0,169	0,202	0,215	0,228	0,251	0,24	0,243	0,253	--

5.2.4.1 b)	Interharmonics											P
HYD 4000-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [Hz]	I_h [%]											
75	0,182	0,027	0,031	0,035	0,045	0,050	0,043	0,056	0,056	0,057	0,058	--
125	0,074	0,013	0,014	0,014	0,017	0,018	0,015	0,018	0,018	0,018	0,018	--
175	0,088	0,011	0,012	0,012	0,013	0,015	0,014	0,014	0,015	0,015	0,016	--
225	0,078	0,011	0,012	0,013	0,013	0,015	0,014	0,014	0,015	0,014	0,015	--
275	0,043	0,014	0,015	0,016	0,016	0,017	0,017	0,016	0,017	0,016	0,017	--
325	0,037	0,012	0,013	0,014	0,014	0,015	0,016	0,015	0,016	0,015	0,015	--
375	0,036	0,012	0,013	0,014	0,015	0,016	0,017	0,015	0,016	0,016	0,016	--
425	0,028	0,012	0,014	0,015	0,016	0,017	0,018	0,017	0,017	0,017	0,017	--
475	0,027	0,011	0,012	0,013	0,014	0,015	0,016	0,016	0,016	0,016	0,016	--
525	0,025	0,010	0,011	0,012	0,013	0,014	0,016	0,015	0,016	0,015	0,015	--
575	0,022	0,009	0,010	0,011	0,013	0,014	0,015	0,015	0,015	0,015	0,015	--
625	0,019	0,009	0,010	0,011	0,011	0,013	0,014	0,014	0,015	0,014	0,014	--
675	0,017	0,009	0,009	0,010	0,011	0,012	0,014	0,013	0,014	0,014	0,014	--
725	0,015	0,008	0,008	0,009	0,010	0,011	0,013	0,012	0,013	0,013	0,013	--
775	0,015	0,007	0,008	0,009	0,010	0,011	0,012	0,012	0,013	0,013	0,013	--
825	0,015	0,007	0,008	0,008	0,009	0,010	0,012	0,011	0,013	0,012	0,013	--
875	0,014	0,007	0,007	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,012	--
925	0,013	0,007	0,007	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,012	--
975	0,013	0,006	0,007	0,007	0,008	0,009	0,010	0,010	0,011	0,012	0,012	--
1025	0,013	0,007	0,007	0,007	0,008	0,009	0,010	0,010	0,011	0,012	0,012	--
1075	0,012	0,006	0,006	0,007	0,007	0,009	0,009	0,010	0,011	0,011	0,012	--
1125	0,012	0,006	0,006	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1175	0,012	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,011	0,011	--
1225	0,012	0,006	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,010	0,011	--
1275	0,011	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,010	0,011	--
1325	0,012	0,007	0,007	0,007	0,008	0,008	0,009	0,009	0,010	0,011	0,012	--
1375	0,011	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,010	0,011	--
1425	0,012	0,006	0,007	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1475	0,011	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,010	0,010	--
1525	0,011	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1575	0,012	0,005	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1625	0,012	0,005	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1675	0,012	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,008	0,009	0,010	--
1725	0,012	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1775	0,013	0,006	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,009	--
1825	0,013	0,006	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,009	--
1875	0,013	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,009	0,009	--
1925	0,014	0,006	0,004	0,006	0,007	0,007	0,008	0,008	0,009	0,009	0,009	--
1975	0,014	0,006	0,003	0,006	0,007	0,007	0,008	0,008	0,008	0,009	0,009	--

5.2.4.1 b)	Higher Frequencies											P
HYD 4000-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [kHz]	I_h [%]											
2,1	0,100	0,059	0,056	0,073	0,101	0,126	0,131	0,125	0,113	0,098	0,087	--
2,3	0,113	0,079	0,079	0,094	0,119	0,143	0,143	0,136	0,125	0,108	0,092	--
2,5	0,106	0,084	0,083	0,098	0,116	0,138	0,139	0,128	0,121	0,097	0,089	--
2,7	0,060	0,050	0,051	0,071	0,093	0,112	0,109	0,100	0,093	0,075	0,059	--
2,9	0,038	0,035	0,037	0,054	0,069	0,083	0,080	0,071	0,066	0,056	0,044	--
3,1	0,030	0,030	0,031	0,042	0,053	0,059	0,057	0,052	0,047	0,039	0,035	--
3,3	0,023	0,022	0,024	0,031	0,038	0,042	0,039	0,034	0,032	0,028	0,027	--
3,5	0,017	0,016	0,018	0,023	0,027	0,029	0,027	0,024	0,022	0,021	0,022	--
3,7	0,018	0,017	0,018	0,021	0,024	0,025	0,023	0,021	0,021	0,020	0,022	--
3,9	0,014	0,013	0,014	0,017	0,018	0,019	0,017	0,016	0,016	0,016	0,018	--
4,1	0,013	0,013	0,013	0,015	0,016	0,016	0,015	0,015	0,015	0,016	0,017	--
4,3	0,013	0,013	0,013	0,015	0,015	0,015	0,015	0,015	0,015	0,016	0,017	--
4,5	0,013	0,014	0,014	0,015	0,015	0,015	0,015	0,015	0,016	0,017	0,017	--
4,7	0,040	0,041	0,042	0,042	0,042	0,042	0,043	0,043	0,044	0,044	0,045	--
4,9	0,016	0,016	0,016	0,017	0,017	0,018	0,019	0,019	0,019	0,020	0,021	--
5,1	0,016	0,016	0,017	0,017	0,017	0,018	0,018	0,019	0,020	0,020	0,021	--
5,3	0,013	0,013	0,013	0,013	0,014	0,014	0,014	0,015	0,016	0,016	0,017	--
5,5	0,011	0,010	0,010	0,011	0,011	0,011	0,011	0,012	0,013	0,013	0,014	--
5,7	0,009	0,009	0,009	0,009	0,009	0,010	0,009	0,010	0,011	0,011	0,012	--
5,9	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,008	0,008	0,009	0,009	--
6,1	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,009	0,009	0,009	0,009	--
6,3	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,007	--
6,5	0,006	0,006	0,006	0,005	0,005	0,006	0,006	0,006	0,006	0,006	0,006	--
6,7	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
6,9	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,1	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	--
7,3	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,5	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,7	0,005	0,004	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,004	0,004	--
7,9	0,004	0,004	0,004	0,004	0,004	0,005	0,005	0,005	0,004	0,004	0,004	--
8,1	0,004	0,004	0,004	0,004	0,004	0,005	0,004	0,004	0,004	0,004	0,004	--
8,3	0,004	0,004	0,004	0,004	0,004	0,005	0,004	0,004	0,004	0,004	0,004	--
8,5	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,7	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,9	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--

5.2.4.1 b)	Higher Frequencies	P
HYD 4000-ES		
PV-curve simulated according to	/	
Voltage of defined MPP [V]	380Vdc	
Current of defined MPP [A]	10,711	
FFU of PV curve [1]	1	
Impedance [Ω]		
Line	R_A = 0,15 jX_A= 0,15	
Neutral	R_N = 0,01 jX_N= 0,01	

Note:

The normalization current is 17,4A.

The harmonics, interharmonics and higher frequencies are maximum values of all three phases.

The currents of the interharmonics 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.

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)											P
HYD 4600-ES												
Harmonics												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
Order	I_h [%]											
1	2,559	9,020	19,545	29,661	39,884	50,138	60,283	70,471	80,631	90,721	100,746	--
2	0,027	0,030	0,018	0,022	0,029	0,036	0,036	0,042	0,048	0,052	0,057	--
3	0,462	0,595	0,593	0,610	0,624	0,629	0,638	0,649	0,666	0,683	0,719	--
4	0,020	0,014	0,008	0,009	0,010	0,012	0,011	0,011	0,012	0,013	0,013	--
5	0,258	0,302	0,281	0,280	0,279	0,280	0,278	0,279	0,278	0,278	0,269	--
6	0,016	0,012	0,009	0,010	0,010	0,012	0,012	0,012	0,012	0,012	0,011	--
7	0,173	0,162	0,145	0,144	0,142	0,142	0,139	0,132	0,128	0,124	0,116	--
8	0,014	0,010	0,009	0,011	0,011	0,013	0,013	0,013	0,013	0,012	0,011	--
9	0,120	0,096	0,096	0,091	0,088	0,081	0,074	0,071	0,065	0,061	0,055	--
10	0,014	0,010	0,010	0,011	0,011	0,013	0,013	0,013	0,014	0,013	0,013	--
11	0,074	0,066	0,070	0,049	0,039	0,035	0,030	0,025	0,021	0,019	0,016	--
12	0,012	0,009	0,009	0,009	0,010	0,012	0,012	0,012	0,013	0,012	0,011	--
13	0,067	0,056	0,046	0,023	0,025	0,027	0,025	0,021	0,019	0,019	0,023	--
14	0,012	0,008	0,007	0,009	0,010	0,011	0,011	0,011	0,012	0,012	0,011	--
15	0,045	0,044	0,027	0,022	0,026	0,033	0,036	0,037	0,035	0,033	0,039	--
16	0,011	0,007	0,007	0,009	0,008	0,010	0,010	0,010	0,011	0,010	0,010	--
17	0,045	0,048	0,032	0,031	0,037	0,050	0,054	0,053	0,050	0,050	0,055	--
18	0,009	0,006	0,006	0,007	0,007	0,009	0,009	0,009	0,010	0,010	0,010	--
19	0,042	0,044	0,031	0,030	0,045	0,055	0,058	0,058	0,058	0,056	0,057	--
20	0,008	0,006	0,006	0,007	0,007	0,009	0,009	0,009	0,010	0,010	0,009	--
21	0,046	0,045	0,030	0,033	0,045	0,059	0,066	0,066	0,065	0,062	0,065	--
22	0,008	0,006	0,006	0,006	0,007	0,008	0,008	0,008	0,008	0,009	0,010	--
23	0,050	0,049	0,035	0,039	0,050	0,068	0,073	0,072	0,069	0,066	0,068	--
24	0,008	0,006	0,005	0,006	0,007	0,007	0,007	0,008	0,009	0,009	0,010	--
25	0,054	0,048	0,035	0,039	0,052	0,069	0,072	0,071	0,069	0,066	0,064	--
26	0,009	0,006	0,006	0,005	0,006	0,007	0,008	0,008	0,008	0,008	0,009	--
27	0,059	0,049	0,036	0,041	0,055	0,071	0,075	0,075	0,073	0,066	0,065	--
28	0,009	0,006	0,005	0,006	0,006	0,007	0,008	0,008	0,008	0,008	0,009	--
29	0,059	0,046	0,034	0,040	0,056	0,070	0,075	0,074	0,070	0,065	0,065	--
30	0,010	0,006	0,005	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	--
31	0,066	0,049	0,039	0,044	0,060	0,075	0,079	0,076	0,075	0,069	0,064	--
32	0,010	0,006	0,006	0,005	0,006	0,007	0,007	0,008	0,008	0,008	0,008	--
33	0,070	0,050	0,042	0,047	0,064	0,080	0,083	0,082	0,078	0,071	0,067	--

5.2.4.1 b)	Test Harmonics DIN EN 61000-4-7 (≥75 A per Phase)											P
HYD 4600-ES												
Harmonics												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
34	0,011	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	--
35	0,069	0,047	0,039	0,046	0,064	0,080	0,083	0,079	0,075	0,068	0,064	--
36	0,011	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	--
37	0,069	0,046	0,038	0,047	0,065	0,082	0,084	0,079	0,077	0,070	0,064	--
38	0,012	0,006	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,008	0,007	--
39	0,071	0,048	0,042	0,051	0,069	0,087	0,090	0,086	0,082	0,072	0,063	--
40	0,013	0,007	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,008	0,008	--
41	0,064	0,041	0,036	0,047	0,067	0,085	0,087	0,083	0,075	0,064	0,057	--
42	0,015	0,007	0,007	0,007	0,007	0,008	0,008	0,009	0,010	0,010	0,009	--
43	0,064	0,043	0,037	0,051	0,071	0,089	0,090	0,087	0,077	0,068	0,060	--
44	0,015	0,009	0,009	0,009	0,009	0,010	0,010	0,011	0,012	0,012	0,012	--
45	0,063	0,044	0,041	0,055	0,075	0,095	0,095	0,090	0,079	0,070	0,057	--
46	0,058	0,049	0,013	0,023	0,026	0,025	0,044	0,044	0,043	0,041	0,040	--
47	0,056	0,040	0,037	0,052	0,073	0,092	0,090	0,084	0,078	0,063	0,051	--
48	0,062	0,049	0,014	0,022	0,045	0,024	0,043	0,043	0,042	0,040	0,038	--
49	0,049	0,038	0,036	0,053	0,071	0,089	0,089	0,083	0,076	0,059	0,052	--
50	0,045	0,044	0,012	0,024	0,024	0,032	0,031	0,029	0,030	0,031	0,032	--
THC [%]	0,64	0,731	0,702	0,721	0,753	0,781	0,792	0,796	0,801	0,804	0,826	--
THDU40 [%]	0,163	0,149	0,129	0,141	0,17	0,196	0,21	0,223	0,222	0,226	0,242	--

5.2.4.1 b)	Interharmonics											P
HYD 4600-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [Hz]	I_h [%]											
75	0,187	0,245	0,033	0,036	0,039	0,042	0,044	0,050	0,051	0,054	0,060	--
125	0,076	0,091	0,014	0,014	0,015	0,018	0,016	0,017	0,017	0,017	0,018	--
175	0,094	0,057	0,012	0,012	0,013	0,015	0,014	0,015	0,014	0,015	0,016	--
225	0,082	0,044	0,012	0,013	0,013	0,015	0,014	0,014	0,014	0,015	0,016	--
275	0,041	0,031	0,013	0,013	0,014	0,015	0,015	0,014	0,014	0,014	0,015	--
325	0,041	0,026	0,013	0,014	0,014	0,015	0,016	0,015	0,015	0,015	0,016	--
375	0,042	0,024	0,014	0,015	0,016	0,017	0,017	0,017	0,017	0,016	0,017	--
425	0,032	0,020	0,013	0,013	0,014	0,016	0,016	0,016	0,016	0,016	0,017	--
475	0,028	0,019	0,012	0,013	0,014	0,015	0,016	0,015	0,016	0,016	0,017	--
525	0,027	0,017	0,011	0,012	0,013	0,015	0,015	0,015	0,015	0,015	0,016	--
575	0,024	0,015	0,010	0,011	0,012	0,014	0,014	0,014	0,015	0,015	0,016	--
625	0,021	0,014	0,010	0,010	0,012	0,013	0,014	0,014	0,014	0,014	0,015	--
675	0,017	0,012	0,009	0,010	0,011	0,012	0,013	0,013	0,013	0,014	0,015	--
725	0,016	0,011	0,008	0,009	0,010	0,011	0,012	0,012	0,013	0,013	0,014	--
775	0,015	0,010	0,008	0,009	0,009	0,011	0,011	0,011	0,012	0,013	0,013	--
825	0,015	0,009	0,007	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,013	--
875	0,014	0,009	0,007	0,008	0,009	0,010	0,010	0,011	0,011	0,012	0,012	--
925	0,014	0,009	0,007	0,008	0,009	0,010	0,010	0,011	0,012	0,012	0,013	--
975	0,012	0,008	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,011	0,012	--
1025	0,013	0,008	0,007	0,007	0,008	0,009	0,010	0,010	0,011	0,011	0,012	--
1075	0,012	0,008	0,006	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1125	0,011	0,008	0,006	0,006	0,007	0,008	0,009	0,009	0,010	0,010	0,012	--
1175	0,011	0,007	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,010	0,011	--
1225	0,011	0,007	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,010	0,011	--
1275	0,011	0,007	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,010	0,011	--
1325	0,012	0,007	0,007	0,007	0,007	0,008	0,009	0,009	0,010	0,011	0,012	--
1375	0,011	0,007	0,006	0,006	0,006	0,007	0,008	0,008	0,009	0,010	0,011	--
1425	0,013	0,007	0,007	0,007	0,007	0,008	0,008	0,009	0,010	0,010	0,012	--
1475	0,011	0,006	0,005	0,006	0,006	0,007	0,008	0,008	0,009	0,009	0,010	--
1525	0,011	0,006	0,006	0,006	0,006	0,007	0,007	0,008	0,009	0,009	0,010	--
1575	0,012	0,006	0,005	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,010	--
1625	0,012	0,006	0,006	0,006	0,006	0,007	0,007	0,008	0,008	0,009	0,010	--
1675	0,012	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,010	--
1725	0,013	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,010	--
1775	0,013	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,009	0,009	--
1825	0,013	0,006	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,009	--
1875	0,013	0,007	0,006	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,009	--
1925	0,014	0,007	0,004	0,006	0,007	0,007	0,008	0,008	0,008	0,009	0,009	--
1975	0,014	0,007	0,004	0,006	0,006	0,007	0,007	0,007	0,008	0,008	0,009	--

5.2.4.1 b)	Higher Frequencies											P
HYD 4600-ES												
P/P_{rE} [%]	5	10	20	30	40	50	60	70	80	90	100	Max
f [kHz]	I_h [%]											
2,1	0,100	0,062	0,055	0,072	0,100	0,125	0,127	0,122	0,110	0,097	0,087	--
2,3	0,113	0,082	0,078	0,094	0,118	0,142	0,140	0,133	0,123	0,107	0,092	--
2,5	0,108	0,088	0,085	0,099	0,117	0,138	0,137	0,127	0,120	0,098	0,090	--
2,7	0,059	0,052	0,050	0,071	0,091	0,111	0,106	0,098	0,091	0,075	0,059	--
2,9	0,038	0,037	0,036	0,053	0,067	0,081	0,077	0,068	0,064	0,055	0,045	--
3,1	0,029	0,030	0,030	0,042	0,052	0,059	0,055	0,050	0,045	0,038	0,035	--
3,3	0,022	0,022	0,023	0,031	0,037	0,041	0,038	0,033	0,031	0,027	0,028	--
3,5	0,017	0,016	0,017	0,023	0,026	0,029	0,026	0,023	0,022	0,021	0,022	--
3,7	0,018	0,017	0,018	0,021	0,024	0,025	0,023	0,021	0,021	0,020	0,022	--
3,9	0,013	0,013	0,014	0,017	0,018	0,019	0,017	0,016	0,016	0,016	0,018	--
4,1	0,013	0,013	0,013	0,015	0,016	0,016	0,015	0,015	0,015	0,016	0,017	--
4,3	0,013	0,013	0,013	0,014	0,015	0,015	0,015	0,015	0,015	0,016	0,017	--
4,5	0,013	0,014	0,014	0,014	0,015	0,015	0,015	0,016	0,016	0,017	0,017	--
4,7	0,040	0,041	0,041	0,042	0,042	0,043	0,042	0,043	0,043	0,044	0,045	--
4,9	0,016	0,016	0,017	0,017	0,018	0,018	0,019	0,019	0,019	0,020	0,020	--
5,1	0,016	0,017	0,017	0,017	0,017	0,018	0,018	0,019	0,019	0,020	0,020	--
5,3	0,013	0,013	0,013	0,014	0,014	0,014	0,015	0,015	0,016	0,016	0,017	--
5,5	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,012	0,013	0,013	0,014	--
5,7	0,010	0,009	0,009	0,010	0,009	0,009	0,010	0,010	0,011	0,011	0,012	--
5,9	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,008	0,008	0,009	0,009	--
6,1	0,008	0,009	0,008	0,008	0,008	0,008	0,008	0,008	0,009	0,009	0,009	--
6,3	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,007	0,007	--
6,5	0,006	0,006	0,006	0,005	0,005	0,006	0,006	0,006	0,006	0,006	0,006	--
6,7	0,006	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
6,9	0,006	0,006	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,1	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	--
7,3	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,5	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005	--
7,7	0,005	0,005	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,004	0,004	--
7,9	0,004	0,005	0,004	0,004	0,004	0,005	0,005	0,005	0,004	0,004	0,004	--
8,1	0,004	0,004	0,004	0,004	0,004	0,005	0,004	0,004	0,004	0,004	0,004	--
8,3	0,004	0,005	0,004	0,004	0,004	0,005	0,004	0,004	0,004	0,004	0,004	--
8,5	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,7	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--
8,9	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	--

5.2.4.1 b)	Higher Frequencies	P
HYD 4600-ES		
PV-curve simulated according to	/	
Voltage of defined MPP [V]	380Vdc	
Current of defined MPP [A]	12,368A	
FFU of PV curve [1]	1	
Impedance [Ω]		
Line	R_A = 0,15 jX_A= 0,15	
Neutral	R_N = 0,01 jX_N= 0,01	

Note:

The normalization current is 20,0A.

The harmonics, interharmonics and higher frequencies are maximum values of all three phases.

The currents of the interharmonics 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.

5.2.6	Feed in of DC current	P

HYD 3000-ES			
Power Level [% of VA_r]	30% S_{Emax} to 40%S_{Emax}	60% S_{Emax} to 70%S_{Emax}	>95% S_{Emax}
AC Power [VA]	1,112	1,989	3,004
AC Voltage [V]	229,0	229,6	232,1
AC Current [A]	4,856	8,661	12,946
DC Current in AC [A]	0,046	0,057	0,023
DC Current in AC [% of I_r]	0,350	0,439	0,173
Average. DC Current in AC [mA]	0,011	0,014	0,015
Average. DC Current in AC [% of Ir]	0,087	0,110	0,115

HYD 4600-ES			
Power Level [% of VA_r]	30% S_{Emax} to 40%S_{Emax}	60% S_{Emax} to 70%S_{Emax}	>95% S_{Emax}
AC Power [VA]	1,662	3,059	4,603
AC Voltage [V]	228,9	229,8	230,5
AC Current [A]	7,260	13,315	19,965
DC Current in AC [A]	0,071	0,079	0,092
DC Current in AC [% of I_r]	0,354	0,395	0,461
Average. DC Current in AC [mA]	0,017	0,023	0,027
Average. DC Current in AC [% of Ir]	0,087	0,114	0,134

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_{AC}, U_{AC}, $I_{dc\ in\ AC}$ of each phase has to be recorded. Measurement of $I_{dc\ in\ AC}$ 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:

An inverter must not feed more than 0,5% of its rated current I_r or a maximum of 20 mA (the higher value is to be selected) as direct current.

Diagram of Feed in of DC current: HYD 3000-ES

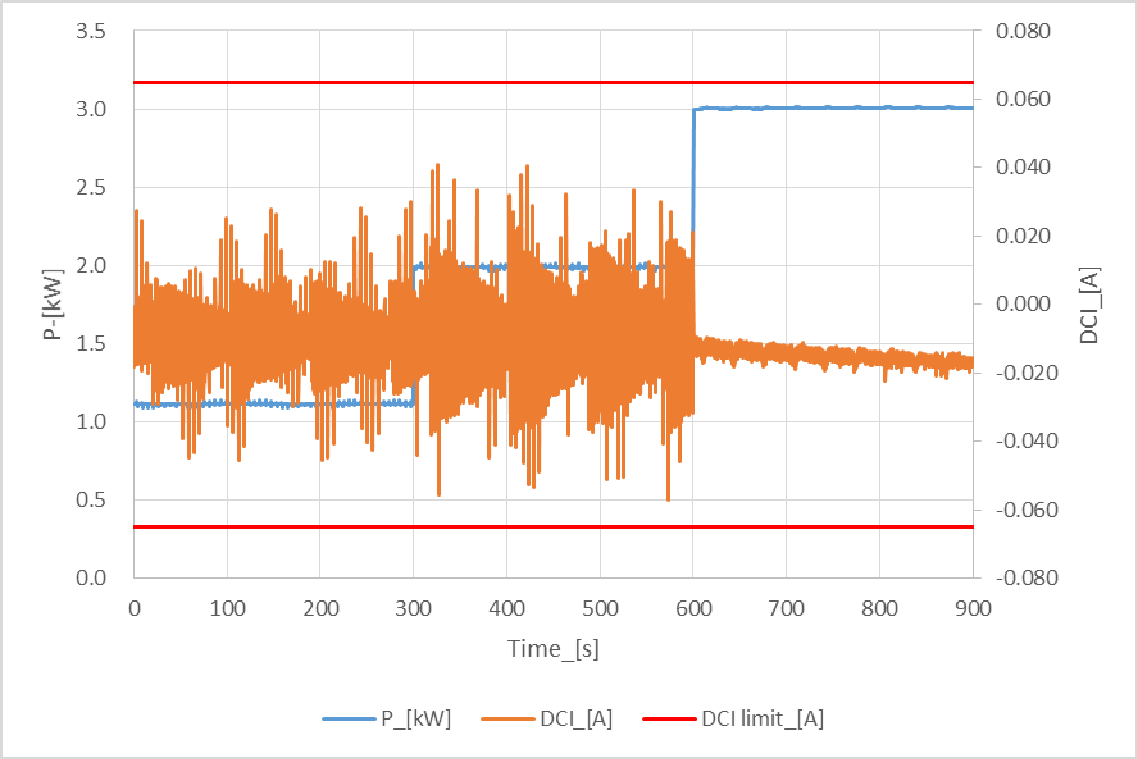
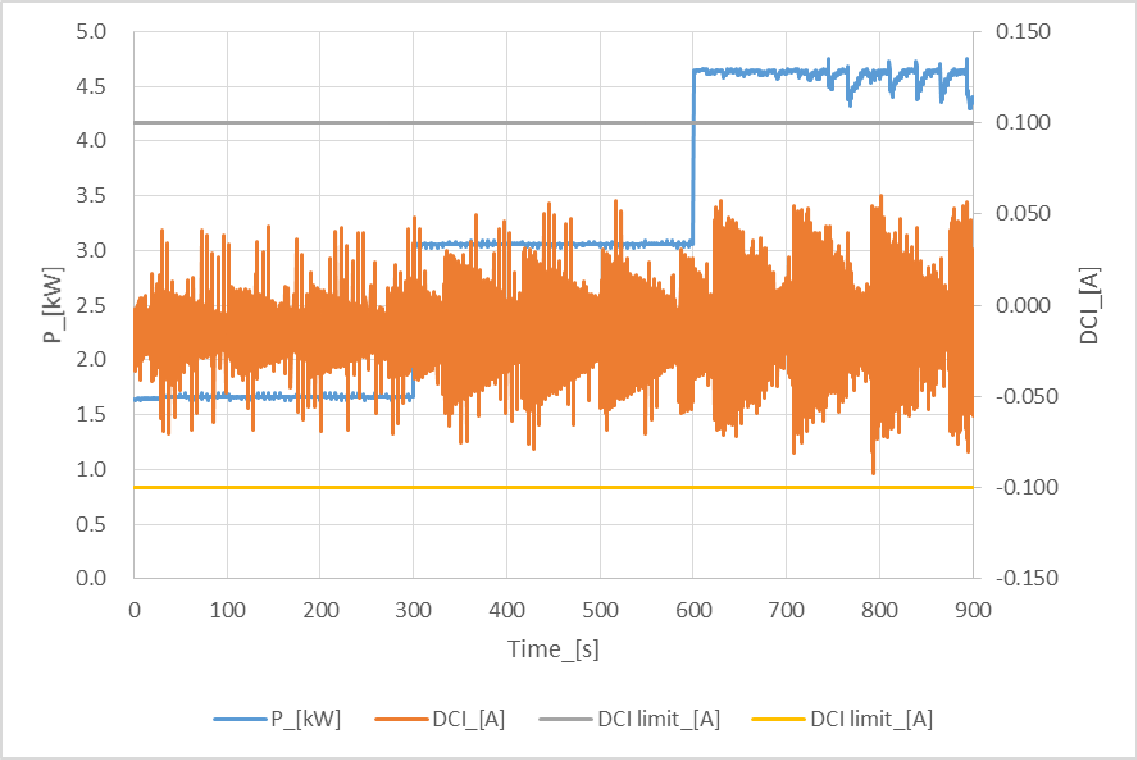


Diagram of Feed in of DC current: HYD 4600-ES



5.3	Evidence of symmetry behaviour of inverters	
Clause	**Requirement – Test**	**Verdict**
5.3.1	General	**N/A**
5.3.2.1	Calculation of the asymmetry of three-phase inverters	**N/A**
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**

5.4	Evidence of the behaviour of the generating unit on the network	
Clause	**Requirement – Test**	**Verdict**
5.4.1	General	**P**
5.4.2	Measurement of the active and reactive power range	**P**
5.4.3.3	Measurement of setting accuracy	**P**
5.4.3.4	Measurement of the power gradient	**P**
5.4.3.5	Measurement Priority Interfaces / Energy Management	**N/A**
5.4.4	Active power feed-in for PGUs at overfrequency	**P**
5.4.5	Active power feed-in of Storage systems for overfrequency	**N/A**
5.4.6	Active power feed-in for PGUs at underfrequency	**P**
5.4.7	Active power feed-in for storage systems at underfrequency	**N/A**
5.4.8	Static voltage stability / reactive power supply	**P**
5.4.8.2	Tests of the Reactive power / cos φ setting accuracy	**P**
	The regulating and control behaviour of the reactive power	**P**
5.4.8.3	Test of the displacement factor/active power characteristic curve cos φ (P)	**P**
	Test 1) for conducted PGUs - Accuracy (characteristic)	**P**
	Test 2) for conducted PGUs - dynamics	**P**
	Test 3) supply-dependent PGUs - Accuracy (characteristic curve)	**P**
	Test 4) supply-dependent PGUs - Dynamic	**P**
5.4.8.4.1	Test of the accuracy of the Q(U) regulation	**P**
5.4.8.4.2	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 S_{Emax} and P_{Emax})	**P**
Test Condition:	The measurements were performed in the testing laboratory at the grid-simulator. Test voltage between 0,9 Un and 1,09 Un with ± 2% Un until the test Test frequency: 50 Hz ± 0,5%	
Note: If an examination is required for any other requirements, these apply to this test.		

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 4105:2018-11, 5.7.2.2 are met)	**P**

Setting values	cos φ = 1:	1,0
	cos φ over-excited:	0,9
	cos φ under-excited:	0,9

Test: HYD 3000-ES				
600 s mean value	U [V]	$P_{Emax600\ c)}$ [W]	$S_{Emax600\ c)}$ [VA]	cos $\varphi_{Emax600}$ [1]
0,90 U_n at 100% P_{Emax}				
cos φ = 1	207,32	3067	3068	0,9998
cos φ max. over-excited	207,64	2873	3176	0,9045
0,95 U_n at 100% P_{Emax}				
cos φ max. under-excited	219,03	2872	3180	0,9032
1,0 U_n at 100% P_{Emax}				
cos φ = 1	230,18	3048	3049	0,9998
cos φ max. under-excited	230,36	2874	3186	0,9021
cos φ max. over-excited	230,24	2828	3139	0,9011
1,05 U_n at 100% P_{Emax}				
cos φ max. over-excited	241,66	2829	3136	0,9019
1,09 U_n at 100% P_{Emax}				
cos φ = 1	250,57	3031	3032	0,9998
cos φ max. under-excited	251,08	2829	3134	0,9027
$S_{Emax600}$ and $P_{Emax\ 600}$				
$S_{Emax600}$= max($S_{Emax600\ a)}$, $S_{Emax600\ b)}$, $S_{Emax600\ c)}$) [VA]		3186		
$P_{Emax\ 600}$= max($P_{Emax600\ a)}$, $P_{Emax600\ b)}$, $P_{Emax600\ c)}$) [W]		3067		

Test: HYD 3600-ES				
600 s mean value	U [V]	$P_{Emax600\ c)}$ [W]	$S_{Emax600\ c)}$ [VA]	cos $\varphi_{Emax600}$ [1]
0,90 U_n at 100% P_{Emax}				
cos φ = 1	207,66	3623	3624	0,9998
cos φ max. over-excited	207,54	3431	3815	0,8995
0,95 U_n at 100% P_{Emax}				
cos φ max. under-excited	218,90	3439	3828	0,8984
1,0 U_n at 100% P_{Emax}				
cos φ = 1	230,37	3622	3622	0,9998
cos φ max. under-excited	230,34	3428	3820	0,8972
cos φ max. over-excited	207,44	3469	3844	0,9024
1,05 U_n at 100% P_{Emax}				
cos φ max. over-excited	241,74	3436	3834	0,8961

1,09 U_n at 100% P_{Emax}				
cos φ = 1	251,16	3625	3626	0,9997
cos φ max. under-excited	251,03	3467	3828	0,9055
$S_{Emax600}$ and $P_{Emax\ 600}$				
$S_{Emax600}$= max($S_{Emax600\ a)}$, $S_{Emax600\ b)}$, $S_{Emax600\ c)}$) [VA]		2844		
$P_{Emax\ 600}$= max($P_{Emax600\ a)}$, $P_{Emax600\ b)}$, $P_{Emax600\ c)}$) [W]		3625		
Test: HYD 4000-ES				
600 s mean value	U [V]	$P_{Emax600\ c)}$ [W]	$S_{Emax600\ c)}$ [VA]	cos $φ_{Emax600}$ [1]
0,90 U_n at 100% P_{Emax}				
cos φ = 1	207,57	4043	4044	0,9998
cos φ max. over-excited	207,51	3726	4142	0,8996
0,95 U_n at 100% P_{Emax}				
cos φ max. under-excited	218,81	3599	4006	0,8983
1,0 U_n at 100% P_{Emax}				
cos φ = 1	230,24	4057	4058	0,9998
cos φ max. under-excited	230,26	3720	4146	0,8973
cos φ max. over-excited	230,15	3736	4134	0,9037
1,05 U_n at 100% P_{Emax}				
cos φ max. over-excited	241,67	3729	4160	0,8963
1,09 U_n at 100% P_{Emax}				
cos φ = 1	251,06	4042	4044	0,9997
cos φ max. under-excited	251,00	3739	4129	0,9057
$S_{Emax600}$ and $P_{Emax\ 600}$				
$S_{Emax600}$= max($S_{Emax600\ a)}$, $S_{Emax600\ b)}$, $S_{Emax600\ c)}$) [VA]		4160		
$P_{Emax\ 600}$= max($P_{Emax600\ a)}$, $P_{Emax600\ b)}$, $P_{Emax600\ c)}$) [W]		4057		
Test: HYD 4600-ES				
600 s mean value	U [V]	$P_{Emax600\ c)}$ [W]	$S_{Emax600\ c)}$ [VA]	cos $φ_{Emax600}$ [1]
0,90 U_n at 100% P_{Emax}				
cos φ = 1	207,57	4599	4599	0,9998
cos φ max. over-excited	207,59	4140	4600	0,8996
0,95 U_n at 100% P_{Emax}				
cos φ max. under-excited	218,81	4031	4487	0,8983
1,0 U_n at 100% P_{Emax}				
cos φ = 1	230,33	4595	4596	0,9998
cos φ max. under-excited	230,26	4121	4593	0,8973
cos φ max. over-excited	230,19	4149	4589	0,9041
1,05 U_n at 100% P_{Emax}				
cos φ max. over-excited	241,67	4131	4585	0,8963
1,09 U_n at 100% P_{Emax}				

cos φ = 1	251,14	4597	4598	0,9997
cos φ max. under-excited	251,02	4166	4599	0,9058
$S_{Emax600}$ and $P_{Emax\ 600}$				
$S_{Emax600}$= max($S_{Emax600\ a)}$, $S_{Emax600\ b)}$, $S_{Emax600\ c)}$) [VA]		4600		
$P_{Emax\ 600}$= max($P_{Emax600\ a)}$, $P_{Emax600\ b)}$, $P_{Emax600\ c)}$) [W]		4599		

5.4.3 5.4.3.3	**Measurement of setting accuracy**	**P**

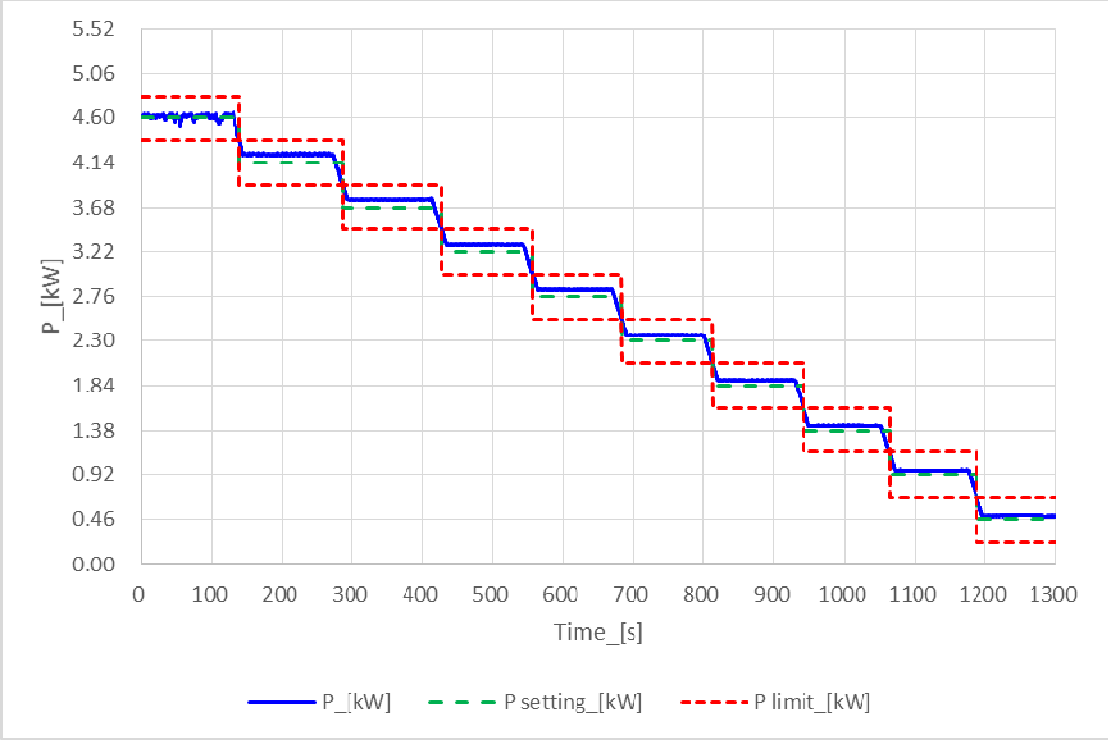
Test:

HYD 4600-ES

1-min mean value P/P_{rE} [%]	100	90	80	70	60	50	40	30	20	10
$P_{Setpoint}$ [W]	4,600	4,140	3,680	3,220	2,760	2,300	1,840	1,380	0,920	0,460
P_{E60} [W]	4,611	4,226	3,761	3,296	2,829	2,364	1,898	1,432	0,965	0,494
ΔP_{E60} [%]	0,249	1,879	1,753	1,645	1,495	1,389	1,257	1,126	0,972	0,747

Limit		
ΔP_{E60} in %	≤ ±5% of P_{rE}	P

Graph of the setting accuracy:



Test:

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

For adjustable PGUs in increments of 10% P_{rE} 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.

Assessment criterion:

a) for adjustable PGUs:
- no network disconnection
- the active power value does not exceed the setpoint by more than ±5% P_{rE}
- the setting time determined this way is ≤1min

Note:

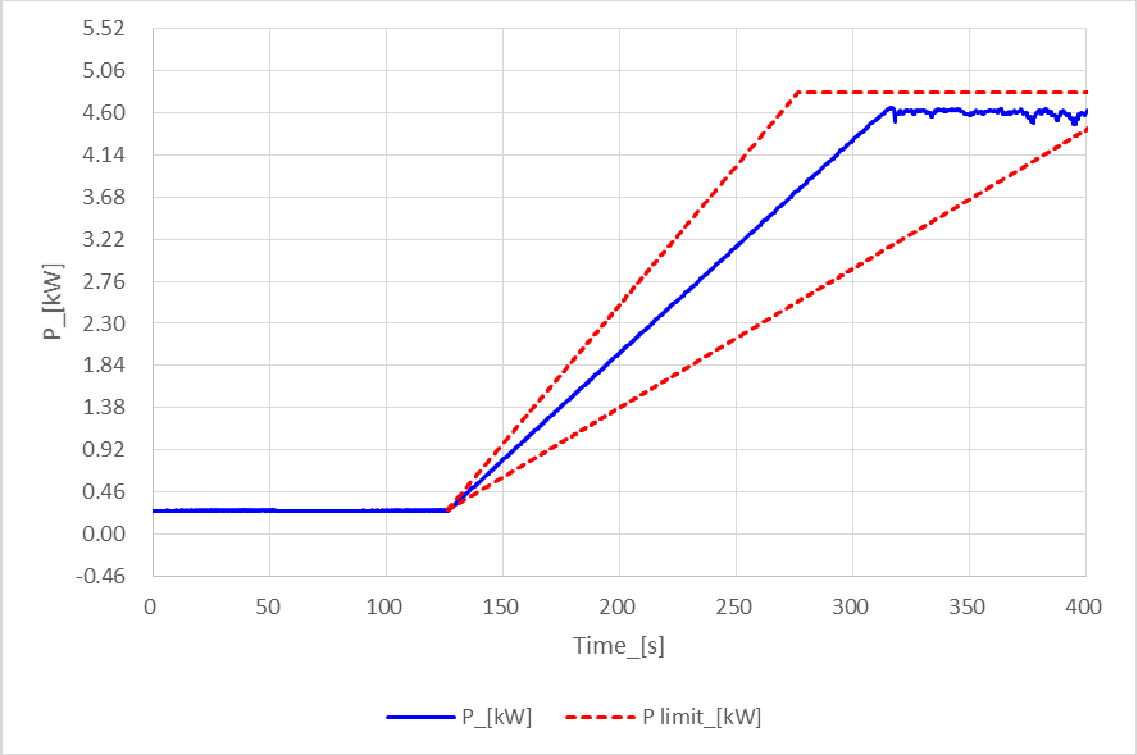
The setting time is ≤ 1min. See below "Graph of the setting accuracy".

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

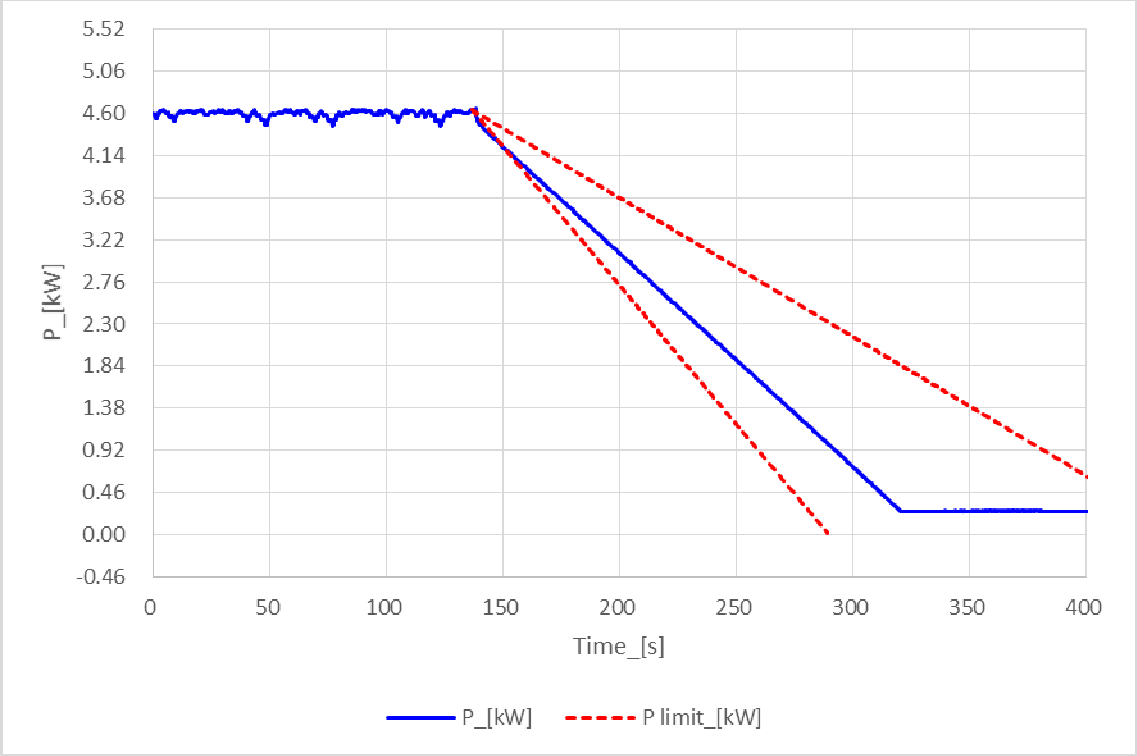
5.4.3.4	Measurement of the power gradient	P

Inverter name

Graph of the gradient <5% to 100% P_{rE}



Graph of the gradient 100% to <5% P_{rE}



Test:

The measurement of the power gradient takes place :

- Via a setpoint change from 100% to 5% of the rated effective power P_{rE} at time t_0. If the technical performance is >5%, this should be specified.

- Via a setpoint change from 5% to 100% of the rated effective power P_{rE} at time t_0. Is the technical Performance >5%, this should be specified.

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

Assessment criterion:

for adjustable PGUs:

- no network disconnection

- the active power value does not exceed the setpoint by more than 5% P_{rE}

- the power gradient determined according 5.4.3.4 not be less than 0,33% P_{rE}/s and not more than 0,66% P_{rE}/s. The first gradient is to be created 30 s after the setpoint jump has been set.

The formation of gradients is ended 30 s before the static end value is reached.

NOTE These times were determined by the maximum or minimum prescribed gradients and with a performance delta of ±10% P_{rE} around the target value.

5.4.4	**Active power feed-in for PGU´s at overfrequency** (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)	**P**

Test cycle for adjustable PGUs:										
HYD 4600-ES										
Test 1:										
1-min mean value:	50,00	50,25	50,70	51,40	50,70	50,25	50,00	51,65	50,15	50,00
Expected active power output [% of P_{Emax}]	100	98	80	52	80	98	100	0	0	100
Measurement: 100% P_{Emax}; start frequency 50,20Hz; droop s setting = 5% (40% P_{ref}/Hz)										
Frequency [Hz]	50,00	50,25	50,70	51,40	50,70	50,25	50,00	51,60	50,15	50,00
$P_{setpoint}$ [W]	100,00	98,00	80,00	52,00	80,00	98,00	100,00	0,00	0,00	100,00
P_{E60} [W]	100,72	100,02	81,78	53,33	81,78	100,04	99,65	0,00	0,00	99,96
ΔP_{E60} [%]	0,72	2,02	1,78	1,33	1,78	2,04	-0,35	0,00	0,00	-0,04
Available DC-power [%]	100									

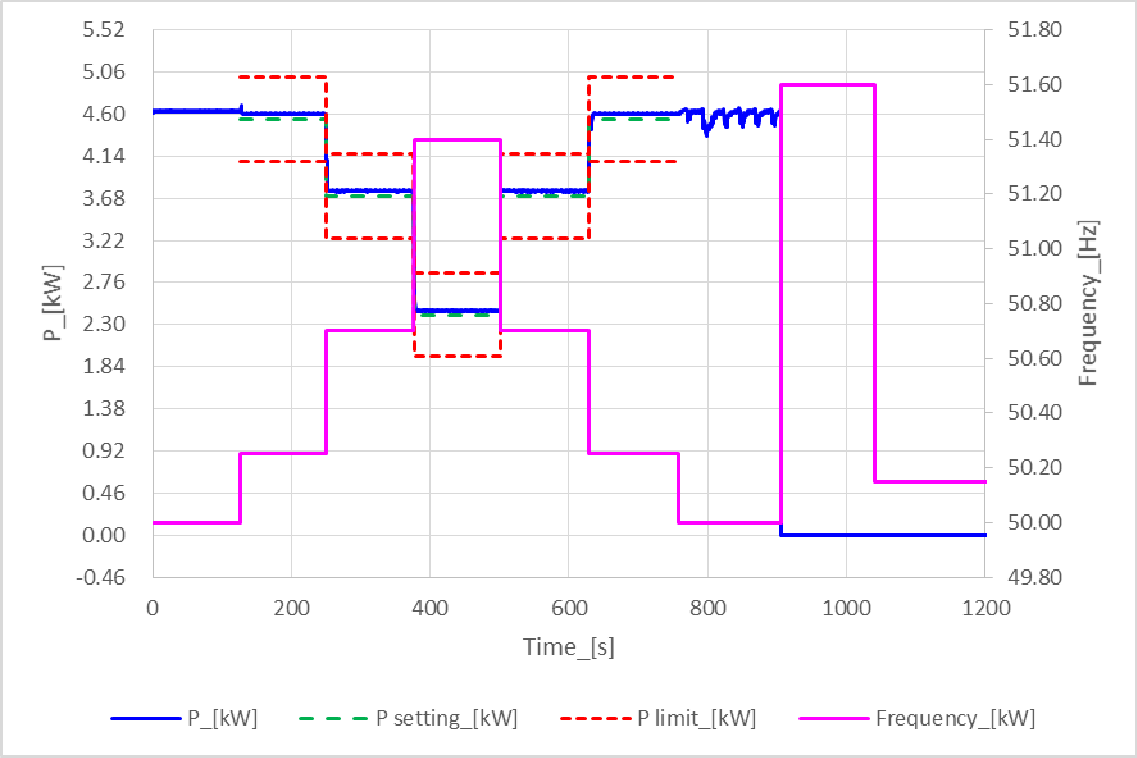
Test 2:							
1-min mean value:	50,00	50,40	50,70	51,40	50,70	50,40	50,00
Expected active power output [% of P_{Emax}]	60	60	58	51	58	60 - 100	100
Measurement: 60% P_{Emax}; start frequency 50,50Hz; droop s setting = 12% (16,67% P_{ref}/Hz)							
Frequency [Hz]	50,00	50,40	50,70	51,40	50,70	50,40	50,00
$P_{setpoint}$ [W]	60,00	60,00	58,00	51,00	58,00	60,00	100,00
P_{E60} [W]	60,17	60,17	57,63	50,50	57,63	59,80	99,89
ΔP_{E60} [%]	0,17	0,17	-0,37	-0,50	-0,37	-0,20	-0,11
Available DC-power [%]	60		100				

Limit		
ΔP_{E60} in %	≤ ±10% of P_{Emax}	P

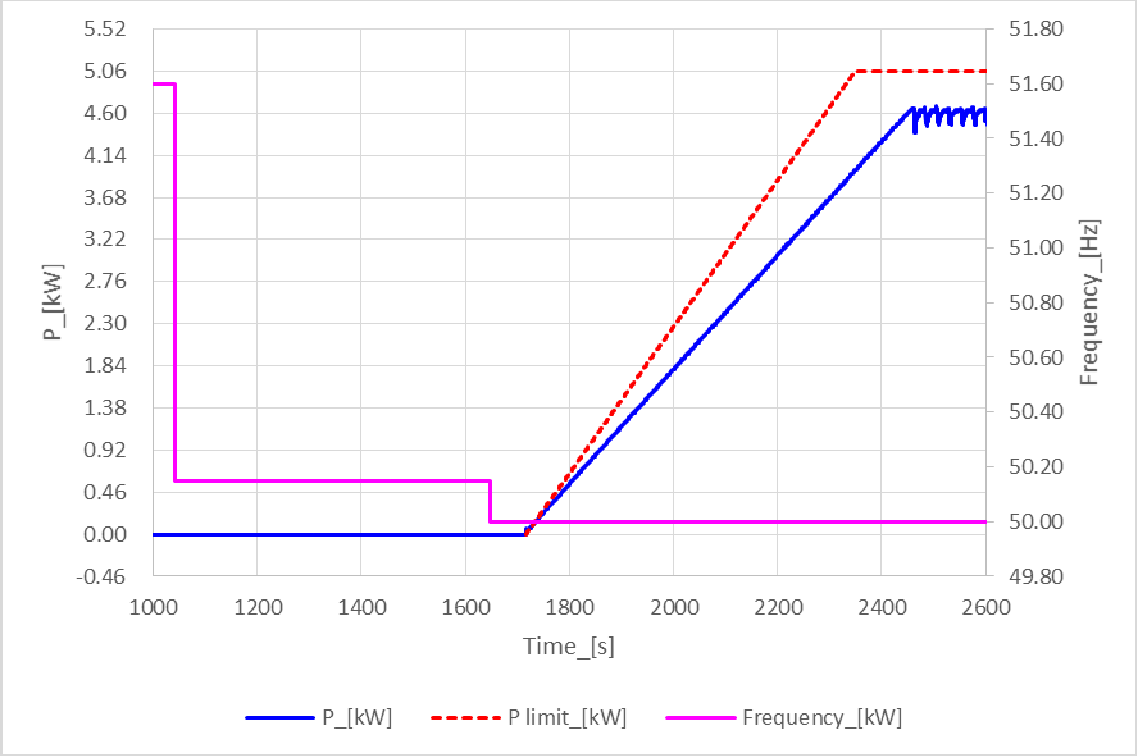
DC setting values:	
PV-curve simulated according to	/
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	12,368A
FFU of PV curve [1]	1
P_{DC} [kW]	4,700

5.4.4	**Active power feed-in for PGU´s at overfrequency** (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)	**P**

Graph Test 1@ 100% P_{Emax}

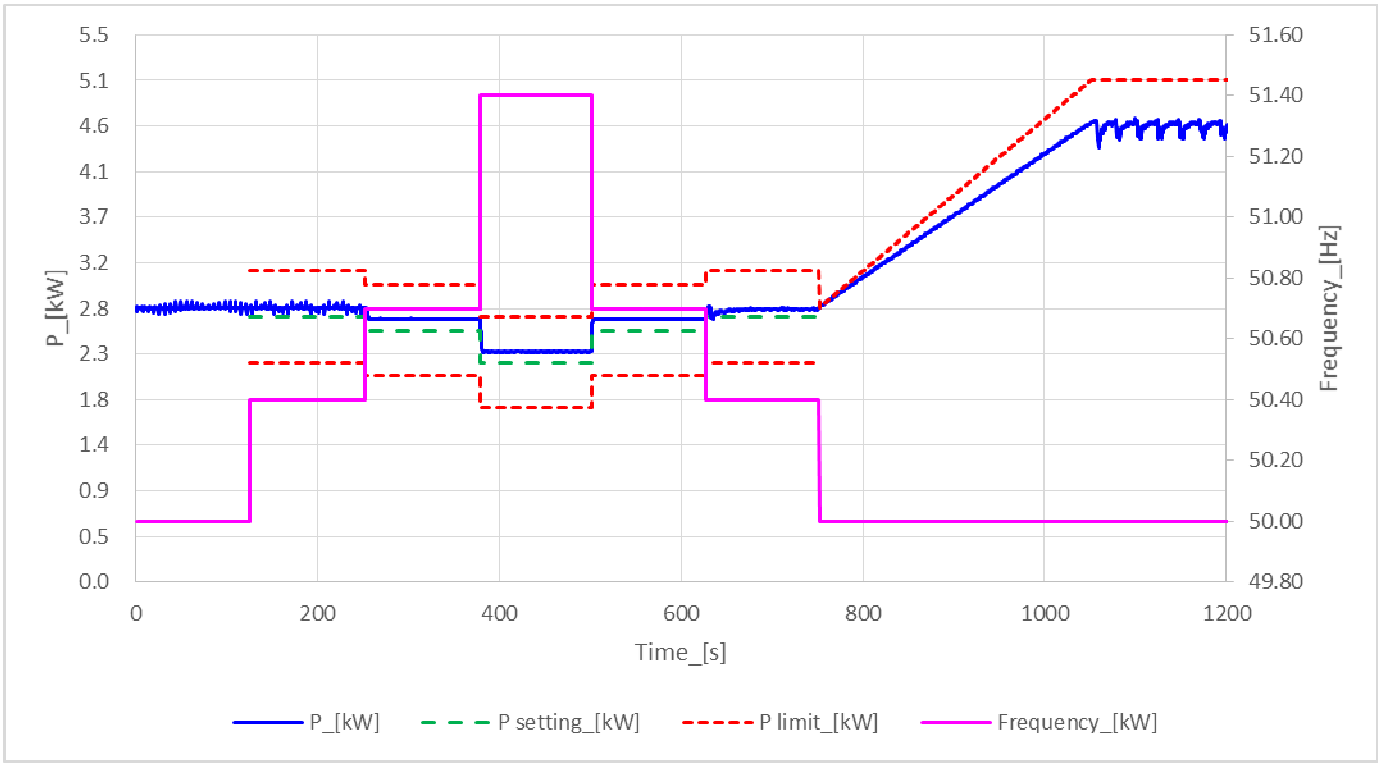


Gradient Test 1



5.4.4	**Active power feed-in for PGU´s at overfrequency** (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)	**P**

Graph Test2 @ 60% P_{Emax}



5.4.4	**Active power feed-in for PGU´s at overfrequency** (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)	**P**

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}.

