Product Service

TEST REPORT

EN 50549-1:2019/AC:2019

TUV SUD Test Report for *Requirements for generating plants to be connected in parallel with distribution networks - Part 1: Connection to a LV distribution network - Generating plants up to and including Type B*

Report No.: Date of issue: Project handler:	64.290.22.30587.02 2023-08-25 Jinjing Peng
Testing laboratory: Address: Testing location:	TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch TÜV SÜD Testing Center, D1 building, No. 63 Chuangqi Road, Shilou Town, Panyu District, Guangzhou 511447, China Same as above
Client: Client number: Address: Contact person:	Huawei Digital Power Technologies Co.,Ltd. 114387 Office 01, 39th Floor, Block A Antuoshan Headquarters Towers 33 Antuoshan 6th Road, Futian District 518043 Shenzhen PEOPLE'S REPUBLIC OF CHINA Chen Dongxiang
Standard:	This TUV SUD test report form is based on the following requirements: *EN 50549-1:2019/AC:2019*
TRF number and revision*:*	*TRF EN 50549-1:2019/AC:2019 rev.0/2019-04*
TRF originated by:	TUV SUD Product Service, Mr. Billy Qiu
Copyright blank test report:	This test report is based on the content of the standard (see above). The test report considered selected clauses of the a.m. standard(s) and experience gained with product testing. It was prepared by TUV SUD Product Service. TUV SUD Group takes no responsibility for and will not assume liability for damages resulting from the reader's interpretation of the reproduced material due to its placement and context.
General disclaimer:	This test report may only be quoted in full. Any use for advertising purposes must be granted in writing. This report is the result of a single examination of the object in question and is not generally applicable evaluation of the quality of other products in regular production.
Scheme: Non-standard test method: National deviations:	☐ GS Mark ☐ NRTL Mark ☐ EU-Directive ☐ TUV Mark ☒ Type verification of conformity ☒ No ☐ Yes, see details under Summary of testing N/A
Number of pages *(Report)*:	111
Number of pages *(Attachments)*:	N/A
Compiled by:	Jinjing Peng *(Printed Name and Signature)* Peng Jinjing
Approved by:	Lucas Lu *(Printed Name and Signature)* Lucas Lu

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Guangzhou Branch, TÜV SÜD Group
5F, Communication Building, 163 Pingyun Rd,
Huangpu Ave. West, Guangzhou 510656, P. R. China

Test sample: Type of test object: Trademark: Model and/or type reference:	Solar Inverter & Hybrid Inverter Type Test HUAWEI Solar Inverter models: SUN2000-12KTL-M5, SUN2000-15KTL-M5, SUN2000-17KTL-M5, SUN2000-20KTL-M5, SUN2000-25KTL-M5 Hybrid Inverter models: SUN2000-12K-MB0, SUN2000-15K-MB0, SUN2000-17K-MB0, SUN2000-20K-MB0, SUN2000-25K-MB0
Rating(s):	See page 12 to 13
Manufacturer: Manufacturer number: Address:	Huawei Digital Power Technologies Co.,Ltd. 114387 Office 01, 39th Floor, Block A Antuoshan Headquarters Towers 33 Antuoshan 6th Road, Futian District 518043 Shenzhen PEOPLE'S REPUBLIC OF CHINA
Sub-contractors/ tests (clause): Name:	-- --
Order description:	☒ Complete test according to TRF
	☐ Partial test according to manufacturer's specifications
	☐ Preliminary test
	☐ Spot check
	☐ Others:
Date of order: Date of receipt of test item: Date(s) of performance of test:	2022-05-11, 2023-05-12 2022-09-01, 2023-07-20 2022-09-01 to 2022-10-30, 2023-07-22 to 2023-08-23

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Test item particulars:	
Equipment mobility ....:	☐ movable ☐ hand-held ☐ stationary ☒ fixed ☐ transportable ☐ for building-in
Connection to the mains......................:	☐ pluggable equipment ☐ direct plug-in ☒ permanent connection ☐ for building-in
Enviromental category ....:	☒ outdoor ☐ indoor unconditional ☐ indoor conditional
Over voltage category Mains ....:	☐ OVC I ☐ OVC II ☒ OVC III ☐ OVC IV
Over voltage category PV ....:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Mains supply tolerance (%).................:	+/- 10%
Tested for power systems ....:	TN system
IT testing, phase-phase voltage (V) ...:	N/A
Class of equipment.............................:	☒ Class I ☐ Class II ☐ Class III ☐ Not classified
Mass of equipment (kg)......................:	21 kg
Pollution degree.................................:	Internal(PD2), External(PD3)
IP protection class ....:	IP 66

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General product information:

(1) The unit is non-isolated (transformerless) Solar Inverter or Hybrid Inverter for connection with public grid, for outdoor use, and defined as type A generator according to Regulation (EU) 2016/631 (RfG).