In the measurement points h) and i) shall no active power be given.

- 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 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 PGU, 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 proofed by a manufacturer's declaration.

d) for linear generators with S_{Emax} ≤ 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).

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

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**

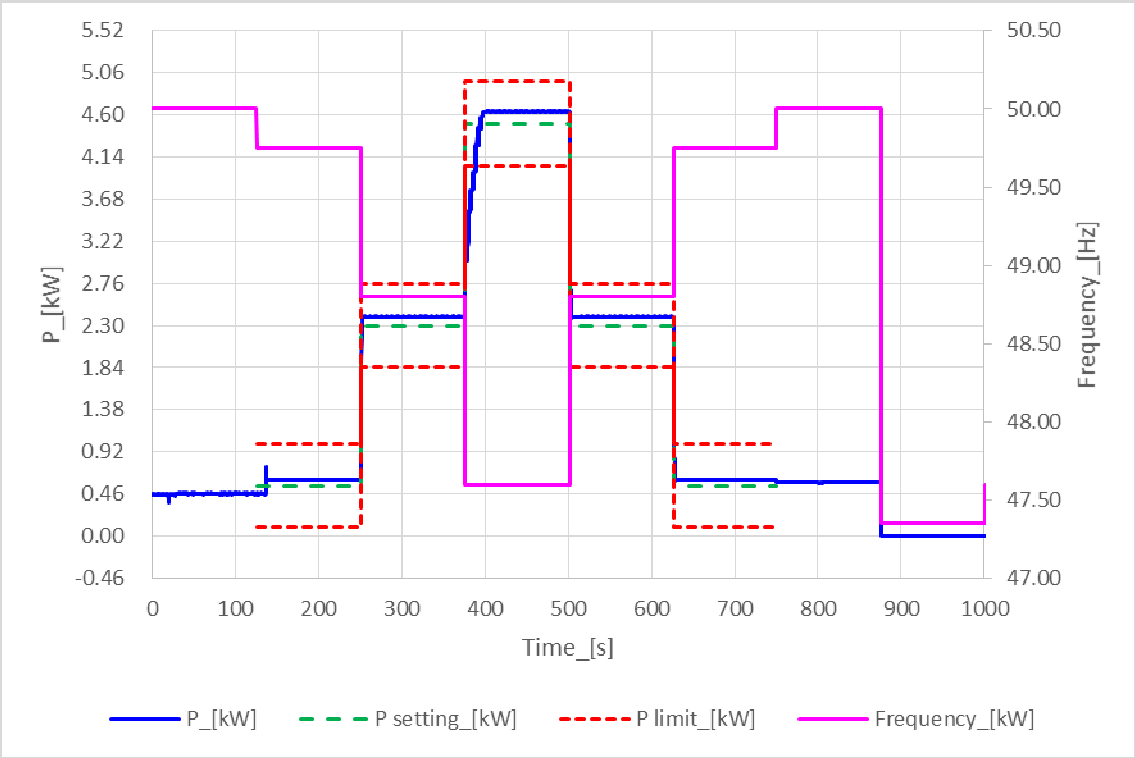
Test cycle for adjustable PGUs:										
HYD 4600-ES										
Test 1:										
1-min mean value:	50,00	49,75	48,80	47,60	48,80	49,75	50,00	47,35	47,60	50,00
Expected active power output [% of P_{Emax}]:	10	12	50	98	50	12	100	0	0	10
Measurement: 10% P_{Emax}; start frequency 49,80Hz; droop s setting = 5% (40% P_{ref}/Hz)										
Frequency [Hz]:	50,00	49,75	48,80	47,60	48,80	49,75	50,00	47,35	47,60	50,00
$P_{setpoint}$ [W]:	10,00	12,00	50,00	98,00	50,00	12,00	10,00	0,00	0,00	10,00
P_{E60} [W]:	9,96	13,33	52,04	100,76	52,07	13,33	12,70	0,00	0,00	10,07
ΔP_{E60} [%]	-0,04	1,33	2,04	2,76	2,07	1,33	2,70	0,00	0,00	0,07
Available DC-power [%]:	100									

Test 2:							
1-min mean value:	50,00	49,75	49,20	48,80	49,20	49,85	50,00
Expected active power output [% of P_{Emax}]:	60	62	84	100	84	60	60
Measurement: 60% P_{Emax}; start frequency 49,80Hz; droop s setting = 5% (40% P_{ref}/Hz)							
Frequency [Hz]:	50,00	49,75	49,20	48,80	49,20	49,85	50,00
$P_{setpoint}$ [W]:	60,00	62,00	84,00	100,00	84,00	60,00	60,00
P_{E60} [W]:	60,93	64,13	86,52	99,50	86,54	62,63	62,63
ΔP_{E60} [%]	0,93	2,13	2,52	-0,50	2,54	2,63	2,63
Available DC-power [%]:	60						

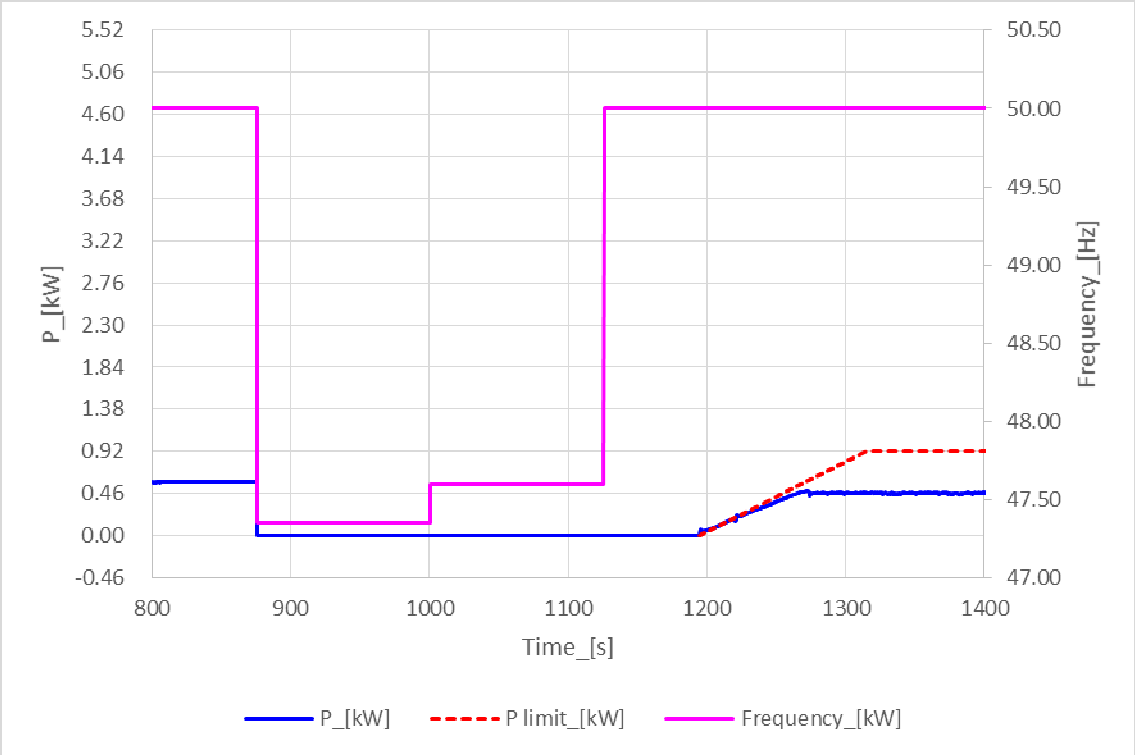
Limit:		
ΔP_{E60} in %	≤ ±10% of P_{Emax}	P

DC setting values:	
PV-curve simulated according to	/
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	12,368A
FFU of PV curve [1]	1
P_{DC} [W]	4,700

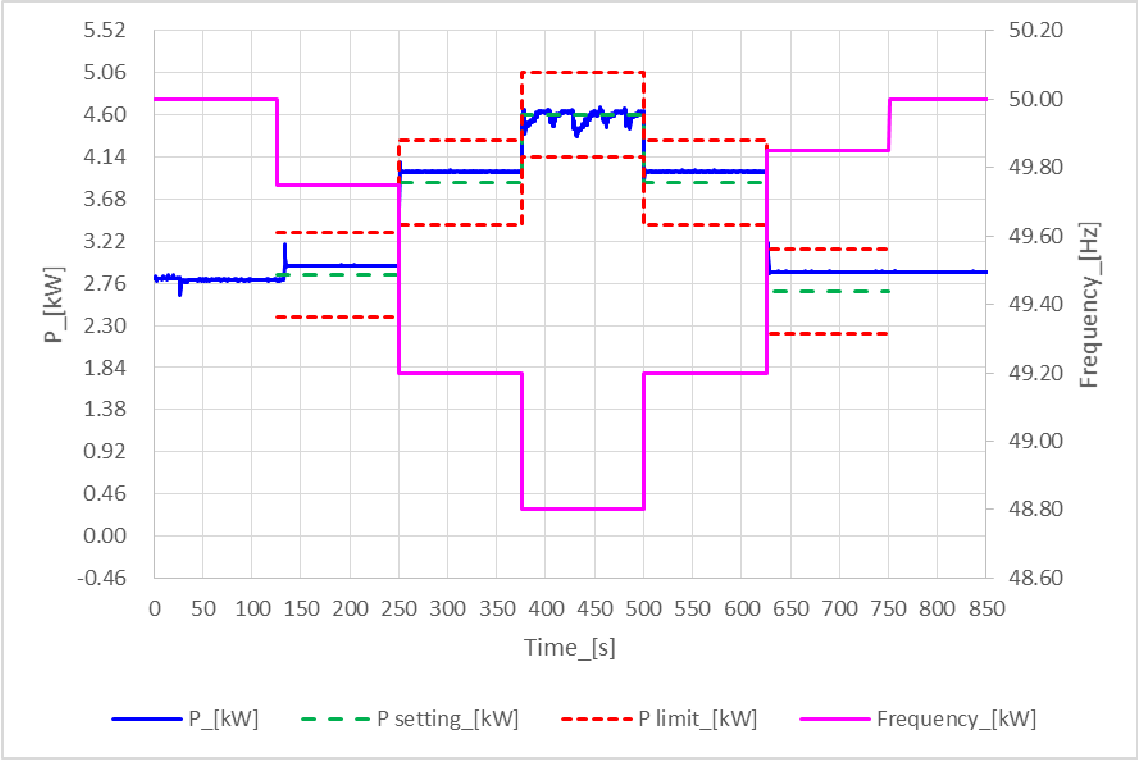
Graph Test 1@ 100% P_{Emax}



Gradient Test 1



Graph Test2 @ 60% P_{Emax}



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 PGU, 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 proofed 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 resynchronization/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:

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

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 PGU in normal operation.	
5.4.8.2	**Tests of the Reactive power / cos φ setting accuracy**	**P**

Setting values	cos φ under-excited	0,90	0,95
	cos φ over-excited	0,90	0,95

Test:

HYD 3000-ES

60 s mean value	0,9 U_n		U_n		1,1 U_n	
Active power	40 – 60% P_{Emax}	S_{Emax}	40 – 60% P_{Emax}	S_{Emax}	40 – 60% P_{Emax}	S_{Emax}
cos φ 0,9 over-excited						
U [V]	227,08	207,29	230,08	230,13	253,08	253,03
P_{E60} [W]	1464	2845	1464	2840	1453	2840
Q_{E60} [VAr]	700	1346	702	1362	712	1378
S_{E60} [VA]	1622	3148	1624	3150	1619	3156
cos $\varphi_{E60\ over\text{-}excited}$	0,9022	0,9039	0,9017	0,9016	0,8980	0,8997
$Q_{expected}$ [VA]	707	1372	708	1373	705	1376
ΔQ_{E60} [%]	-0,25	-0,87	-0,20	-0,35	0,21	0,06
cos φ 0,9 under-excited						
U [V]	206,95	227,09	229,89	230,13	252,82	252,96
P_{E60} [W]	1525	2919	1529	2920	1518	2920
Q_{E60} [VAr]	-750	-1411	-738	-1410	-715	-1394
S_{E60} [VA]	1700	3243	1698	3243	1678	3236
cos $\varphi_{E60\ under\text{-}excited}$	0,8973	0,9003	0,9005	0,9005	0,9048	0,9025
$Q_{expected}$ [VA]	-741	-1413	-740	-1414	-731	-1411
ΔQ_{E60} [%]	-0,30	0,07	0,07	0,11	0,56	0,56
cos φ 0,95 over-excited						
U [V]	207,14	207,25	230,12	230,18	253,01	253,05
P_{E60} [W]	1508	2972	1512	2962	1499	2977
Q_{E60} [Var]	474	950	492	965	504	985
S_{E60} [VA]	1581	3120	1590	3116	1582	3135
cos $\varphi_{E60\ over\text{-}excited}$	0,9540	0,9525	0,9509	0,9508	0,9478	0,9493
$Q_{expected}$ [VA]	494	974	497	973	494	979
ΔQ_{E60} [%]	-0,65	-0,81	-0,15	-0,27	0,35	0,21

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 PGU in normal operation.	
5.4.8.2	**Tests of the Reactive power / cos φ setting accuracy**	**P**

Setting values	cos φ under-excited	0,90	0,95
	cos φ over-excited	0,90	0,95

cos φ 0,95 under-excited						
U [V]	207,13	207,19	228,36	230,11	248,62	253,00
P_{E60} [W]	1528	3013	1531	2972	1522	3018
Q_{E60} [Var]	-516	-1004	-504	-977	-486	-976
S_{E60} [VA]	1613	3176	1612	3129	1597	3172
cos $\varphi_{E60\ under\text{-}excited}$	0,9473	0,9487	0,9498	0,9499	0,9526	0,9515
$Q_{expected}$ [VA]	-504	-992	-503	-977	-499	-991
ΔQ_{E60} [%]	-0,42	-0,40	-0,03	-0,02	0,43	0,50

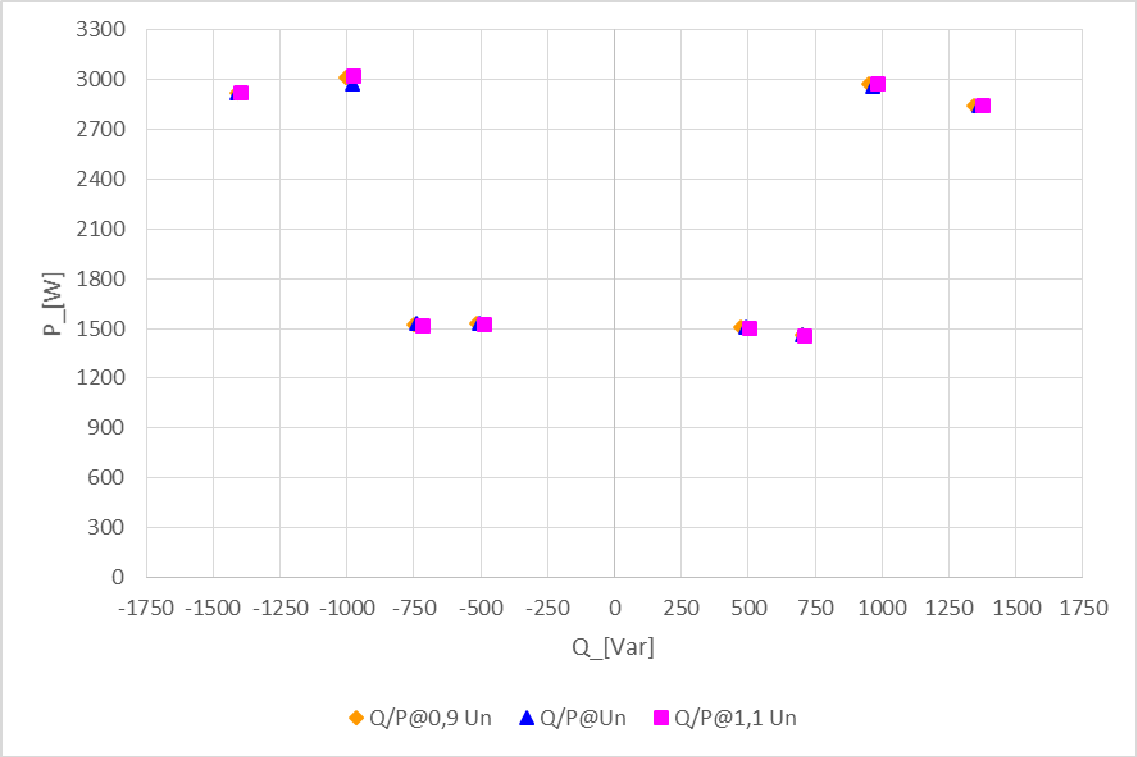
HYD 4600-ES						
60 s mean value	0,9 U_n		U_n		1,1 U_n	
Active power	40 – 60% P_{Emax}	S_{Emax}	40 – 60% P_{Emax}	S_{Emax}	40 – 60% P_{Emax}	S_{Emax}
cos φ 0,9 over-excited						
U [V]	207,21	207,26	230,1	230,17	253,05	253,02
P_{E60} [W]	2200	4150	2208	4143	2189	4147
Q_{E60} [VAr]	1030	1964	1059	1987	1074	2012
S_{E60} [VA]	2430	4592	2449	4595	2438	4609
cos $\varphi_{E60\ over\text{-}excited}$	0,9057	0,9039	0,9017	0,9016	0,8977	0,8997
$Q_{expected}$ [VA]	1059	2002	1067	2003	1063	2009
ΔQ_{E60} [%]	-0,63	-0,82	-0,19	-0,34	0,25	0,06
cos φ 0,9 under-excited						
U [V]	206,67	207,2	229,55	219,82	252,75	252,98
P_{E60} [W]	2197	4126	2203	4121	2189	4117
Q_{E60} [VAr]	-1080	-2007	-1063	-1993	-1030	-1964
S_{E60} [VA]	2449	4588	2446	4578	2419	4562
cos $\varphi_{E60\ under\text{-}excited}$	0,8974	0,8992	0,9006	0,9002	0,9049	0,9026
$Q_{expected}$ [VA]	-1067	-2000	-1066	-1995	-1054	-1988
ΔQ_{E60} [%]	-0,28	-0,15	0,07	0,06	0,54	0,54
cos φ 0,95 over-excited						
U [V]	206,67	207,2	229,55	219,82	252,75	252,98
P_{E60} [W]	2197	4126	2203	4121	2189	4117
Q_{E60} [Var]	-1080	-2007	-1063	-1993	-1030	-1964
S_{E60} [VA]	2449	4588	2446	4578	2419	4562

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 PGU in normal operation.					
5.4.8.2	**Tests of the Reactive power / cos φ setting accuracy**					**P**
Setting values	cos φ under-excited			0,90		0,95
	cos φ over-excited			0,90		0,95
$\cos \varphi_{E60 \text{ over-excited}}$	0,8974	0,8992	0,9006	0,9002	0,9049	0,9026
$Q_{expected}$ [VA]	-1067	-2000	-1066	-1995	-1054	-1988
ΔQ_{E60} [%]	-0,28	-0,15	0,07	0,06	0,54	0,54
cos φ 0,95 under-excited						
U [V]	207,06	207,24	229,86	220,56	252,86	253,05
P_{E60} [W]	2268	4362	2275	4343	2258	4364
Q_{E60} [Var]	-766	-1452	-747	-1435	-716	-1409
S_{E60} [VA]	2394	4598	2394	4575	2369	4586
$\cos \varphi_{E60 \text{ under-excited}}$	0,9474	0,9488	0,9500	0,9495	0,9532	0,9516
$Q_{expected}$ [VA]	-747	-1436	-748	-1428	-740	-1432
ΔQ_{E60} [%]	-0,40	-0,36	0,01	-0,14	0,51	0,49
Limit						
$\cos \varphi_{E60}$	cos φ = 0,89 to 0,91 I and cos φ = 0,89 to 0,91 (i) cos φ = 0,94 to 0,96 I and cos φ = 0,94 to 0,96 (i) cos φ = 0,94 to 0,96 I and cos φ = 0,94 to 0,96 (i) cos φ = 0,97 to 0,99 I and cos φ = 0,97 to 0,99 (i)				P	
cos φ settling steps	≤ 0,01				P	
ΔQ_{E60} in %	≤ ±4% P_{Emax}				P	

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 PGU in normal operation.		
5.4.8.2	**Tests of the Reactive power / cos φ setting accuracy**		**P**
Setting values	cos φ under-excited	0,90	0,95
	cos φ over-excited	0,90	0,95

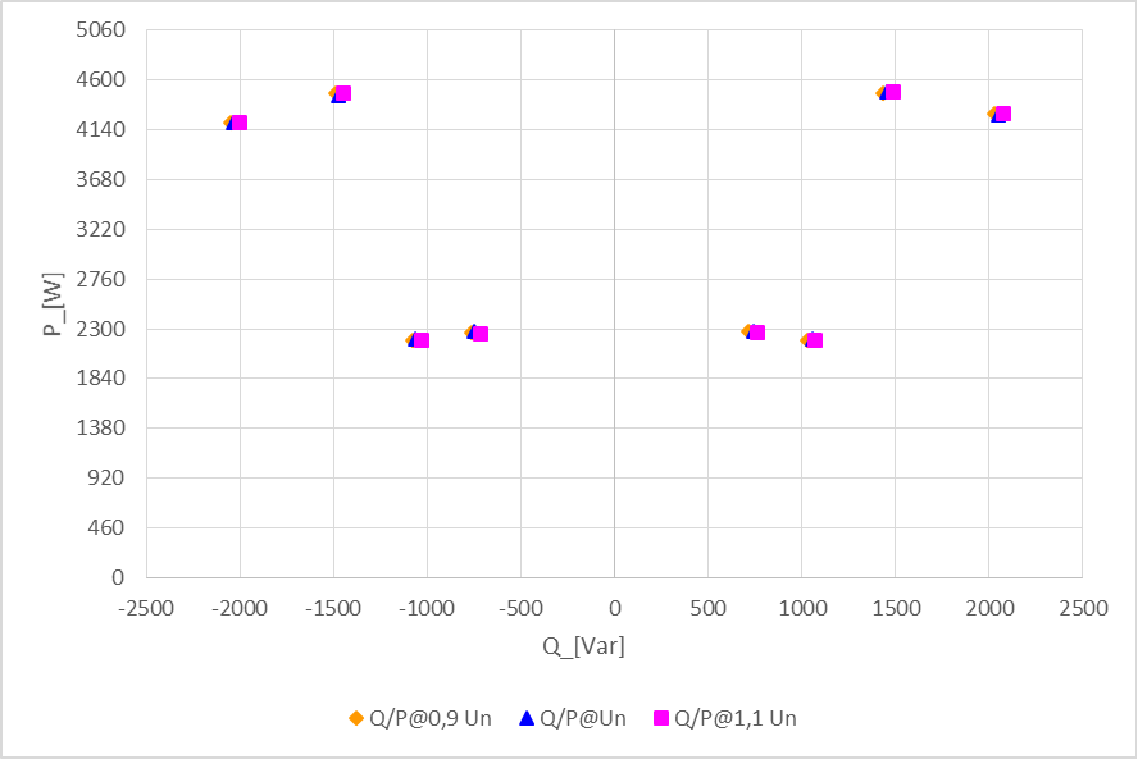
Graph: Q/P diagram

HYD 3000-ES



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 PGU in normal operation.		
5.4.8.2	**Tests of the Reactive power / cos φ setting accuracy**		**P**
Setting values	cos φ under-excited	0,90	0,95
	cos φ over-excited	0,90	0,95

HYD 4600-ES



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 0,98 over-excited and φ 0,98 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 $\Sigma S_{Emax} > 4{,}6$ 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 0,98 over-excited and φ 0,98 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 $S_{Emax.}$ The test is performed only at U_n.

Assessment criterion:

applies for PGUs Type 2 - only inverter $\Sigma S_{Emax} \leq 4{,}6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.95 and one time at 0,98 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 $\Sigma S_{Emax} \geq 4{,}6$ 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 $\Sigma S_{Emax} \leq 4{,}6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.95 and one time at 0,98 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 $\Sigma S_{Emax} \geq 4.6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.95 and one time at 0,98 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 under excited ±0,02.

Note:

The tests had been performed on the HYD 4600-ES and HYD 3000-ES are valid for the HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

	The regulating and control behavior of the reactive power	P

The regulating or control behaviour of the reactive power is based on the PT-1 behaviour shown in Figure 10. Each reactive power value, which results from the control behaviour specified by the network operator, can be set between 6s and 60s (for Type 1 between 10s and 60s). The signal runtime includes the detection of the mains voltage or the active and reactive power.

Step response with the tolerances relevant for the evaluation

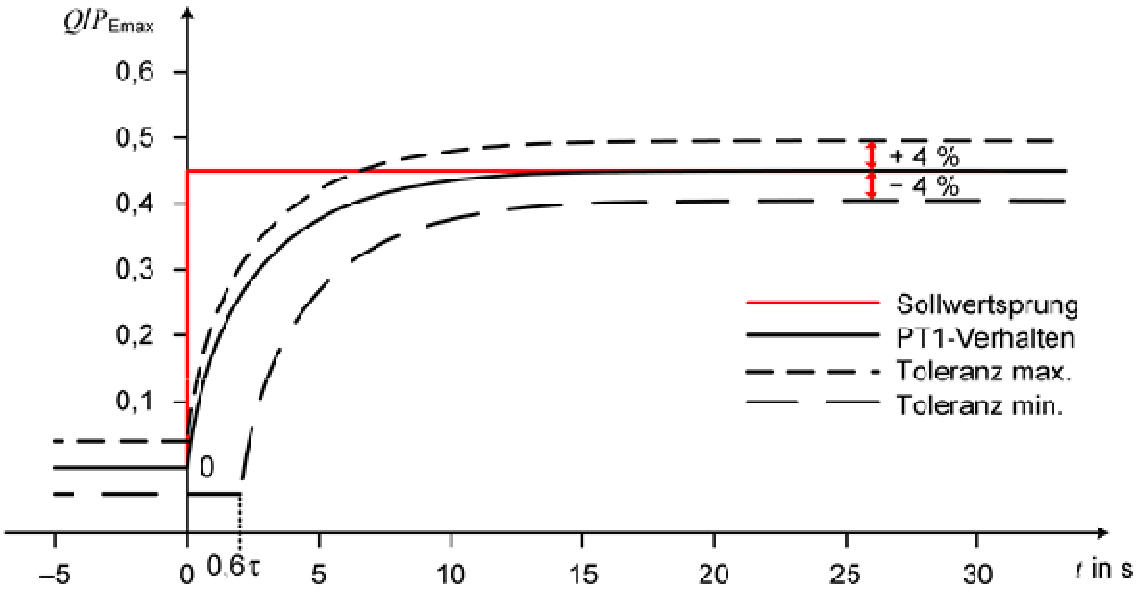


Figure 10 - Illustration at 3 tau = 10 s

Comment:

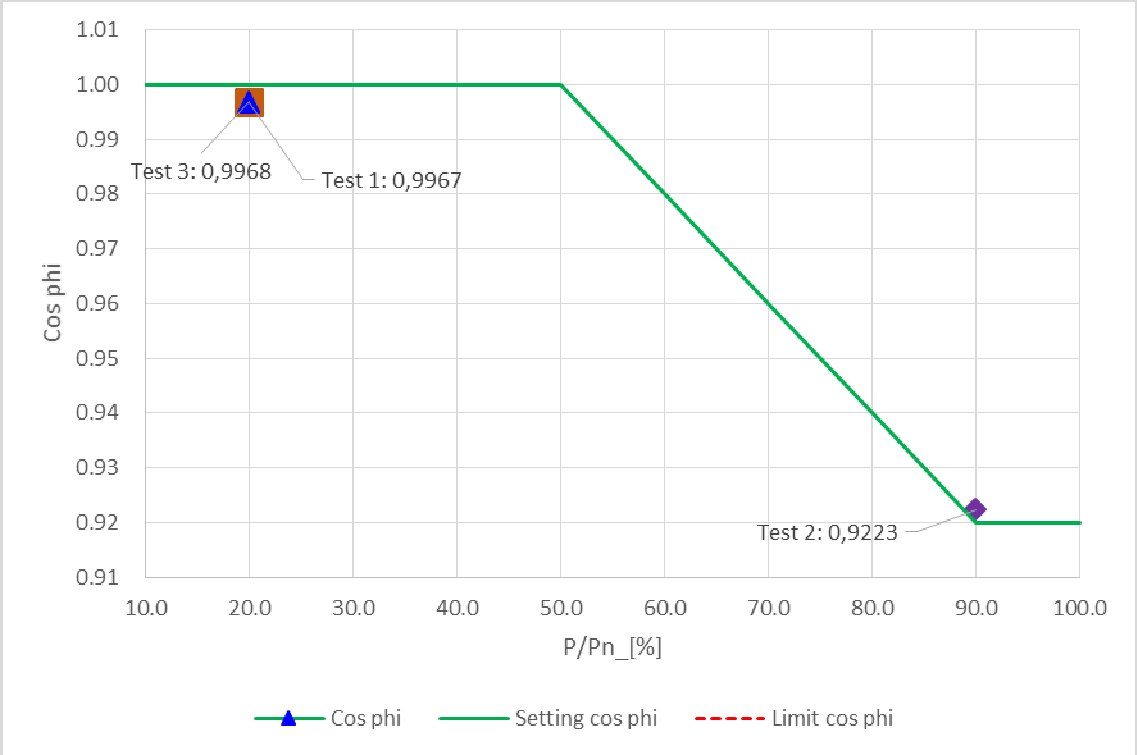
The regulation and control behaviour according to PT-1 is implemented and checked for all reactive power control modes.

5.4.8.3	**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**

HYD 3000-ES			
Test 1) for conducted PGUs - Accuracy (characteristic) (must be used for battery inverter)			
Measurement: 20-100-20% P_{Emax}			
P_{Emax}/P [%]	20	100	20
U [V]	230,3	230,1	230,3
P_{E30} [W]	589	2673	589
P_{E30} of P_{Emax} [%]	19,633	89,100	19,633
Q_{E30} [Var]	24	-1134	24
$Q_{expected}$	0	-1176	0
ΔQ_{E30} [%]	0,80	1,39	0,80
cos φ_{E30}	0,9967	0,9223	0,9968
cos $\varphi_{setpoint}$ of P_{E30}	230,3	230,1	230,3
P gradient [% of P_{rE}/s]	0,52		
Limit			
ΔQ_{E30} in %	≤ ±4,0% relative to P_{Emax}		P
DC setting values:			
DC Battery (Source) input current	60,0A		
DC Battery (Source) input voltage	50,0V		
P_{DC} [W]	3000W		

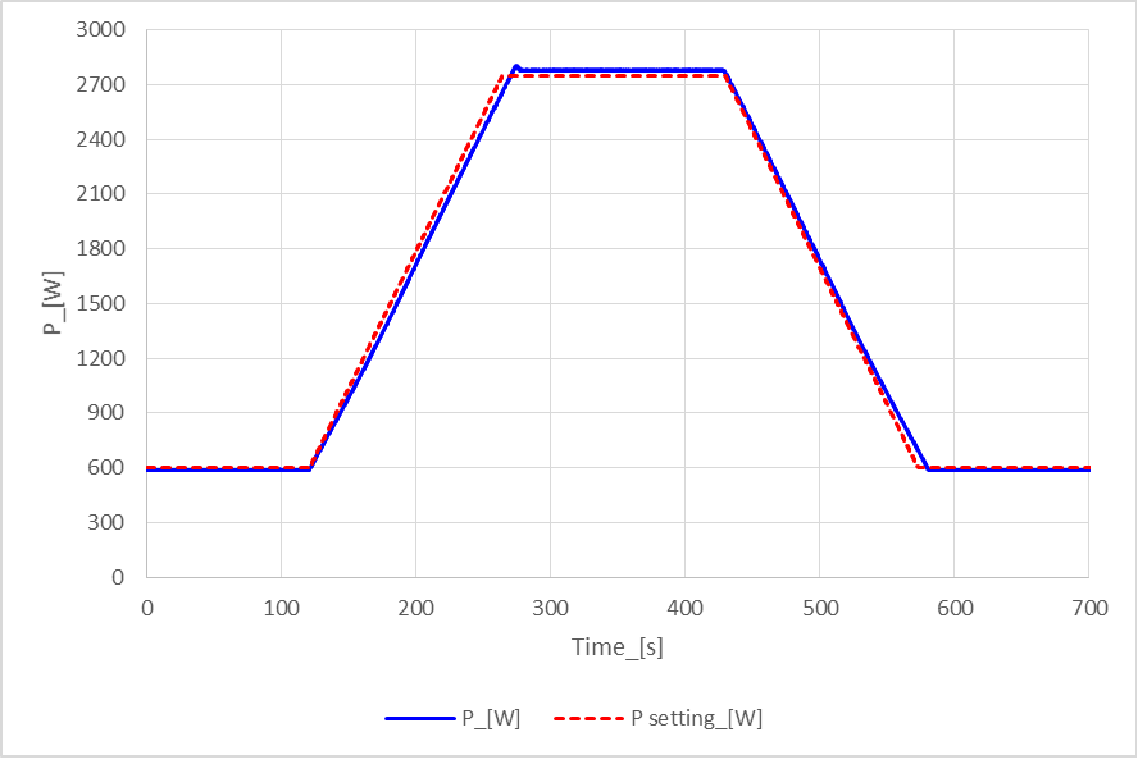
5.4.8.3	**Test of the displacement factor/active power characteristic curve cos φ (P)** The test serves as verification of the standard cos φ (P) curve according to VDE-AR-N 4105:2018-11, 5.7.2.4.	**P**

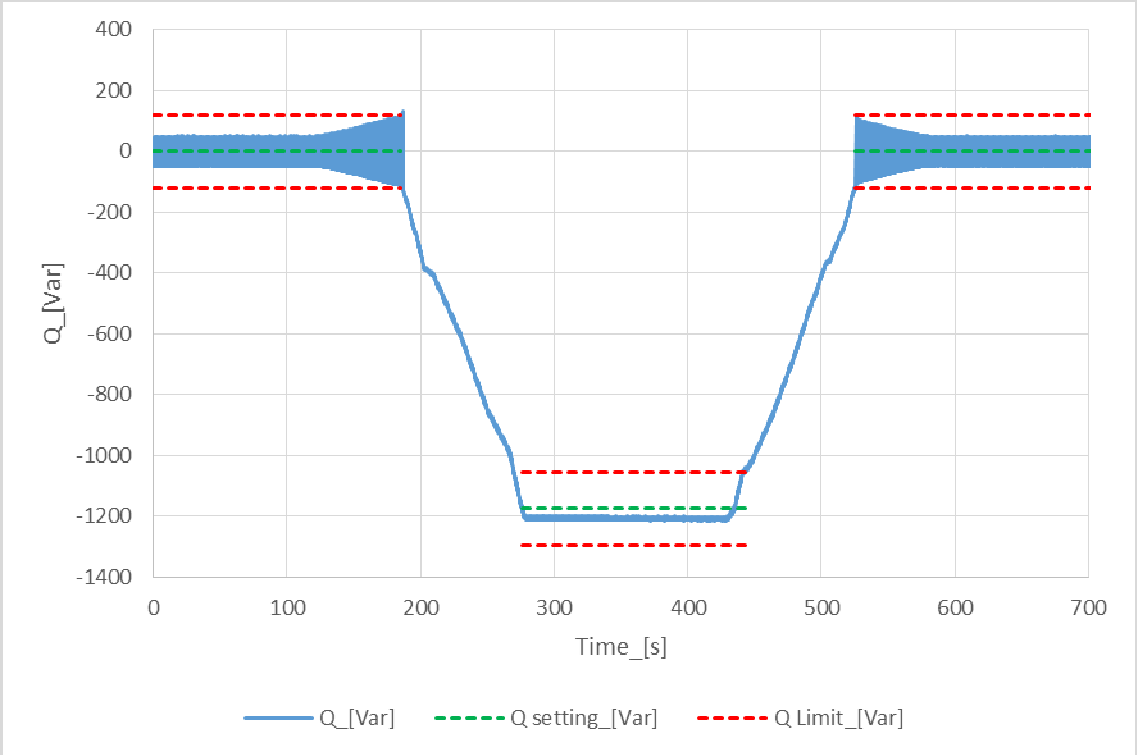
Graph of Test 1)



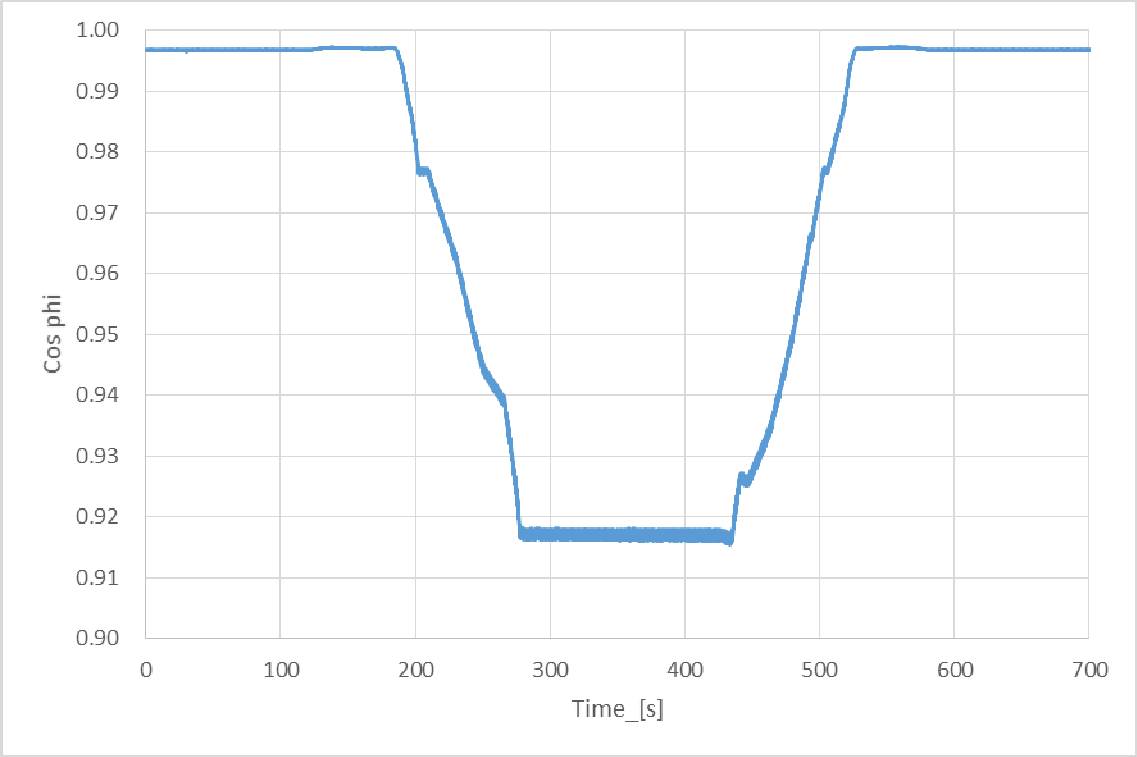
5.4.8.3	**Test of the displacement factor/active power characteristic curve cos φ (P)** The test serves as verification of the standard cos φ (P) curve according to VDE-AR-N 4105:2018-11, 5.7.2.4.	**P**

Graph of Test 1)





5.4.8.3	**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**



Assessment criterion:

Test 5.4.8.3 (1) and (3) are passed if, for all calculated reactive power values, the maximum deviation between the reactive power setpoint (calculated from the characteristic curve to be verified) and the reactive power actual value at the generator terminals is a maximum of ±4,0% based on P_{Emax}.

5.4.8.3	**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**

HYD 4600-ES

Test c) supply-dependent PGUs - Accuracy (characteristic curve)

Measurement: 20-100% P_{Emax}

P_{Emax}/P [%]	20	30	40	50	60	70	80	90	100
U [V]	230,5	230,6	230,8	230,9	230,7	230,7	230,6	230,4	230,4
P_{E30} [W]	936	1390	1872	2336	2796	3254	3709	4147	4215
P_{E30} of P_{Emax} [%]	20,36	30,22	40,68	50,77	60,79	70,75	80,63	90,15	91,63
Q_{E30} [Var]	37	37	48	-31	-577	-954	-1347	-1747	-1812
$Q_{expected}$	0	0	0	0	-577	-954	-1346	-1748	-1811
ΔQ_{E30} [%]	1,12	1,11	1,44	-0,94	0,00	0,00	-0,03	0,03	-0,04
cos φ_{E30}	0,999	0,999	1,000	0,999	0,979	0,960	0,940	0,922	0,919
cos $\varphi_{setpoint}$ of P_{E30}	0,92	0,92	0,94	0,96	0,98	1,00	1,00	1,00	1,00
P_{DC}[W]	969	1449	1927	2404	2880	3356	3829	4320	4361

Measurement: 100-20% P_{Emax}

P_{Emax}/P [%]	100	90	80	70	60	50	40	30	20
U [V]	230,4	230,5	230,6	230,6	230,7	230,9	230,8	230,6	230,5
P_{E30} [W]	4209	4144	3694	3255	2796	2336	1872	1405	936
P_{E30} of P_{Emax} [%]	91,50	90,10	80,30	70,75	60,79	50,78	40,69	30,53	20,35
Q_{E30} [Var]	-1809	-1747	-1330	-956	-578	-50	46	42	37
$Q_{expected}$	-1808	-1747	-1330	-956	-578	0	0	0	0
ΔQ_{E30} [%]	-0,03	-0,01	0,01	0,01	0,00	-1,09	1,01	0,90	0,80
cos φ_{E30}	0,919	0,922	0,941	0,960	0,979	0,999	1,000	1,000	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
P_{DC}[W]	4355	4317	3842	3356	2880	2405	1927	1448	969

Limit

ΔQ_{E30} in %	≤ ±4,0% relative to P_{Emax}	P

HYD 3000-ES									
Test c) supply-dependent PGUs - Accuracy (characteristic curve)									
Measurement: 20-100% P_{Emax}									
P_{Emax}/P [%]	20	30	40	50	60	70	80	90	100
U [V]	230,3	230,4	230,5	230,6	230,7	230,8	230,9	231,0	231,1
P_{E30} [W]	619	914	1226	1529	1829	2126	2421	2715	2793
P_{E30} of P_{Emax} [%]	20,62	30,46	40,86	50,97	60,96	70,85	80,71	90,50	93,10
Q_{E30} [Var]	-19	-33	-27	-31	-385	-643	-910	-1173	-1233
$Q_{expected}$	0	0	0	0	-372	-622	-883	-1163	-1213
ΔQ_{E30} [%]	-0,58	-1,01	-0,83	-0,95	-0,41	-0,63	-0,84	-0,30	-0,58
cos φ_{E30}	1,000	0,999	1,000	1,000	0,979	0,957	0,936	0,918	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
P_{DC}[W]	642	952	1262	1574	1884	2193	2503	2810	2904
Measurement: 100-20% P_{Emax}									
P_{Emax}/P [%]	100	90	80	70	60	50	40	30	20
U [V]	231,0	231,1	230,9	230,8	230,7	230,6	230,5	230,4	230,3
P_{E30} [W]	2794	2715	2422	2125	1829	1530	1225	923	619
P_{E30} of P_{Emax} [%]	93,14	90,50	80,73	70,85	60,95	50,99	40,84	30,76	20,62
Q_{E30} [Var]	-1233	-1195	-911	-642	-385	-31	-27	-24	-19
$Q_{expected}$	-1213	-1163	-883	-622	-372	0	0	0	0
ΔQ_{E30} [%]	-0,60	-0,98	-0,84	-0,62	-0,41	-0,95	-0,82	-0,72	-0,58
cos φ_{E30}	0,917	0,915	0,936	0,957	0,979	1,000	1,000	1,000	1,000
cos $\varphi_{setpoint}$ of P_{E30}	0,92	0,92	0,94	0,96	0,98	1,00	1,00	1,00	1,00
P_{DC}[W]	2906	2810	2503	2193	1884	1575	1262	952	642
Limit									
ΔQ_{E30} in %	≤ ±4,0% relative to P_{Emax}						P		

5.4.8.3	**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 d): supply-dependent PGUs - Dynamic				
HYD 3000-ES				
P_{Emax}/P_n [%]	100	40	100	75
U [V]	230,4	230,8	230,4	230,6
P_{E30} [W]	2703	1304	2760	2281
P_{E30} of P_{Emax} [%]	81,90	39,51	83,62	69,11
Q_{E30} [Var]	-1199	-17	-1220	-751
$Q_{expected}$	-1197	-74	-1186	-751
ΔQ_{E30} [%]	-0,04	1,74	-1,02	-0,02
cos φ_{E30}	0,914	0,998	0,919	0,950
cos $\varphi_{setpoint}$ of P_{E30}	0,92	1	0,92	0,95
T_0[s]	0,0	4,2	4,0	2,0
Limit				
ΔQ_{E30} in %	≤ ±4,0% relative to P_{Emax}		P	

DC setting values:	
PV-curve simulated according to	/
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	7,469A
FFU of PV curve [1]	1
P_{DC} [W]	3026

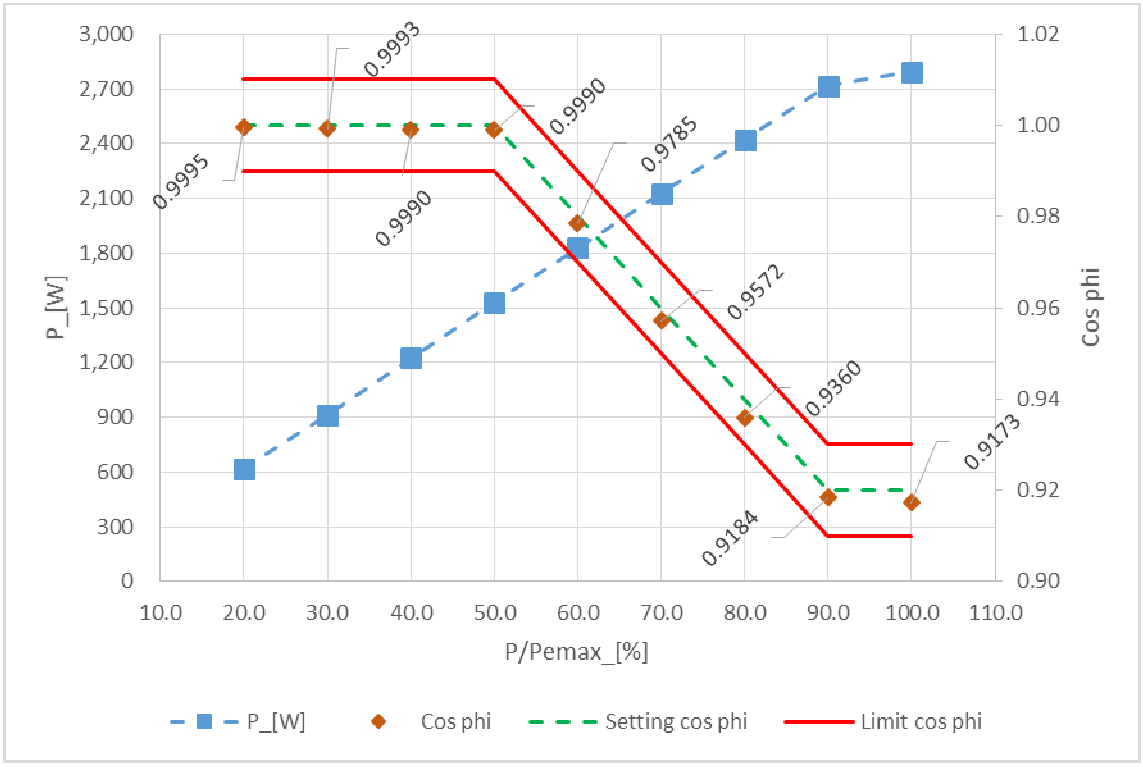
5.4.8.3	**Test of the displacement factor/active power characteristic curve cos φ (P)** The test serves as verification of the standard cos φ (P) curve according to VDE-AR-N 4105:2018-11, 5.7.2.4.	**P**

Test d): supply-dependent PGUs - Dynamic				
HYD 4600-ES				
P_{Emax}/P_n [%]	100	40	100	75
U [V]	230,4	230,8	230,4	230,6
P_{E30} [W]	4217	1872	4218	3483
P_{E30} of P_{Emax} [%]	127,77	56,74	127,83	105,53
Q_{E30} [Var]	-1916	19	-1862	-1152
$Q_{expected}$	-1915	-26	-1811	-1151
ΔQ_{E30} [%]	-0,04	1,38	-1,54	-0,03
cos φ_{E30}	0,909	1,000	0,919	0,950
cos $\varphi_{setpoint}$ of P_{E30}	0,92	1,00	0,92	0,95
T_0[s]	0	4,2	4,0	2,0
Limit				
ΔQ_{E30} in %	≤ ±4,0% relative to P_{Emax}		P	

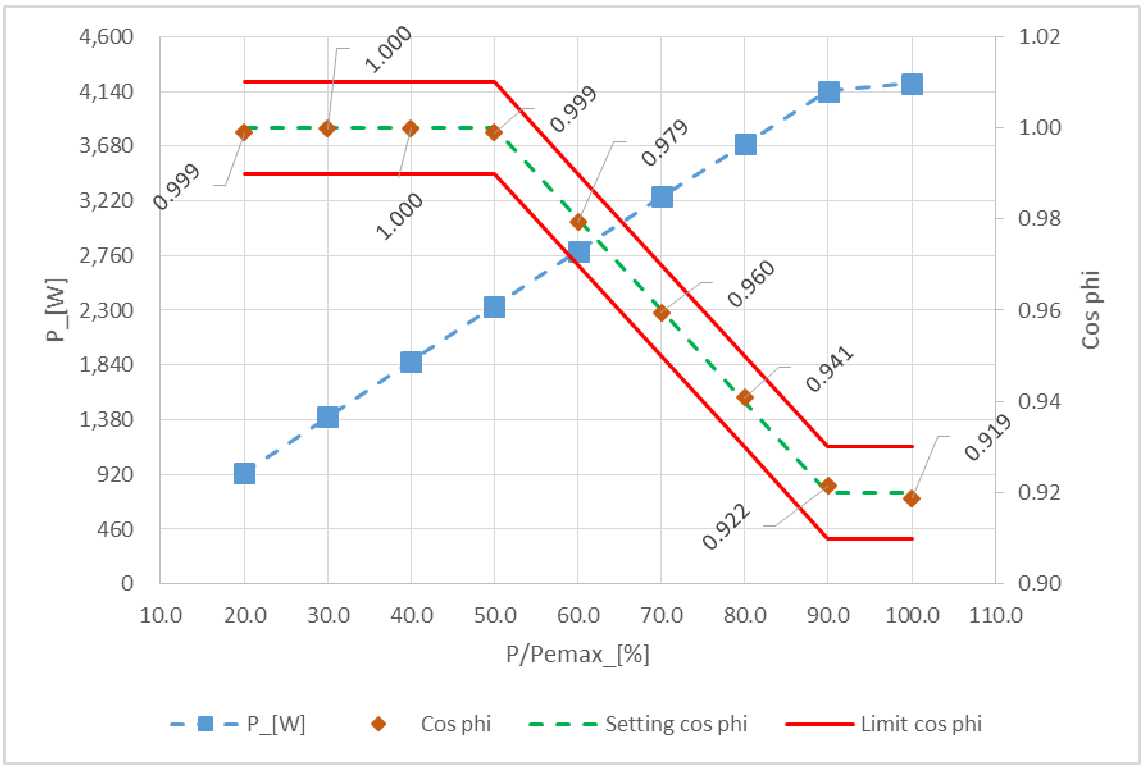
DC setting values:	
PV-curve simulated according to	/
Voltage of defined MPP [V]	384Vdc
Current of defined MPP [A]	11,406A
FFU of PV curve [1]	1
P_{DC} [W]	4362W

Graph of Test c)

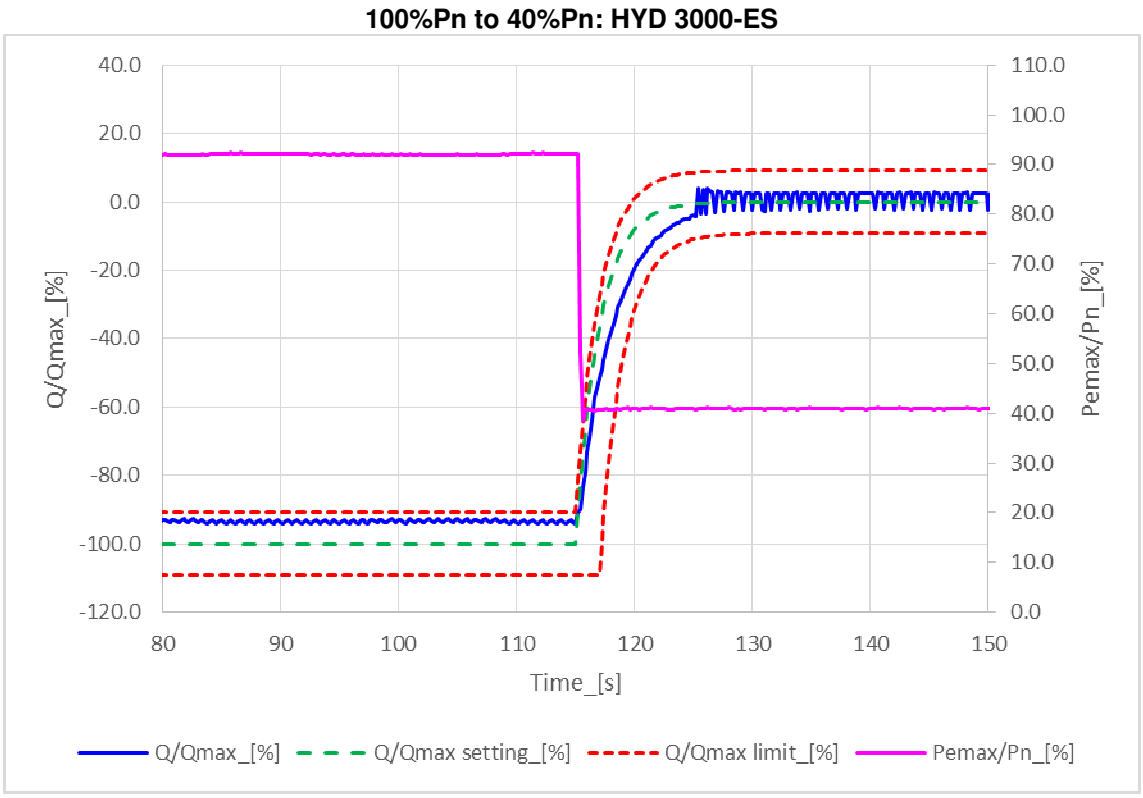
HYD 3000-ES

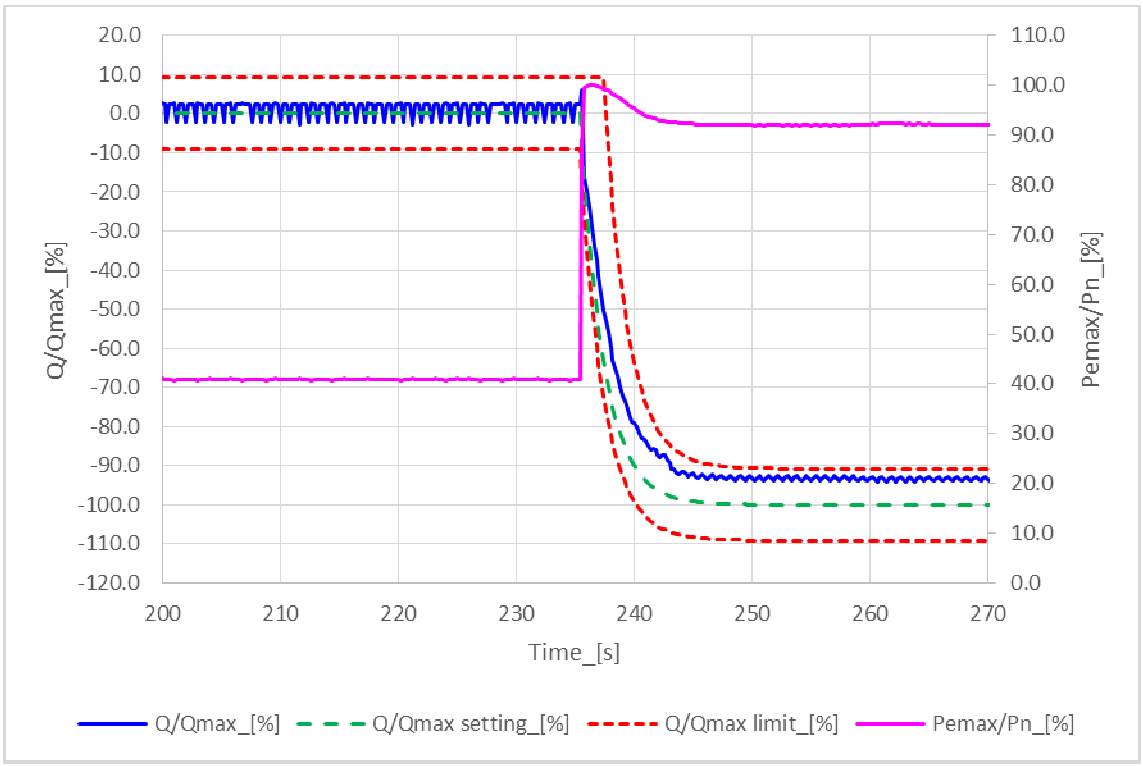


HYD 4600-ES

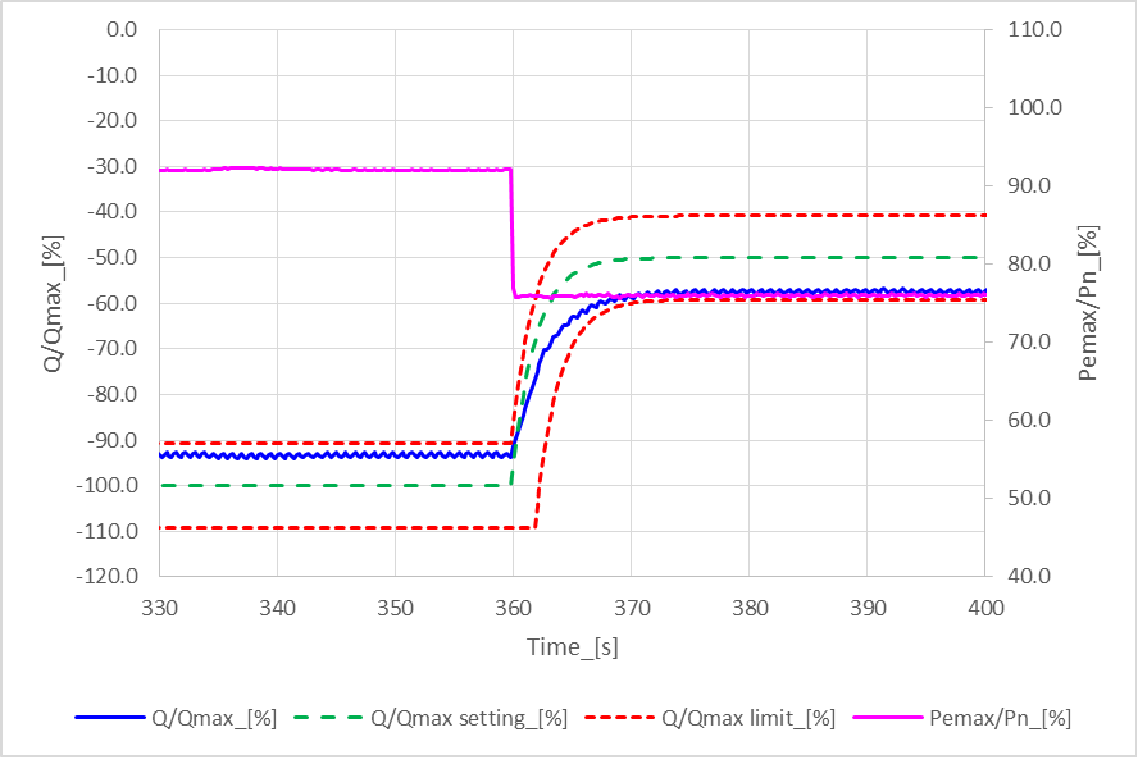


Graph of Test d)

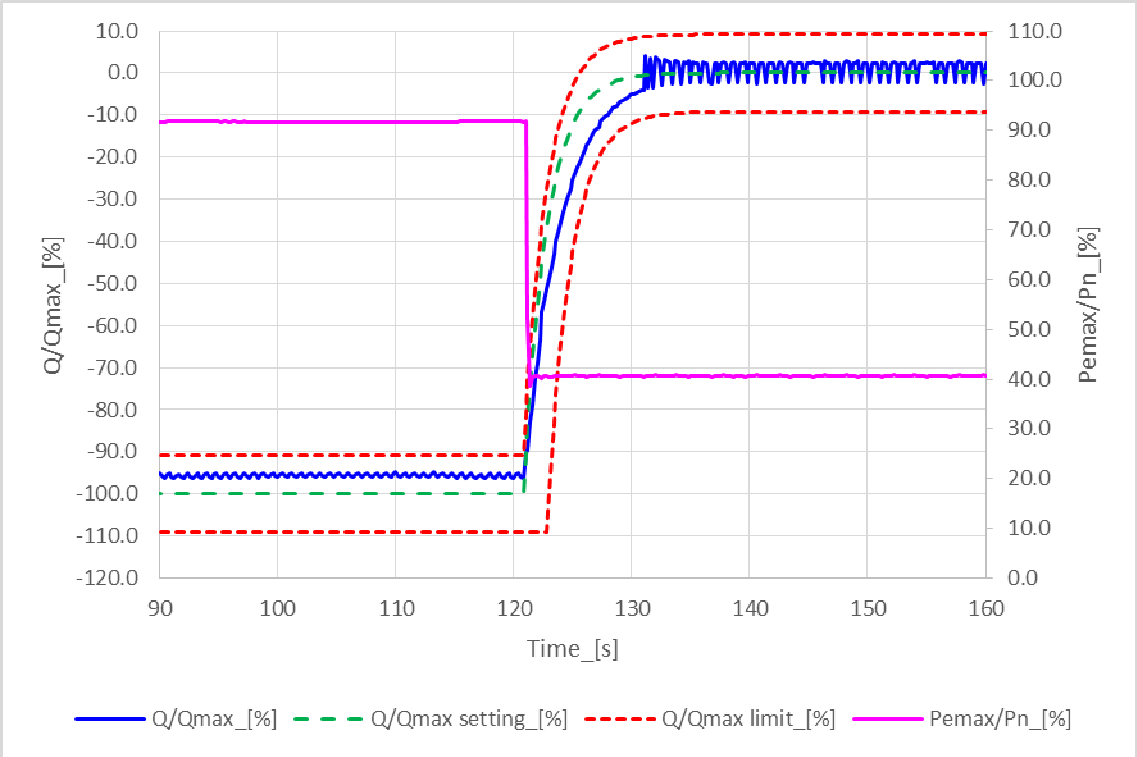




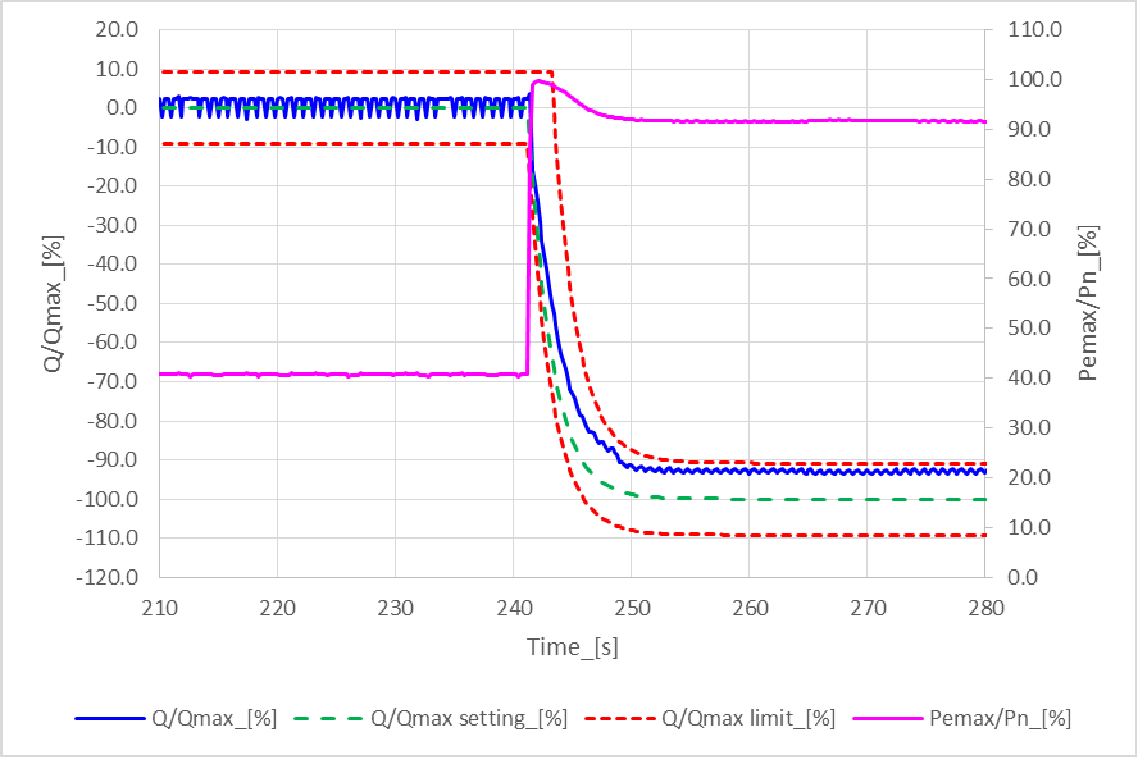
100%Pn to 75%Pn: HYD 3000-ES



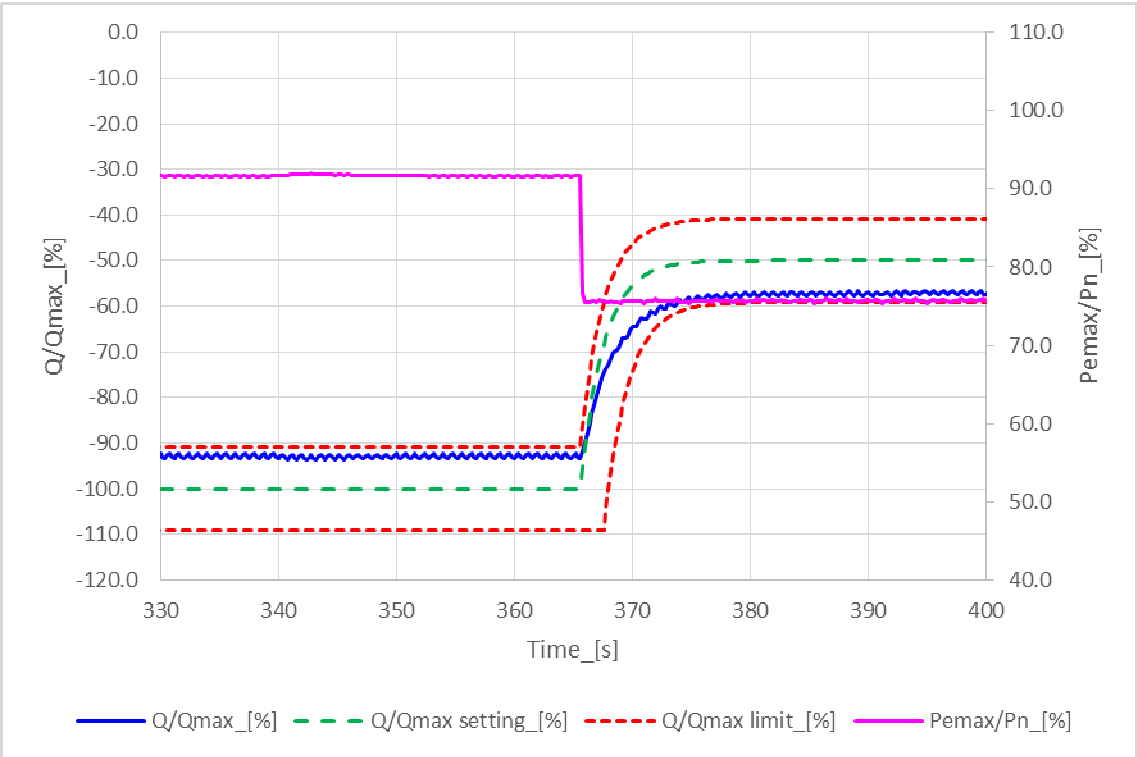
100%Pn to 40%Pn: HYD 4600-ES



40%Pn to 100%Pn: HYD 4600-ES



100%Pn to 75%Pn: HYD 4600-ES



Assessment criterion:

Test 5.4.8.3 (2) is considered to have been passed if the PGU meets the requirements for the performance gradient in VDE AR-N 4105: 2018-11, 5.7.4.2.

Test 5.4.8.3 (4) is passed if the step response of the reactive power in test steps c) and e) shows PT1 behavior according to VDE-AR-N 4105: 2018-11, 5.7.2.5 and for test step d) optionally the power gradient lies between the limits defined in VDE AR-N 4105: 2018-11, 5.7.4.1 or the step response of the reactive power also has PT1 behavior according to VDE-AR-N 4105: 2018-11, 5.7.2.5.

The tests had been performed on the HYD 4600-ES and HYD 3000-ES are valid for the HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

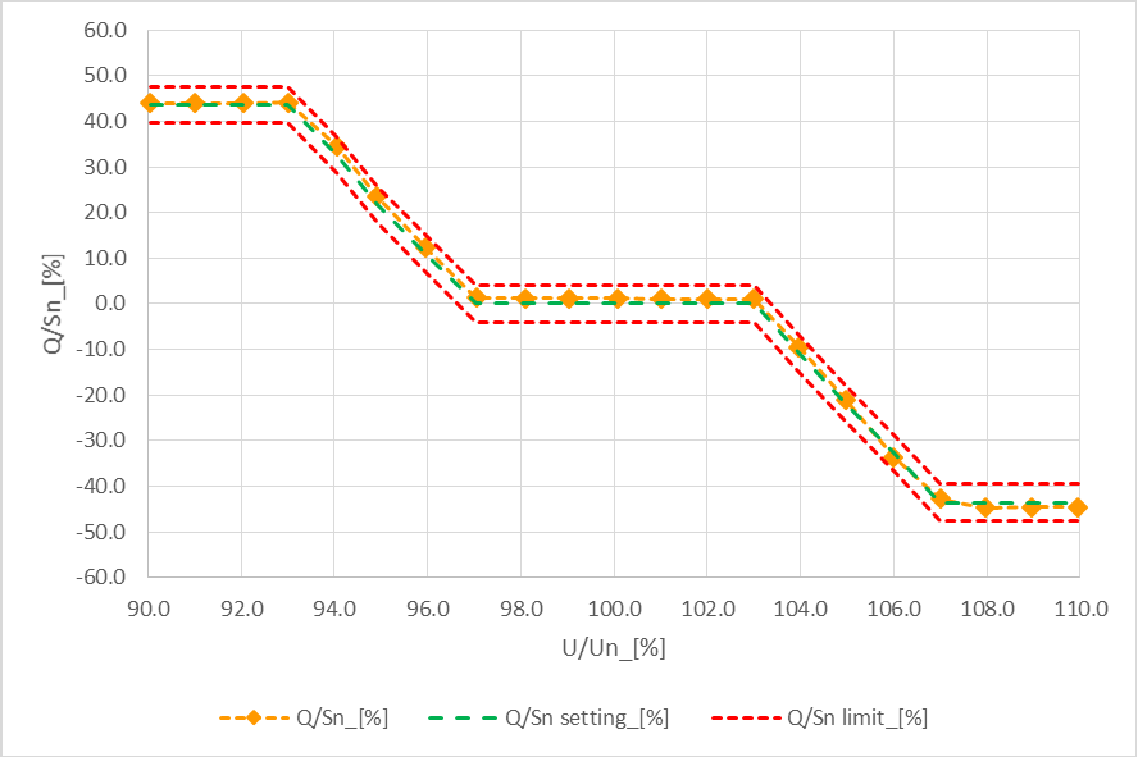
5.4.8.4	**Test the reactive power-voltage characteristic Q(U)** The validation of the Q (U) regulation according to VDE-AR-N 4105: 2018-05, 5.7.2.4 is divided into two partial tests, so that on the one hand the accuracy and on the other hand the dynamics of the Q (U) control is checked. For all inverter-coupled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

HYD 3000-ES

Vac [% U_n] Set point	Vac_L1 [V] measured	P [kW] measured	PF measured	Q [kVar] measured	Q [kVar] expected	Settling time[s]
100	230,2	3010,1	0,9999	26,4	0	0,2
99	227,9	2984,6	0,9999	36,0	0	0,2
98	225,6	2935,7	0,9999	33,7	0	0,2
97	223,4	2942,3	0,9999	33,7	0	0,2
96	220,8	2937,0	0,9938	326,5	327	0,2
95	218,4	2934,3	0,9749	670,1	654	0,2
94	216,5	2977,5	0,9485	994,3	981	0,2
93	214,1	2856,6	0,9076	1321,2	1308	0,2
92	211,8	2857,8	0,9078	1320,1	1308	0,2
91	209,5	2858,8	0,9080	1319,1	1308	0,2
90	207,3	2860,1	0,9082	1318,2	1308	0,2
91	209,5	2859,8	0,9080	1319,6	1308	0,2
92	211,7	2859,6	0,9078	1321,0	1308	0,2
93	214,0	2859,4	0,9076	1322,5	1308	0,2
94	216,5	2971,1	0,9439	1039,2	981	0,2
95	218,4	2926,9	0,9721	706,2	654	0,2
96	220,8	2950,6	0,9922	369,0	327	0,2
97	223,4	2939,3	0,9999	39,9	0	0,2
98	225,6	2958,4	0,9999	35,6	0	0,2
99	227,9	2948,9	0,9999	34,9	0	0,2
100	230,2	2968,3	0,9999	34,2	0	0,2
101	232,5	3002,5	0,9999	32,6	0	0,2
102	234,8	3012,7	1,0000	31,0	0	0,2
103	237,0	3013,4	0,9999	31,3	0	0,2
104	239,5	3013,3	0,9955	-285,5	-327	0,2
105	241,9	3007,6	0,9786	-631,6	-654	0,2
106	244,5	2941,1	0,9458	-1009,8	-981	0,2
107	246,3	2824,1	0,9102	-1284,6	-1308	0,2
108	248,8	2797,0	0,9019	-1339,7	-1308	0,2
109	251,0	2797,7	0,9021	-1338,5	-1308	0,2
110	253,0	2797,7	0,9023	-1337,1	-1308	0,2

5.4.8.4	**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.					
5.4.8.4.1	**Test of the reactive power-voltage characteristic Q(U)**					**P**
109	251,0	2796,5	0,9021	-1337,9	-1308	0,2
108	248,8	2795,6	0,9019	-1339,1	-1308	0,2
107	246,3	2818,7	0,9088	-1293,5	-1308	0,2
106	244,5	2922,5	0,9406	-1055,1	-981	0,2
105	241,8	3005,8	0,9786	-631,1	-654	0,2
104	239,5	3011,7	0,9954	-287,1	-327	0,2
103	236,9	3011,7	0,9999	31,7	0	0,2
102	234,8	3012,2	0,9999	30,9	0	0,2
101	232,5	3011,1	0,9999	30,8	0	0,2
100	230,2	3011,3	1,0000	30,1	0	0,2

5.4.8.4	**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.	
5.4.8.4.1	**Test of the reactive power-voltage characteristic Q(U)**	**P**
Graph of Q(U) curve		



5.4.8.4	**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.	
5.4.8.4.1	**Test of the reactive power-voltage characteristic Q(U)**	**P**

HYD 4600-ES

Vac [% U_n] Set point	Vac_L1 [V] measured	P [kW] measured	PF measured	Q [kVar] measured	Q [kVar] expected	Settling time[s]
100	230,2	4596,9	0,9999	53,8	0	0,2
99	227,9	4554,2	0,9999	56,0	0	0,2
98	225,6	4524,2	0,9999	54,5	0	0,2
97	223,4	4554,8	0,9999	60,6	0	0,2
96	220,8	4491,3	0,9915	576,3	501	0,2
95	218,3	4528,4	0,9709	1113,4	1003	0,2
94	216,2	4321,0	0,9392	1579,0	1504	0,2
93	214,1	4174,7	0,9076	1931,3	2006	0,2
92	211,8	4176,1	0,9078	1929,6	2006	0,2
91	209,5	4177,4	0,9080	1927,9	2006	0,2
90	207,3	4179,8	0,9081	1927,1	2006	0,2
91	209,5	4179,5	0,9080	1929,0	2006	0,2
92	211,8	4179,5	0,9078	1931,3	2006	0,2
93	214,1	4179,2	0,9076	1933,4	2006	0,2
94	216,5	4318,7	0,9387	1667,6	1504	0,2
95	218,5	4429,6	0,9694	1121,5	1003	0,2
96	220,8	4528,6	0,9899	649,2	501	0,2
97	223,4	4495,6	0,9997	95,8	0	0,2
98	225,6	4519,6	0,9999	53,8	0	0,2
99	227,9	4516,5	0,9999	53,7	0	0,2
100	230,2	4579,0	0,9999	54,1	0	0,2
101	232,5	4588,2	0,9999	54,7	0	0,2
102	234,8	4595,2	0,9999	47,3	0	0,2
103	237,2	4596,8	0,9999	48,0	0	0,2
104	239,8	4579,4	0,9947	-476,4	-502	0,2
105	242,1	4493,8	0,9782	-972,0	-1003	0,2
106	244,6	4337,1	0,9465	-1477,5	-1505	0,2
107	246,4	4171,9	0,9121	-1874,4	-2006	0,2
108	248,8	4110,4	0,8995	-1996,9	-2006	0,2
109	251,0	4111,6	0,8997	-1995,1	-2006	0,2
110	253,0	4111,9	0,8999	-1993,3	-2006	0,2
109	251,0	4112,3	0,8997	-1995,5	-2006	0,2

5.4.8.4	**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.					
5.4.8.4.1	**Test of the reactive power-voltage characteristic Q(U)**					**P**
108	248,8	4112,3	0,8995	-1997,7	-2006	0,2
107	246,5	4178,3	0,9131	-1866,1	-2006	0,2
106	244,6	4322,4	0,9428	-1527,9	-2006	0,2
105	242,2	4473,9	0,9747	-1025,6	-1505	0,2
104	239,8	4591,5	0,9940	-509,2	-1003	0,2
103	237,0	4595,0	0,9999	47,8	-502	0,2
102	234,8	4594,1	0,9999	47,7	0	0,2
101	232,5	4593,8	1,0000	45,9	0	0,2
100	230,2	4592,1	1,0000	46,0	0	0,2

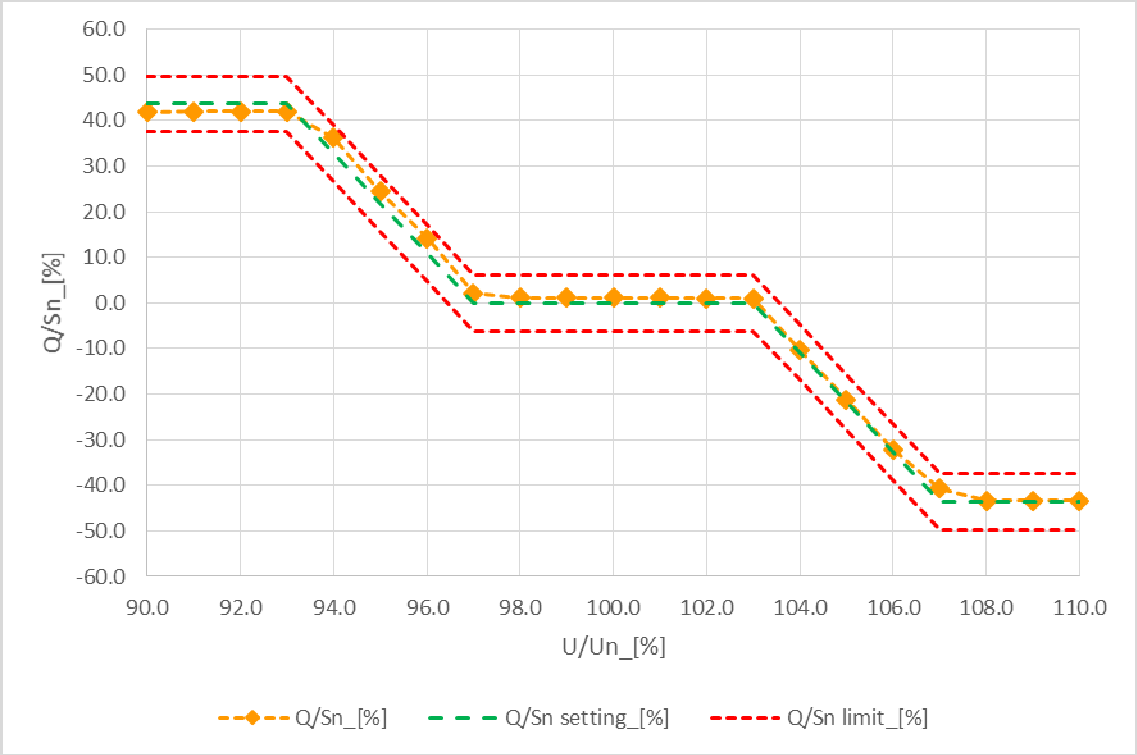
Assessment criterion:

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}.

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

The tests had been performed on the HYD 4600-ES and HYD 3000-ES are valid for the HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

5.4.8.4	**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.	
5.4.8.4.1	**Test of the reactive power-voltage characteristic Q(U)**	**P**
Graph of Q(U) curve		



5.4.8.4.2	Test of the dynamics of the Q(U) regulation	P

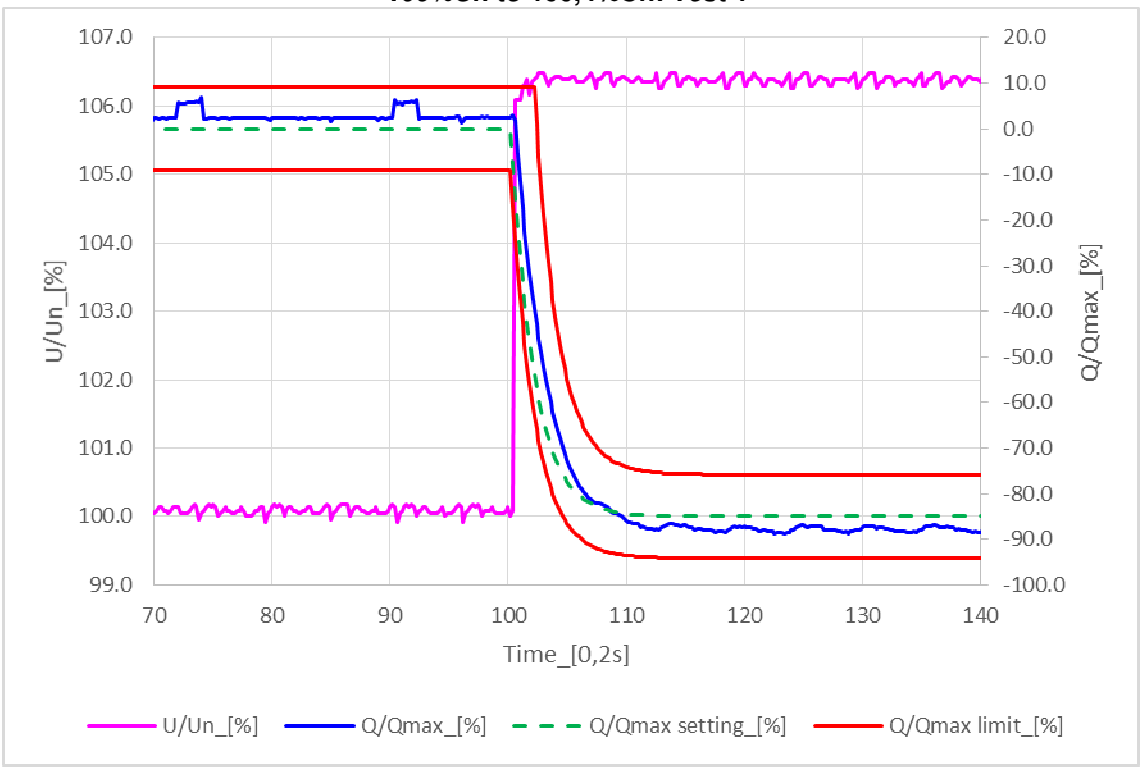
HYD 3000-ES

Voltage jump Vac [% U_n]	Q [kVar] measured	Q [%Qmax] measured	T=3τmeasured
100 to 106,4	2,659	-86,938	9,2 s
	2,657	-87,499	9,2 s
	2,685	-88,248	9,2 s
100 to 93,6	2,693	83,848	9,2 s
	2,232	85,019	9,2 s
	2,707	91,203	9,2 s

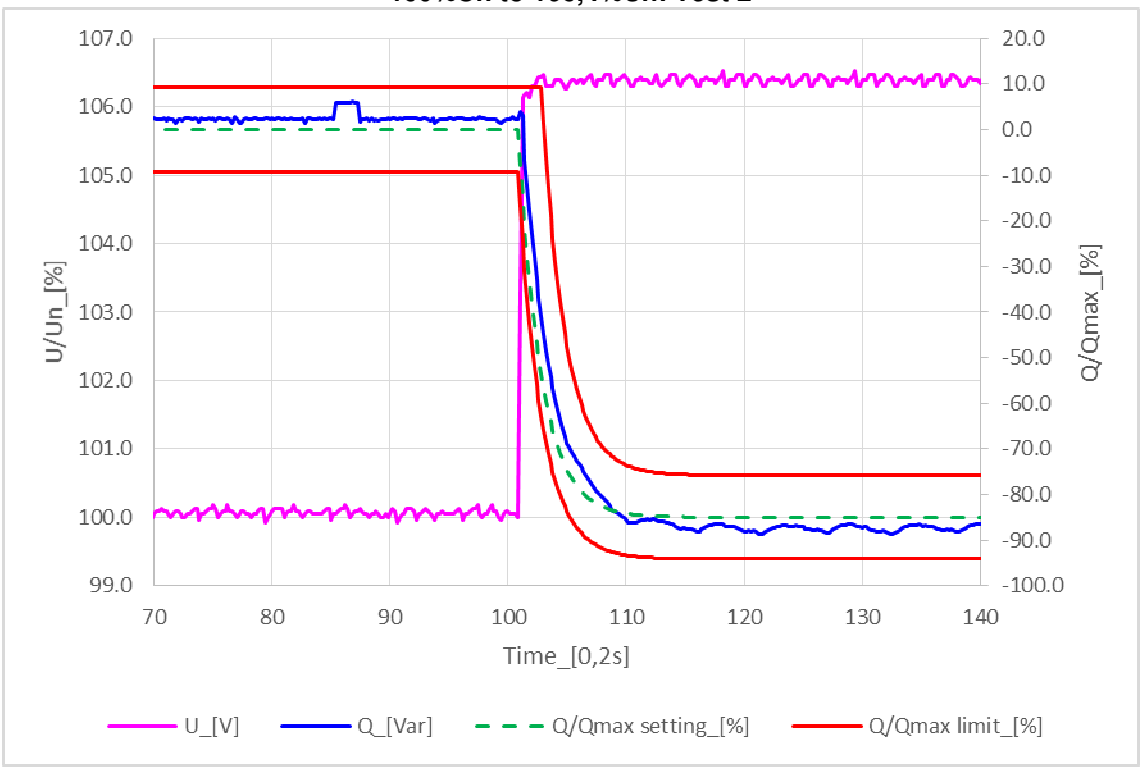
PV-curve simulated according to	/
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	9,010A
FFU of PV curve [1]	1
Impedance [Ω]	
Line	R_A = 0,15 jX_A= 0,15
Neutral	R_N = 0,01 jX_N= 0,01

Graph of Q(U) dynamics

100%Un to 106,4%Un: Test 1

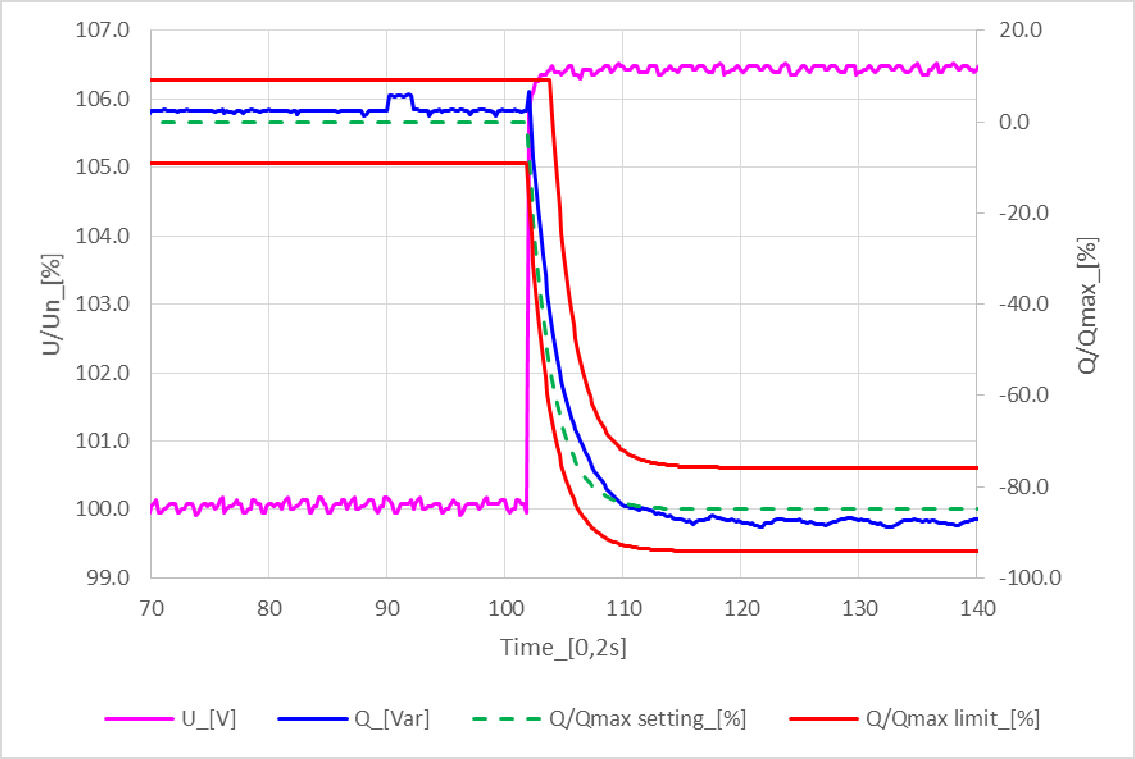


100%Un to 106,4%Un: Test 2

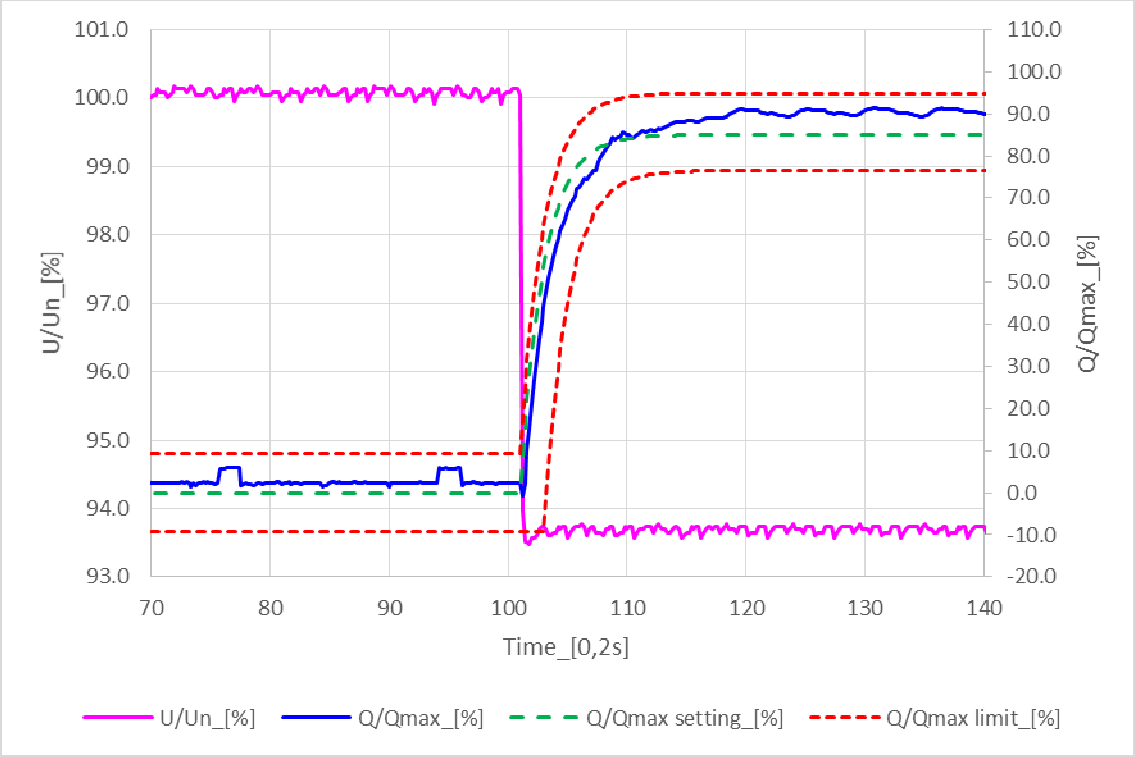


5.4.8.4.2	Test of the dynamics of the Q(U) regulation	P

100%Un to 106,4%Un: Test 3

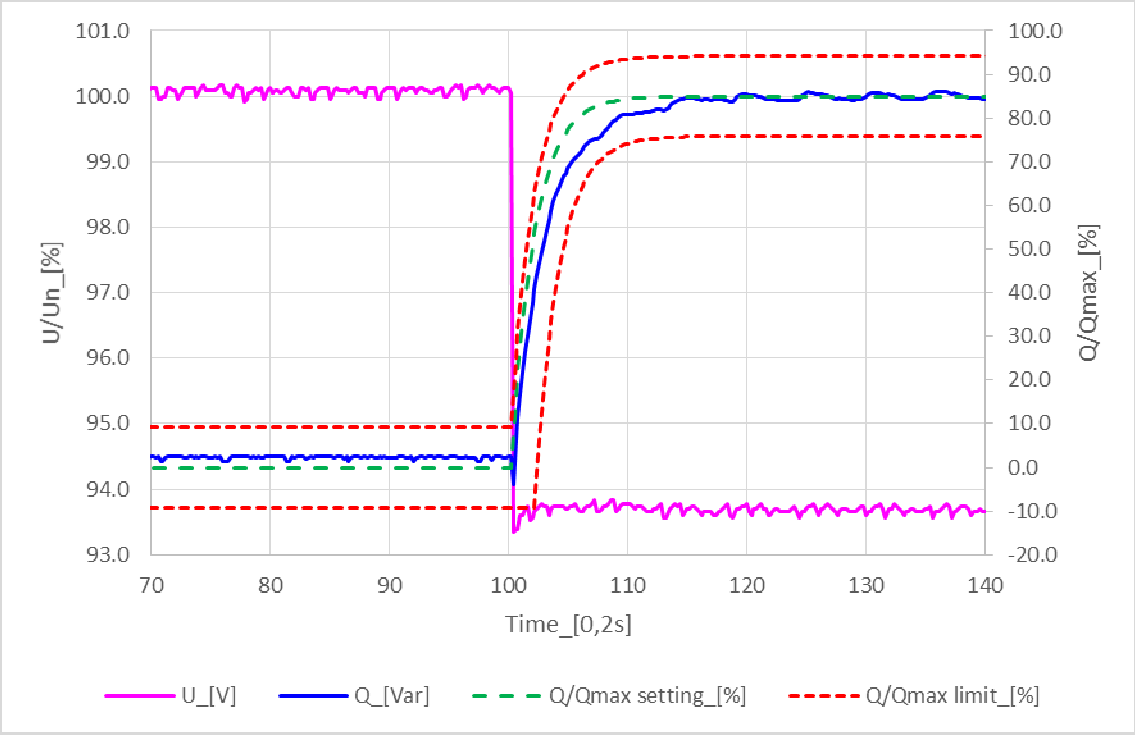


100%Un to 93%Un: Test 1

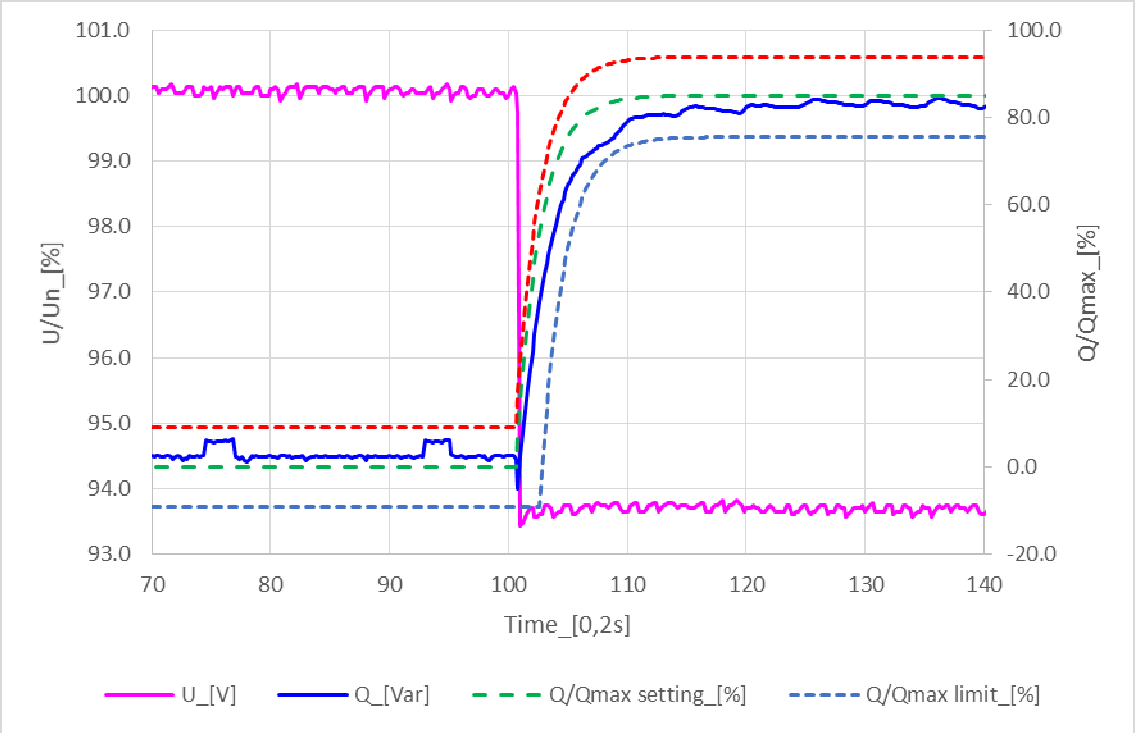


5.4.8.4.2	Test of the dynamics of the Q(U) regulation	P

100%Un to 93%Un: Test 2



100%Un to 93%Un: Test 3

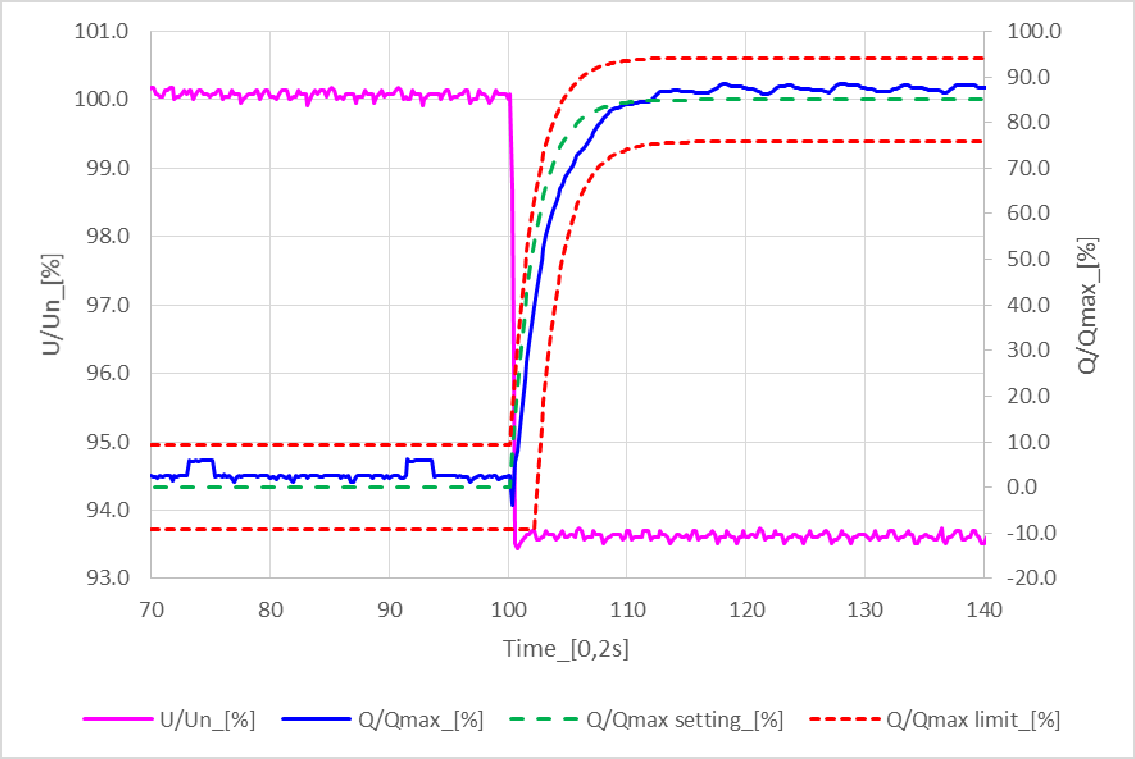


HYD 4600-ES			
Voltage jump Vac [% U_n]	Q [kVar] measured	Q [%Qmax] measured	T=3τmeasured
100 to 106,4	2,625	88,119	9,3
	2,715	86,841	9,5
	2,744	87,717	9,5
100 to 93,6	2,610	-82,618	9,00
	2,668	-82,900	8,60
	2,627	-83,972	9,00