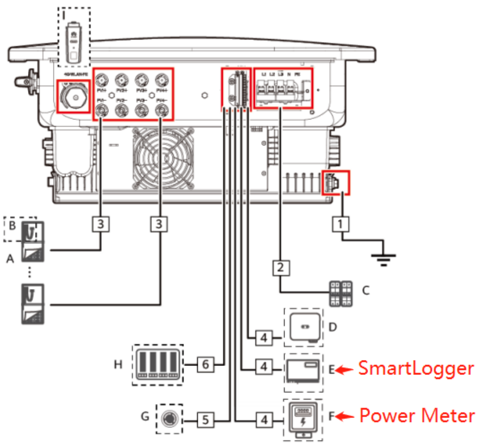
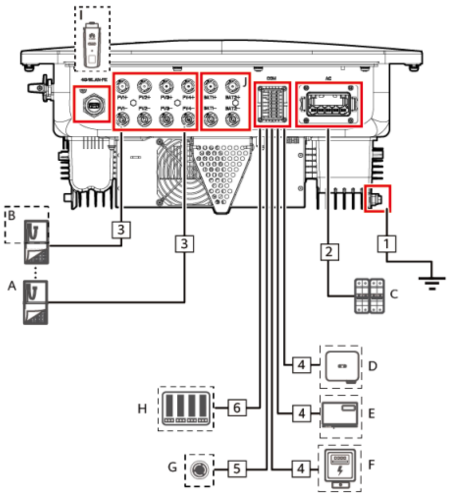
(2) Low voltage electrical installations shall comply with national and local regulation. Only qualified electricians are allowed to install and maintain the converter.

(3) In order to protect the inverter, user and installer, external DC and AC circuit breaker shall be equipped for all source port (battery, AC grid) at the end-use application.

(4) The unit has below reactive power control modes, shall comply with national and local regulation:
   1) Q setpoint mode
   2) Q(U) mode
   3) Cos φ setpoint mode
   4) Cos φ (P)

(5) Software version: V200R023, Firmware version: V200R023.

(6) RS485 communication port is used as the logic interface of the unit to control active power. By connecting to the SmartLogger which provides display the protection settings and remoted control function.

M5 Series	MB0 Series
	

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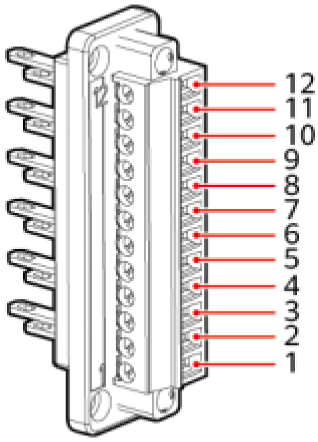
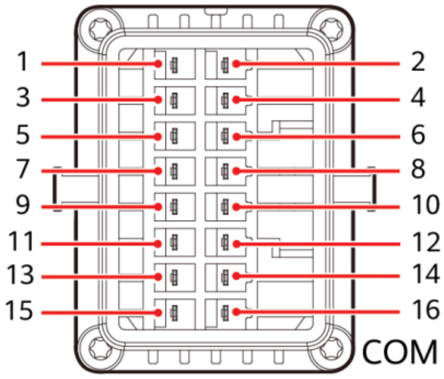


IS16W00008

Figure 5-14 Pin definitions



IS10W00002

Pin	Definition	Function	Description
1	GND	Ripple control	GND port for the DIN1 to DIN5 signals
2	DIN1		Dry contact for grid scheduling
3	DIN2		
4	DIN3		
5	DIN4		
6	DIN5	Rapid shutdown signal+	For the rapid shutdown DI signal or connecting to the signal cable of an NS protective device
7	GND	GND	-
8	-	-	-
9	485A1	RS485A1 differential signal+	For inverter cascading or connecting to the RS485 signal port of a SmartLogger
10	485B1	RS485B1 differential signal–	
11	485A2	RS485A2 differential signal+	Connecting to the RS485 signal port of a power meter
12	485B2	RS485B2 differential signal–	