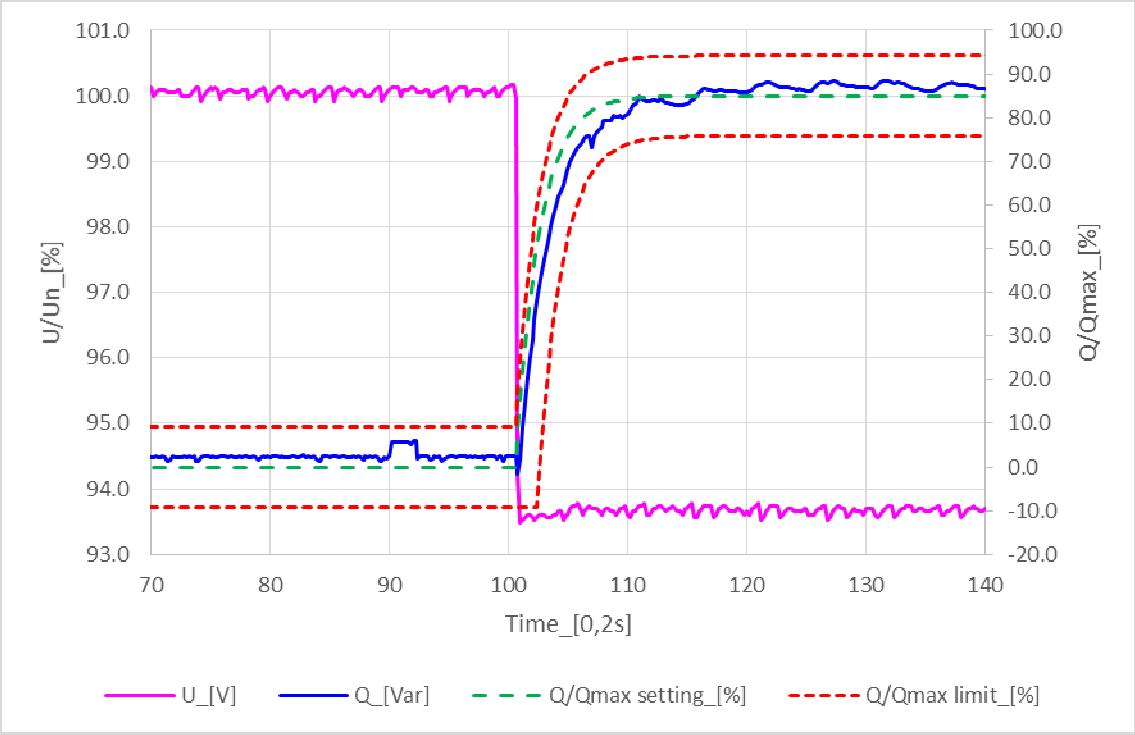
PV-curve simulated according to	/
Voltage of defined MPP [V]	380Vdc
Current of defined MPP [A]	13,856A
FFU of PV curve [1]	1
Impedance [Ω]	
Line	R_A = 0,15 jX_A= 0,15
Neutral	R_N = 0,01 jX_N= 0,01

Graph of Q(U) dynamics

100%Un to 93,6%Un: Test 1

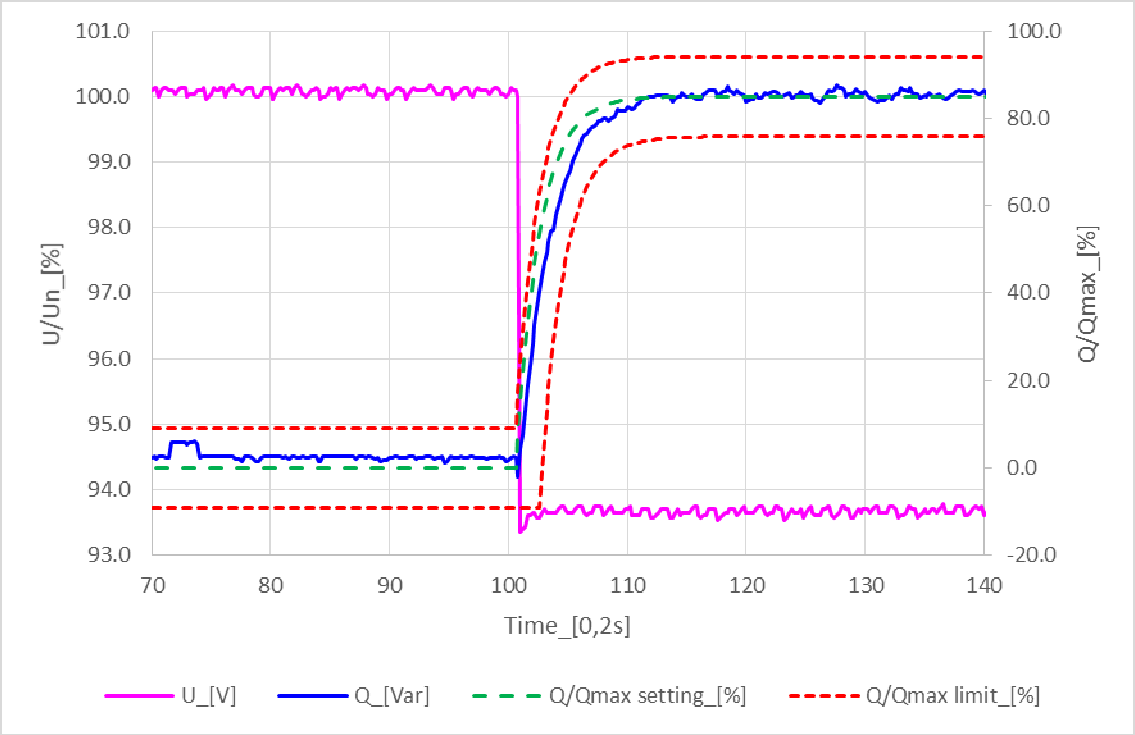


100%Un to 93,6%Un: Test 2

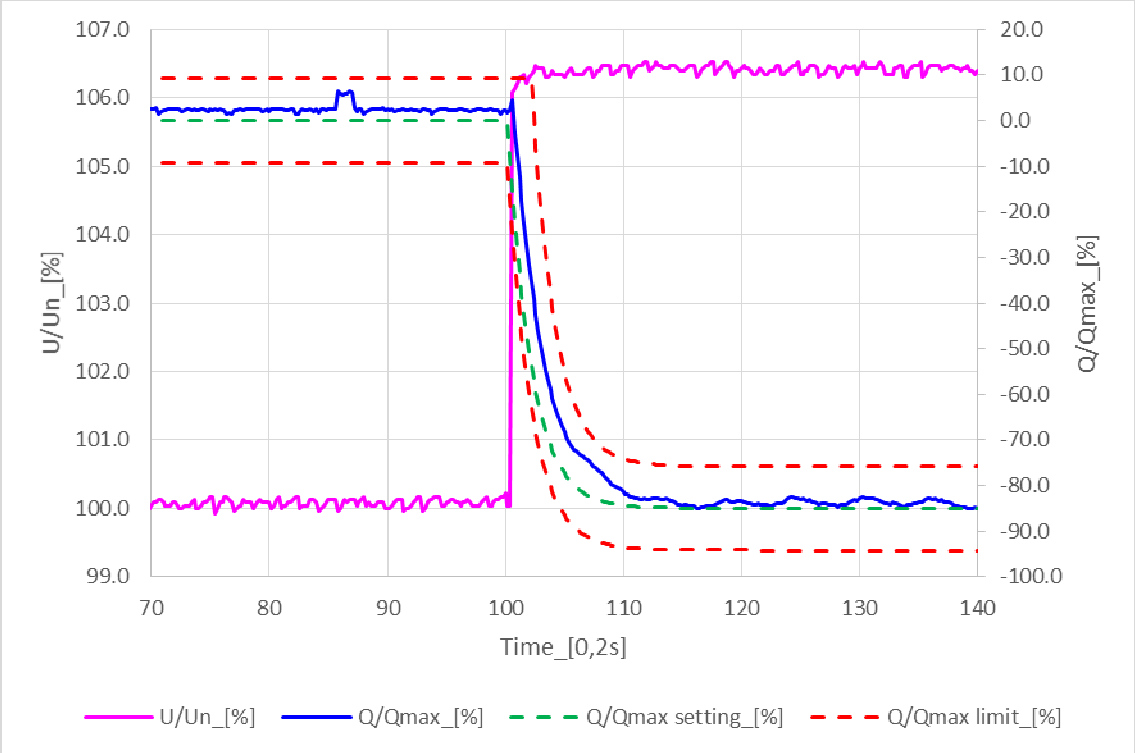


5.4.8.4.2	Test of the dynamics of the Q(U) regulation	P

100%Un to 93,6%Un: Test 3

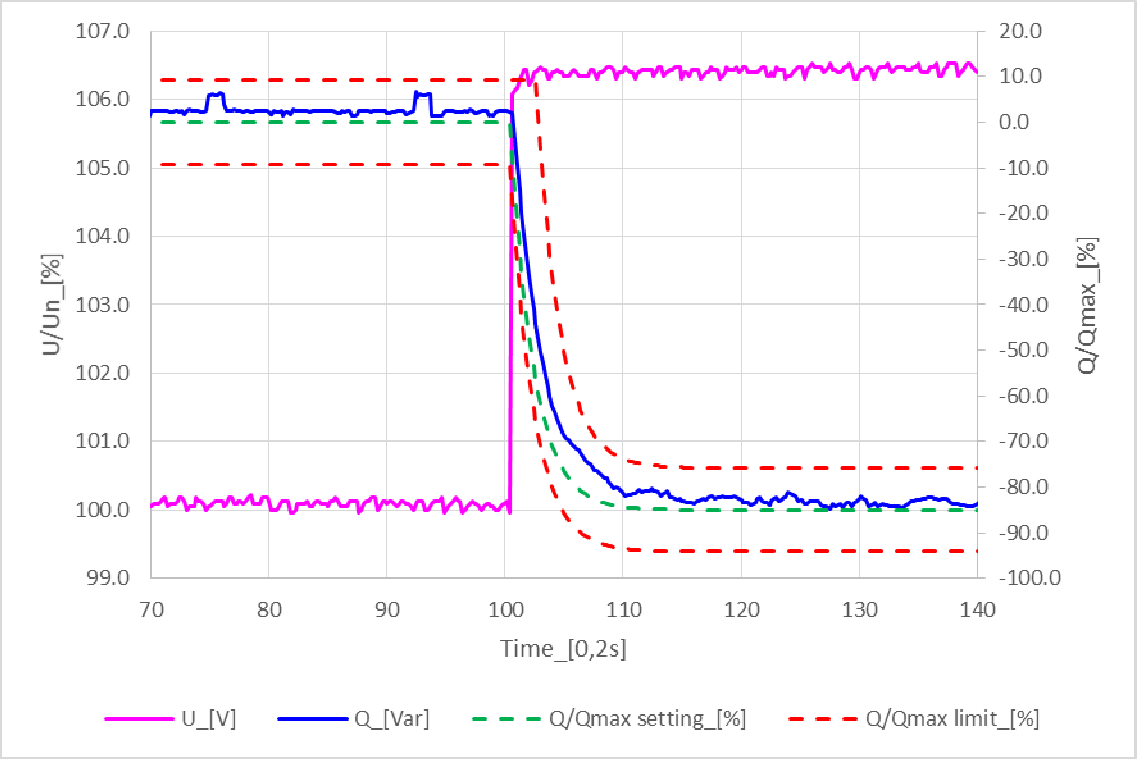


100%Un to 106,4%Un: Test 3

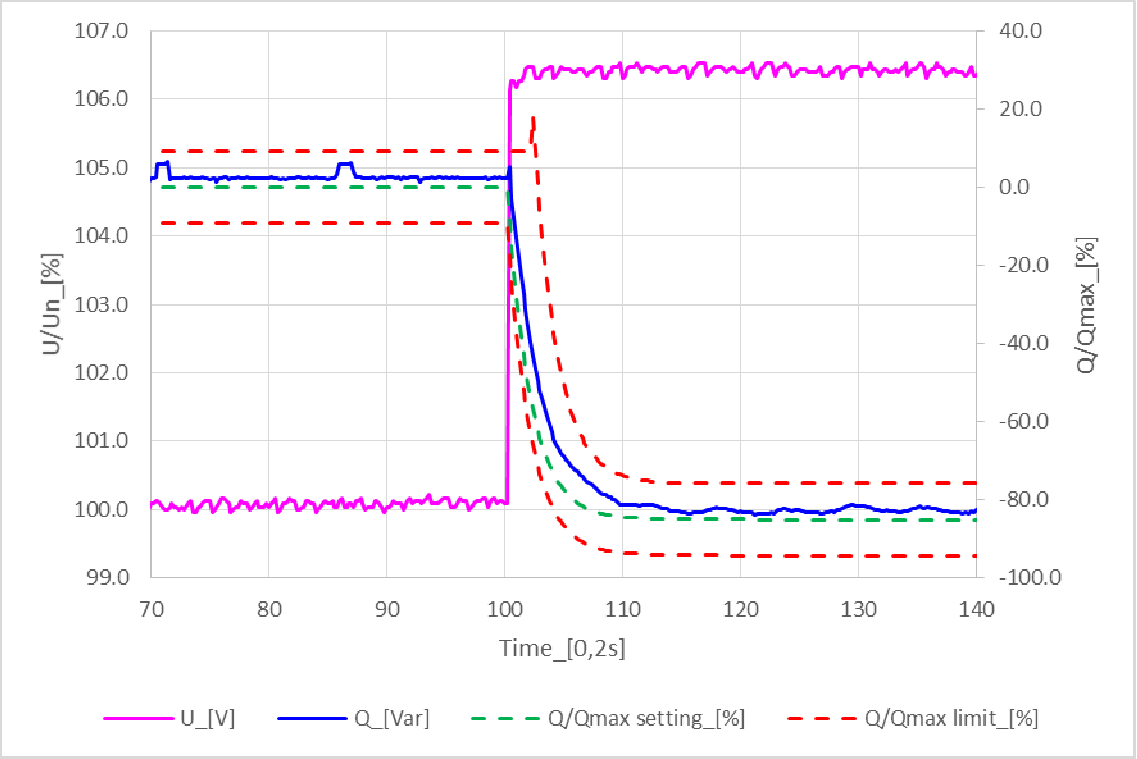


5.4.8.4.2	Test of the dynamics of the Q(U) regulation	P

100%Un to 106,4%Un: Test 3



100%Un to 106,4%Un: Test 3



Assessment criterion:

For passing the test on the dynamics of the Q (U) control, the measured, time profiles of the reactive power have to be determined in the "positive sequence" Q_{PGU} during the entire measuring period in the PT1-like tolerances according to VDE-AR-N 4105: 2018-11, 5.7.2.5. For this purpose, the tolerance bands are entered into the diagram of the respective measurement according to the formulas below. It should be distinguished according to the expected PGU behavior (inductive, capacitive). An exemplary representation of the tolerance bands for the capacitive case is shown in Figure 6. Physically caused compensation processes (for example with type 1 PGU) are to be excluded from the evaluation, if they decay in a time range smaller than one third of the Q (U) - set time.

The variable T corresponds to the set - up time of the generating plant and three times the parameterized PT1 time constant Tau (T = 3Tau). The measurement of the time starts at the time of the excitation in 5. 4.8.3.2a) or the manipulation in 5.4.8.3.2 b).

Since the increase or decrease of the voltage according to the formula given in 5.4.8.3.2 represents only an approximation to the real behavior of the closed control loop, the steady-state final value Qset is determined from the measurement. For this purpose, a 10 - second mean value is formed at the end of the one - minute measurement period via the three - phase reactive power in the positive sequence system. Likewise, the starting value of the reactive power (positive sequence) Qstart (= offset) before the respective voltage change is determined over a 10-second averaging.

The response time of the overall system to be evaluated is measured starting from the excitation according to 5.4.8.3.2 a) or the manipulation according to 5.4.8.3.2 b) until reaching 95% of the steady end value in the positive sequence Qsoll and is with the factor 5/3 to multiply. This factor takes into account the effect of the feedback on the control dynamics of the Q (U) control and is strongly related to the formula of the net replacement reactance.

5.5	Testing of NS protection	
Clause	**Requirement – Test**	**Verdict**
5.5.2	NS protection	**P**
5.5.2.1	Functional safety	**P**
5.5.3	Central NS-protection	**N/A**
5.5.4	Integrated NS-protection	**P**
5.5.6	Interface switch	**P**
5.5.6.2	Central interface switch	**N/A**
5.5.6.3	Integrated interface switch	**P**
5.5.7.2	Check of setting values	**P**
5.5.7.3	Wiring check	**N/A**
5.5.7.4	Voltage and frequency control	**P**
5.5.7.4.1	Voltage and frequency control – Single Phase	**P**
	Voltage and frequency control – Multi Phase (Phase to N)	**N/A**
	Voltage and frequency control – Multi Phase (Phase to Phase)	**N/A**
	Voltage and frequency control – Measuring the rise-in voltage protection as a running 10-minute mean value	**P**
	Voltage and frequency control – Frequency measurement	**P**
5.5.7.5	Reporting of NS protection	**P**
5.5.9	Constructional characteristics of NS protection	**P**
5.5.10.1	General	**P**
5.5.10.2	Passive Islanding Protection	**N/A**
5.5.10.3	Islanding protection according table 6 – Load imbalance (real, reactive load) for test condition A (PGU output = 100%)	**P**
	Islanding protection according table 6 – Load imbalance (real, reactive load) for test condition A (PGUT output = 66%)	**P**
	Islanding protection according table 6 – Load imbalance (real, reactive load) for test condition A (PGU output = 33%)	**P**

5.5.2	NS protection	P
The test for error detection with subsequent shutdown is carried out by means of error simulation, if necessary with additional error tests (see VDE-AR-N 4105: 2018-11, 6.1).		
5.5.2.1	Functional safety	P

HYD 4600-ES

Component No.	Fault	Test condition:		Test time: [min]	Fuse no.[A]	Fault condition:		Result:
		AC	DC			AC	DC	
Relay RY1 defect	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate Relay fault, error code “ID55” (RecoverRelayFail). Do not connect to AC mainsn. No damage, no hazards.
Relay RY2 defect	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate Relay fault, error code “ID55” (RecoverRelayFail). Do not connect to AC mainsn. No damage, no hazards.
Relay RY3 defect	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate Relay fault, error code “ID55” (RecoverRelayFail). Do not connect to AC mainsn. No damage, no hazards.
Relay RY4 defect	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate Relay fault, error code “ID55” (RecoverRelayFail). Do not connect to AC mainsn. No damage, no hazards.
Relay RY5 defect	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate Relay fault, error code “ID55” (RecoverRelayFail). Do not connect to AC mainsn. No damage, no hazards.
Relay RY6 defect	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate Relay fault, error code “ID55” (RecoverRelayFail). Do not connect to AC mainsn. No damage, no hazards.
Monitoring voltage defect R508	short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid. Q59 damage. No hazards.
Monitoring voltage defect Q59 pin 1-2	short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID55” (RecoverRelayFail). No damage, no hazards.

5.5.2	NS protection							P
The test for error detection with subsequent shutdown is carried out by means of error simulation, if necessary with additional error tests (see VDE-AR-N 4105: 2018-11, 6.1).								
5.5.2.1	**Functional safety**							**P**
HYD 4600-ES								
Monitoring voltage defect U46 pin 1-2	short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID55” (RecoverRelayFail). U46 damage, no hazards.
Monitoring voltage defect R511	short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID55” (RecoverRelayFail). U46 damage, no hazards.
Monitoring voltage defect R509	open	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	The unit was in check state. No damage. No hazards.
Monitoring voltage defect U46 pin 3-4	short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID55” (RecoverRelayFail). U46 damage, no hazards.
Voltage measurement disabled R204	Open	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID01” (The grid voltage is too high). No damage. No hazards.
Loss of control XL1	Short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID53, ID54” (SPI communication is fault, SCI communication is fault). No damage. No hazards.
Loss of control C738(3.3VDD)	Short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID53, ID54” (SPI communication is fault, SCI communication is fault). No damage. No hazards.
Communication microcontroller defect U4 pin1 to pin2	Short	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Output a.c. relays operated, disconnected with grid , error code “ID53, ID54, ID75” (SPI communication is fault, SCI communication is fault, Unrecoverable EEPROM write). No damage. No hazards.

5.5.2	NS protection							P
The test for error detection with subsequent shutdown is carried out by means of error simulation, if necessary with additional error tests (see VDE-AR-N 4105: 2018-11, 6.1).								
5.5.2.1	**Functional safety**							**P**
HYD 4600-ES								
ISO defect R531	Short circuit before energized	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect R598	Open circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect R602	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect R605	Open circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect R355	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect R303	Open circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect R307	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.
ISO defect U23 pin 13-14	Short circuit before energized	230V 0,02A	520V 0,02A	3Min.	--	230V 0,02A	520V 0,02A	Indicate ISO fault, error code “ID56” (The insulation resistance is too low). Do not connect to AC mainsn. No damage, no hazards.

5.5.2	NS protection							P
The test for error detection with subsequent shutdown is carried out by means of error simulation, if necessary with additional error tests (see VDE-AR-N 4105: 2018-11, 6.1).								
5.5.2.1	**Functional safety**							**P**
HYD 4600-ES								
GFCI defect R292	Open	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Indicate GFCI fault, error code “ID48” (The GFCI sampling value between the master DSP and slave DSP is not consistent). Do not connect to AC mainsn. No damage, no hazards.
GFCI defect R297	Open	230V 26,2A	520V 12,1A	3Min.	--	230V 0,02A	520V 0,02A	Indicate GFCI fault, error code “ID48” (The GFCI sampling value between the master DSP and slave DSP is not consistent). Do not connect to AC mainsn. No damage, no hazards.

Note:

The errors in the control circuit simulate that the safety is even ensured during a single fault.

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

Assessment criterion:

The NA protection must send a shutdown command to the coupling switch.

If the error is detected, the device is switched off within 10 s after error detection.

If the auxiliary voltage fails with the central NA protection or if the control fails with the integrated NA protection, the switch-off command must be given immediately.

5.5.4	Integrated NS protection	P
The integrated NA protection is tested in 5.5.7 and in connection with the examination of the entire NS protection chain and switch.		
Note: For test results see 5.5.2.1 Functional safety.		

5.5.6.3	**Integrated interface switch**	**P**
5.5.6.3.1	**Test (functional chain integrated NS-protection and integrated interface switch)**	**P**
Following monitoring options of an interface switch are valid (a) or (b) or (c):		
(a) Use of a interface switch in which a control voltage must be constantly applied when switched on and which switches off automatically when this voltage is not present. The operational switch-on and switch-off processes is monitored		
The disconnection of the control voltage leads to the instantaneous disconnection of the interface switch.		P
A simulated defect during the closing and opening of the interface switch leads to an instantaneous shutdown of the PGU. A restart is not possible.		P
A simulated defect of the interface switch after the NS protection as operated leads to an instantaneous shutdown of the PGU. A restart is not possible.		P
The switch-off time of the whole reaction chain is within 200ms.		P
(b) The interface switch is switched on and off at least once a day by the NS protection and the proper functioning of the coupling switch is monitored.		
A simulated defect of the interface switch during the daily test leads to an instantaneous shutdown of the PGU. A restart is not possible.		P
A simulated defect of the interface switch after the NS protection has operated leads to an instantaneous shutdown of the PGU. A restart is not possible.		P
A function for daily switching on and off is available and explained by a manufacturer's declaration.		P
(c) Use of the integrated coupling switch and the integrated NA protection for PV and battery converters according to DIN EN 62109 (VDE 0126-14-1).		
The integrated interface switch and NS protection is comply with DIN EN 62109 (VDE 0126-14-1). See IEC 62109-2 test report LD190808N030-R1 issued by Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch dated on Apr. 16, 2020		P
Note: See test results 5.5.2.1 functional safety.		

The inverter has a galvanic separating break device. The interface switch is short-circuit proof for the maximum short-circuit current of the power generation unit.	
Max. initial short-circuit current of the PGU (power generation unit)	= 26 A, 277 Vac
Max. switching current relay	= 31 A, 277 Vac

Datasheet of the relay (interface protection relay / Interface switch): HF161F-W

HF161F-W SOLAR RELAY

c UL us
File No.:E134517

File No.:40031410

File No.:10002050943

Features

- 31A switching capitable
- Applicable to inverter used for photovoltaic power generation systems
- Ideal for UPS
- 1.5mm contact gap (compliant to European Photovoltaic Standard VDE0126)
- The clearance distance between contact and coil is bigger than 6.4mm, the creepage distance is bigger than 8mm.
- Low coil holding voltage contributes to saving energy of equipment.
- UL insulation system: Class F
- Environmental friendly product (RoHS compliant)
- Outline Dimensions: (30.4 x 15.9 x 23.3) mm

CONTACT DATA

Contact arrangement	1A
Contact resistance	100mΩ max.(at 1A 6VDC)
Contact material	$AgSnO_2$
Contact rating	Resistive: 26A 250VAC Inductive: 31A 250VAC (cosø=0.8) 0.1s:10s
Max. switching voltage	277VAC
Max. switching current	31A
Max. switching power	7750VA
Mechanical endurance	1×10^6 OPS
Electrical endurance	3×10^4 OPS (See approval reports for more details)

COIL

Coil power	Approx. 1.4W
Holding voltage	35% to 120%UN (at 23°C) 45% to 80%UN (at 85°C)

Notes: 1) The coil holding voltage is the voltage of coil after being applied rated voltage for 100ms.
2) By lower coil holding voltage, the purpose of saving power consumption could be achieved. The magnetic system is designed for this reduced holding power. When the holding voltage was lowered to 35% that of rated voltage, the power consumption could be decreased to approx.170mW. Continuous operation without power reduction is not permitted for ambient temperatures of > 23°C!

CHARACTERISTICS

Insulation resistance		1000MΩ (at 500VDC)
Dielectric strength	Between coil & contacts	4500VAC 1min
	Between open contacts	2500VAC 1min
Surge voltage (between coil & contacts)		10kV (1.2/50μs)
Operate time (at nomi. volt.)		20ms max.
Release time (at nomi. volt.)		10ms max.
Temperature rise (at nomi. volt.)		95K max. (Contact load current 31A, rated voltage excitation, at 60°C) 70K max. (Contact load current 31A, 80% of rated voltage excitation, at 85°C)
Shock resistance	Functional	196m/s²
	Destructive	980m/s²
Vibration resistance		10Hz to 55Hz 1.5mm DA
Ambient temperature		-40°C to 60°C (Apply rated voltage to coil) -40°C to 85°C (Apply holding voltage to coil, which is 45% to 80% that of rated voltage)
Humidity		5% to 85% RH
Termination		PCB
Unit weight		Approx. 21g
Construction		Flux proofed

Notes: The data shown above are initial values.

COIL DATA at 23°C

Nominal Voltage VDC	Pick-up Voltage VDC max.	Drop-out Voltage VDC min.	Max. Allowable Voltage VDC	Coil Resistance Ω
9	6.3	0.9	10.8	58 x (1±10%)
12	8.4	1.2	14.4	103 x (1±10%)
18	12.6	1.8	21.6	230 x (1±10%)
24	16.8	2.4	28.8	410 x (1±10%)

Notes: The maximum voltage is the voltage value of coil over voltage, which is the instantaneous voltage relay could bear within very short function time period.

SAFETY APPROVAL RATINGS

UL/CUL	$AgSnO_2$	26A 277VAC at 75°C 22A 277VAC at 85°C
VDE	$AgSnO_2$	26A 277VAC at 75°C 22A 277VAC at 85°C 31A 250VAC COSØ=0.8 0.1s:10s

Notes: Only some typical ratings are listed above. If more details are required, please contact us.

HONGFA RELAY
ISO9001、ISO/TS16949、ISO14001、OHSAS18001、IECQ QC 080000 CERTIFIED 2013 Rev. 1.00

The inverter has a galvanic separating break device. The interface switch is short-circuit proof for the maximum short-circuit current of the power generation unit.	
Max. initial short-circuit current of the PGU (power generation unit)	= 33 A, 250 Vac
Max. switching current relay	= 33 A, 250 Vac
Datasheet of the relay (interface protection relay / Interface switch): LF-G(AFLG)	

Panasonic Automation Controls Catalog

Ideal for solar inverter compact size, 1a 22A/33A power relays

LF-G RELAYS (ALFG)

RoHS compliant

FEATURES

• High capacity
High capacity control possible at 22 A/33 A (High capacity type) 250 V AC rating in compact size (L: 15.7 × W: 30.1 × H: 23.3 mm L: .618 × W: 1.185 × H: .917 inch)

• Contact gap: 1.5 mm .059 inch and 1.8 mm* .071 inch**
Compliant with European photovoltaic standard (IEC62109* and VDE0126**).

* Safety standard of PV power inverter
** German safety standard of PV power inverter
*** Due to addition of altitude stipulation (2,000 m 6,561.68 ft or more) to IEC62109.

EN61810-1 certified: 2.5 kV surge breakdown voltage (between contacts)

• High insulation resistance
Creepage distance between contact and coil terminal: Min. 9.5 mm .354 inch
Clearance distance between contact and coil terminal: Min. 6.5 mm .256 inch
Surge breakdown voltage: 6 kV

• Coil holding voltage contributes to saving energy of equipment
The coil holding voltage can be reduced up to 35%V of the nominal coil voltage (Ambient temperature: 20°C 68°F).
Power consumption at the lowest coil holding voltage: 170 mW equivalent

*Coil holding voltage is the coil voltage after 100 ms from the applied nominal coil voltage.
*When the ambient temperature during use is 85°C 185°F, make the coil holding voltage between 45% and 80%V of the nominal coil voltage.

• Conforms to various safety standards
UL/C-UL and VDE approved

TYPICAL APPLICATIONS

• Photovoltaic power generation systems (Power conditioner)
• Uninterruptible Power Supplies (UPS)
• Home appliances
• Office equipment

ORDERING INFORMATION

ALFG [ ] P F [ ] [ ] [ ]

LF-G relay

Contact arrangement
1: 1 Form A Standard type
2: 1 Form A High capacity type

Terminal shape
P: PCB type

Coil insulation class
F: UL Class F

Nominal coil voltage (DC)
09: 9V, 12: 12V, 18: 18V, 24: 24V

Contact gap
Nil: 1.5 mm .059 inch
1: 1.8 mm .071 inch

Note: Certified by UL/C-UL and VDE

TYPES

Contact arrangement	Nominal coil voltage	Part No.			
		Contact Gap 1.5 mm .059 inch type		Contact Gap 1.8 mm .071 inch type	
		Standard type	High capacity type	Standard type	High capacity type
1 Form A	9 V DC	ALFG1PF09	ALFG2PF09	ALFG1PF091	ALFG2PF091
	12 V DC	ALFG1PF12	ALFG2PF12	ALFG1PF121	ALFG2PF121
	18 V DC	ALFG1PF18	ALFG2PF18	ALFG1PF181	ALFG2PF181
	24 V DC	ALFG1PF24	ALFG2PF24	ALFG1PF241	ALFG2PF241

Standard packing: Carton: 50 pcs.; Case: 200 pcs.

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LF-G (ALFG)

RATING

■ Coil data

Nominal coil voltage	Pick-up voltage (at 20°C 68°F) (Initial)	Drop-out voltage (at 20°C 68°F) (Initial)	Nominal operating current [±10%] (at 20°C 68°F)	Coil resistance [±10%] (at 20°C 68°F)	Nominal operating power	Max. applied voltage (at 20°C 68°F)
9V DC	70%V or less of nominal voltage	10%V or more of nominal voltage	155mA	58Ω	1,400mW	120%V of nominal voltage
12V DC			117mA	103Ω		
18V DC			78mA	230Ω		
24V DC			59mA	410Ω		

■ Specifications

Characteristics	Item		Specifications		
			Standard type	High capacity type	
			Contact Gap 1.5 mm .059 inch type Contact Gap 1.8 mm .071 inch type	Contact Gap 1.5 mm .059 inch type	Contact Gap 1.8 mm .071 inch type
Contact	Arrangement		1 Form A		
	Contact resistance (Initial)		Max. 100 mΩ (By voltage drop 6 V DC 1A)		
	Contact material		AgSnO2 type		
Rating	Nominal switching capacity		22A 250V AC	31A 250V AC	33A 250V AC
	Max. switching power		5,500VA	7,750VA	8,250VA
	Max. switching voltage		250V AC		
	Max. switching current		22A (AC)	31A (AC)	33A (AC)
	Nominal operating power		1,400mW		
	Min. switching capacity (Reference value) *1		100mA 5V DC		
Electrical characteristics	Insulation resistance (Initial)		Min. 1,000MΩ (at 500V DC) Measurement at same location as "Breakdown voltage" section.		
	Breakdown voltage (Initial)	Between open contacts	2,500 Vrms for 1 min. (Detection current: 10 mA)		
		Between contact and coil	4,000 Vrms for 1 min. (Detection current: 10 mA)		
	Surge breakdown voltage *2 (Between contact and coil) (Initial)		6,000V		
	Temperature rise *3 (coil)		Max. 95°C 203°F (By resistive method, nominal coil voltage applied to the coil; contact carrying current: 22A, at 60°C 140°F) Max. 70°C 158°F (By resistive method, 80%V of nominal coil voltage applied to the coil; contact carrying current: 22A, at 85°C 185°F)	Max. 95°C 203°F (By resistive method, nominal coil voltage applied to the coil; contact carrying current: 31A, at 60°C 140°F) Max. 70°C 158°F (By resistive method, 80%V of nominal coil voltage applied to the coil; contact carrying current: 31A, at 85°C 185°F)	Max. 95°C 203°F (By resistive method, nominal coil voltage applied to the coil; contact carrying current: 33A, at 60°C 140°F) Max. 70°C 158°F (By resistive method, 80%V of nominal coil voltage applied to the coil; contact carrying current: 33A, at 85°C 185°F)
	Coil holding voltage *4		35 to 120%V (contact carrying current: 22A, at 20°C 68°F) 45 to 80%V (contact carrying current: 22A, at 85°C 185°F)	35 to 120%V (contact carrying current: 31A, at 20°C 68°F) 45 to 80%V (contact carrying current: 31A, at 85°C 185°F)	35 to 120%V (contact carrying current: 33A, at 20°C 68°F) 45 to 80%V (contact carrying current: 33A, at 85°C 185°F)
	Operate time (at 20°C 68°F)		Max. 20 ms (at nominal coil voltage excluding contact bounce time.)		
	Release time (at 20°C 68°F)		Max. 10 ms (at nominal coil voltage excluding contact bounce time, without diode)		
Mechanical characteristics	Shock resistance	Functional	Min. 100 m/s² (Half-wave pulse of sine wave: 11 ms; detection time: 10μs.)		
		Destructive	Min. 1,000 m/s² (Half-wave pulse of sine wave: 6 ms.)		
	Vibration resistance	Functional	10 to 55 Hz at double amplitude of 1.5 mm (Detection time: 10μs.)		
		Destructive	10 to 55 Hz at double amplitude of 1.5 mm		
Expected life	Mechanical		Contact Gap 1.5 mm .059 inch type: Min. 10^7 (at 180 times/min.) Contact Gap 1.8 mm .071 inch type: Min. 5×10^6 (at 180 times/min.)		
	Electrical	Resistive load	22A 250V AC, Min. 3×10^4 (at 20 times/min.)	—	—
		Inductive load	Destructive: 22A 250V AC (cosφ = 0.8), Min. 3×10^4 (on:off = 0.1s:10s) Overload: 35A 250V AC (cosφ = 0.8), Min. 50 (on:off = 0.1s:10s)	Destructive: 31A 250V AC (cosφ = 0.8), Min. 3×10^4 (on:off = 0.1s:10s) Overload: 47A 250V AC (cosφ = 0.8), Min. 50 (on:off = 0.1s:10s)	Destructive: 33A 250V AC (cosφ = 0.8), Min. 3×10^4 (on:off = 0.1s:10s) Overload: 50A 250V AC (cosφ = 0.8), Min. 50 (on:off = 0.1s:10s)
Conditions	Conditions for operation, transport and storage *5		Ambient temperature: −40°C to +60°C −40°F to +140°F (When nominal coil voltage applied) −40°C to +85°C −40°F to +185°F (Coil holding voltage is when 45 to 80%V of nominal coil voltage is applied.) Humidity: 5 to 85% R.H. (Not freezing and condensing at low temperature) Air pressure: 86 to 106 kPa		
Unit weight			Approx. 23 g .81 oz		

Notes: *1. This value can change due to the switching frequency, environmental conditions, and desired reliability level, therefore it is recommended to check this with the actual load.
*2. Wave is standard shock voltage of ±1.2×50μs according to JEC-212-1981
*3. In accordance with UL class-F
*4. Coil holding voltage is the coil voltage after 100 ms from the applied nominal coil voltage.
*5. The upper limit of the ambient temperature is the maximum temperature that can satisfy the coil temperature rise value. Refer to Usage, transport and storage conditions in NOTES.

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5.5.7.2	Check of setting values				P
5.5.7.2.1	Test				P
Setting values:					
PGU type	Description	Parameter name	Set value in p.u.	Set value L-N	Set value L-L *2)
	nominal voltage	U_n	1	230,0 V	400 V
	Nominal frequency	f_n	1	50 Hz	50 Hz
a) name set of parameter (Parameter setup name in manual or software)					
Stirling generators, fuel cells, coupled directly or via a converter Synchronous and asynchronous generators with $P_n \leq 50$ kW	Excitation threshold U>>	AU>>	1,15	264,5V	460V
	Delay time U>>	tU>>	-	100ms	100ms
	Excitation threshold U>	AU>	1,10	253,0V	440V
	Delay time U> * 1)	tU>	-	100ms *1)	100ms *1)
	Excitation threshold U<	AU<	0,8	184,0 V	320V
	Delay time U<	tU<	-	100ms	100ms
	Excitation threshold U<<	AU<<	deactivated	-	-
	Delay time U<<	tU<<	deactivated	-	-
	Excitation threshold f>	Af>	1,03	51,5Hz	51,5Hz
	Delay time f>	tf>	-	100ms	100ms
	Excitation threshold f<	Af<	0,95	47,5Hz	47,5Hz
	Delay time f<	tf<	-	100ms	100ms
b) name set of parameter (Parameter setup name in manual or software)					
directly coupled synchronous and asynchronous generators with $P_n > 50$ kW	Excitation threshold U>>	AU>>	1,25	287,5V	500V
	Delay time U>>	tU>>	-	100ms	100ms
	Excitation threshold U>	AU>	1,10	253,0V	440V
	Delay time U> * 1)	tU>	-	100ms *1)	100ms *1)
	Excitation threshold U<	AU<	0,8	184,0V	320V
	Delay time U<	tU<	-	1s	1s
	Excitation threshold U<<	AU<<	0,45	103,5V	180V
	Delay time U<<	tU<<	-	300ms	300ms
	Excitation threshold f>	Af>	1,03	51,5Hz	51,5Hz
	Delay time f>	tf>	-	100ms	100ms
	Excitation threshold f<	Af<	0,95	47,5Hz	47,5Hz
	Delay time f<	tf<	-	100ms	100ms

c) name set of parameter (Parameter setup name in manual or software)					
Inverter	Excitation threshold U>>	AU>>	1,25	287,5V	500V
	Delay time U>>	tU>>	-	100ms	100ms
	Excitation threshold U>	AU>	1,10	253,0V	440V
	Delay time U> * 1)	tU>	-	100ms *1)	100ms *1)
	Excitation threshold U<	AU<	0,8	184,0V	320V
	Delay time U<	tU<	-	3s	3s
	Excitation threshold U<<	AU<<	0,45	103,5V	180V
	Delay time U<<	tU<<	-	300ms	300ms
	Excitation threshold f>	Af>	1,03	51,5Hz	51,5Hz
	Delay time f>	tf>	-	100ms	100ms
	Excitation threshold f<	Af<	0,95	47,5Hz	47,5Hz
	Delay time f<	tf<	-	100ms	100ms

Factory settings correspond to the values in Table 36	P
There are no factory settings. The information on the setting values in the instructions manual correspond to those in Table 36.	P
External NS protection: settings and delay times are password protected settable	P
External NS protection: It is possible to read the setting values without a tool	P
Integrated NS protection: the setting values are visible via a data interface or display	P
The limit values for U> can be set between 110% and 115% and, in the case of directly coupled synchronous and asynchronous generators with P_{rE} >50kW, the time delay for U< and U<< can be set. All other limit values are protected against unauthorized access.	P

Assessment criterion:

The exam is passed if the following points are met:

The factory setting values correspond

a) With integrated NA protection of VDE-AR-N 4105: 2018-11, 6.5.2 Table 2 (see also Table 36).

b) With central NA protection, either the factory settings of VDE-AR-N 4105: 2018-11, 6.5.2, Table 2 (see also Table 36) or these values can be set.

- In the event of an operator input, the test object only goes into operation after settings have been selected.

The setting values that can be changed according to 4105: 2018-11, 6.5.1 and 6.5.2 can be set within the specified limits and are protected against unauthorized access.

The setting values that cannot be changed according to VDE-AR-N 4105: 2018-11, 6.5.1 and 6.5.2 cannot be changed or are protected from unauthorized access by an additional separate protection system

5.5.7.4	Voltage and frequency control	P
5.5.7.4.1	Voltage and frequency control – Single Phase	P

Integrated NS protection single phase ≤30kVA

Setting values of the NS protection:	Setting	Value [V]	Time [ms]	Setting	Value [V]	Time [ms]
	U>	287,5	100	N/A	N/A	N/A
	U<	184,0	3000	U<<	103,5	300

Operating time of the monitoring device:

HYD 4600-ES

L1 to N:	**Under voltage 1 (4.2):**			**Over voltage 1 (1.2):**		
Ramp [start V to stop V]	>188,6 → <179,4			<282,9 → >292,1		
Step size [V]	<1,15			<1,15		
Step length [s]	>3,200			>0,400		
Limit [V]	184,0 ±1% U_n			287,5 ±1% U_n		
Measurement [V]	184,2	184,5	184,7	286,9	286,8	286,6

L1 to N:	**Under voltage 1 (5.2):**			**Over voltage 1 (2.2):**		
Jump [start V to stop V]	>200,1 → <179,4			<282,9 → >292,1		
Step size [V]	>9,2			>9,2		
Step length [s]	>3,200			>0,400		
Limit [s]	3,000 ≤t ≤3,100			≤0,100		
Measurement [s]	3,045	3,038	3,031	0,092	0,095	0,089

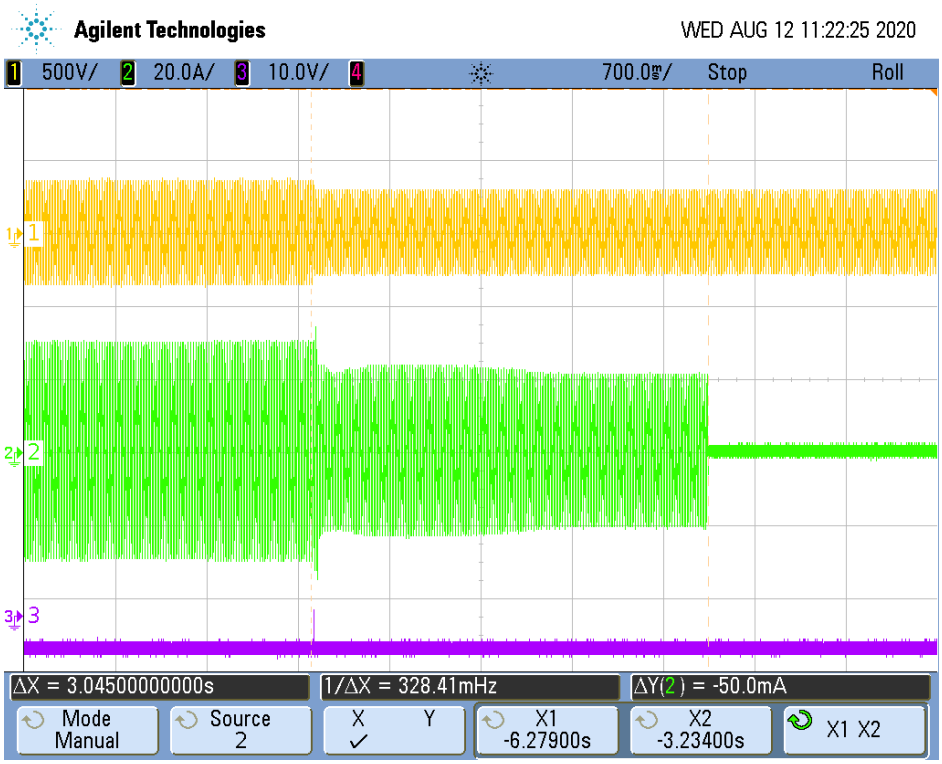
L1 to N:	**Under voltage 2 (6.2):**		
Ramp [start V to stop V]:	>108,1 → <98,9		
Step size [V]	<1,15		
Step length [s]	>0,500		
Limit [V]:	103,5 ±1% U_n		
Measurement [V:]	104,3	104,3	104,3

L1 to N:	**Under voltage 2 (7.2):**		
Jump [start V to stop V]:	>108,1 → <98,9		
Step size [V]	>9,2		
Step length [s]	>0,500		
Limit [s]:	0,300 ≤t ≤0,400		
Measurement [s]:	0,310	0,330	0,337

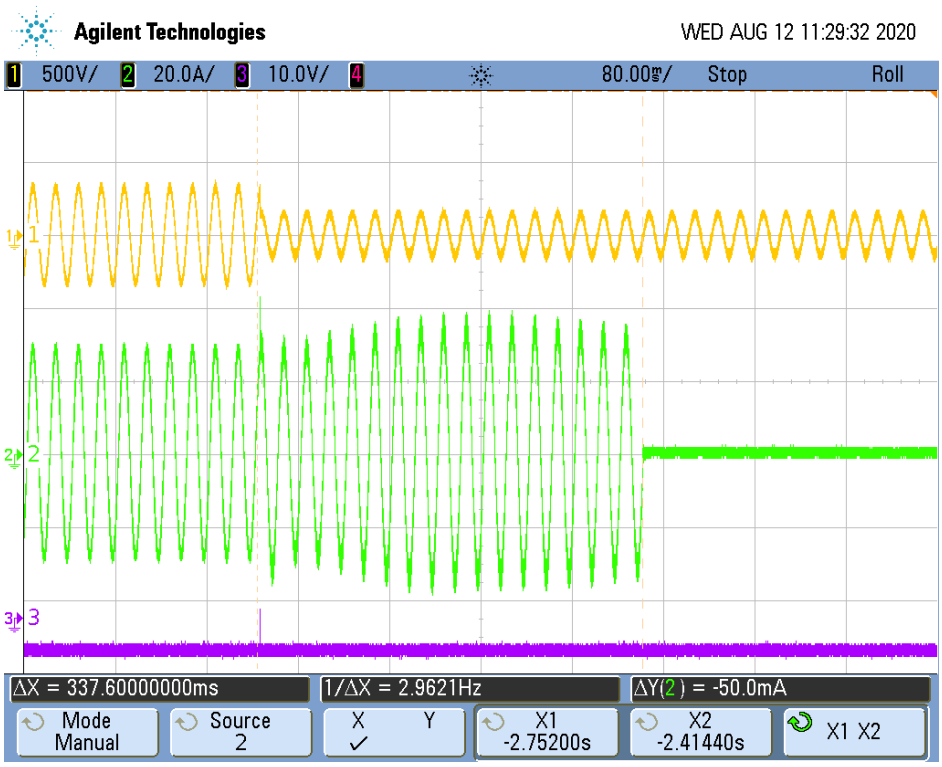
Note:
The disconnection time includes disconnect time + operate time of the integrated relay. Therefore limit is give with +100ms according to Table 2 set values of the NS-protection according to VDE AR-N 4105:2018.
The permitted tolerance between setting value and trip value of the voltage may not exceed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

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

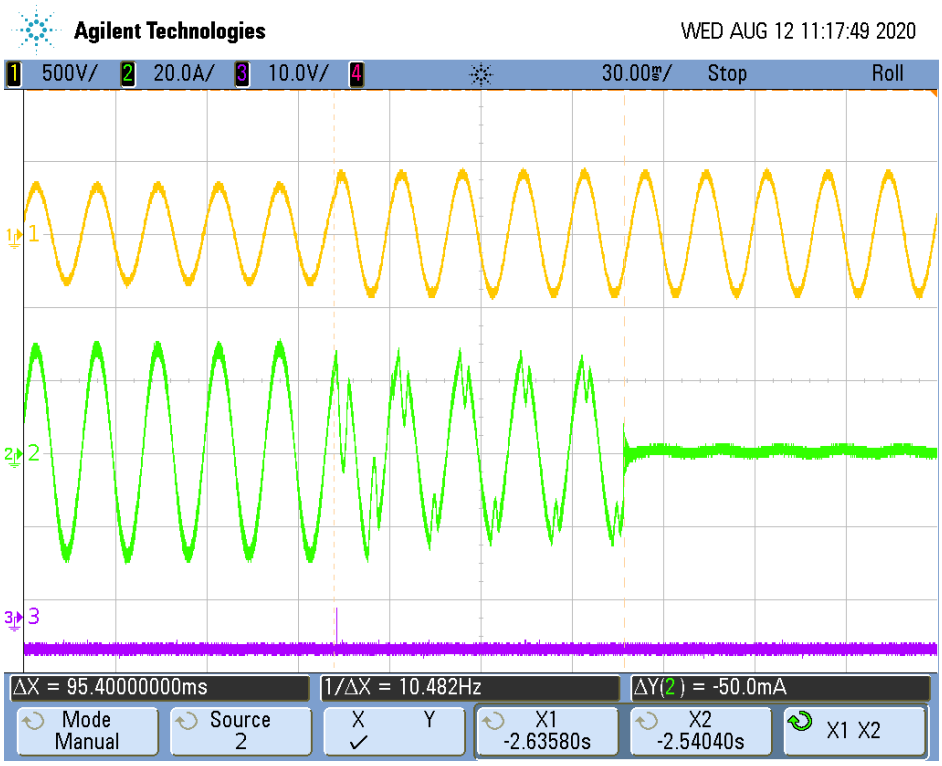
Under voltage 1: L1 to N



Under voltage 2: L1 to N



Over voltage 1: L1 to N



5.5.7.4	**Voltage and frequency control**	**P**
5.5.7.4.1	**Voltage and frequency control – Measuring the rise-in voltage protection as a running 10-minute mean value**	**P**

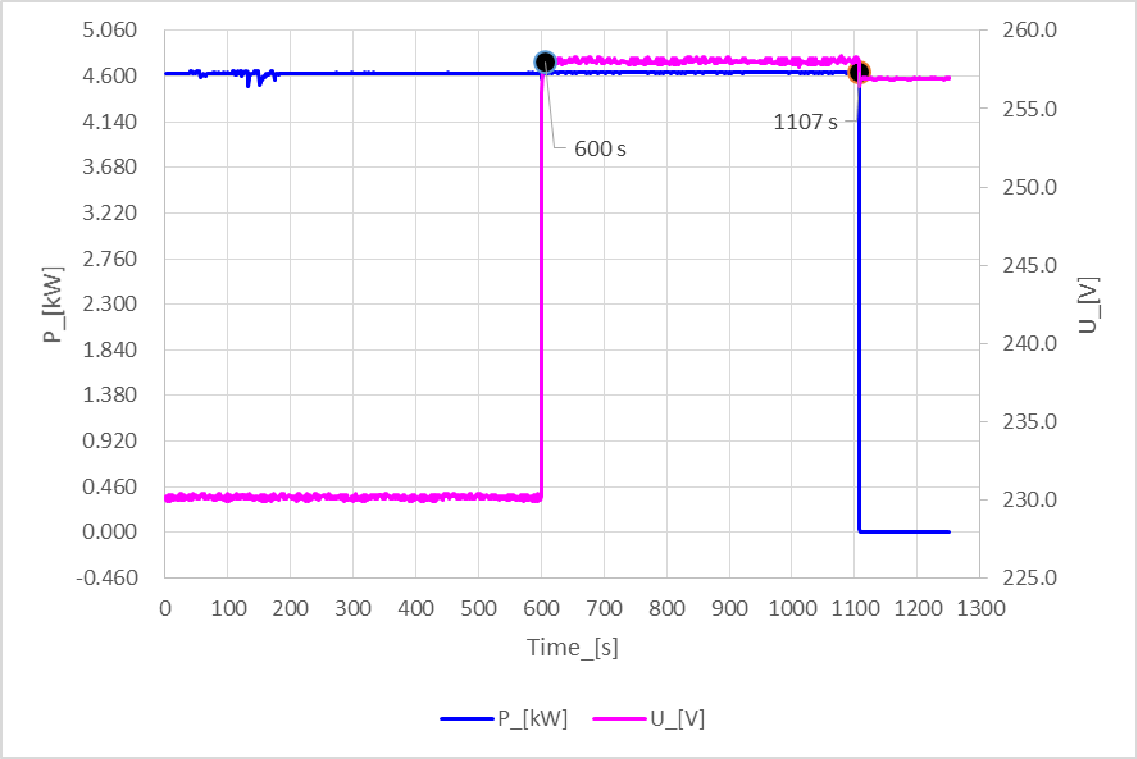
Setting values of the NS protection:	Setting U> [V]	253,0
	Setting $T_{disconnection\ U>}$ [s]	600
	Setting $T_{disconnection}$ [ms]	/

Operating time of the monitoring device:	
HYD 4600-ES	
L1-N,	**Over voltage 10-minute mean value (3.1):**
Ramp [start V to stop V]	230,0 → 257,6
Step size [V]	27,6
Step length [s]	>600,2
Limit for disconnection [s]	450 – 550
Measurement [s]	507 s
L1-N,	**Over voltage 10-minute mean value (3.2):**
Ramp [start V to stop V]	230,0 → >248,4
Step size [V]	18,4
Step length [s]	>600,2
Limit for reconnection [s]	no disconnection (also after 600s)
Measurement [s]	No disconnection
L1-N,	**Over voltage 10-minute mean value (3.3):**
Ramp [start V to stop V]	243,8 → >262,2
Step size [V]	18,4
Step length [s]	>600,2
Limit for disconnection[s]	225 – 375
Measurement [s]	326 s

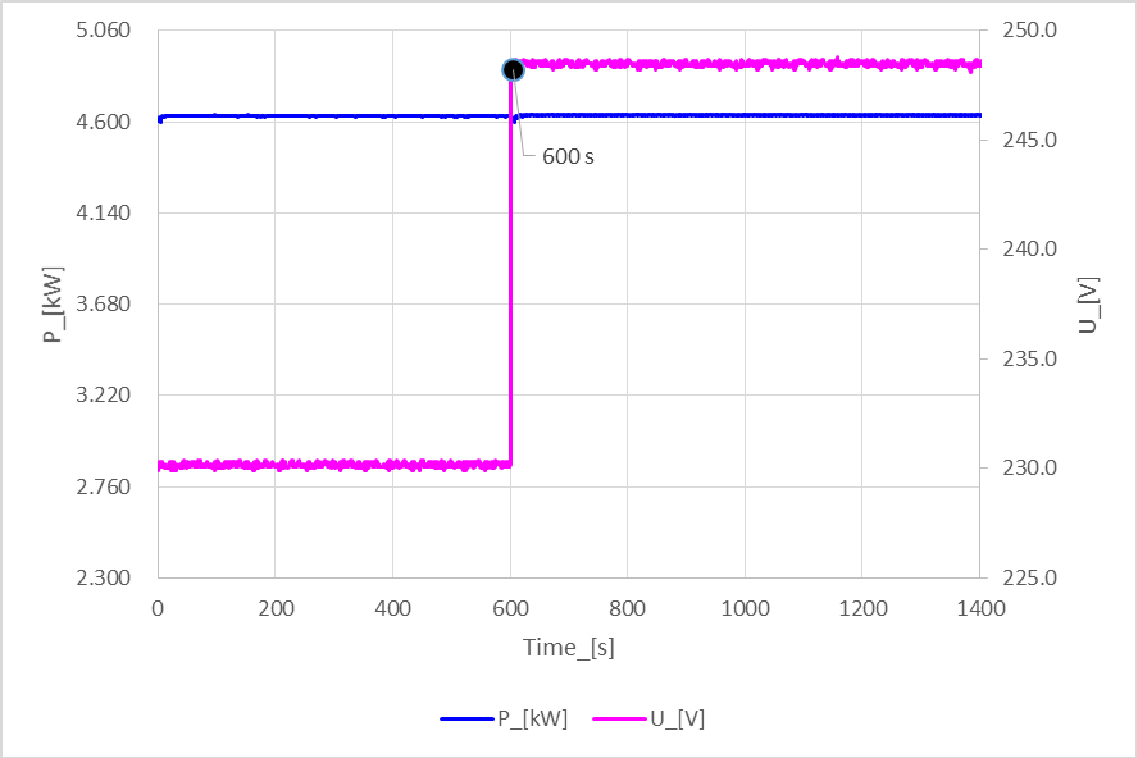
Note:

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

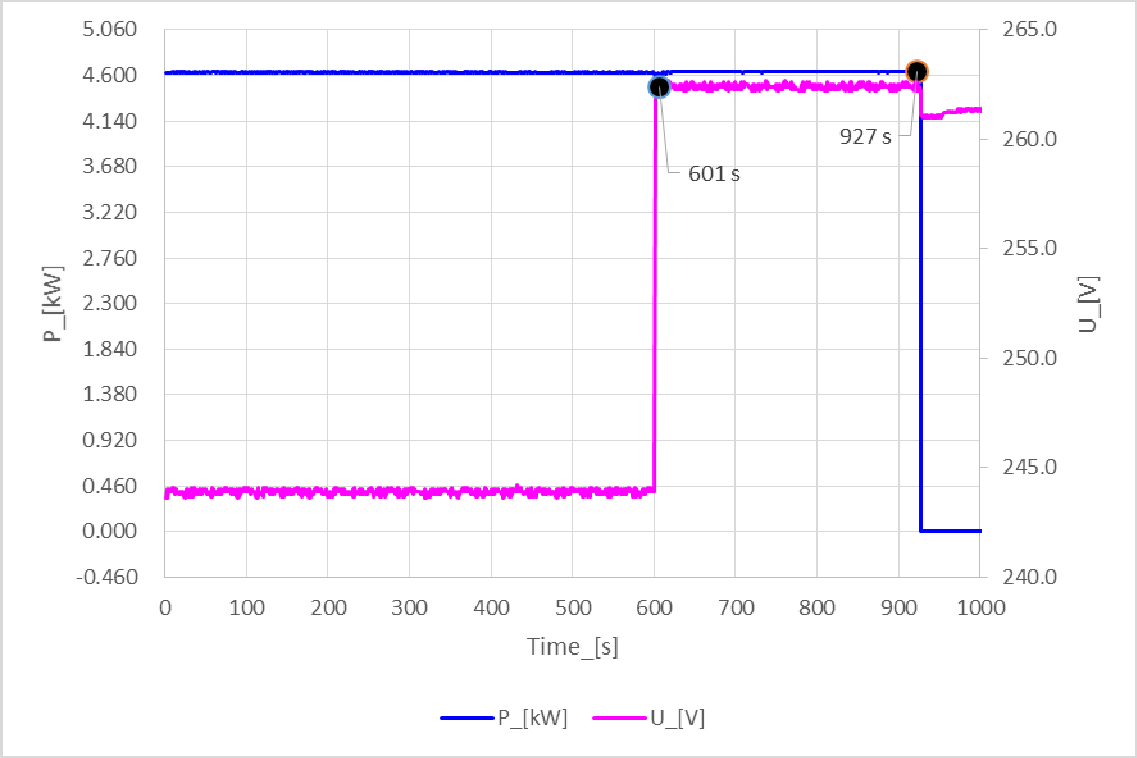
Over voltage 10-minute mean value (3.1): 230,0V to 257,6V



Over voltage 10-minute mean value (3.2): 230,0V to 248,4V



Over voltage 10-minute mean value (3.3): 243,8V to 262,2V



5.5.7.4	Voltage and frequency control	P
5.5.7.4.1	Voltage and frequency control – Frequency measurement	P

Setting values of the NS protection:	Setting	Value [Hz]	Time [s]
	f<	47,50	/
	f>	51,50	/

Operating time of the monitoring device:

HYD 4600-ES

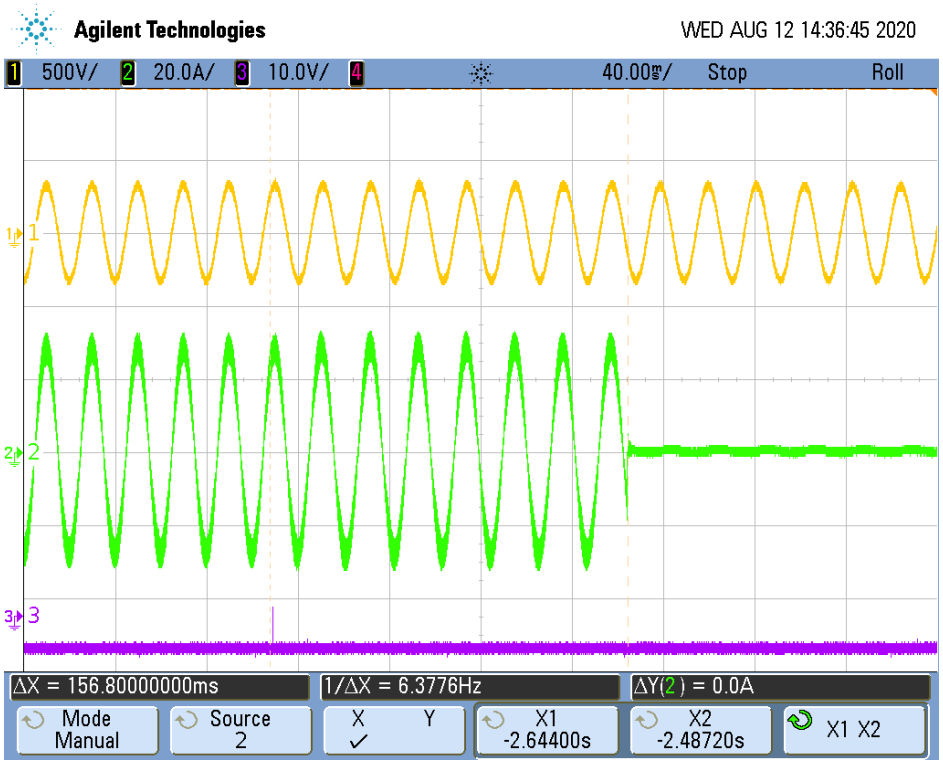
	Under frequency (10.1):			**Over frequency (8.1):**		
Ramp [start Hz to stop Hz]	47,60 → 47,40			51,40 → 51,60		
Step size [Hz]	<0,025			<0,025		
Step length [s]	>0,4			>0,4		
Limit [Hz]	47,50 ±1% f_n			51,50 ±1% f_n		
Measurement [Hz]	47,50	47,50	47,50	51,50	51,50	51,50
	Under frequency (11.1):			**Over frequency (9.1):**		
Jump [start Hz to stop Hz]	47,60 → 47,40			51,40 → 51,60		
Step size [Hz]	>0,2			>0,2		
Step length [s]	>0,4			>0,4		
Limit [s]	0,100 ≤t ≤0,200			0,100 ≤t ≤0,200		
Disconnection time [s]	0,143	0,157	0,146	0,140	0,136	0,152

Note:

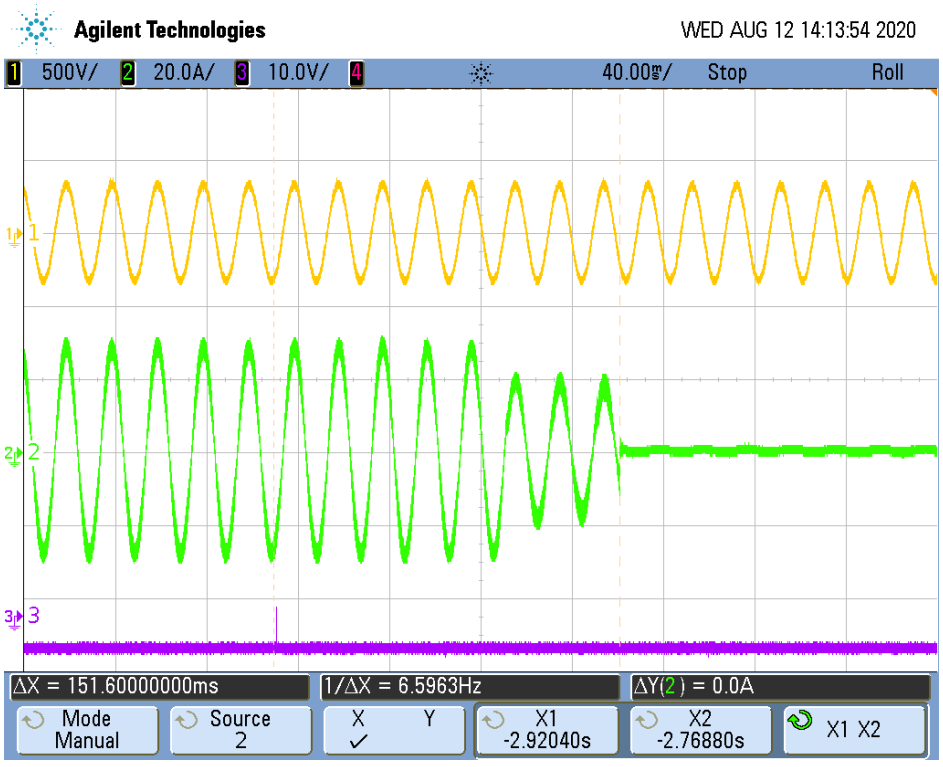
The setting value and the trip value of the frequency may not vary by more than ±0,1 % f_n.

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

Under frequency



Over frequency



5.5.7.5	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.

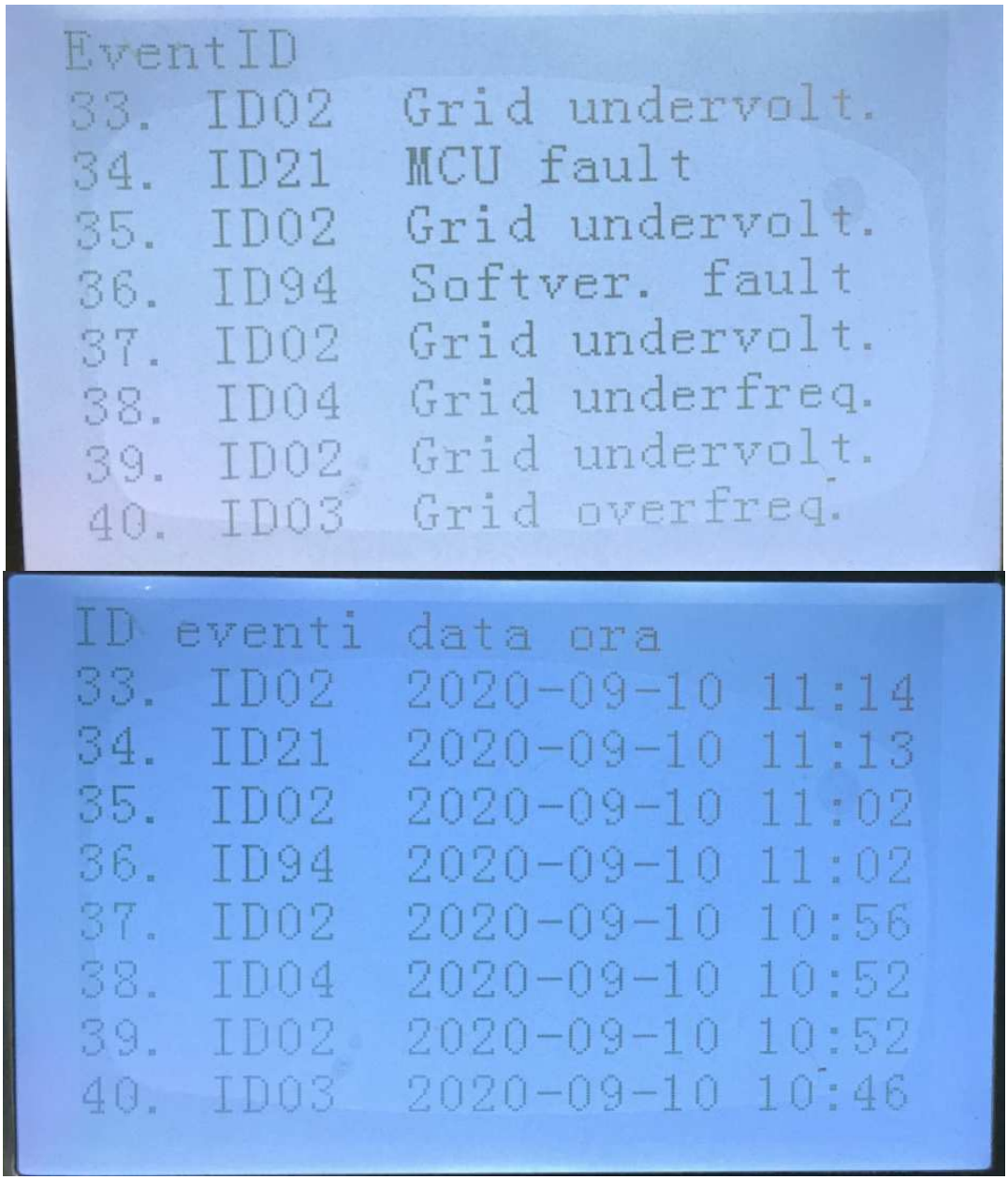
Central NS protection:

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.

Picture of 5 last dated failure:



Assessment criterion:

At least the last 5 error messages including time stamps that were recorded before the voltage interruption and at least 5 error messages including time stamps that were recorded after the voltage interruption must be documented.

5.5.9	**Constructional characteristics of NS protection**	**P**
5.5.9.1	**General**	**P**
These tests serve to demonstrate the requirements of VDE-AR-N 4105: 2018-11, 6.5.2.		
5.5.9.2	**Test**	**P**
Type of NS protection: Internal		
NS-protection is sealed or a password protection is used (or both)		P
adjustability of U> and the time delays for U< and U<< is given		P
All other protective functions are either permanently protected or protected from unauthorized access by additional, separate protection (example password)		P

5.5.10	Islanding detection	P
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 by means of the three-phase voltage monitoring (possible only for power generation systems without inverters or for single-phase power generation units with inverters). (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°.		
5.5.10.1	**General**	**P**
These tests serve as proof of the requirements of VDE-AR-N 4105: 2018-11, 6.5.3. The maximum switch-off time is 9 s.		

5.5.10.2	Passive Islanding detection	N/A
The passive procedure is implemented by the voltage increase and voltage decrease protection of the NS protection.		
Note: A passive procedure is possible with the help of three-phase voltage monitoring (only for generating units without converter or for single-phase generating units with converter) The three-phase voltage monitoring is also permissible with the structural integration of several single-phase generating units that feed into different external conductors, as long as the currents of these generating units are regulated independently of each other so that any phase positions can be set.		

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

Test conditions	Frequency: 50 ±1% f_n U_n = 230 ±1%U_n Distortion factor of chokes ≤2%
Disconnection limit	2s (IEC 62116)

HYD 4600-ES

No	P_{PGU} [1] [% of PGU 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_{PGU} [W per phase]	V_{DC} [V]	Q_f [1]	Run on Time [s]	Re-marks [5]
					L1	L2	L3					
1	100	100	0	0	0,119	/	/	4580	427	1,004	0,591	BL
4	100	100	-5	-5	0,197	/	/	4580	427	1,030	0,413	IB
5	100	100	-5	0	0,167	/	/	4580	427	1,057	0,362	IB
6	100	100	-5	+5	0,190	/	/	4580	427	1,083	0,438	IB
7	100	100	0	-5	1,191	/	/	4580	427	0,978	0,511	IB
8	100	100	0	+5	1,184	/	/	4580	427	1,209	0,498	IB
9	100	100	+5	-5	2,185	/	/	4580	427	0,932	0,391	IB
10	100	100	+5	0	2,158	/	/	4580	427	0,956	0,439	IB
11	100	100	+5	+5	2,179	/	/	4580	427	0.980	0,382	IB

Parameter at 0% per phase	L= 36,63mH	R= 11,55Ω	C= 276,69µF

Note:

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

[1] P_{PGU}: PGU output power

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

[3] Q_{AC}: Reactive power flow at S1 in Figure 1. Positive means power from PGU 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:

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

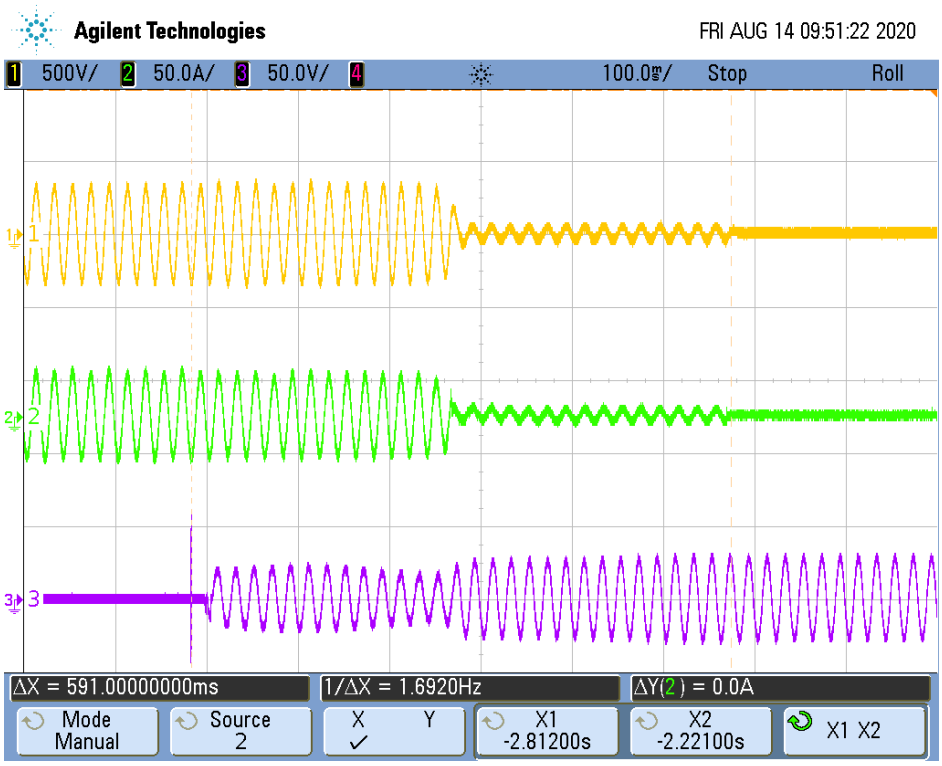
PGU input voltage [6] ≥ 75% of rated input voltage range

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

[7] Based on PGU 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 × PGU maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the PGU should not be operated outside of its allowable input voltage range.

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

5.5.10.3	Islanding protection according table 6 - Load imbalance (real, reactive load) for test condition A (PGU output = 100%)	P
Scope pictures of the disconnection time		
Disconnection at No. 1 at 0%		



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

Test conditions	Frequency: 50 ±1% f_n U_n = 230 ±1%U_n Distortion factor of chokes ≤2%
Disconnection limit	2s (IEC 62116)

No	P_{PGU} [1] [% of PGU 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_{PGU} [W per phase]	V_{DC} [V]	Q_f [1]	Run on Time [s]	Re-marks [5]
					L1	L2	L3					
1	66	66	0	-5	0,166	/	/	3035	277	0,975	0,377	BL
2	66	66	0	-4	0,161	/	/	3035	277	0,980	0,405	IB
3	66	66	0	-3	0,156	/	/	3035	277	0,985	0,373	IB
4	66	66	0	-2	0,153	/	/	3035	277	0,990	0,360	IB
5	66	66	0	-1	0,151	/	/	3035	277	0,995	0,389	IB
6	66	66	0	0	0,150	/	/	3035	277	1,000	0,624	IB
7	66	66	0	1	0,151	/	/	3035	277	1,005	0,550	IB
8	66	66	0	2	0,153	/	/	3035	277	1,010	0,490	IB
9	66	66	0	3	0,156	/	/	3035	277	1,015	0,483	IB
10	66	66	0	4	0,161	/	/	3035	277	1,020	0,499	IB
11	66	66	0	5	0,166	/	/	3035	277	1,025	0,397	IB

Parameter at 0% per phase	L= 55,48mH	R= 17,43Ω	C= 182,62µF

Note:

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

[1] P_{PGU}: PGU output power

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

[3] Q_{AC}: Reactive power flow at S1 in Figure 1. Positive means power from PGU 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:

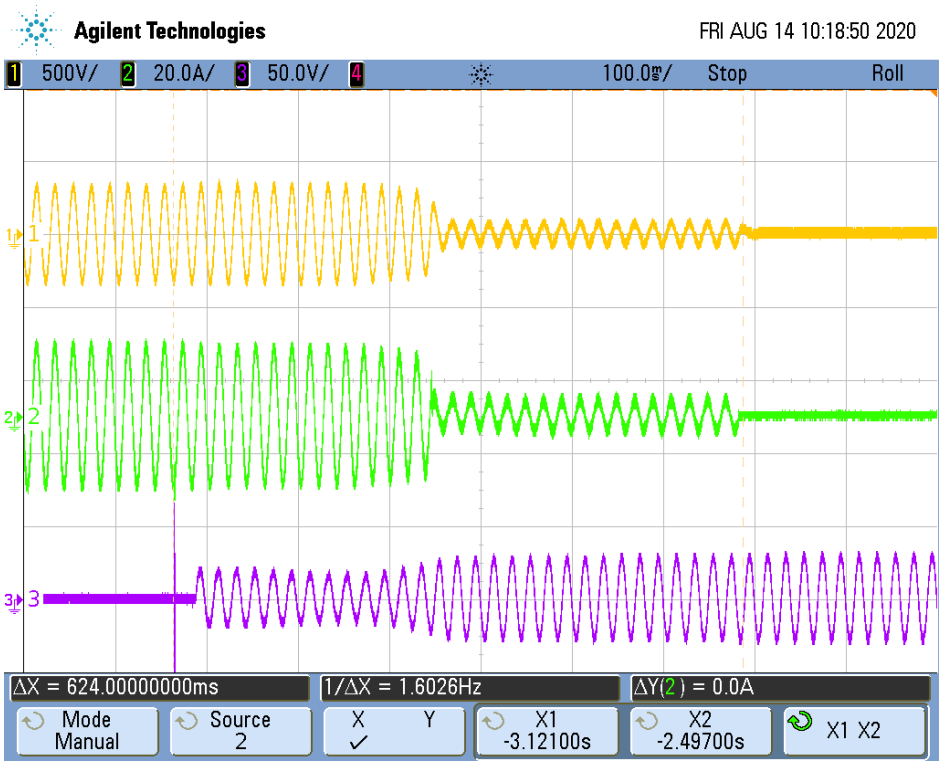
PGU output power P_{PGU} = 50 % – 66 % of maximum

PGU input voltage [6] = 50 % of rated input voltage range, ±10 %

[6] Based on PGU 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 × PGU maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the PGU should not be operated outside of its allowable input voltage range.

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

5.5.10.3	Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (PGU output = 50 % – 66 %)	P
Scope pictures of the disconnection time		
Disconnection at No. 6 at 0%		



5.5.10	**Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (PGU output = 25 % – 33 %)**	**P**
Test conditions	Frequency: 50 ±1% f_n U_n = 230 ±1%U_n Distortion factor of chokes ≤2%	
Disconnection limit	2s (IEC 62116)	

No	P_{PGU} [1] [% of PGU 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_{PGU} [W per phase]	V_{DC} [V]	Q_f [1]	Run on Time [s]	Re-marks [5]
					L1	L2	L3					
1	33	33	0	-5	0,121	/	/	1518	127	0,975	0,328	BL
2	33	33	0	-4	0,118	/	/	1518	127	0,980	0,350	IB
3	33	33	0	-3	0,116	/	/	1518	127	0,985	0,340	IB
4	33	33	0	-2	0,114	/	/	1518	127	0,990	0,384	IB
5	33	33	0	-1	0,113	/	/	1518	127	0,995	0,404	IB
6	33	33	0	0	0,113	/	/	1518	127	1,000	0,427	IB
7	33	33	0	1	0,113	/	/	1518	127	1,005	0,324	IB
8	33	33	0	2	0,114	/	/	1518	127	1,010	0,408	IB
9	33	33	0	3	0,116	/	/	1518	127	1,015	0,396	IB
10	33	33	0	4	0,118	/	/	1518	127	1,020	0,390	IB
11	33	33	0	5	0,121	/	/	1518	127	1,025	0,354	IB

Parameter at 0% per phase	L= 110,93mH	R= 34,85Ω	C= 91,34µF

Note:

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

[1] P_{PGU}: PGU output power

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

[3] Q_{AC}: Reactive power flow at S1 in Figure 1. Positive means power from PGU 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:

PGU output power P_{PGU} = 25 % – 33 % [6] of maximum

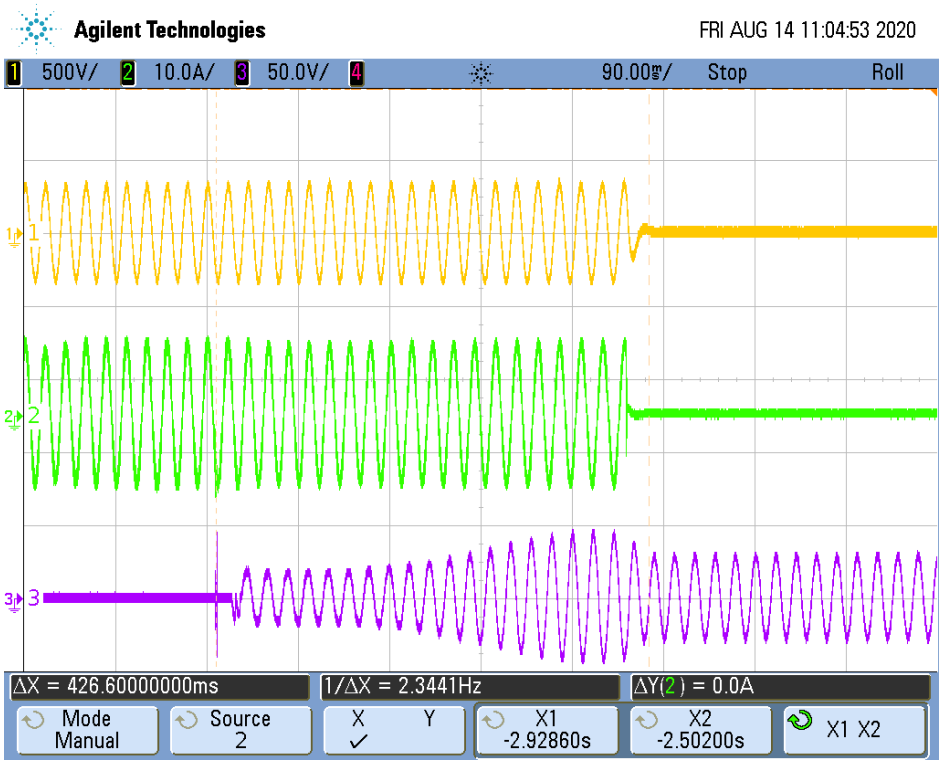
PGU input voltage [7] < 20 % of rated input voltage range

[6] Or minimum allowable PGU output level if greater than 33 %.

[7] Based on PGU 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 × PGU maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the PGU should not be operated outside of its allowable input voltage range.

The tests had been performed on the HYD 4600-ES is valid for the HYD 3000-ES, HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

5.5.10	Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (PGU output = 25 % – 33 %)	P
Scope pictures of the disconnection time		
Disconnection at No. 6 at 0%		



5.6	Testing of connecting conditions and synchronisation	
Clause	**Requirement – Test**	**Verdict**
5.6.1	General	**P**
5.6.2	Connecting conditions and synchronisation	**P**

5.6.2	Connecting conditions and synchronisation		P
Setting values of the NS protection:	Setting $T_{reconnection\ 60s}$ [s]	60,0	
	Setting f< [Hz]	50,06	
	Setting f> [Hz]	47,55	
	Setting V< [V]	250,7	
	Setting V>> [V]	197,8	

Test:

	f_{ist}	Reset time:	Limit:
Connecting conditions for frequencies:			
a)	47,45Hz	No reconnection	No resetting allowed
	Switch to:		
b)	≥47,55Hz	68s	≥60s
c)	50,06Hz	No reconnection	No resetting allowed
	Switch to:		
d)	≥50,0Hz	67s	≥60s
Connecting conditions for voltages:			
e)	84%	No reconnection	No resetting allowed
	Switch to:		
f)	≥86%	70s	≥60s
g)	111%	No reconnection	No resetting allowed
	Switch to:		
h)	≤109%	68s	≥60s

Test:

see points a) to h) for the test process.

The measurement was carried out with a programmable AC source.

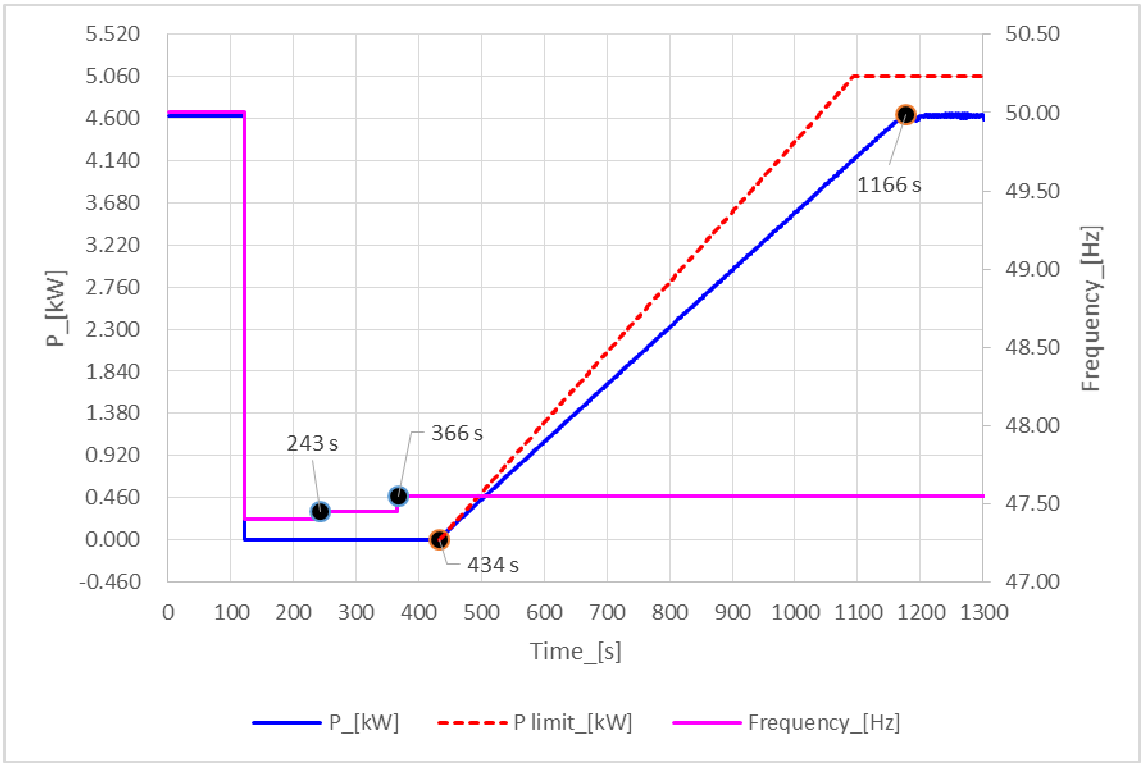
e.g. connecting conditions for frequencies: Point a) and b). The AC source was programmed in such a way that the first step of 230V/50Hz to 200V/47,0Hz resulted in a faulty disconnection. Thereafter the voltage and frequency for 100s is set to 215V/47,45Hz. Switching on again is not permitted. After a lapse of 100s the voltage is set to 230V/47,55Hz. Setting again after 60s is permitted.

The tests had been performed on the HYD 4600-ES and HYD 3000-ES are valid for the HYD 3600-ES and HYD 4000-ES are identical in hardware and software, and the output power derated by software.

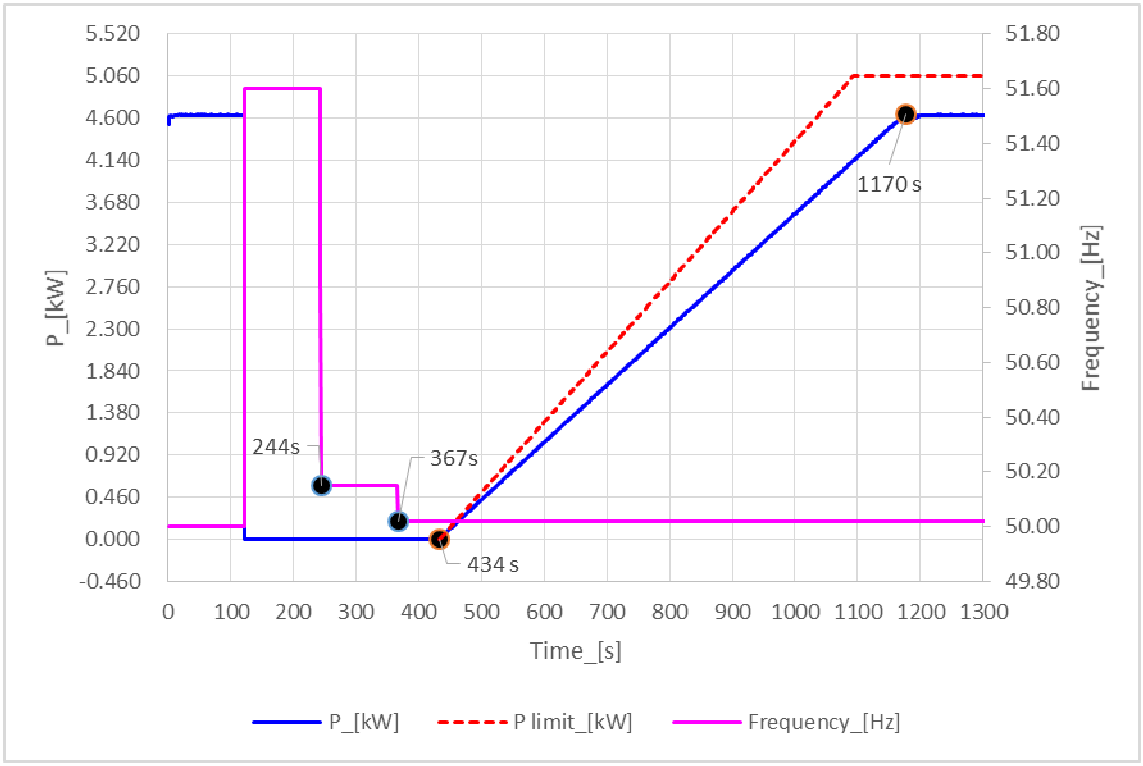
Assessment criterion:

After actuating the NS protection it should be checked that the system can only be switched within the tolerance ranges ((80% U_n ≤U ≤110% U_n) and (47,5Hz ≤f ≤50,05Hz)) at the earliest after 60s after voltage and frequency has remained within the tolerance ranges.