Pin	Definition	Function	Description	Pin	Definition	Function	Description
1	485A1-1	RS485A, RS485 differential signal+	For inverter cascading or connecting to the RS485 signal port of a	2	485A1-2	RS485A, RS485 differential signal+	For inverter cascading or connecting to the RS485 signal port of a
3	485B1-1	RS485B, RS485 differential signal–	SmartLogger	4	485B1-2	RS485B, RS485 differential signal–	SmartLogger
5	PE	Shield layer grounding	-	6	PE	Shield layer grounding	-
7	485A2	RS485A, RS485 differential signal+	Connecting to RS485 signal ports of devices such as power meters and batteries	8	DIN1	Digital input signal 1+	Connecting to the power grid scheduling dry contact or receiving feedback signals of the on/off-grid controller
9	485B2	RS485B, RS485 differential signal–		10	DIN2	Digital input signal 2+	Connecting to the power grid scheduling dry contact
11	EN	Enable signal	For the enable signal of the battery	12	DIN3	Digital input signal 3+	
13	GND	GND	-	14	DIN4	Digital input signal 4+	
15	DIN5	Rapid shutdown	For the rapid shutdown DI signal or connecting to the signal cable of an NS protection device	16	GND	GND of DIN1, DIN2, DIN3, or DIN4	Connecting to GND of DIN1, DIN2, DIN3, or DIN4

Model differences: Solar Inverter models or Hybrid inverter models have same electric circuits topology design, same enclosure structure design, same main control circuits and firmware. Hybrid inverter models have battery interface, solar inverter models do not. The output power and current are limited by software.
Attachments: N/A
Name and address of factory (ies) *(only if certification is provided)*: Factory 1: Liding Electronic Technology (Dongguan) Co., LTD. Address 1: Building 2, No.313, Qingxi North Ring Road, Qingxi Town, Dongguan City, Guangdong Province, P.R.China Factory 2: Huizhou Huazhi New Energy Technology Co.,Ltd. Address 2: No.8 Factory, Xinhua Avenue, Chenjiang Street, Zhongkai High-tech Zone, Huizhou, Guangdong Province, P.R.China Factory 3: Astec Electronics(Luoding) Co.,Ltd. Address 3: No.68 Baocheng Road East, Fucheng, Luoding, Guangdong, P.R.China
General remarks: Defining the sign in the ***generator*** sign convention. "(see remark #)" refers to a remark appended to the report. "(see appended table)" refers to a table appended to the report. Throughout this report ***a point*** is used as the decimal separator. The test results presented in this report relate only to the object tested. This report shall not be reproduced except in full without the written approval of the testing laboratory.
Revision History This report is based on the original certificate No. D 114387 0046 Rev. 00 and original report No: 64.290.22.30587.01, Date: 2022-10-31, the original certificate is cancelled, and reports are replaced by 64.290.22.30587.02, the mainly update as follows: (1) In this revision, hybrid inverter models are added with the same grid connection configuration based on solar inverter models. Detail please refer to model difference. (2) Revise to typo of Maximum AC output current. (3) Updated the software and firmware version number from V200R022 to V200R023, except for the version number, all other features and parameters are the same as before. (4) The below tests were done on new models (SUN2000-25K-MB0): a) Test d for clause 4.6.1 Power response to overfrequency; b) Clause 4.6.2 Power response to underfrequency.

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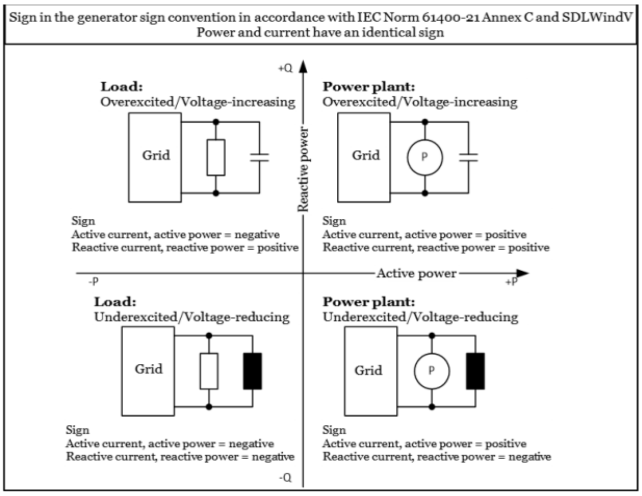
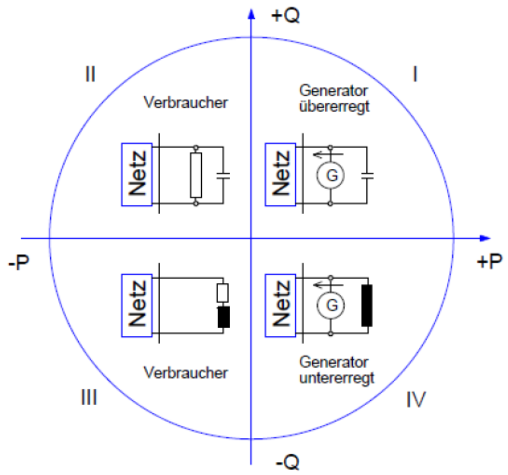
Summary of testing:

The test was performed according to EN 50549-1:2019/AC:2019 for assessment of conformity of RfG European Network Code (RfG 2016/631) as generator type A.