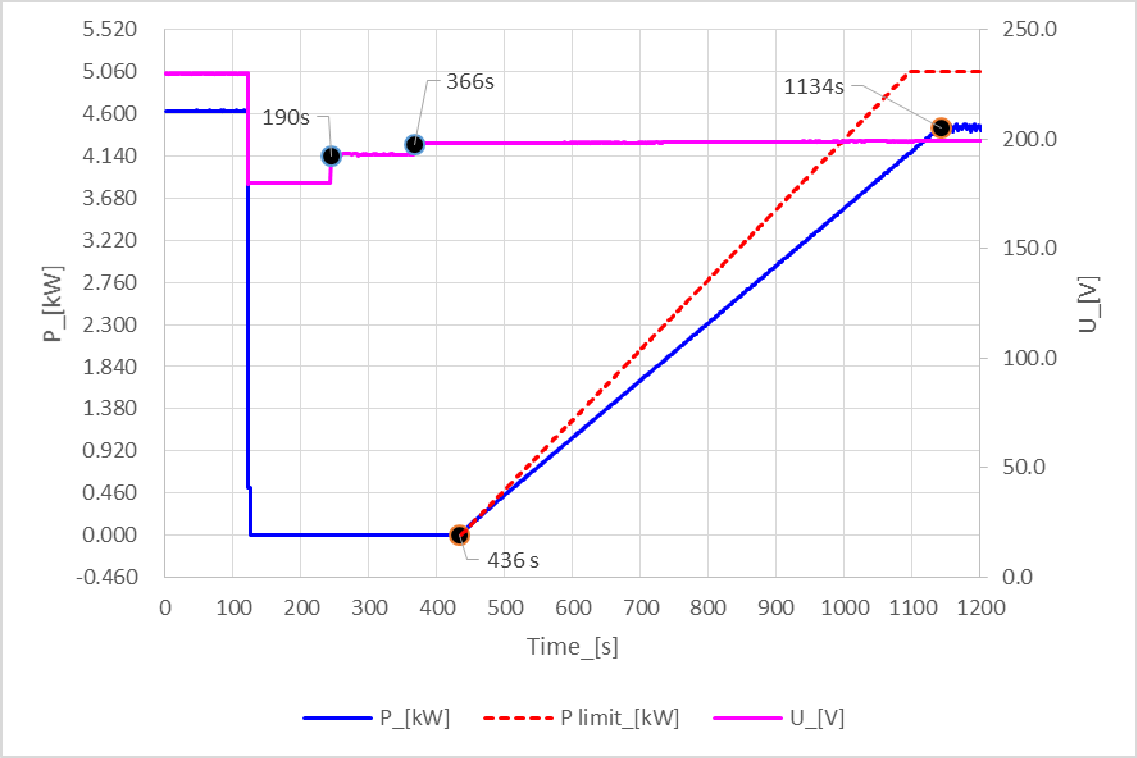
a)47,45Hz to b) 47,55Hz



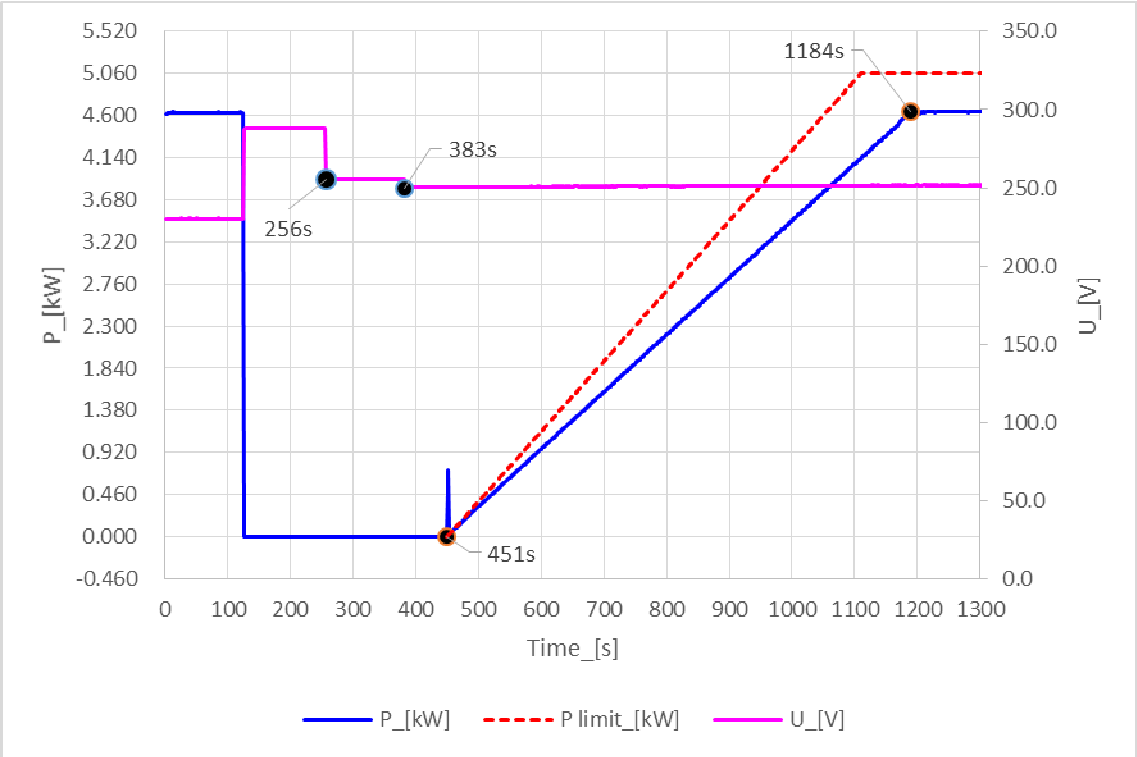
c)50,06Hz to d) 50,00Hz



e) 0,84Un to f) 0,86Un



g) 1,11Un to h) 1,09Un

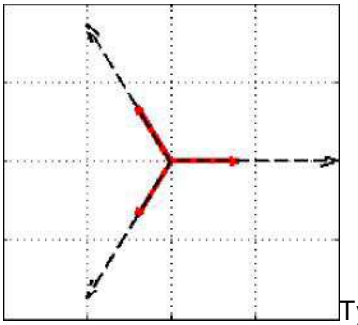


5.7	Evidence of $P_{AV,E}$ –Control	
Clause	**Requirement – Test**	**Verdict**
5.7.1	General	**N/A**
5.7.2.1	Test control dynamic	**N/A**
5.7.2.2	Test disconnection function	**N/A**

5.8	Evidence dynamic grid support	
Clause	**Requirement – Test**	**Verdict**
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**

5.8.1	General	P

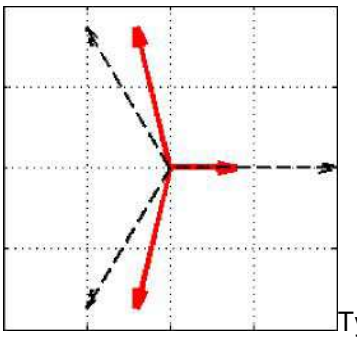
FRT test for three-phase symmetrical (Test ref no. x.1.x)



Typ-A

LVRT test for two-phase asymmetrical fault (Test ref no. 1.2.x to 5.2.x)

Test No.	V/V_{nom}	Phase-to-earth voltages			Phase angles		
		$u_1/u_{1,nom}$	$u_2/u_{2,nom}$	$u_3/u_{3,nom}$	φ_{u1}	φ_{u2}	φ_{u3}
1.2.x	0,1-0,15	0,1-0,15	0,87 ± 0,05	0,87 ± 0,05	0°	-94°	94°
2.2.x	0,20-0,25	0,20-0,25	0,87 ± 0,05	0,87 ± 0,05	0°	-97°	97°
3.2.x	0,50 ± 0,05	0,50 ± 0,05	0,90 ± 0,05	0,90 ± 0,05	0°	-106°	106°
4.2.x	0,75 ± 0,05	0,75 ± 0,05	0,94 ± 0,05	0,94 ± 0,05	0°	-113°	113°
5.2.x	0,92 ± 0,05	0,92 ± 0,05	0,98 ± 0,05	0,98 ± 0,05	0°	-118°	118°
Normal condition	1	1	1	1	0°	-120°	120°



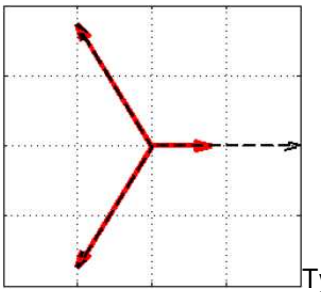
Typ-D

FRT test for two-phase asymmetrical fault (Test ref no. 6.2.x to 7.2.x)

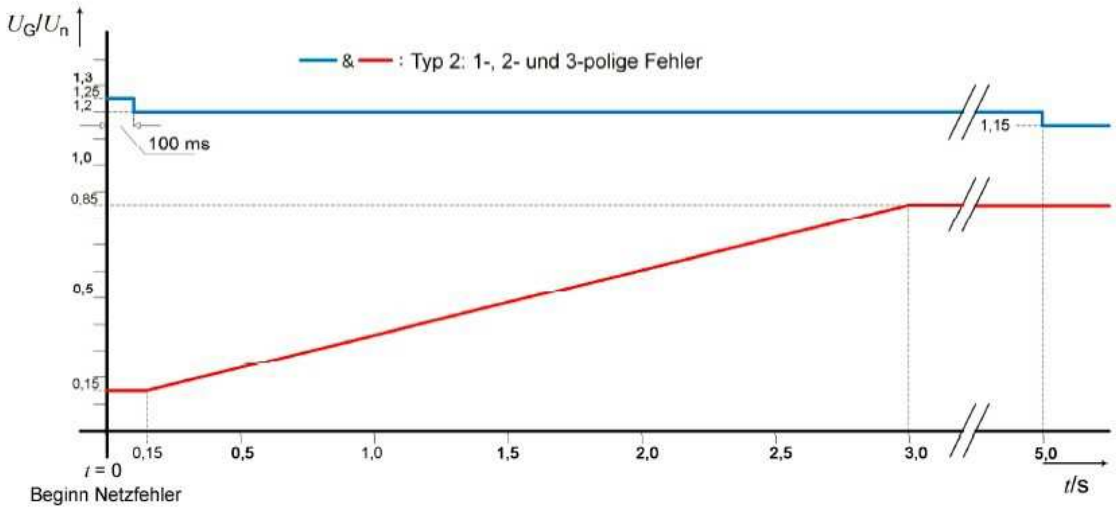
Test No.	V/V_{nom}	Phase-to-earth voltages			Phase angles		
		$u_1/u_{1,nom}$	$u_2/u_{2,nom}$	$u_3/u_{3,nom}$	φ_{u1}	φ_{u2}	φ_{u3}
6.2.x	1,25-1,30	1,25-1,30	1,25-1,30	1,00 ± 0,05	0°	-120°	120°
7.2.x	1,20 ± 0,05	1,20 ± 0,05	1,20 ± 0,05	1,00 ± 0,05	0°	-120°	120°

5.8.1	General							P
Normal condition	1	1	1	1	0°	-120°	120°	

FRT test for two-phase asymmetrical fault (Test ref no. x.3.x)



Typ-B



Legende

& FRT-Kurve für 1-, 2- und 3-polige Netzfehler

UG Effektivwert der aktuellen Spannung an den Generatorklemmen

Bild 12 – Fault-Ride-Through-Grenzkurve für den Spannungsverlauf an den Generatorklemmen für eine Erzeugungseinheit vom Typ 2 und für Speicher

Figure 12 - Fault ride-through limit curve for the voltage curve at the generator terminals for a **type 2** generation unit and for storage

5.8.3	Testing of the dynamic grid support	P
	For PGUs Type 2 and storage systems	P
	1 and 3-phase systems	

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.	R recovery response time [ms]
1	0,15 to 0,25	A	for 0,15 ≥ 150 / for 0,25 ≥ 500	1	0 to ± 0,1	Symmetric	1.1	141,74
				0,2 to 0,6			1.2	70,08
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	1.3	N/A
				0,2 to 0,6			1.4	N/A
		D2		1			1.5	N/A
2	0,50 to 0,60	A	for 0,50 ≥ 1500 / for 0,60 ≥ 2000	1	Max. over excited	Symmetric	2.1	10093,68
				0,2 to 0,6			2.2	330,72
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	2.3	N/A
				0,2 to 0,6			2.4	N/A
3	0,50 to 0,60	A	for 0,50 ≥ 1500 / for 0,60 ≥ 2000	1	Max. under excited	Symmetric	3.1	200,00
				0,2 to 0,6			3.2	300,00
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	3.3	N/A
				0,2 to 0,6			3.4	N/A
4	0,85 to 0,90	A	≥ 60000	1	0 to ± 0,1	Symmetric	4.1	314,96
				0,2 to 0,6			4.2	236,22
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	4.3	N/A
				0,2 to 0,6			4.4	N/A
5	1,20 to 1,25	A	≥ 100	1	0 to ± 0,1	Symmetric	5.1	141,74
				0,2 to 0,6			5.2	261,42
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	5.3	N/A
				0,2 to 0,6			5.4	N/A
		D2		1			5.5	N/A
6	1,15 to 1,20	A	≥ 5000	1	0 to ± 0,1	Symmetric	6.1	204,72
				0,2 to 0,6			6.2	314,96
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	6.3	N/A
				0,2 to 0,6			6.4	N/A
7	1,10 to 1,15	A	≥ 60000	1	0 to ± 0,1	Symmetric	7.1	157,48
				0,2 to 0,6			7.2	314,96
		D1		1		Asymmetric (ph-2ph + Dy5-Trafo	7.3	N/A
				0,2 to 0,6			7.4	N/A

5.8.3	Testing of the dynamic grid support	P

Note:

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

Behaviour 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 2 units and storage systems are not allowed to inject either 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 60ms after the occurrence of this under-/ under voltage dip in any phase.

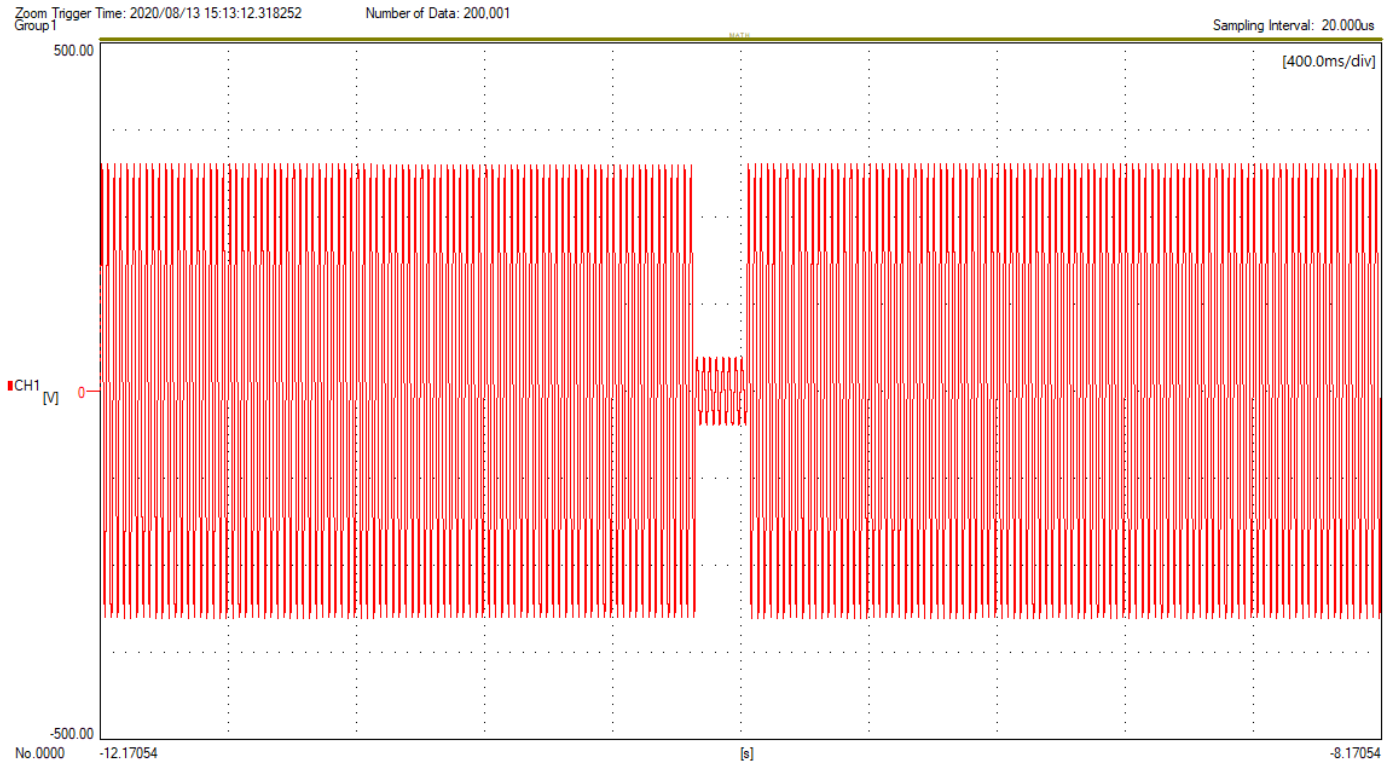
Behaviour after the end of the error:

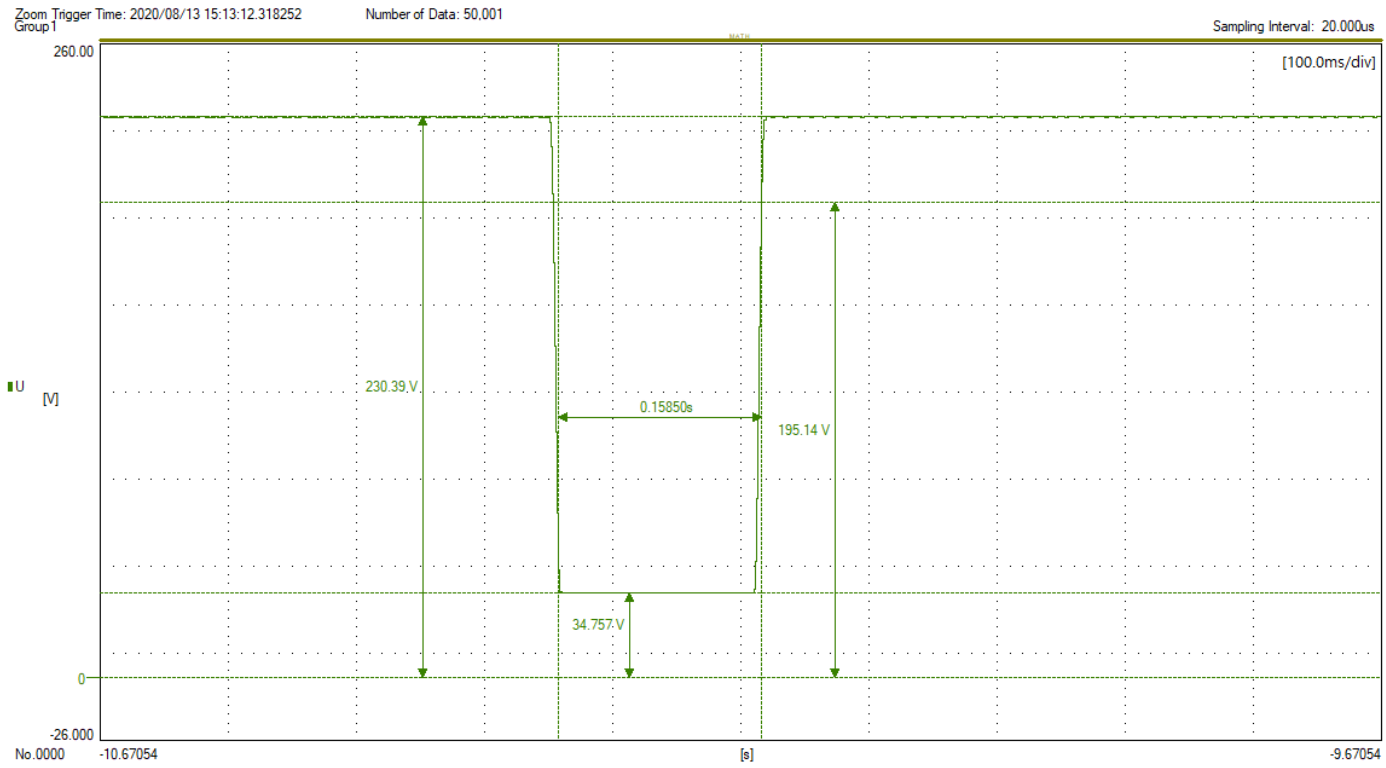
- Not disconnection of the PGU within 60s after the end of the fault.
- Type 2 units and storage systems: Reaction time of active power up to 1s, Reaction time of reactive power according to PT1 behaviour with 3 tau = 10s in accordance with VDE-AR-N 4105: 2018-11, 5.7.2.5

* The EUT is single phase PV inverter which there is no Positive sequence, Zero sequence and Negative sequence distinguish between.

5.8.3	For PGUs Type 2 and storage systems – no load	P

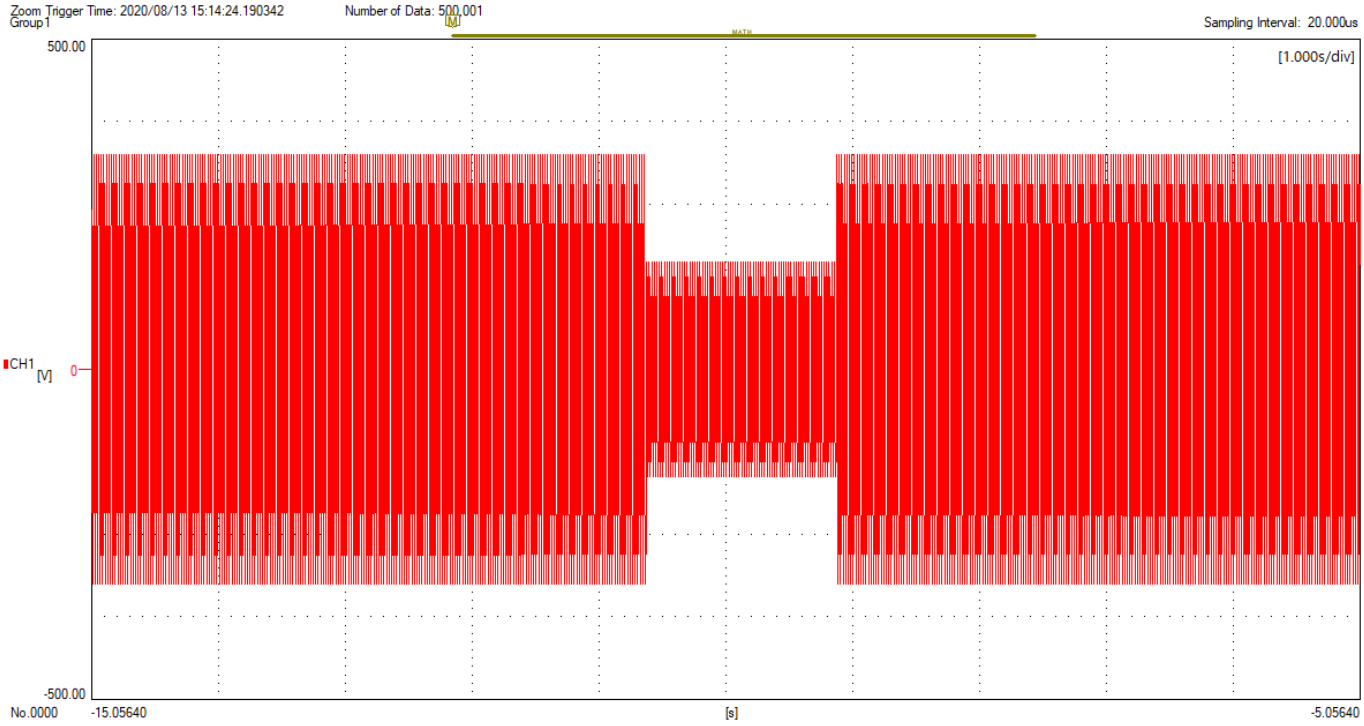
1.1

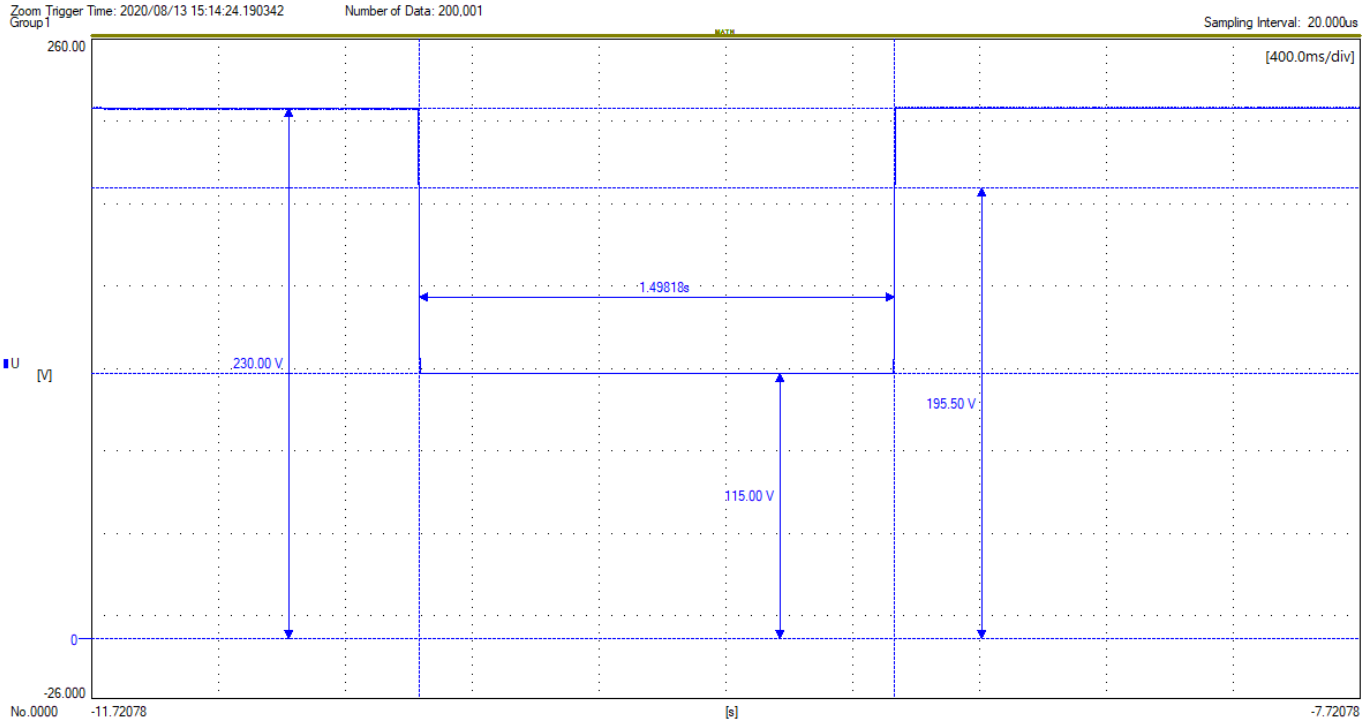




5.8.3	For PGUs Type 2 and storage systems – no load	P

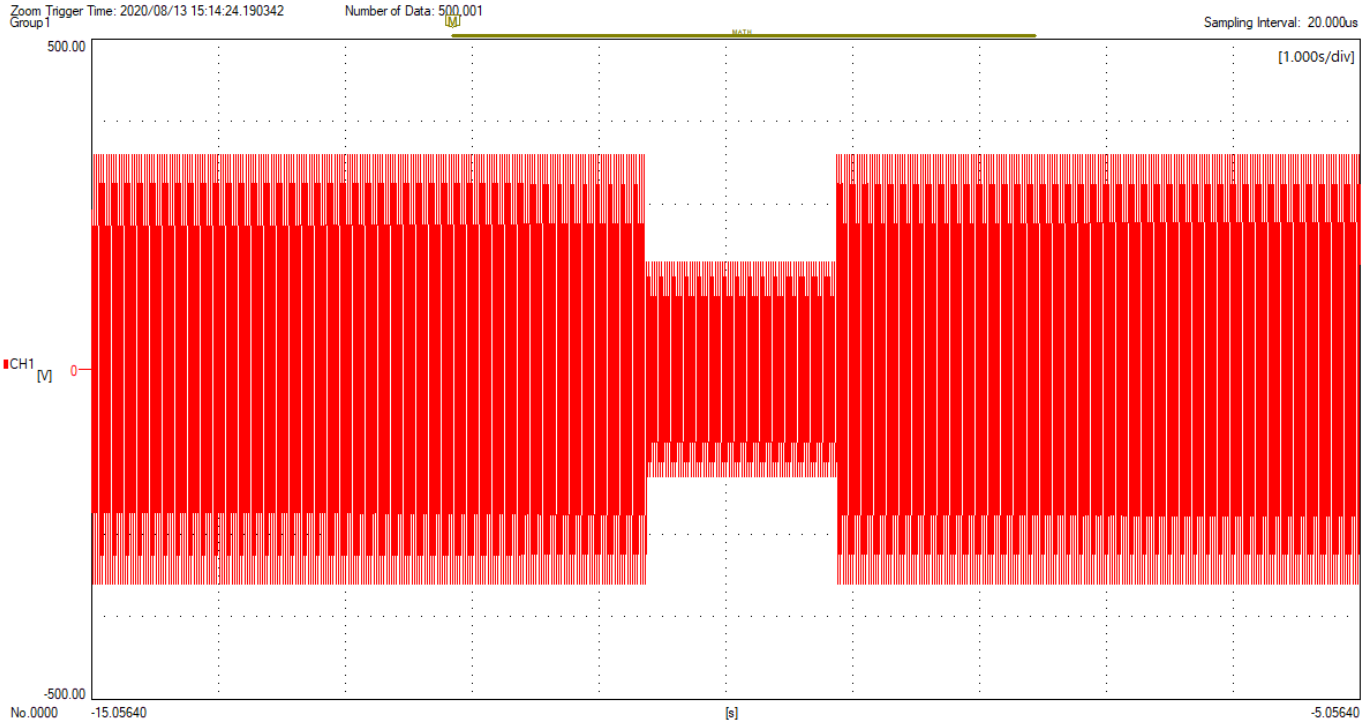
2.1

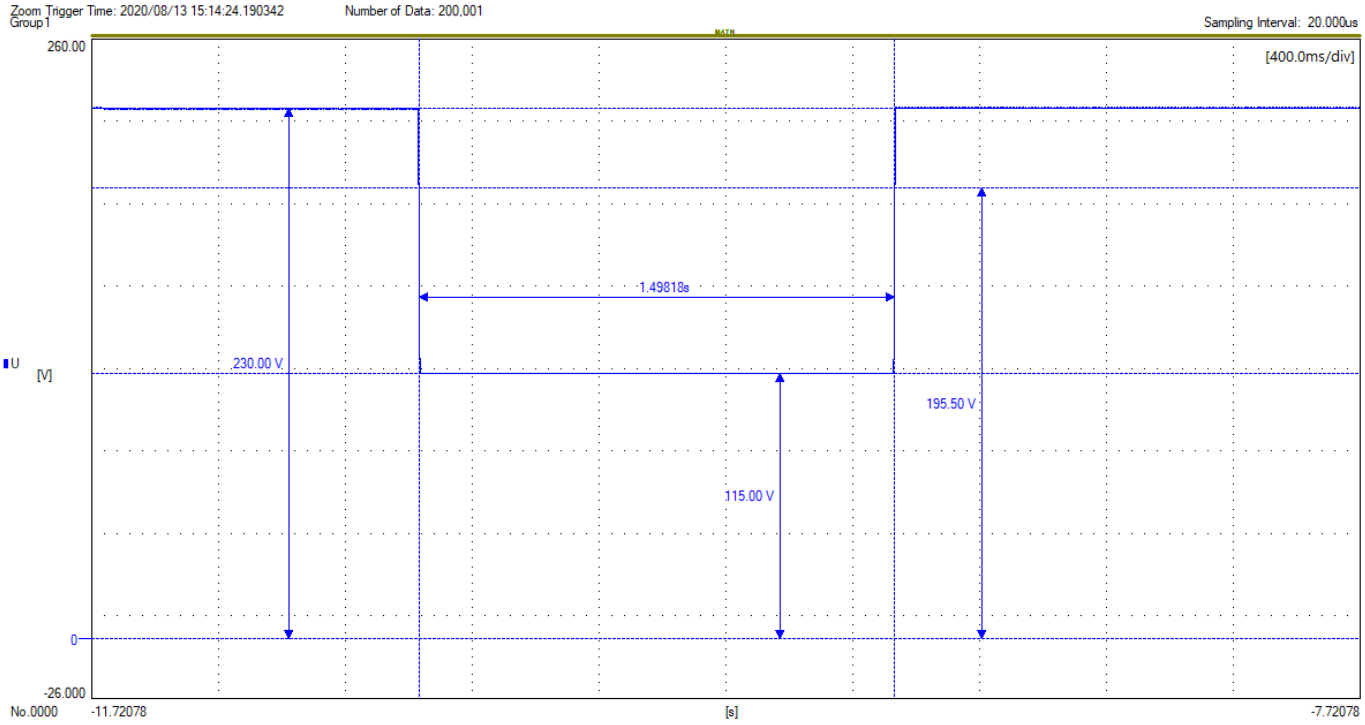




5.8.3	For PGUs Type 2 and storage systems – no load	P

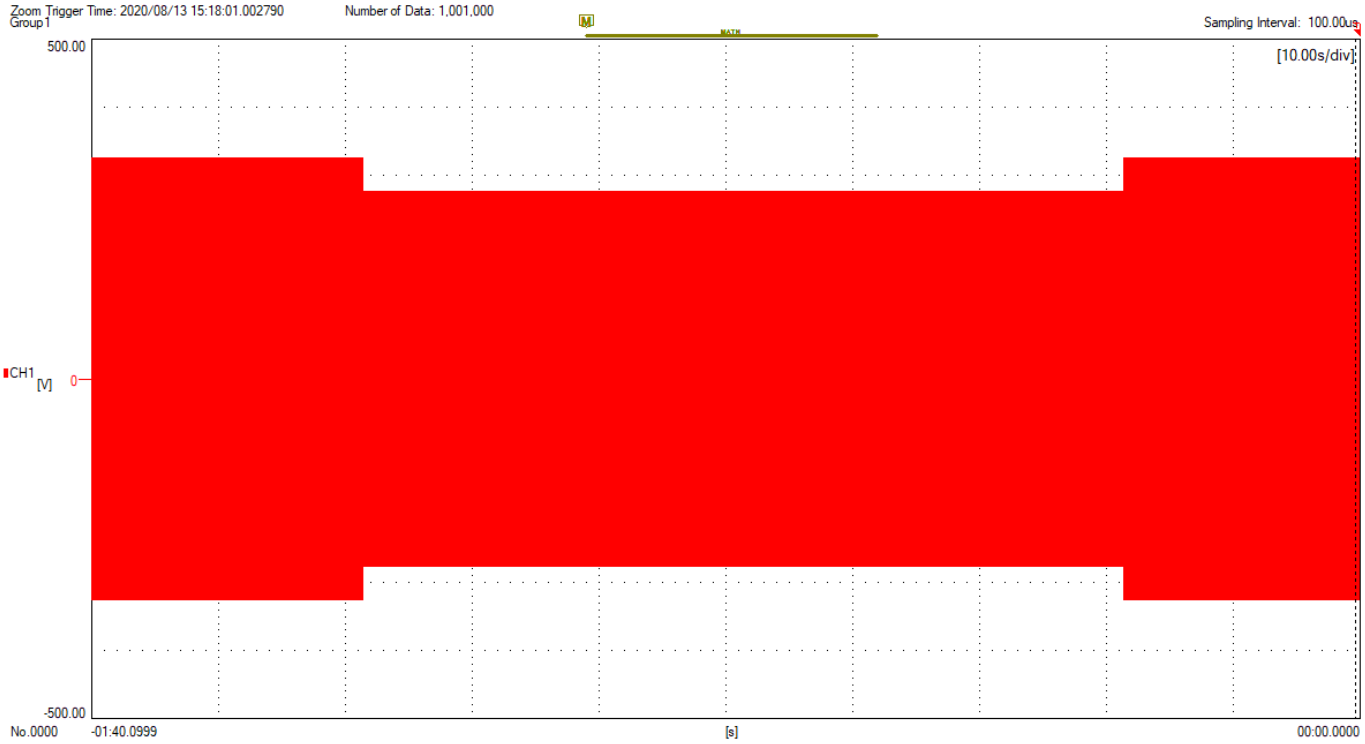
3.1

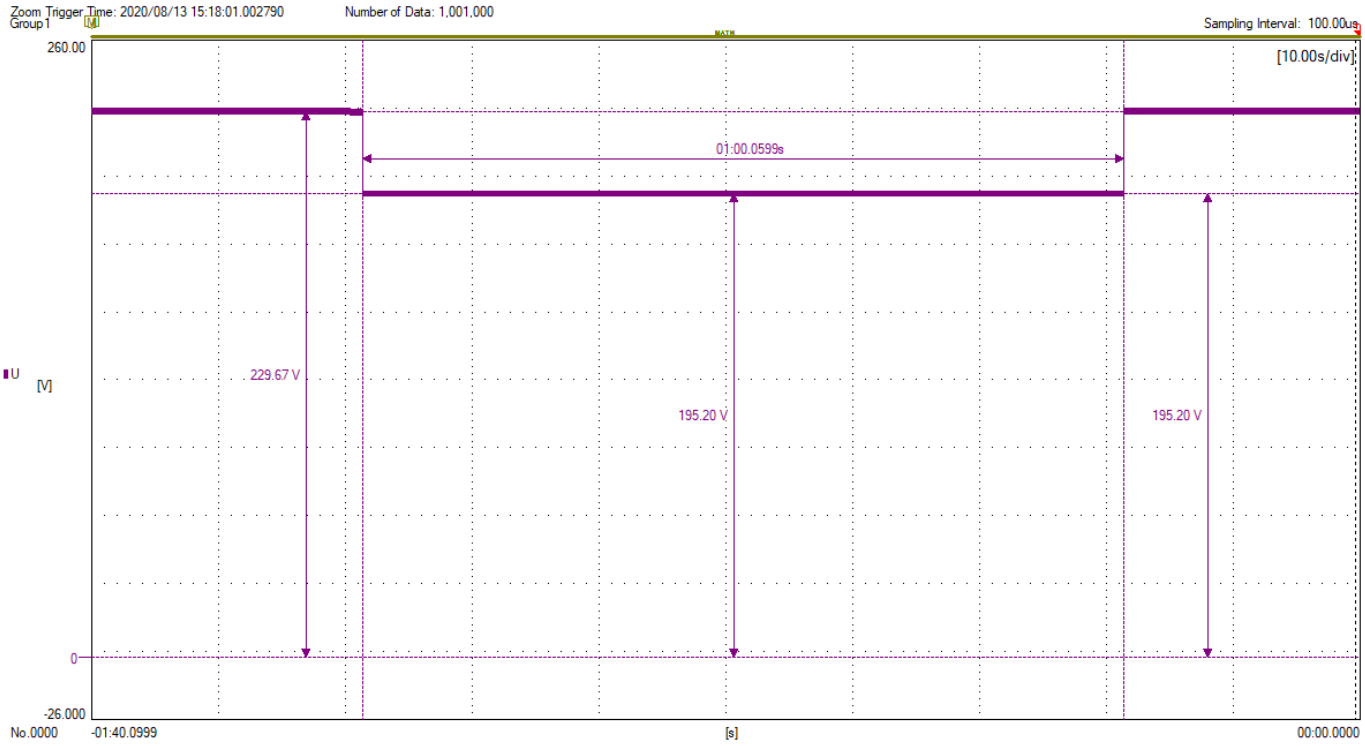




5.8.3	For PGUs Type 2 and storage systems – no load	P

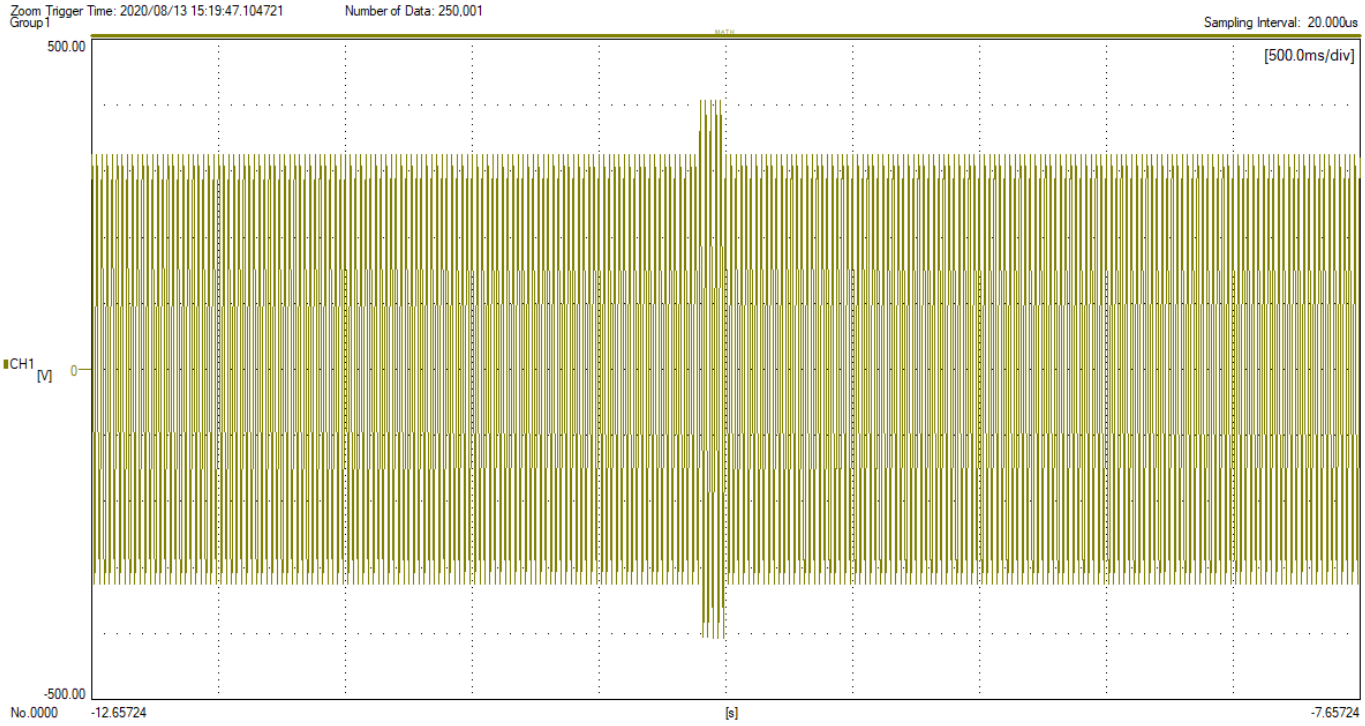
4.1

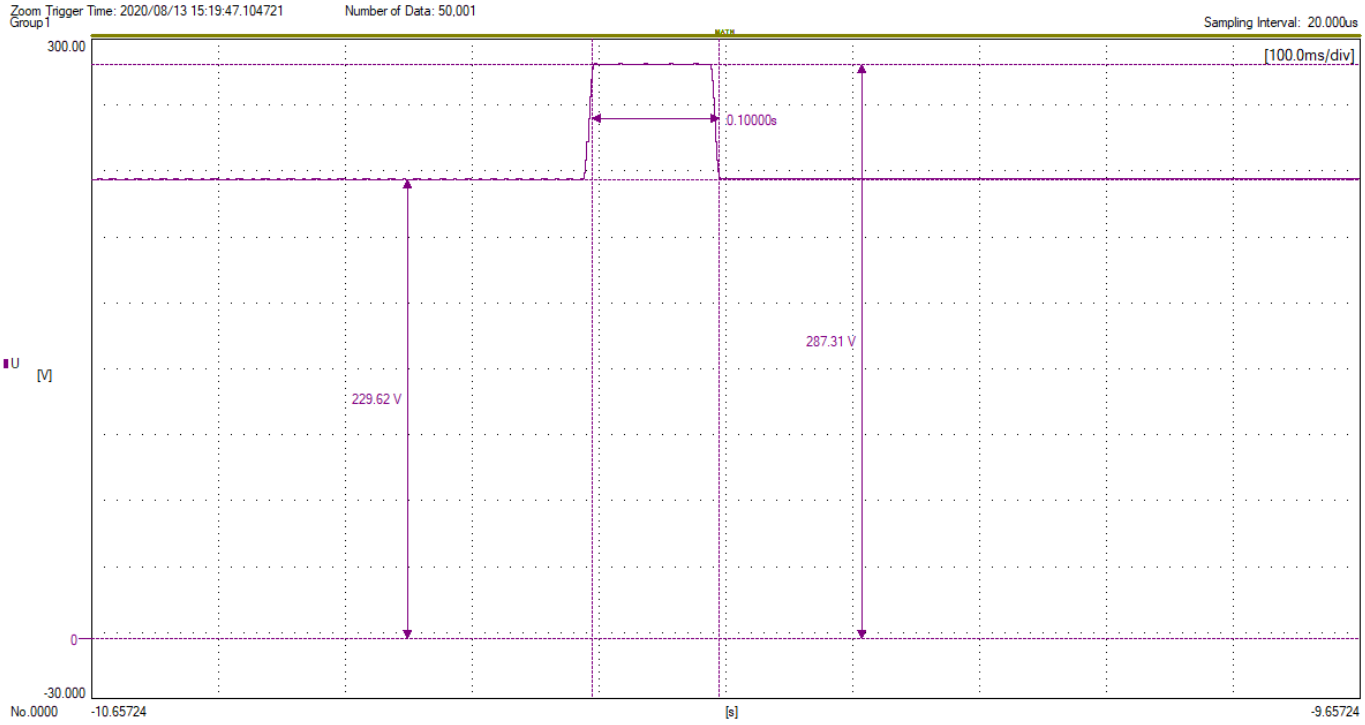




5.8.3	For PGUs Type 2 and storage systems – no load	P

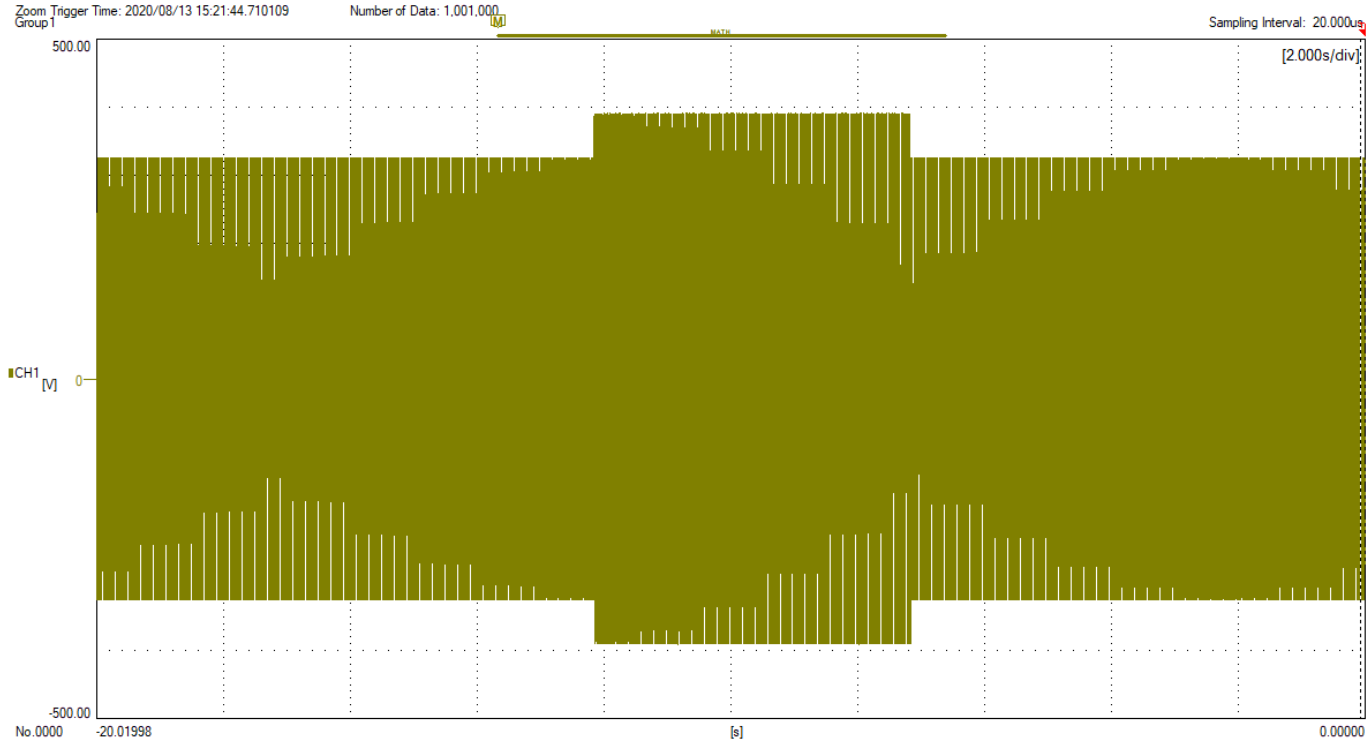
5.1

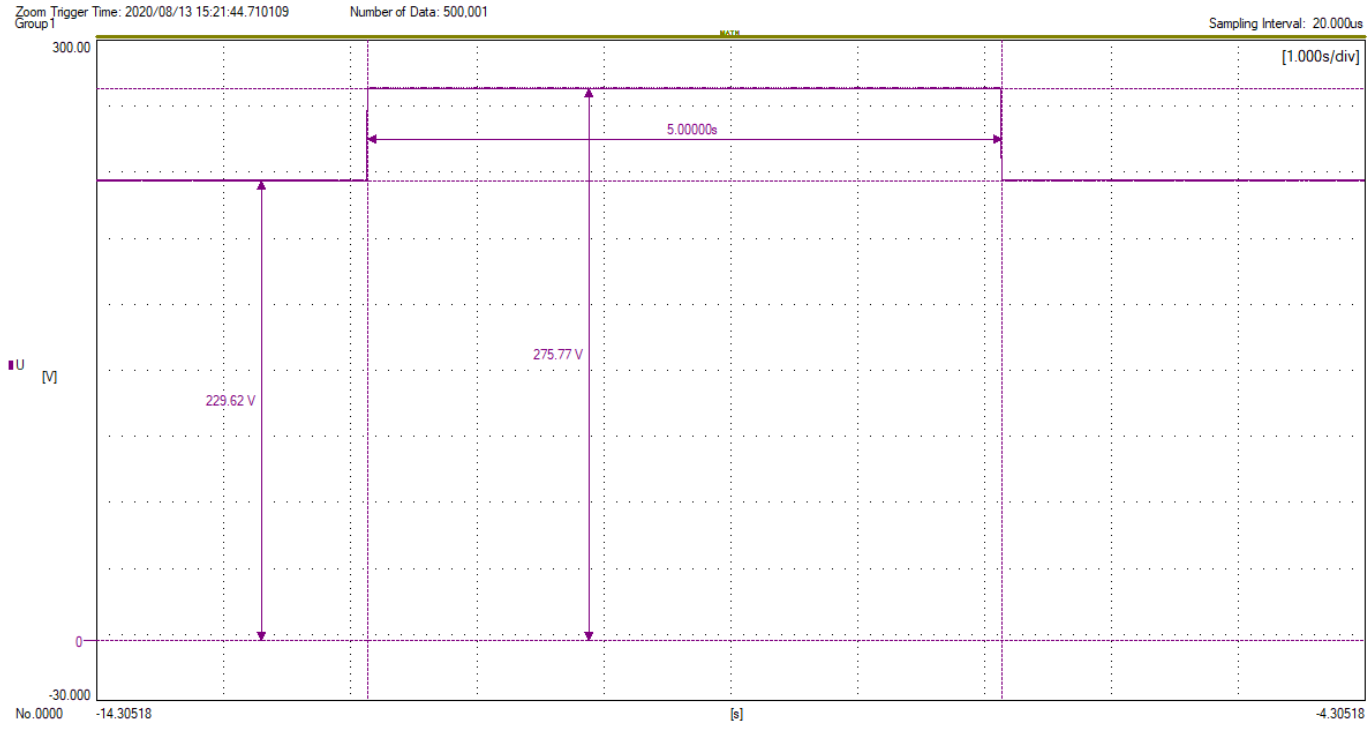




5.8.3	For PGUs Type 2 and storage systems – no load	P

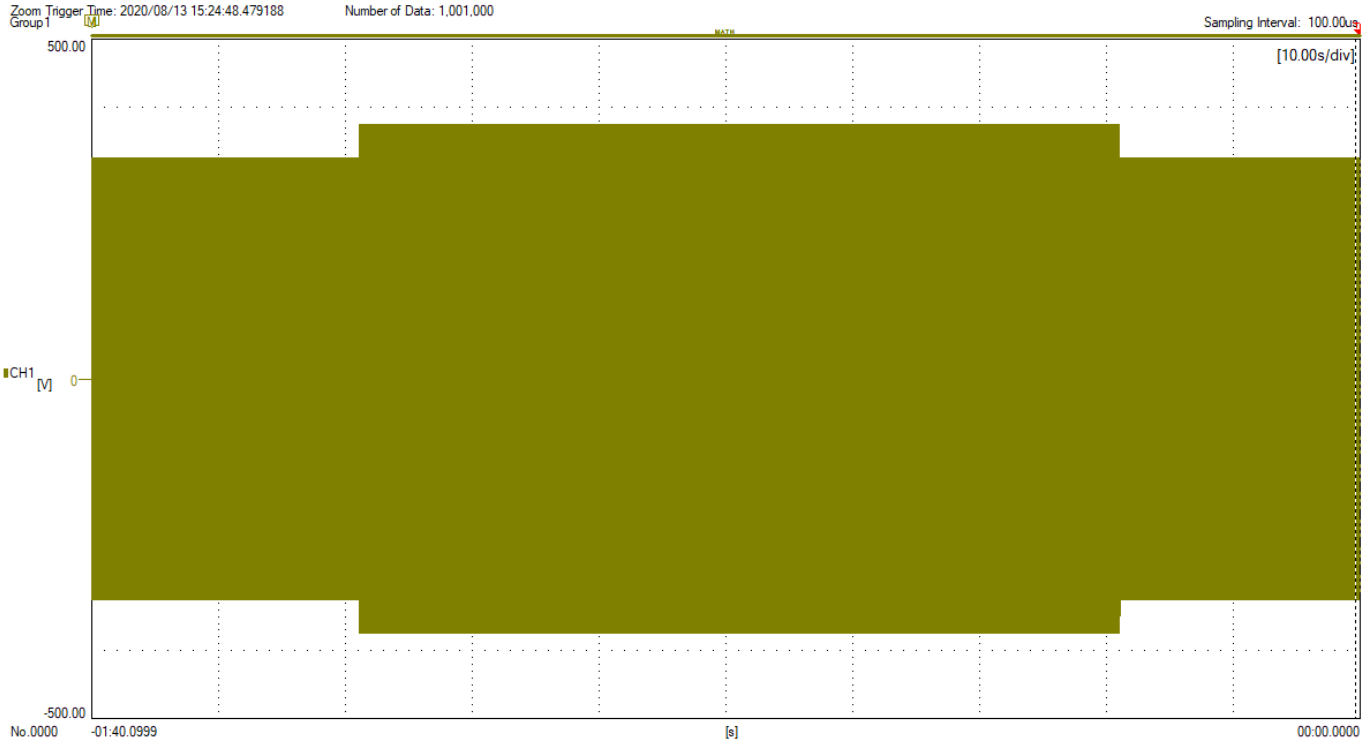
6.1

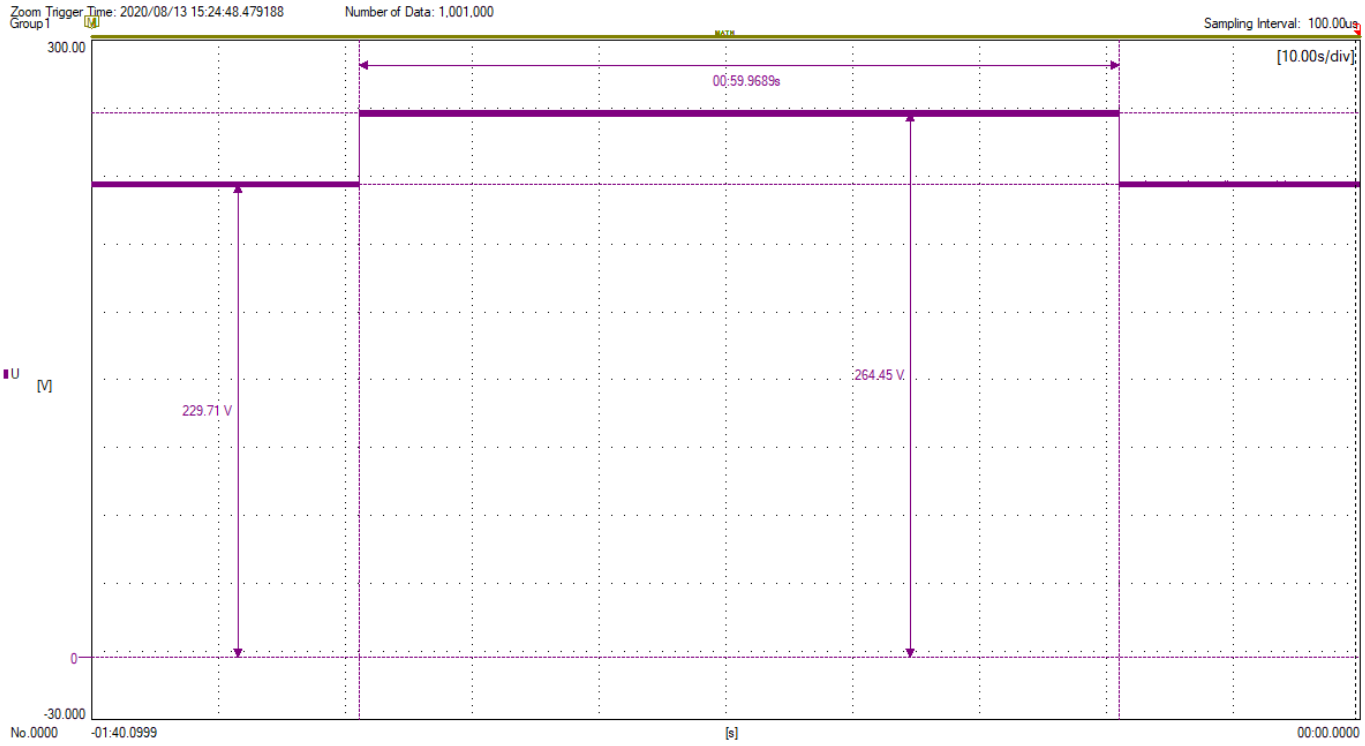




5.8.3	For PGUs Type 2 and storage systems – no load	P

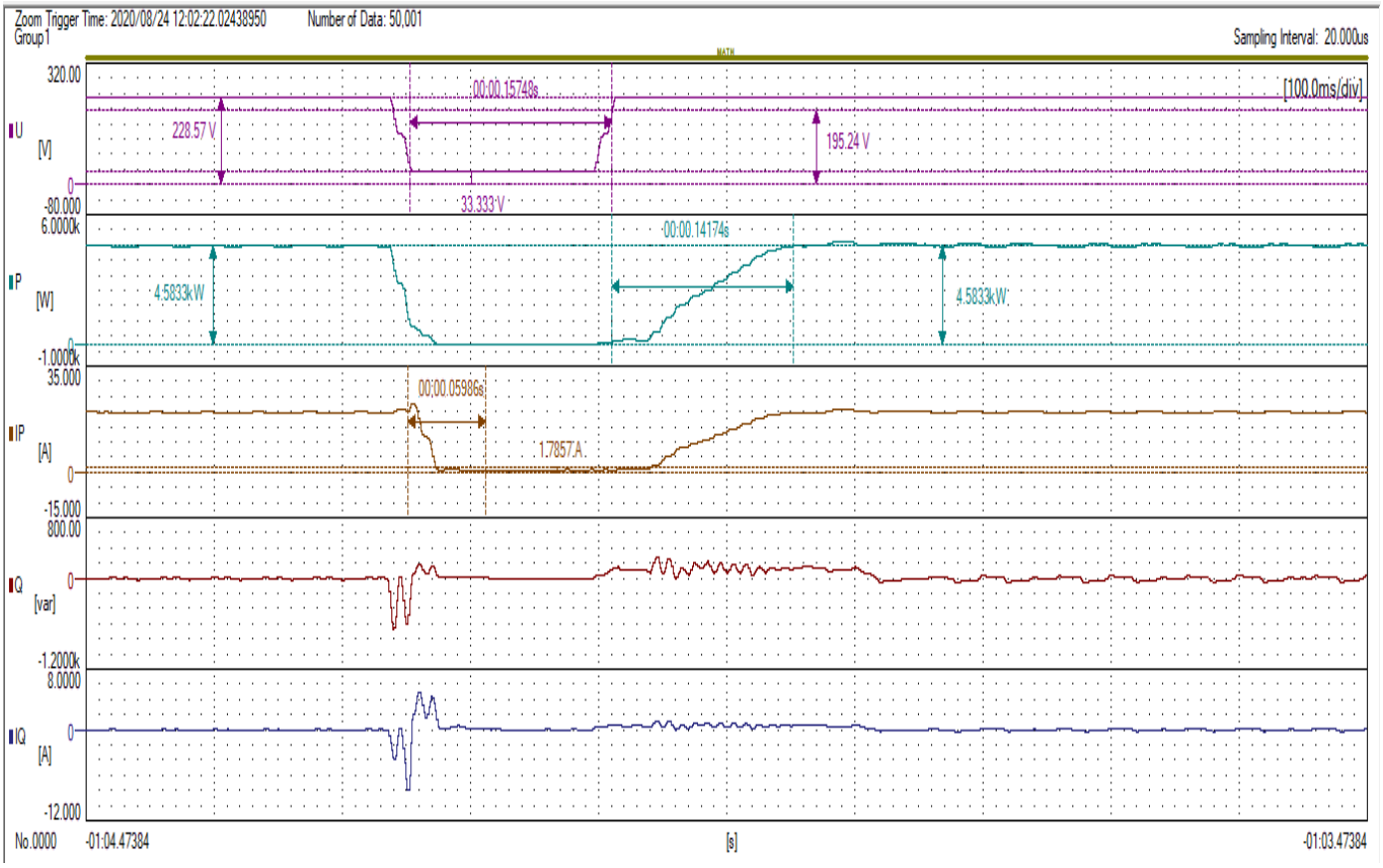
7.1





5.8.3	For PGUs Type 2 and storage systems					P
	1.1					
	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	1.1
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	12:02:22
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,15
	5	Drop duration setpoint	Total	–	[ms]	150
	6	Fault occurrence (t_1)	Total	–	[ms]	1793954
	7	Fault clearance (t_2)	Total	–	[ms]	1801828
	8	Fault duration determined from test	Total	–	[ms]	157,48
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,722
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,004
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,990
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,010
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,150
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,038
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,037
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,005
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,005
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,990
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,005
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

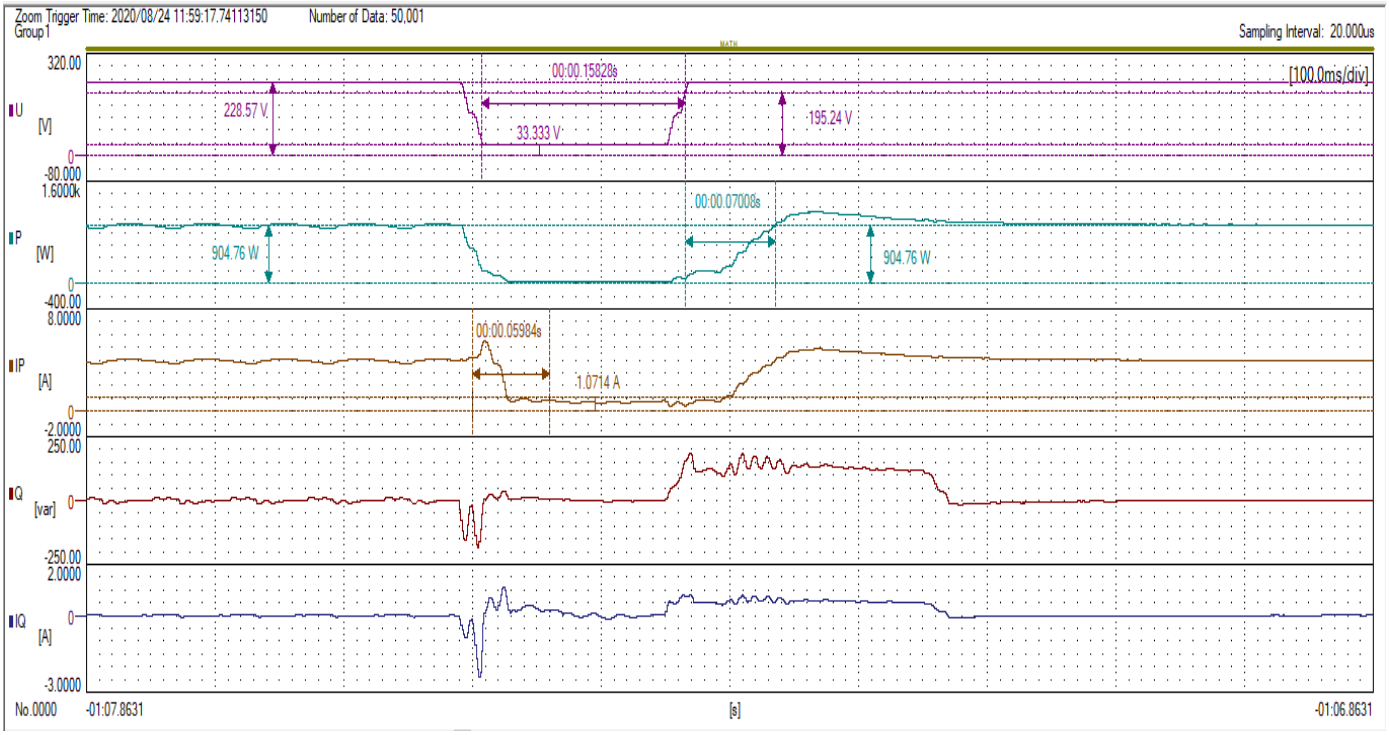


5.8.3	For PGUs Type 2 and storage systems	P

1.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	1.2
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	11:59:17
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,15
	5	Drop duration setpoint	Total	–	[ms]	150
	6	Fault occurrence (t_1)	Total	–	[ms]	1627199
	7	Fault clearance (t_2)	Total	–	[ms]	1635113
	8	Fault duration determined from test	Total	–	[ms]	158,28
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,704
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,197
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,004
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,150
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,040
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,039
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,006
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,001
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,199
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,001
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

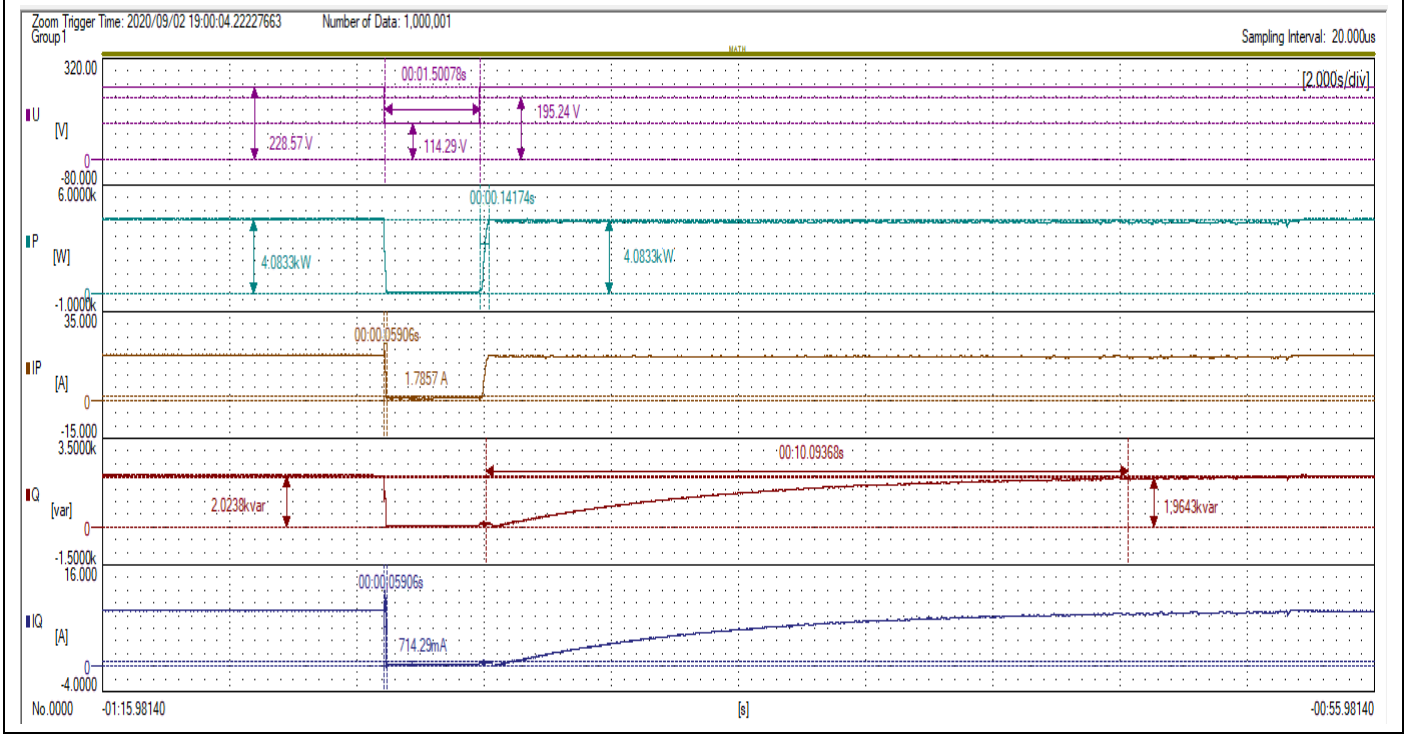


5.8.3	For PGUs Type 2 and storage systems	P

2.1

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	2.1
	1	Date	–	–	[dd.mm.yyyy]	02.09.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	19:00:04
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,5
	5	Drop duration setpoint	Total	–	[ms]	1500
	6	Fault occurrence (t_1)	Total	–	[ms]	1427975
	7	Fault clearance (t_2)	Total	–	[ms]	1503114
	8	Fault duration determined from test	Total	–	[ms]	1502,78
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,500
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,004
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,897
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	1,016
	17	cos φ	-	t1-10 s to t_1	[p.u.]	0,897
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,499
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,041
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,042
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,020
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,004
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,863
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,815
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

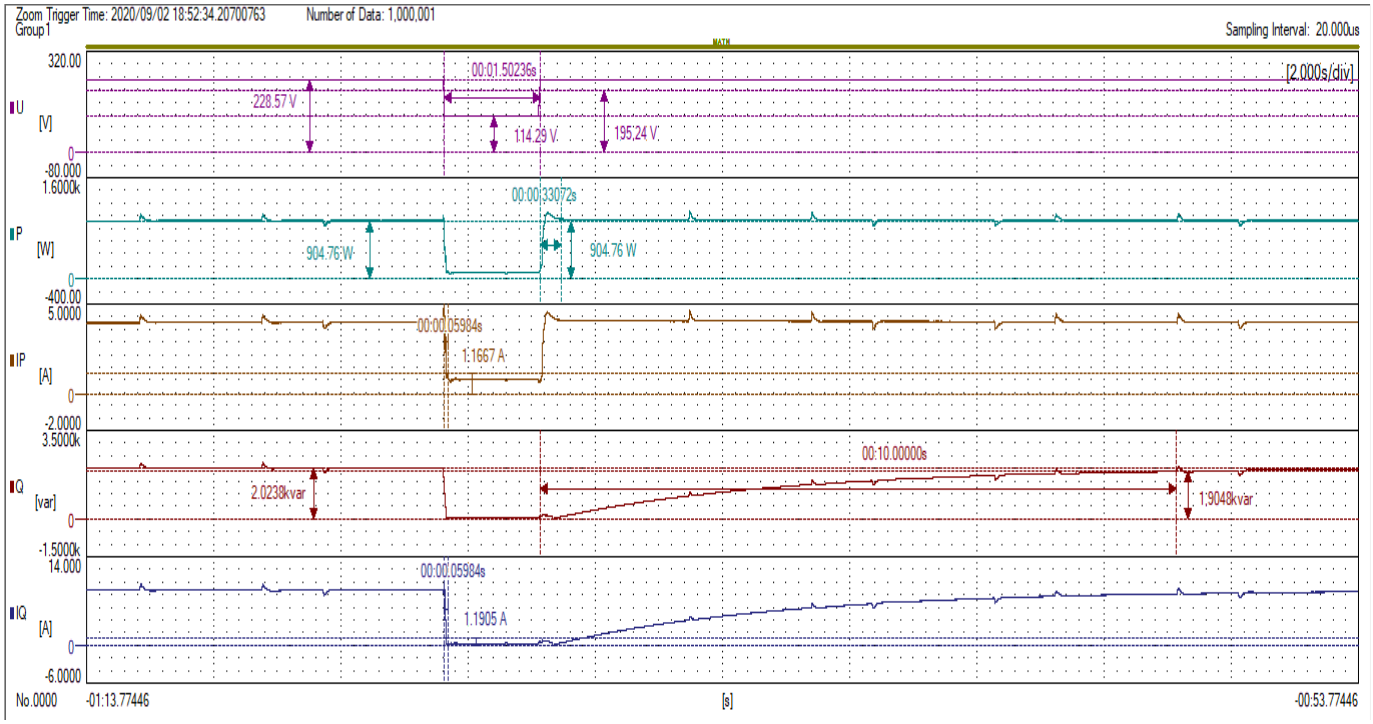


5.8.3	For PGUs Type 2 and storage systems	P

2.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	2.2
	1	Date	–	–	[dd.mm.yyyy]	02.09.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	18:52:34
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,5
	5	Drop duration setpoint	Total	–	[ms]	1500
	6	Fault occurrence (t_1)	Total	–	[ms]	1597749
	7	Fault clearance (t_2)	Total	–	[ms]	1672867
	8	Fault duration determined from test	Total	–	[ms]	1502,36
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,498
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,200
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	1,002
	17	cos φ	-	t1-10 s to t_1	[p.u.]	0,416
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,500
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,051
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,049
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,007
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,002
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,202
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,806
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

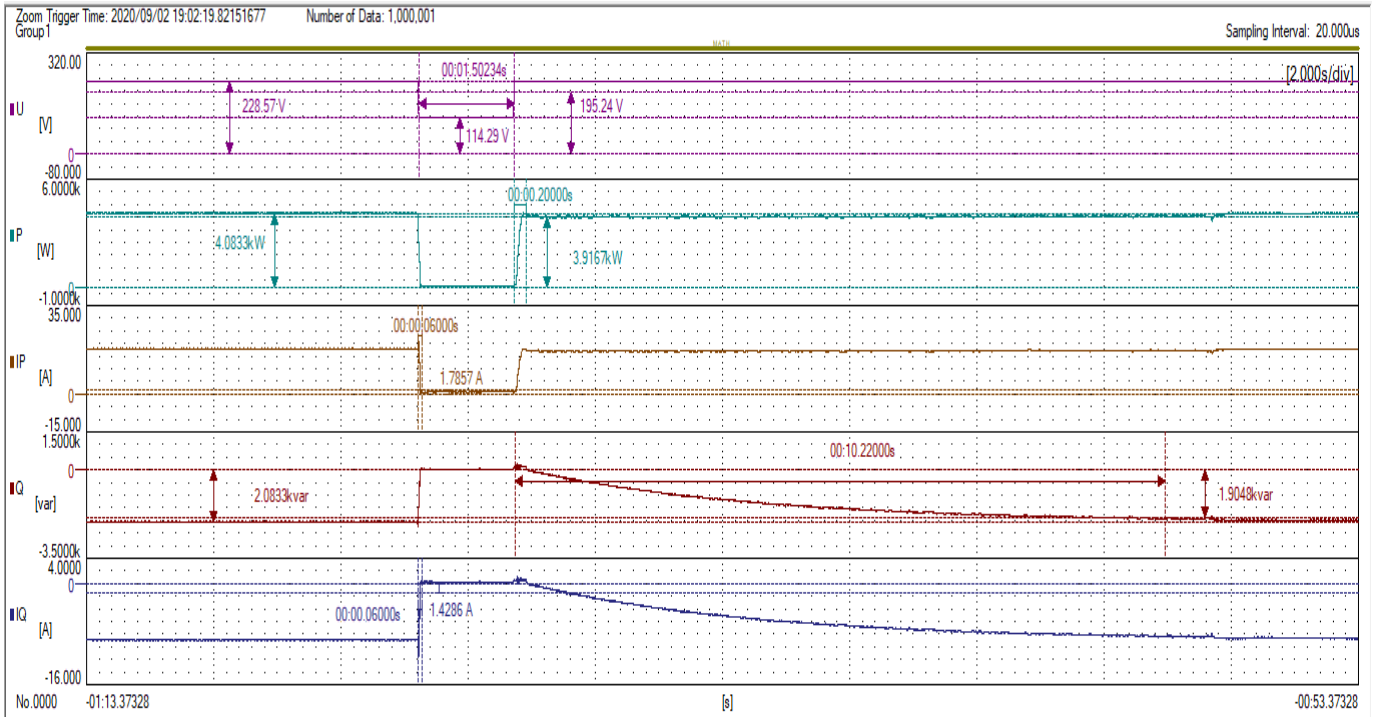


5.8.3	For PGUs Type 2 and storage systems	P

3.1

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	3.1
	1	Date	–	–	[dd.mm.yyyy]	02.09.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	19:02:19
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,5
	5	Drop duration setpoint	Total	–	[ms]	1500
	6	Fault occurrence (t_1)	Total	–	[ms]	1597851
	7	Fault clearance (t_2)	Total	–	[ms]	1672968
	8	Fault duration determined from test	Total	–	[ms]	1502,34
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,500
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,004
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,897
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	1,026
	17	cos φ	-	t1-10 s to t_1	[p.u.]	0,895
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,499
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,037
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,037
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,007
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,004
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,856
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,823
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

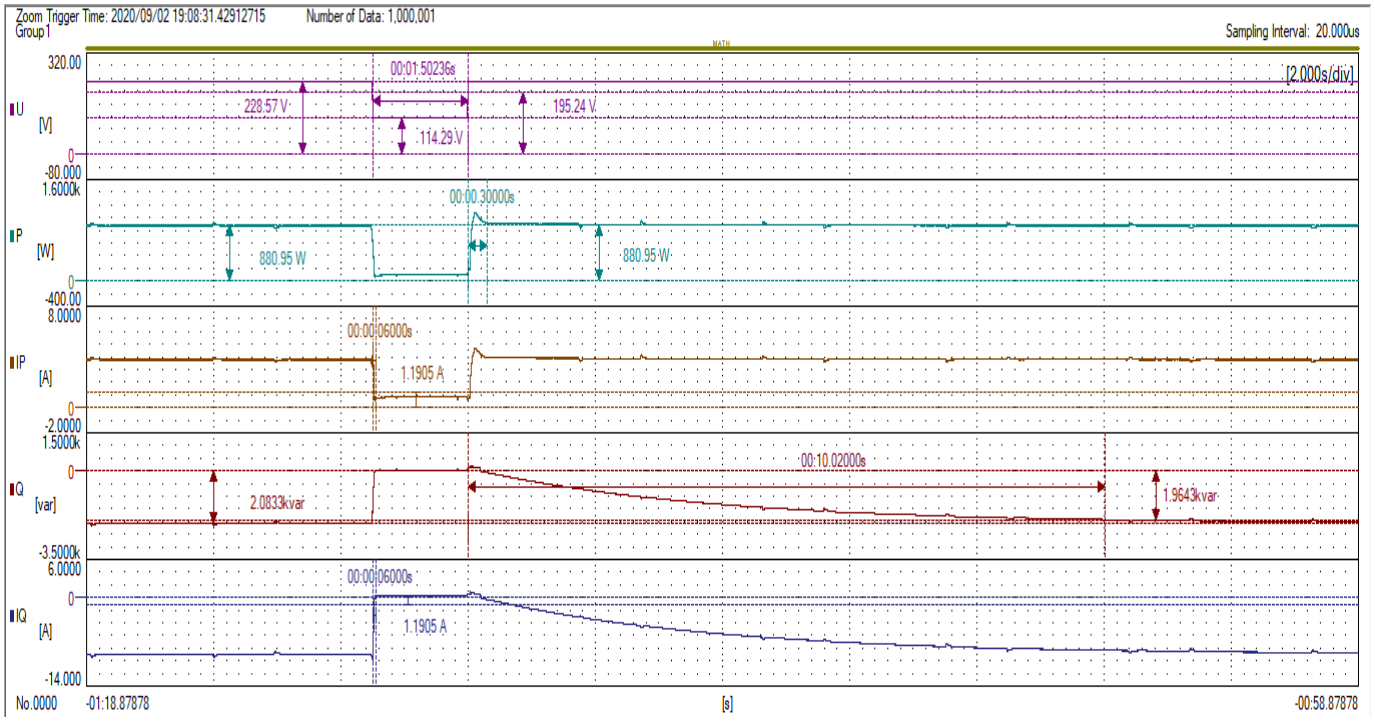


5.8.3	For PGUs Type 2 and storage systems	P

3.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	3.2
	1	Date	–	–	[dd.mm.yyyy]	02.09.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	19:08:31
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,5
	5	Drop duration setpoint	Total	–	[ms]	1500
	6	Fault occurrence (t_1)	Total	–	[ms]	1286041
	7	Fault clearance (t_2)	Total	–	[ms]	1361159
	8	Fault duration determined from test	Total	–	[ms]	1502,36
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,499
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,189
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	1,030
	17	cos φ	-	t1-10 s to t_1	[p.u.]	0,388
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,500
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,030
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,041
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,020
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,001
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,191
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,824
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

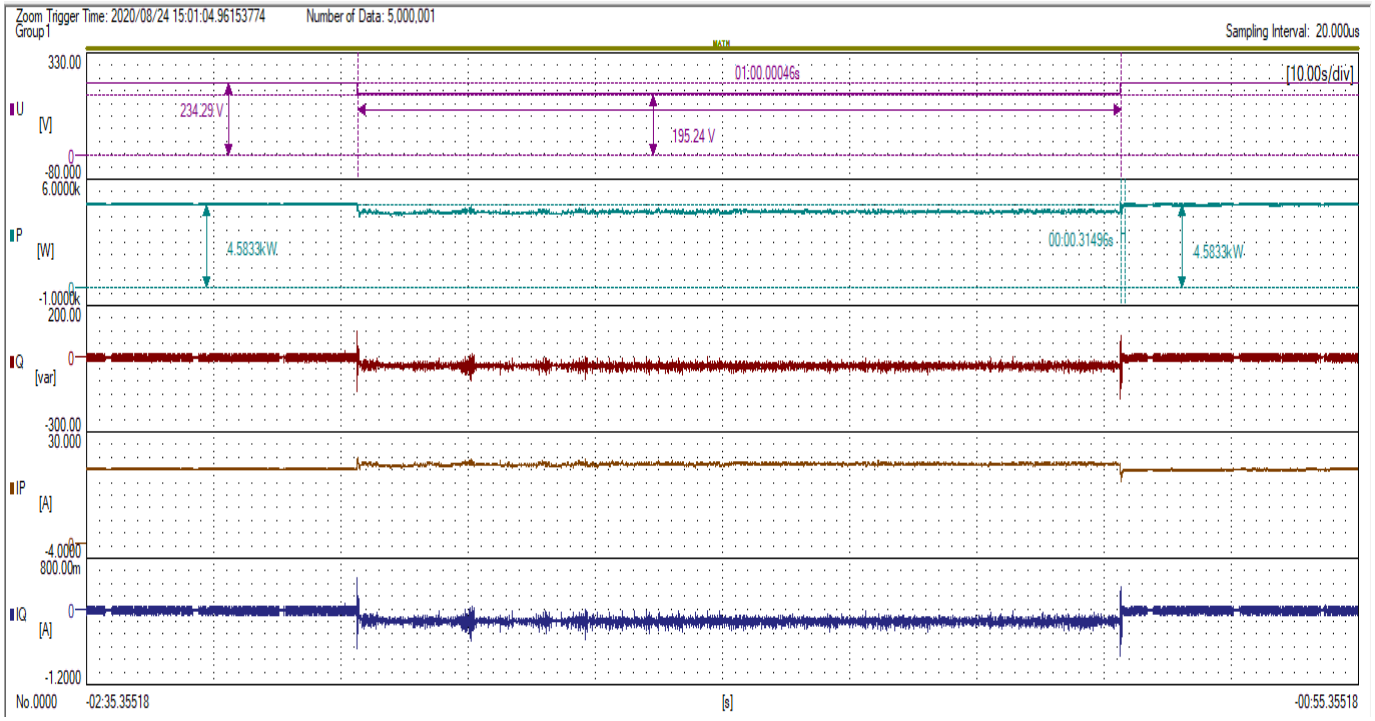


5.8.3	For PGUs Type 2 and storage systems	P

4.1

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	4.1
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	12:02:22
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,85
	5	Drop duration setpoint	Total	–	[ms]	60000
	6	Fault occurrence (t_1)	Total	–	[ms]	3308516
	7	Fault clearance (t_2)	Total	–	[ms]	6308539
	8	Fault duration determined from test	Total	–	[ms]	60000,46
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,150
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,005
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,999
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,004
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,854
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	1,107
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	1,055
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,909
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,005
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,997
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,004
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

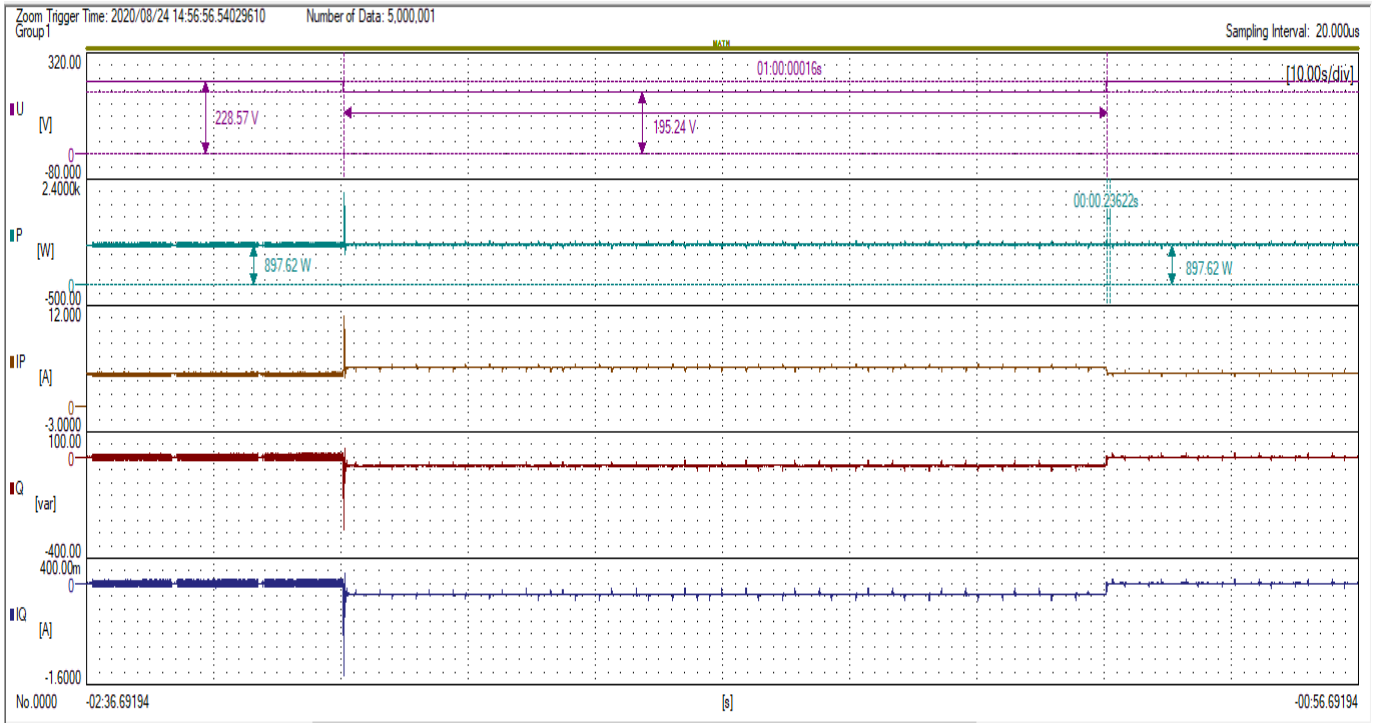


5.8.3	For PGUs Type 2 and storage systems	P

4.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	4.2
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	14:56:56
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	0,85
	5	Drop duration setpoint	Total	–	[ms]	60000
	6	Fault occurrence (t_1)	Total	–	[ms]	3187660
	7	Fault clearance (t_2)	Total	–	[ms]	6187668
	8	Fault duration determined from test	Total	–	[ms]	60000,16
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	0,151
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,194
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,003
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	0,850
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,323
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,195
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,196
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,001
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,197
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,001
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

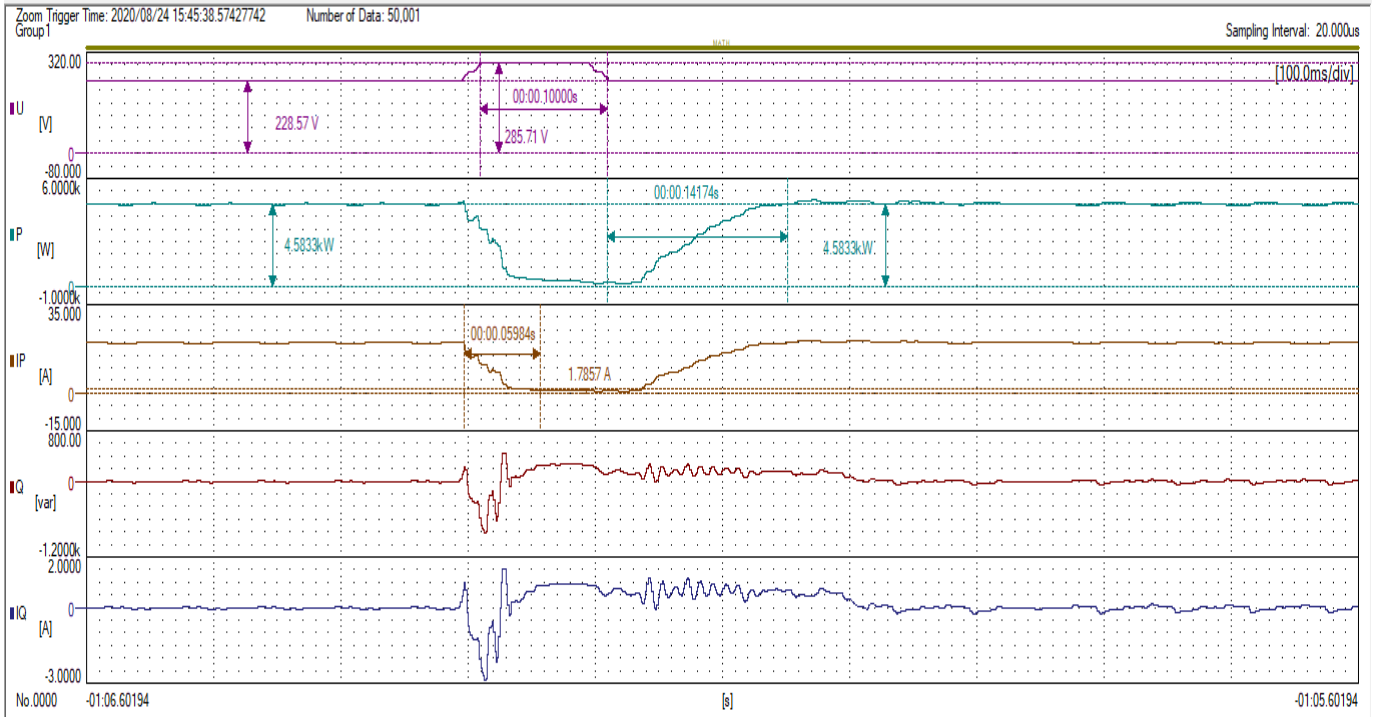


5.8.3	For PGUs Type 2 and storage systems	P

5.1

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	5.1
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	15:45:38
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	1,25
	5	Drop duration setpoint	Total	–	[ms]	100
	6	Fault occurrence (t_1)	Total	–	[ms]	1690370
	7	Fault clearance (t_2)	Total	–	[ms]	1695370
	8	Fault duration determined from test	Total	–	[ms]	100
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	-0,024
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,005
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,995
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,007
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	1,170
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,073
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,053
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,051
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,005
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,995
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,005
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

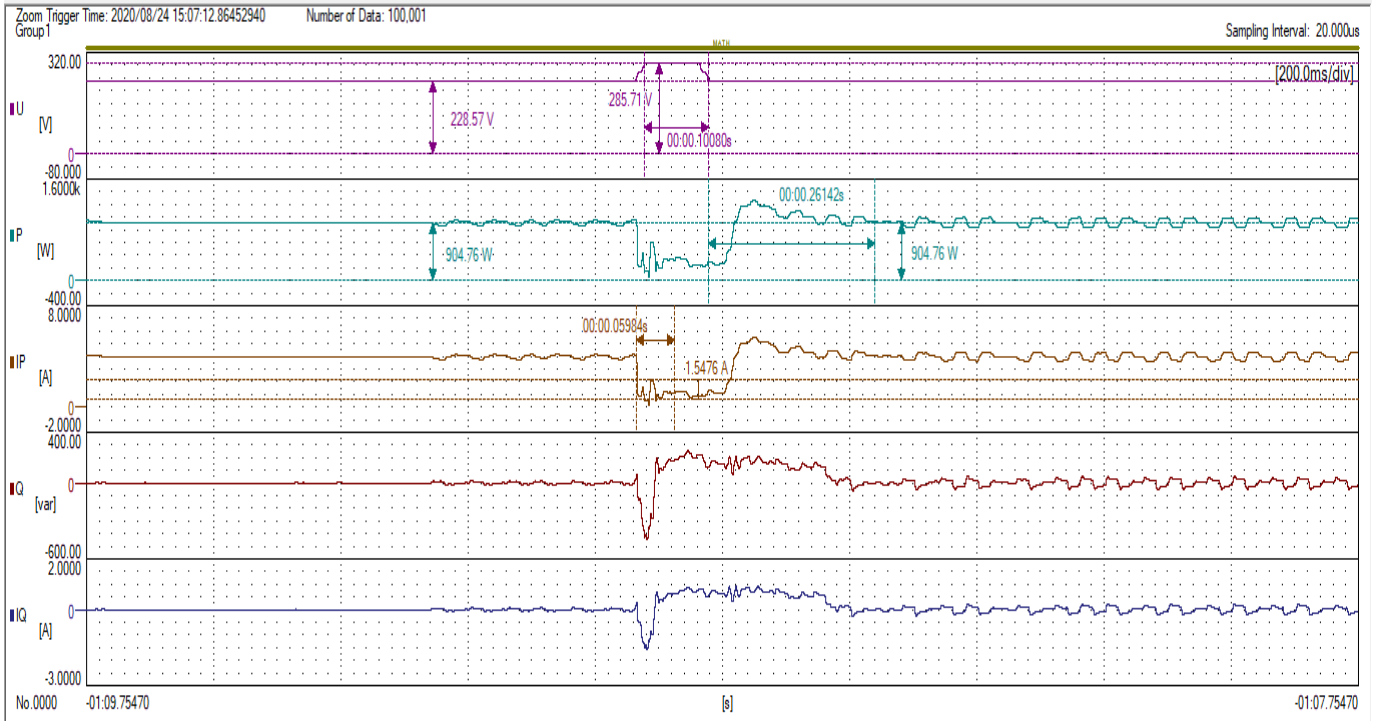


5.8.3	For PGUs Type 2 and storage systems	P

5.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	5.2
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	15:07:12
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	1,25
	5	Drop duration setpoint	Total	–	[ms]	100
	6	Fault occurrence (t_1)	Total	–	[ms]	1561125
	7	Fault clearance (t_2)	Total	–	[ms]	1566165
	8	Fault duration determined from test	Total	–	[ms]	100,8
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	-0,028
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,198
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,005
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	1,172
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,070
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,064
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,052
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,001
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,198
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,004
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

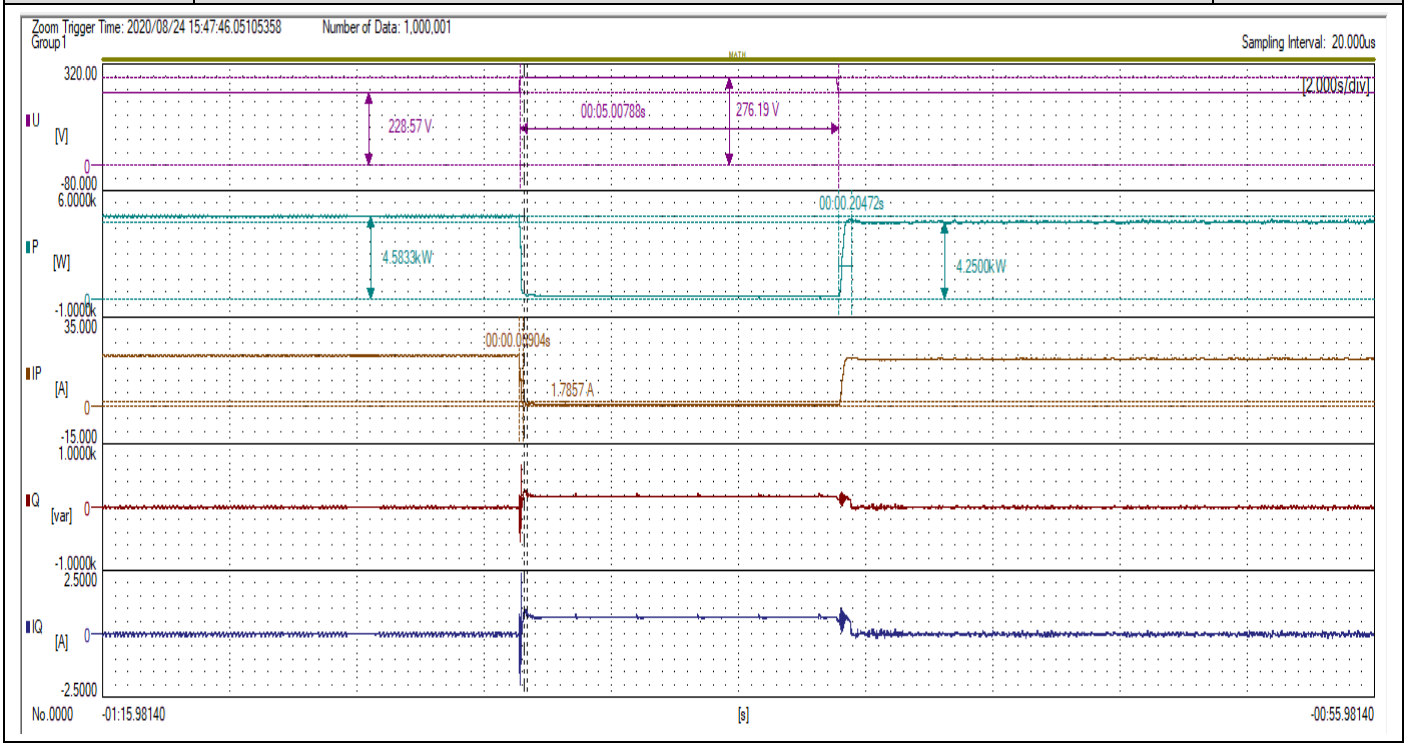


5.8.3	For PGUs Type 2 and storage systems	P

6.1

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	6.1
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	15:47:46
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	1,2
	5	Drop duration setpoint	Total	–	[ms]	5000
	6	Fault occurrence (t_1)	Total	–	[ms]	1534493
	7	Fault clearance (t_2)	Total	–	[ms]	1784887
	8	Fault duration determined from test	Total	–	[ms]	5007,88
	9	Measeured value of voltage drop / increase	Total	t_1+100 ms to t_2 and t1-10 s to t1	[p.u.]	-0,194
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t_1-10 s to t_1	[p.u.]	1,004
	12	Current	Positive sequence	t_1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t_1-10 s to t_1	[p.u.]	0,995
	14		Positive sequence	t_1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t_1-10 s to t_1	[p.u.]	N/A
	16		Total	t_1-10 s to t_1	[p.u.]	0,006
	17	cos φ	-	t_1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t_1+100 ms to t_2-20 ms	[p.u.]	1,199
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,067
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,055
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,042
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,004
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,929
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,005
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

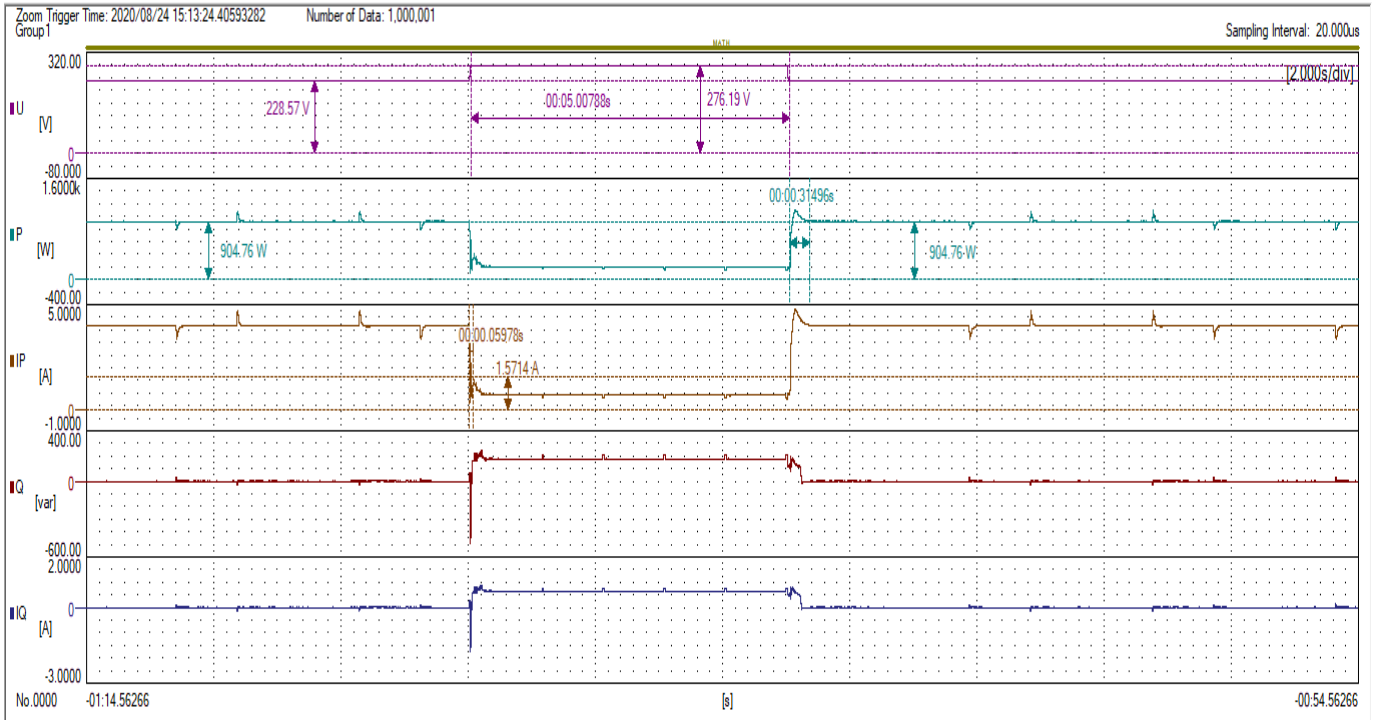


5.8.3	For PGUs Type 2 and storage systems	P

6.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	6.2
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	15:47:46
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	1,2
	5	Drop duration setpoint	Total	–	[ms]	5000
	6	Fault occurrence (t_1)	Total	–	[ms]	1579199
	7	Fault clearance (t_2)	Total	–	[ms]	1829593
	8	Fault duration determined from test	Total	–	[ms]	5007,88
	9	Measeured value of voltage drop / increase	Total	t1+100 ms to t_2 and t1-10 s to t1	[p.u.]	-0,197
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t1-10 s to t_1	[p.u.]	0,200
	14		Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t1-10 s to t_1	[p.u.]	N/A
	16		Total	t1-10 s to t_1	[p.u.]	0,006
	17	cos φ	-	t1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t1+100 ms to t_2-20 ms	[p.u.]	1,199
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,080
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,066
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,043
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,001
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,200
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,001
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

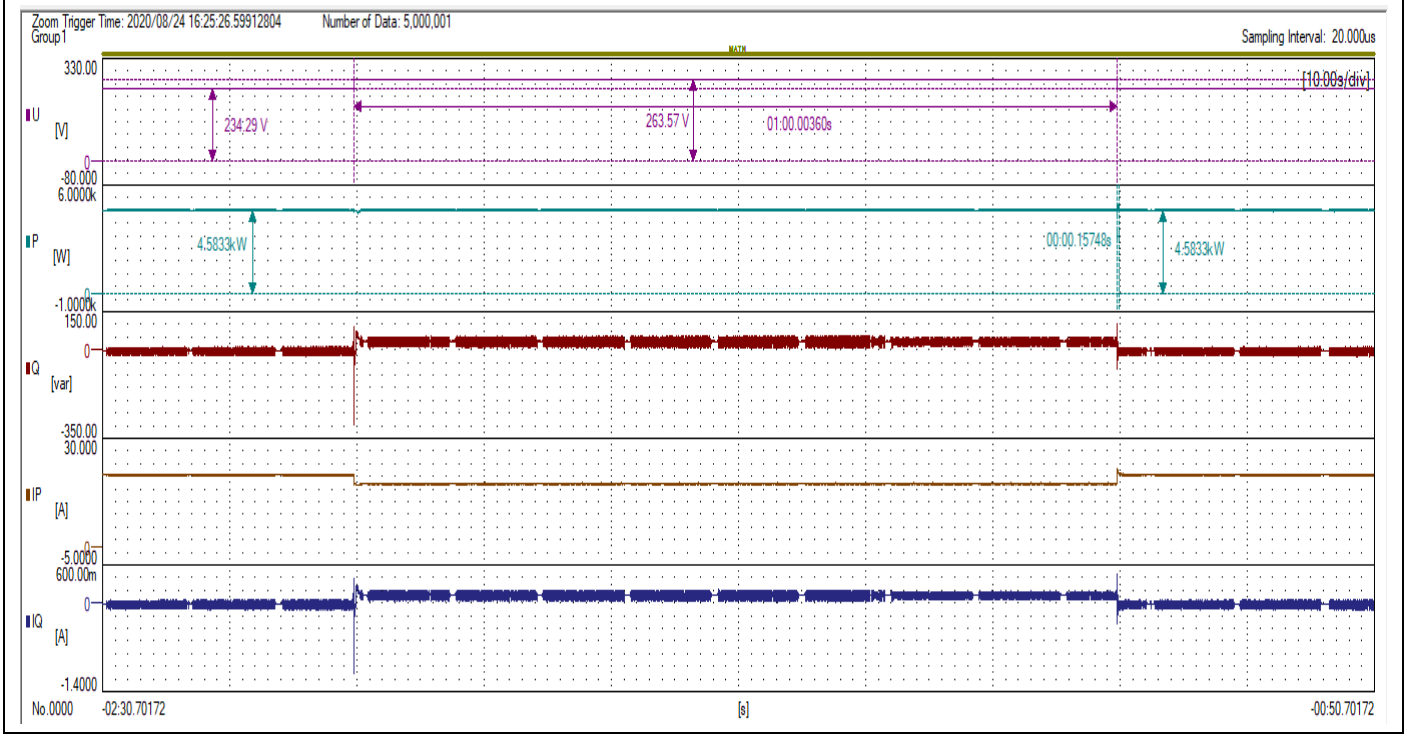


5.8.3	For PGUs Type 2 and storage systems	P

7.1

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	7.1
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	16:25:26
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	1,15
	5	Drop duration setpoint	Total	–	[ms]	60000
	6	Fault occurrence (t_1)	Total	–	[ms]	3464893
	7	Fault clearance (t_2)	Total	–	[ms]	6465073
	8	Fault duration determined from test	Total	–	[ms]	60003,6
	9	Measeured value of voltage drop / increase	Total	t_1+100 ms to t_2 and t1-10 s to t1	[p.u.]	-0,142
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t_1-10 s to t_1	[p.u.]	1,005
	12	Current	Positive sequence	t_1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t_1-10 s to t_1	[p.u.]	0,999
	14		Positive sequence	t_1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t_1-10 s to t_1	[p.u.]	N/A
	16		Total	t_1-10 s to t_1	[p.u.]	0,005
	17	cos φ	-	t_1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t_1+100 ms to t_2-20 ms	[p.u.]	1,147
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,872
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,870
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,999
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,005
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,999
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,004
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

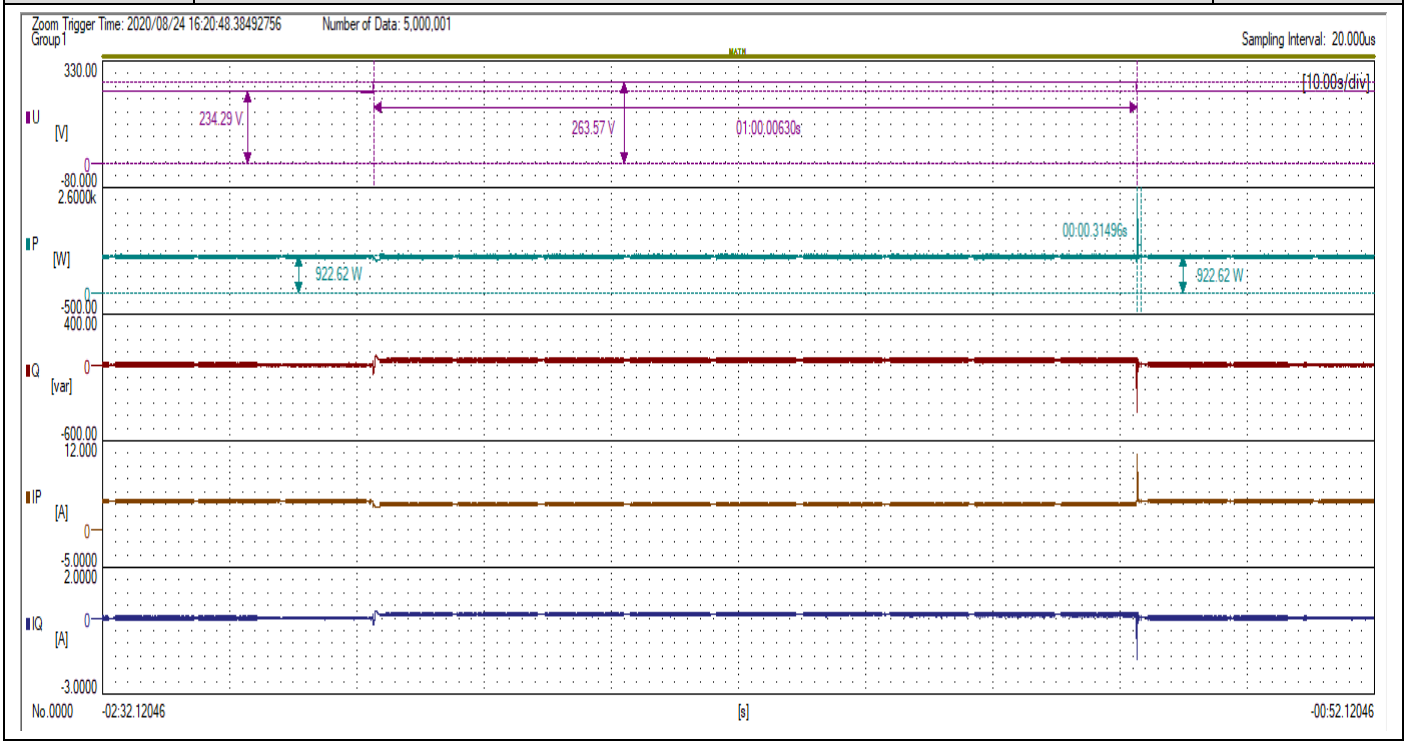


5.8.3	For PGUs Type 2 and storage systems	P

7.2

	No.	Parameter	Phase reference	Reference time	Value (unit)	
General information	0	Test no.	–	–	–	7.2
	1	Date	–	–	[dd.mm.yyyy]	24.08.2020
	2	Time (Start of test)	–	–	[hh:mm:ss.f]	16:20:48
	3	Type of fault (number of affected phases)	–	–	–	A
	4	Drop depth setpoint	Phase	–	[p.u]	1,15
	5	Drop duration setpoint	Total	–	[ms]	60000
	6	Fault occurrence (t_1)	Total	–	[ms]	3470609
	7	Fault clearance (t_2)	Total	–	[ms]	6470924
	8	Fault duration determined from test	Total	–	[ms]	60006,3
	9	Measeured value of voltage drop / increase	Total	t_1+100 ms to t_2 and t1-10 s to t1	[p.u.]	-0,142
	10		Positive sequence			N/A
Before t1	11	Voltage	Phase to Neutral	t_1-10 s to t_1	[p.u.]	1,001
	12	Current	Positive sequence	t_1-500 ms to t_1-100 ms	[p.u.]	N/A
	13	Active power	Total	t_1-10 s to t_1	[p.u.]	0,198
	14		Positive sequence	t_1-10 s to t_1	[p.u.]	N/A
	15	Reactive power	Positive sequence	t_1-10 s to t_1	[p.u.]	N/A
	16		Total	t_1-10 s to t_1	[p.u.]	0,003
	17	cos φ	-	t_1-10 s to t_1	[p.u.]	1,000
t1 till t2	18	Voltage	Phase to Neutral	t_1+100 ms to t_2-20 ms	[p.u.]	1,144
	19	Phase current	Phase 1	t_1+60 ms	[p.u.]	0,167
	20		Phase 2	t_1+60 ms	[p.u.]	N/A
	21		Phase 3	t_1+60 ms	[p.u.]	N/A
	22	Phase current	Phase 1	t_1 +100 ms	[p.u.]	0,166
	23		Phase 2	t_1 +100 ms	[p.u.]	N/A
	24		Phase 3	t_1 +100 ms	[p.u.]	N/A
	25	Active power	Total	t_1+100 ms to t_2-20 ms	[p.u.]	0,198
	26		Positive sequence	t_1+100 ms to t_2-20 ms	[p.u.]	N/A
After t2	27	Voltage	Phase to Neutral	t_2+3 s to t_2+10 s	[p.u.]	1,001
	28	Active power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	29		Total	t_2+3 s to t_2+10 s	[p.u.]	0,198
	30	Response time active power	Positive sequence	-	[s]	N/A
	31	Reactive power	Positive sequence	t_2+3 s to t_2+10 s	[p.u.]	N/A
	32		Total	t_2+3 s to t_2+10 s	[p.u.]	0,005
	33	Response time reactive power	Positive sequence	–	[s]	N/A
	34	EZE didn´t disconnect from grid within 60s after fault ended yes/no?	–	t_2 to t_2+60s	–	yes

5.8.3	For PGUs Type 2 and storage systems	P

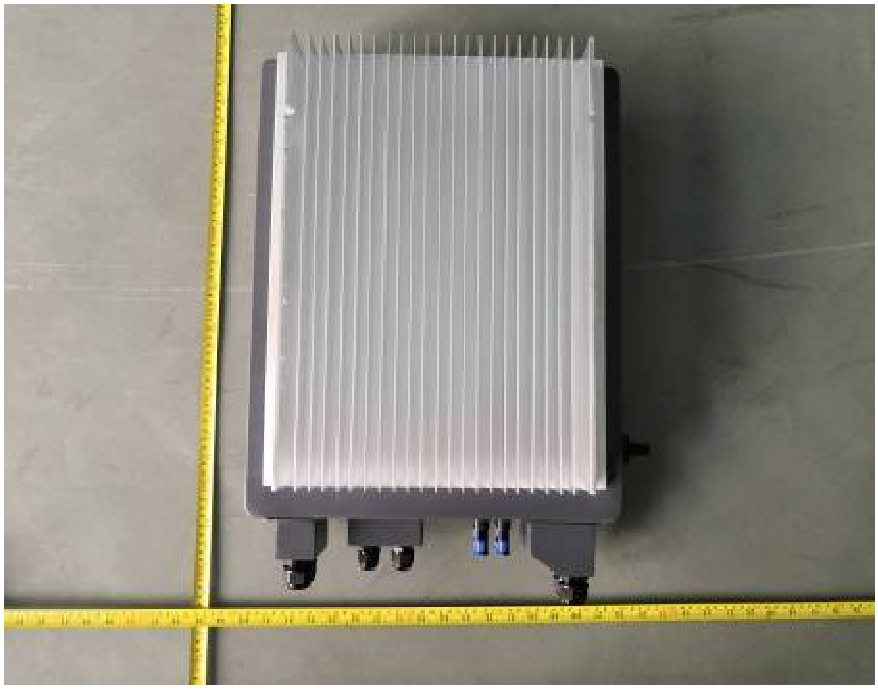


Annex No. 1
Pictures of the unit

Pictures of the unit

Enclosure front view

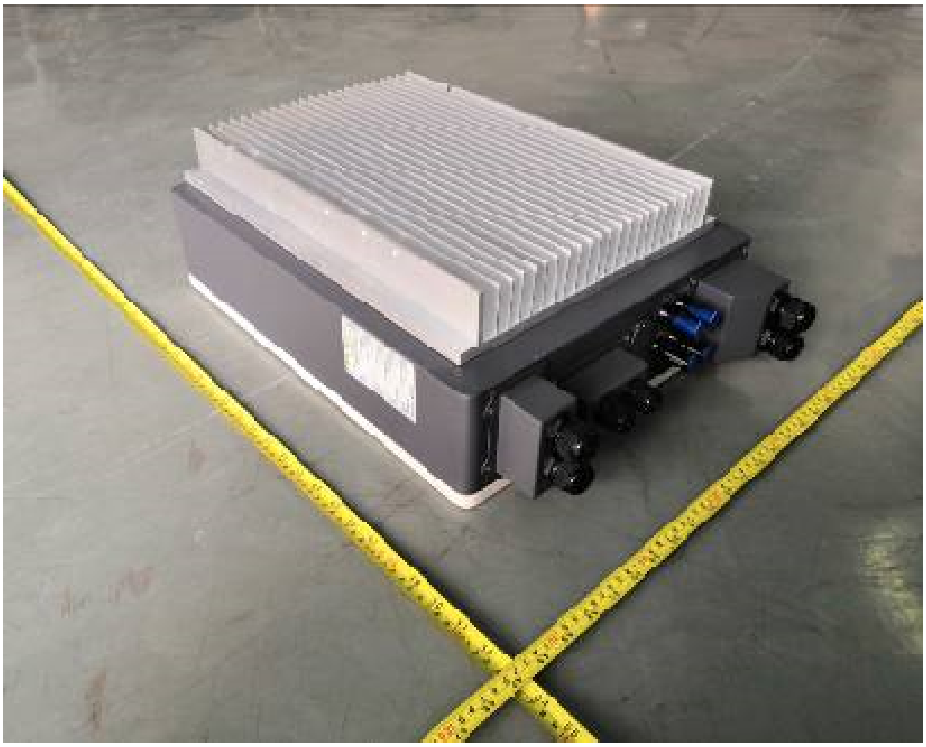
Enclosure rear view



Pictures of the unit

Enclosure front view

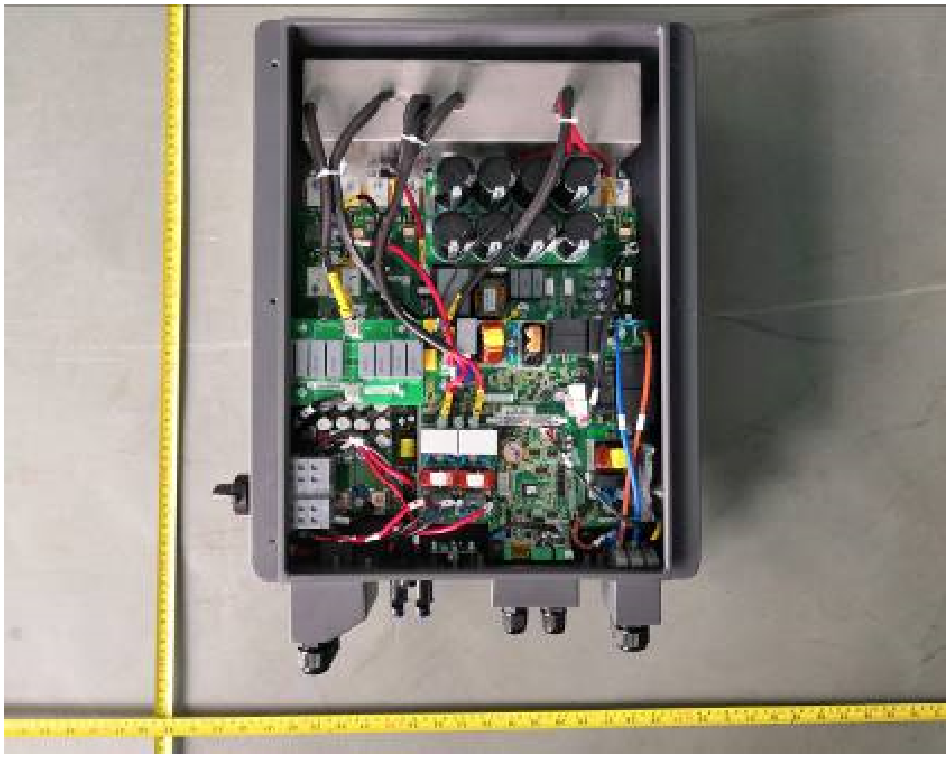
Enclosure rear view



Pictures of the unit

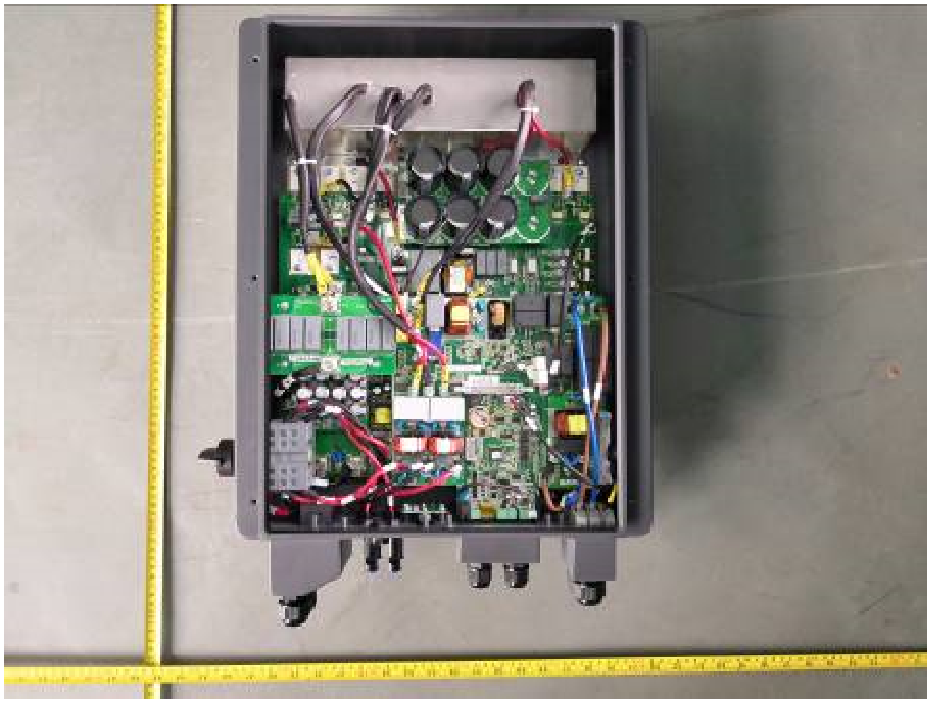
Enclosure Bottom view

Internal view: HYD 6000-ES, HYD 5000-ES

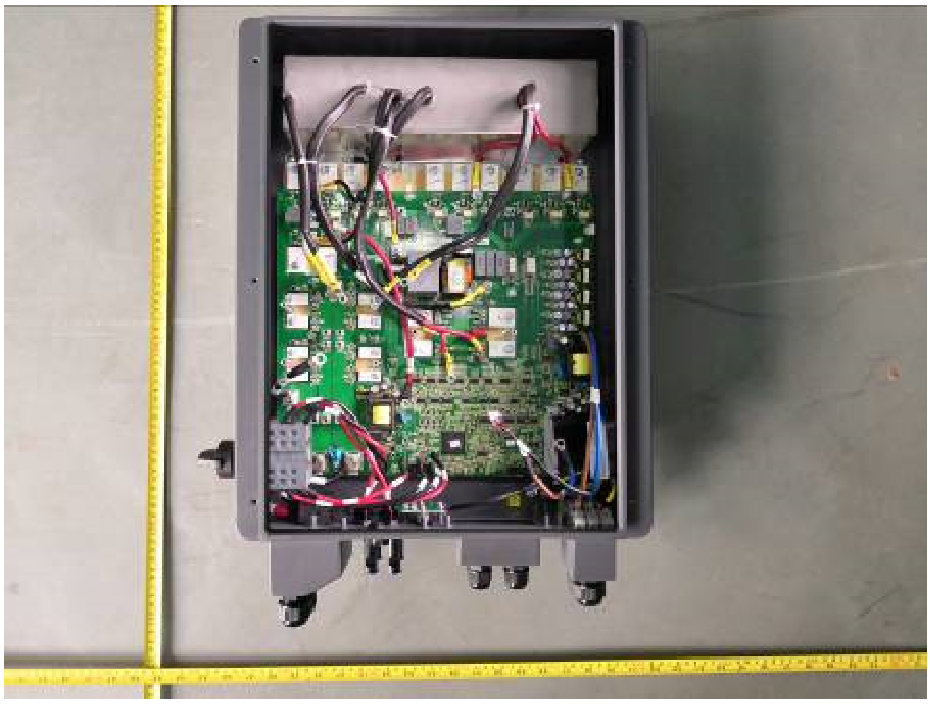


Pictures of the unit

Internal view: HYD 4000-ES, HYD 3600-ES, HYD 3000-ES

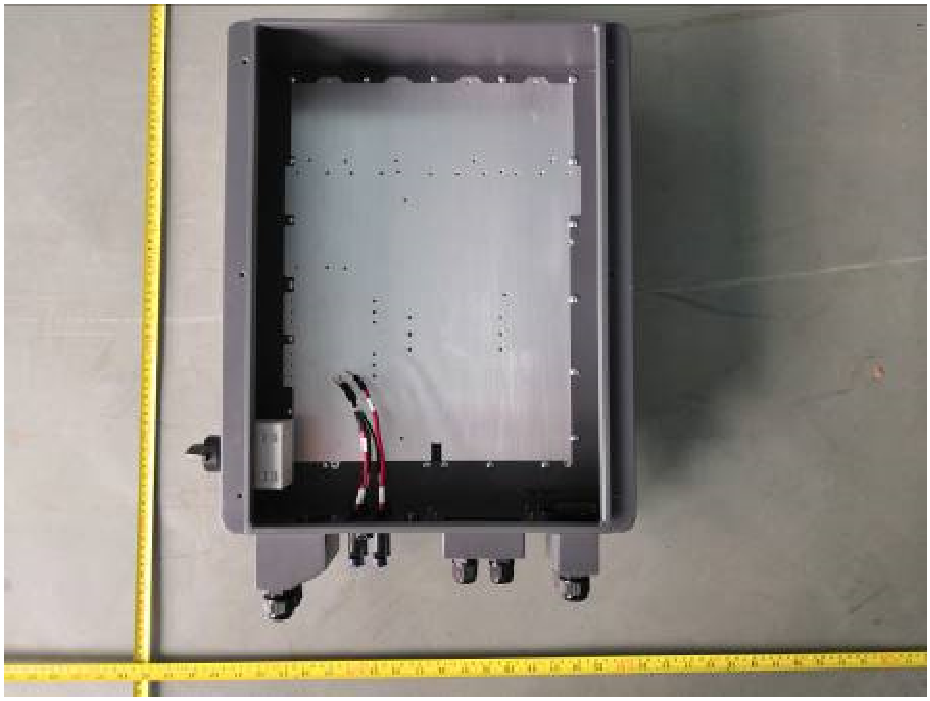


Internal view-1



Pictures of the unit

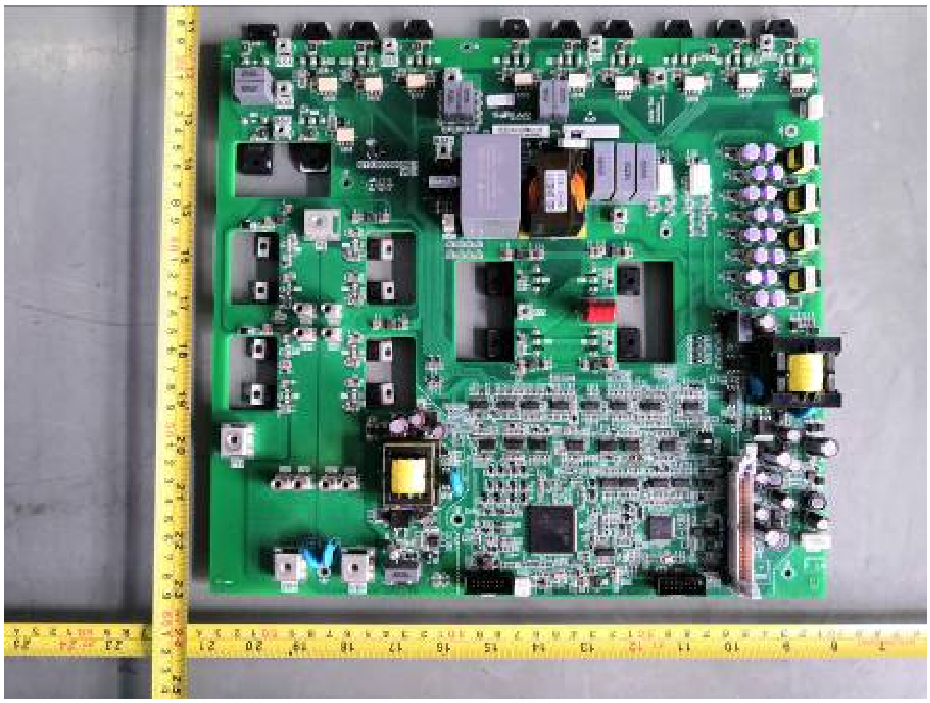
Internal view-2



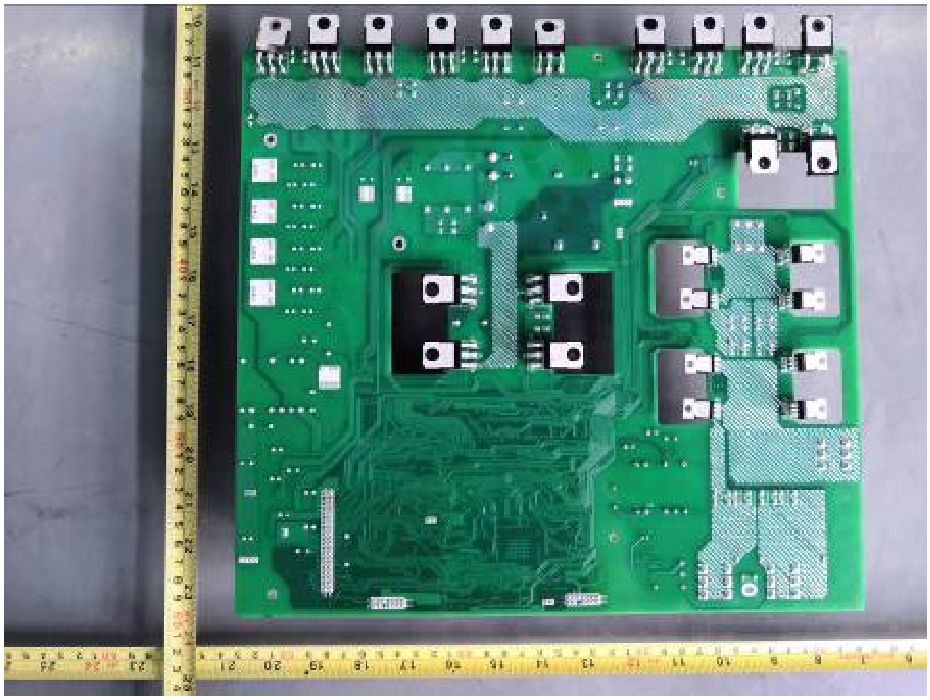
Internal view: Ground terminal

Pictures of the unit

Main power board component side view

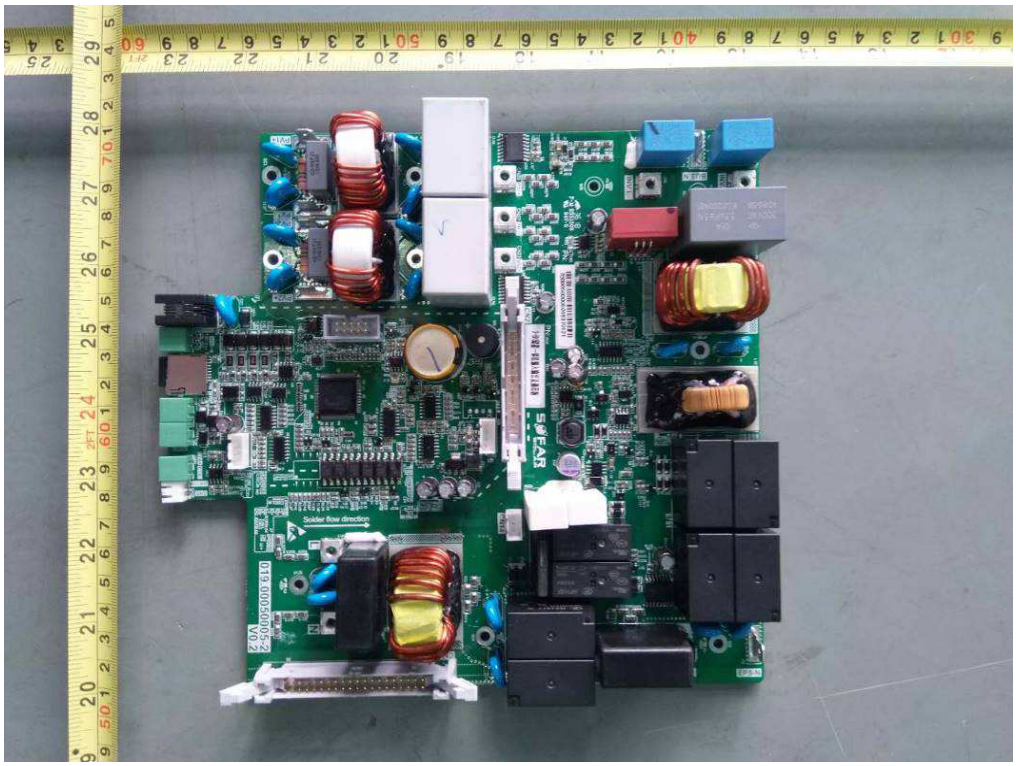


Main power board solder side view

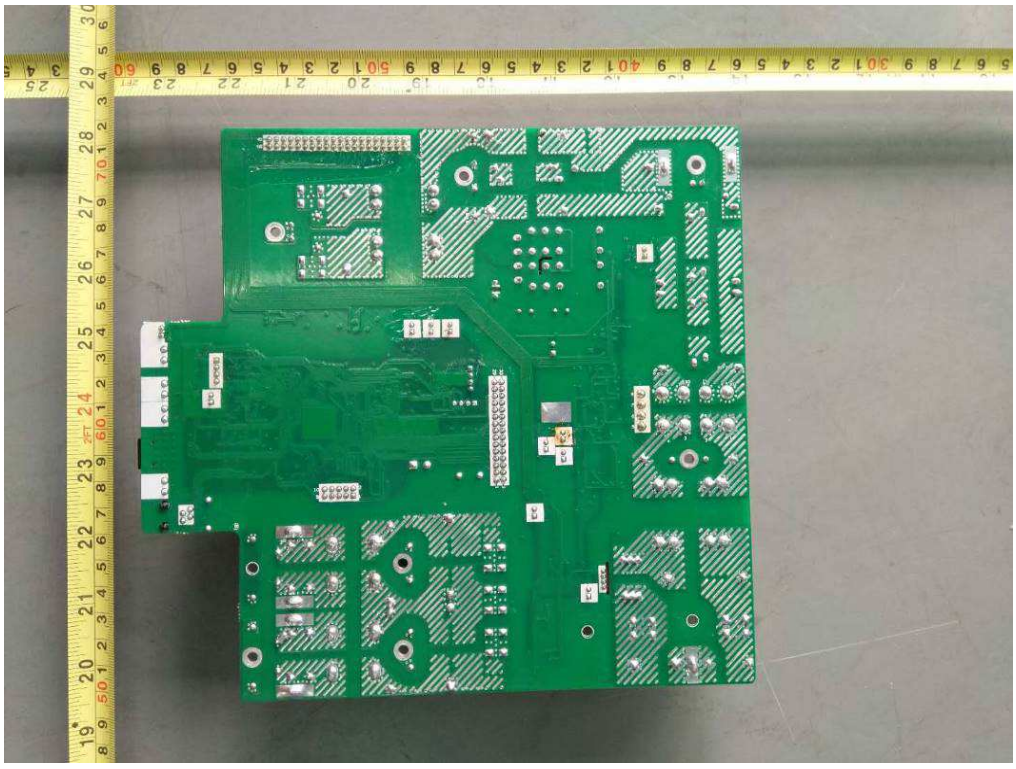


Pictures of the unit

Input&output board component side view

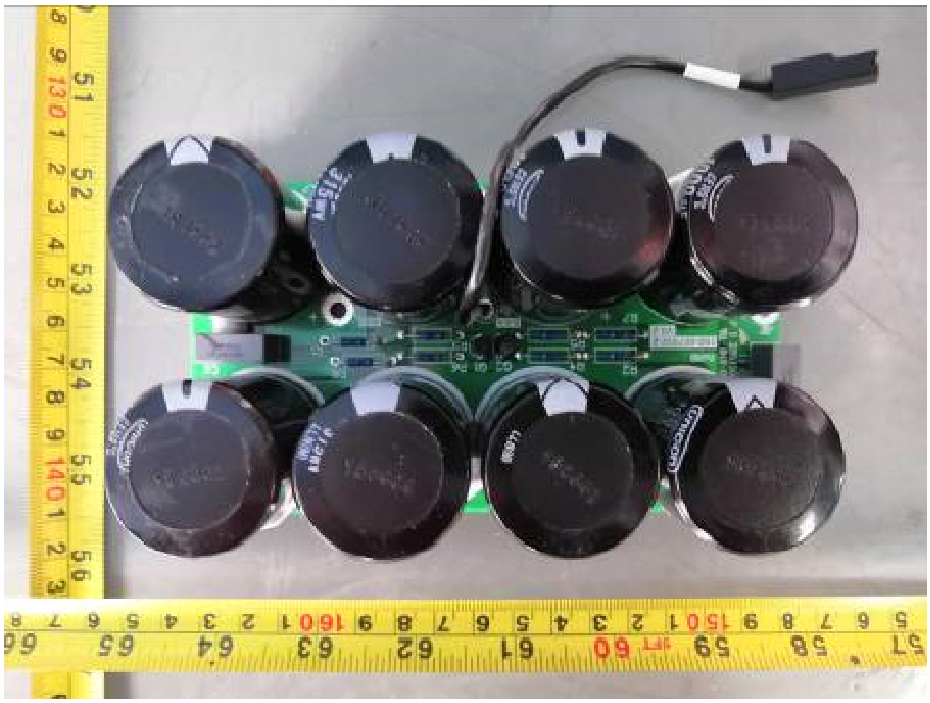


Input&output board solder side view

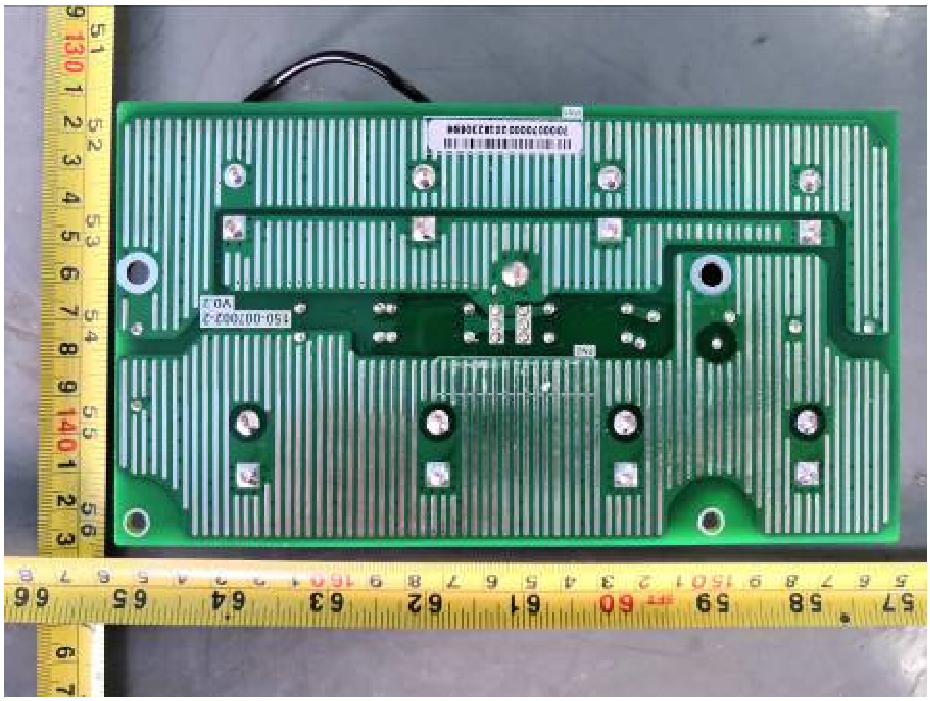


Pictures of the unit

Capcitance board component side view: HYD 6000-ES, HYD 5000-ES

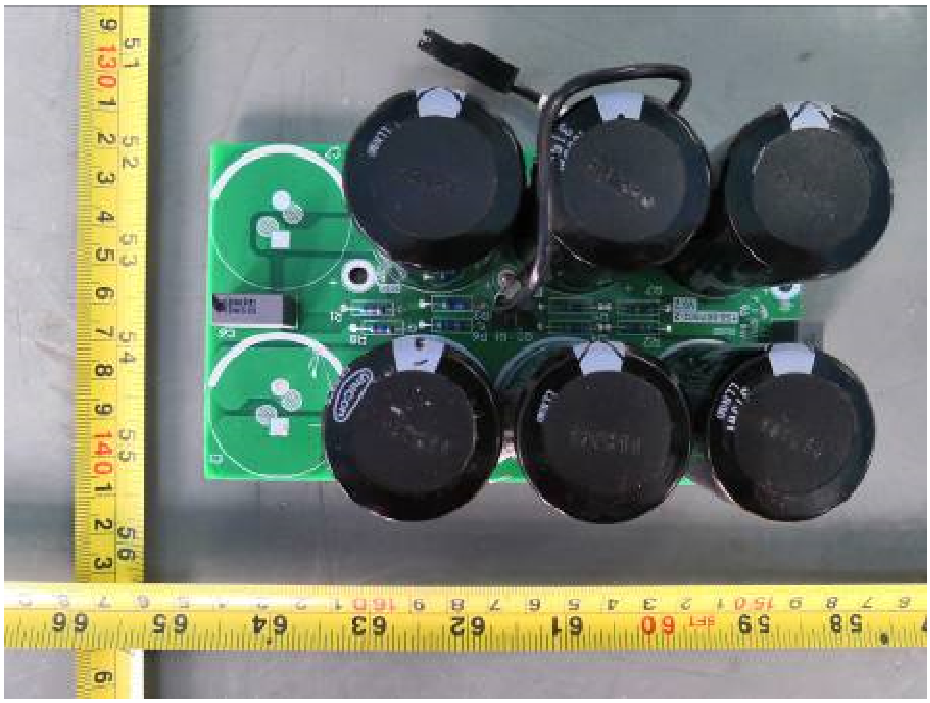


Capcitance board solder side view: HYD 6000-ES, HYD 5000-ES

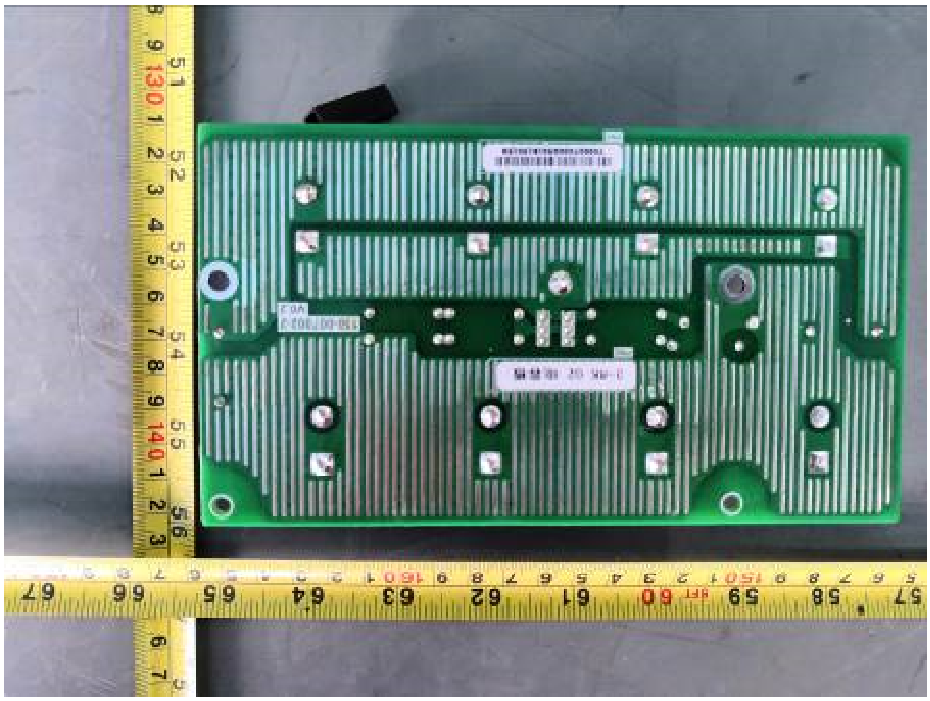


Pictures of the unit

Capcitance board component side view: HYD 4000-ES, HYD 3600-ES, HYD 3000-ES



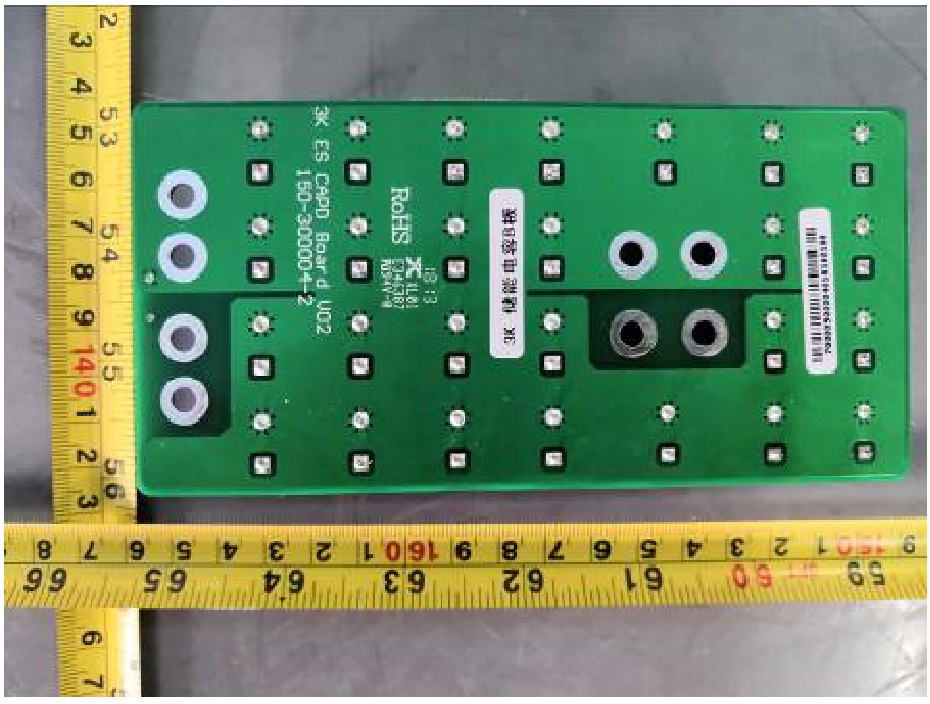
Capcitance board solder side view: HYD 4000-ES, HYD 3600-ES, HYD 3000-ES



Pictures of the unit

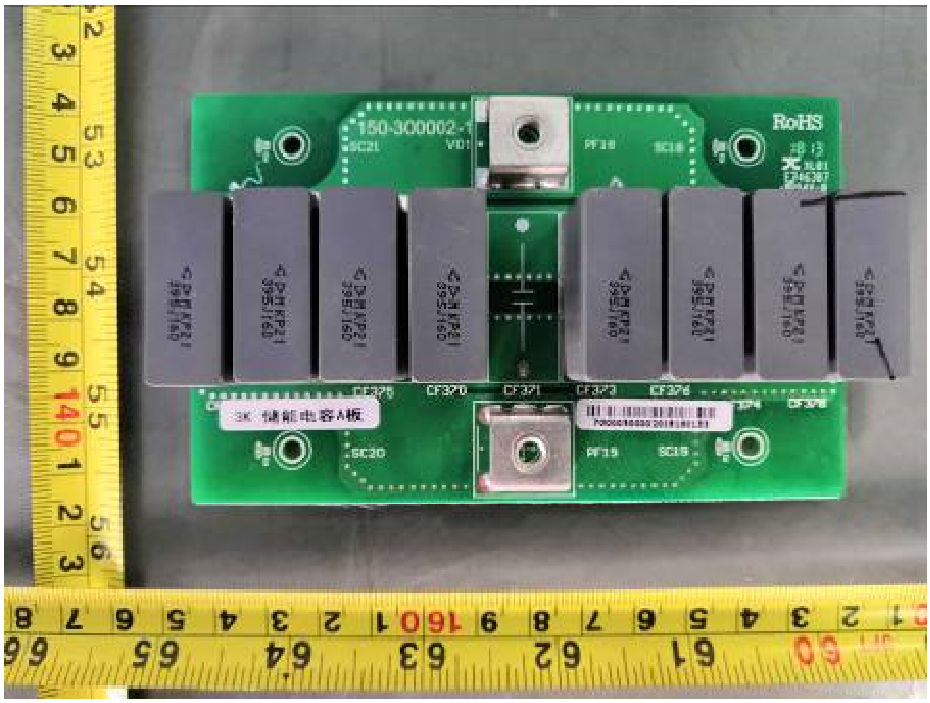
Capcitance B board component side view

Capcitance B board solder side view

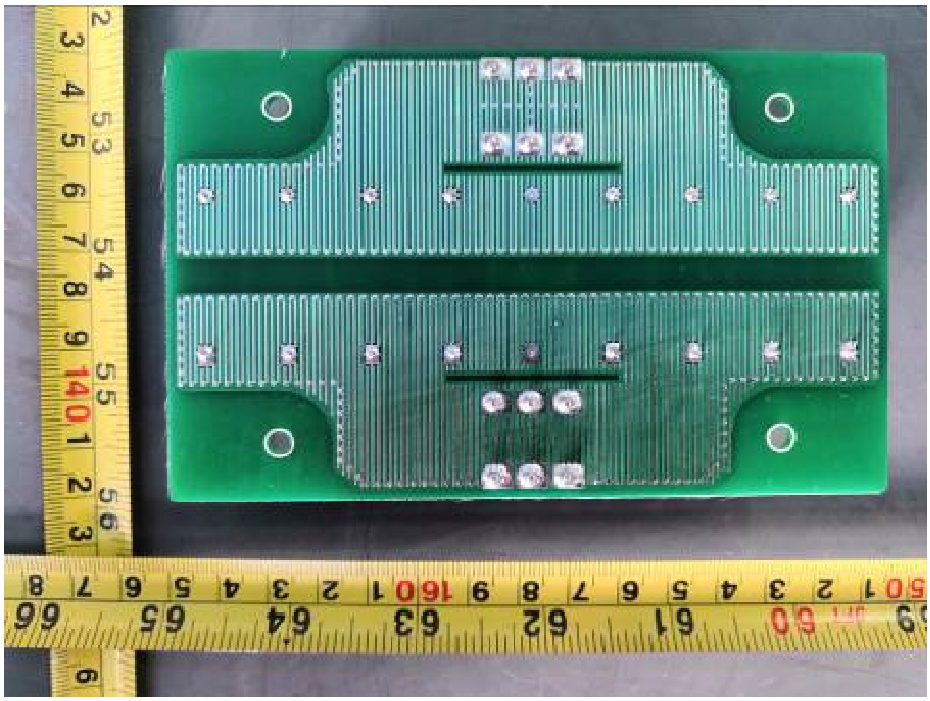


Pictures of the unit

Capcitance A board component side view



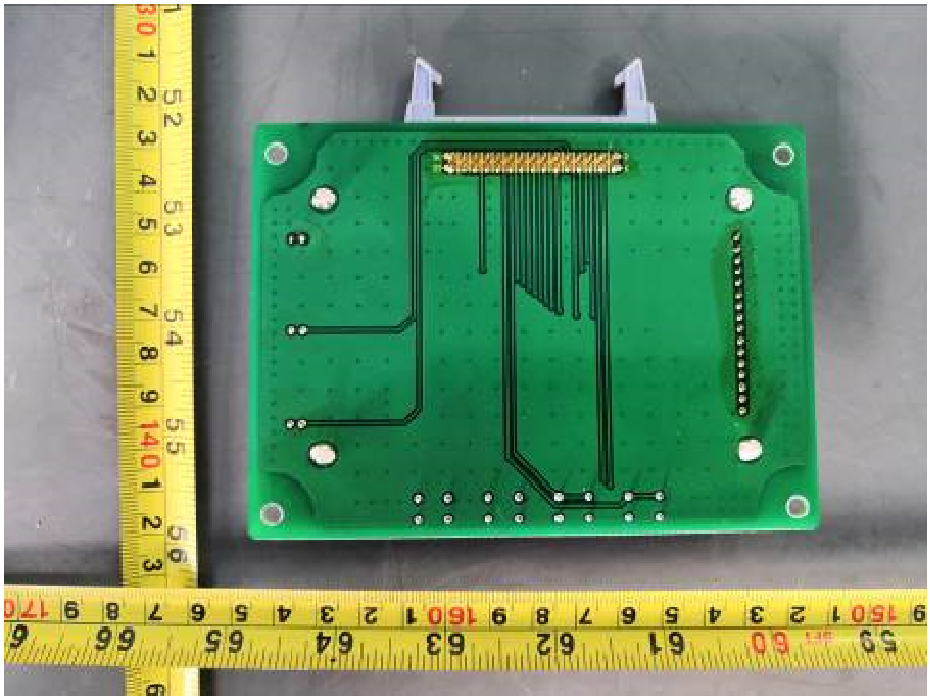
Capcitance A board solder side view



Pictures of the unit

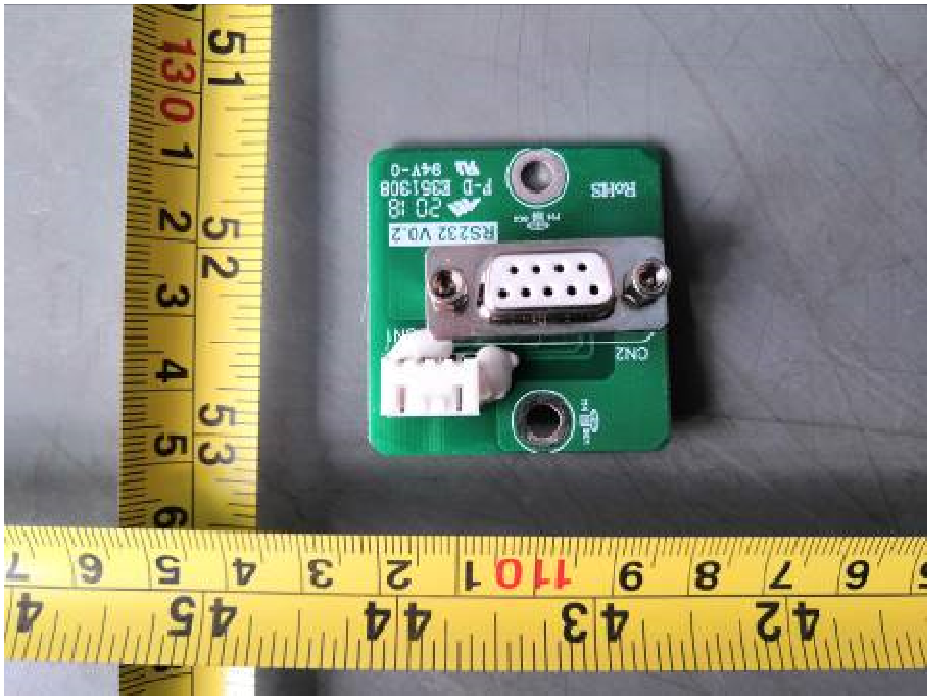
LCD board component side view

LCD board solder side view



Pictures of the unit

RS232 board component side view



RS232 board solder side view

Annex No. 2
Test Equipment list

Date(s) of performance test: 2020-03-20 to 2020-09-14

Equipment	Internal No.	Manufacturer	Type	Serial No.	Next Calibration date
Power Analyser	A4080002DG	YOKOGAWA	WT3000	91M210852	Jun. 16, 2021
AC Source	A7040019DG	Chroma	61512	61512000439	Monitored by Power Analyser
	A7040020DG	Chroma	61512	61512000438	
DC Simulation Power Supply	A7040016DG	Chroma	62150H-1000S	62150EF00490	
	A7040017DG	Chroma	620028	620028EF00120	
RLC Load	A7150027DG	Qunling	ACLT-3803H	93VOO2869	
Eight Channel Digital Phosphor Oscilloscope	A4089017DG	YOKOGAWA	DL850	91N726247	Sep. 23, 2021
Oscilloscope probe	A1490008DG	YOKOGAWA	701901	//	Sep. 22, 2021
	A1490009DG	YOKOGAWA	701901	//	Sep. 22, 2021
	A1490010DG	YOKOGAWA	701901	//	Sep. 22, 2021
Current transducer	A1060007DG	YOKOGAWA	CT200	1130700012	Sep. 02, 2021
	A1060008DG	YOKOGAWA	CT200	1130700017	Sep. 02, 2021
	A1060009DG	YOKOGAWA	CT200	1130700019	Sep. 02, 2021
Power Analyser	//	ZLG	PA5000H	C820290908200211 0001	Mar. 02, 2021
Oscilloscope	//	KEYSIGHT	DSX3014T	MY57231269	Jan. 13, 2021
Oscilloscope	//	Agilent	DS05014A	MY50070288	Jan. 13, 2021
Oscilloscope current probe	//	CYBERTEK	CP1000A	C181000922	Jan. 13, 2021
	//	CYBERTEK	CP1000A	C181000925	Jan. 13, 2021
	//	CYBERTEK	CP1000A	C181000929	Jan. 13, 2021
	//	CYBERTEK	CP1000A	C181000931	Jan. 13, 2021
Oscilloscope probe	//	SANHUA	SI-9110	152627	Jan. 13, 2021
	//	SIALENT	DS5034X	SDS5XEAC3R0011	Jan. 13, 2021
	//	AGILENT	N2863B	YF0139	Jan. 13, 2021

End of Test Report