Generator sign convention has been applied for all measurements and results given in this report. This is described in the following figure and table.





	Inductive (under-excited)	Capacitive(over-excited)
Generator (Discharge mode)	IV. Quadrant P > 0, the equipment supplies active power from the mains (Discharge mode) Q < 0, the equipment draws reactive power from the mains (inductive behaviour)	I. Quadrant P > 0, the equipment supplies active power from the mains (Discharge mode) Q > 0, the equipment supplies reactive power to the mains (capacitive behaviour)
Consumer (Charge mode)	III. Quadrant P < 0, the equipment draw active power from the mains (Charge mode) Q < 0, the equipment draws reactive power from the mains (inductive behaviour)	II. Quadrant P < 0, the equipment draw active power from the mains (Charge mode) Q > 0, the equipment supplies reactive power to the mains (capacitive behaviour)

Tests performed (name of test and test clause):

Clause	Requirement + Test
4.3	Choice of switchgear
4.4.2	Operating frequency range
4.4.3	Minimal requirement for active power delivery at underfrequency
4.4.4	Continuous operating voltage range
4.5.2	Rate of change of frequency (ROCOF) immunity
4.6.1	Power response to overfrequency
4.6.2	Power response to underfrequency
4.7.2.2	Capabilities
4.7.2.3.2	Setpoint control modes
4.7.2.3.3	Voltage related control modes

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4.7.2.3.4	Power related Control mode
4.7.3	Voltage related active power reduction
4.8	Power quality
4.9.3.2	Undervoltage protection
4.9.3.3	Overvoltage protection
4.9.3.4	Overvoltage 10 min mean protection
4.9.3.5	Underfrequency protection
4.9.3.6	Overfrequency protection
4.9.4.2	Active methods tested with a resonant circuit
4.10.2	Automatic reconnection after tripping
4.10.3	Starting to generate electrical power
4.11.1	Ceasing active power
4.11.2	Reduction of active power on set point

Remark: If no special indicates, all the test is applied for model: SUN2000-25KTL-M5.

☐ deviation(s) found

☒ no deviations found

Additional information on Non-standard test method(s)

Sub clause: N/A

Page: N/A

Rational: N/A

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Huangpu Ave. West, Guangzhou 510656, P. R. China

Copy of marking plate:

HUAWEI
型号 Model: SUN2000-12KTL-M5
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER

合格证
QC PASS

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 12 kW
额定视在功率 a.c. Output Rated Apparent Power: 12 kVA
最大视在功率 a.c. Max. Output Apparent Power: 13.2 kVA
额定输出电流 a.c. Output Rated Current:
18.2 A(380 Va.c.)/17.3 A(400 Va.c.)/16.7 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
20.2 A(380 Va.c.)/19.1 A(400 Va.c.)/18.5 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

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Huawei Digital Power Technologies Co., Ltd. MADE IN CHINA
Huawei Digital Power Antuoshan Headquarters, Shenzhen 518043, P.R.C

HUAWEI
型号 Model: SUN2000-15KTL-M5
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER

合格证
QC PASS

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240 V/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 15 kW
额定视在功率 a.c. Output Rated Apparent Power: 15 kVA
最大视在功率 a.c. Max. Output Apparent Power: 16.5 kVA
额定输出电流 a.c. Output Rated Current:
22.8 A(380 Va.c.)/21.7 A(400 Va.c.)/20.9 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
25.2 A(380 Va.c.)/23.9 A(400 Va.c.)/23.1 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

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Huawei Digital Power Antuoshan Headquarters, Shenzhen 518043, P.R.C

HUAWEI
型号 Model: SUN2000-17KTL-M5
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER

合格证
QC PASS

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 17 kW
额定视在功率 a.c. Output Rated Apparent Power: 17 kVA
最大视在功率 a.c. Max. Output Apparent Power: 18.7 kVA
额定输出电流 a.c. Output Rated Current:
25.8 A(380 Va.c.)/24.5 A(400 Va.c.)/23.7 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
28.6 A(380 Va.c.)/27.1 A(400 Va.c.)/26.1 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

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Huawei Digital Power Antuoshan Headquarters, Shenzhen 518043, P.R.C

HUAWEI
型号 Model: SUN2000-20KTL-M5
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER

合格证
QC PASS

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 20 kW
额定视在功率 a.c. Output Rated Apparent Power: 20 kVA
最大视在功率 a.c. Max. Output Apparent Power: 22 kVA
额定输出电流 a.c. Output Rated Current:
30.4 A(380 Va.c.)/28.9 A(400 Va.c.)/27.8 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
33.6 A(380 Va.c.)/31.9 A(400 Va.c.)/30.8 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

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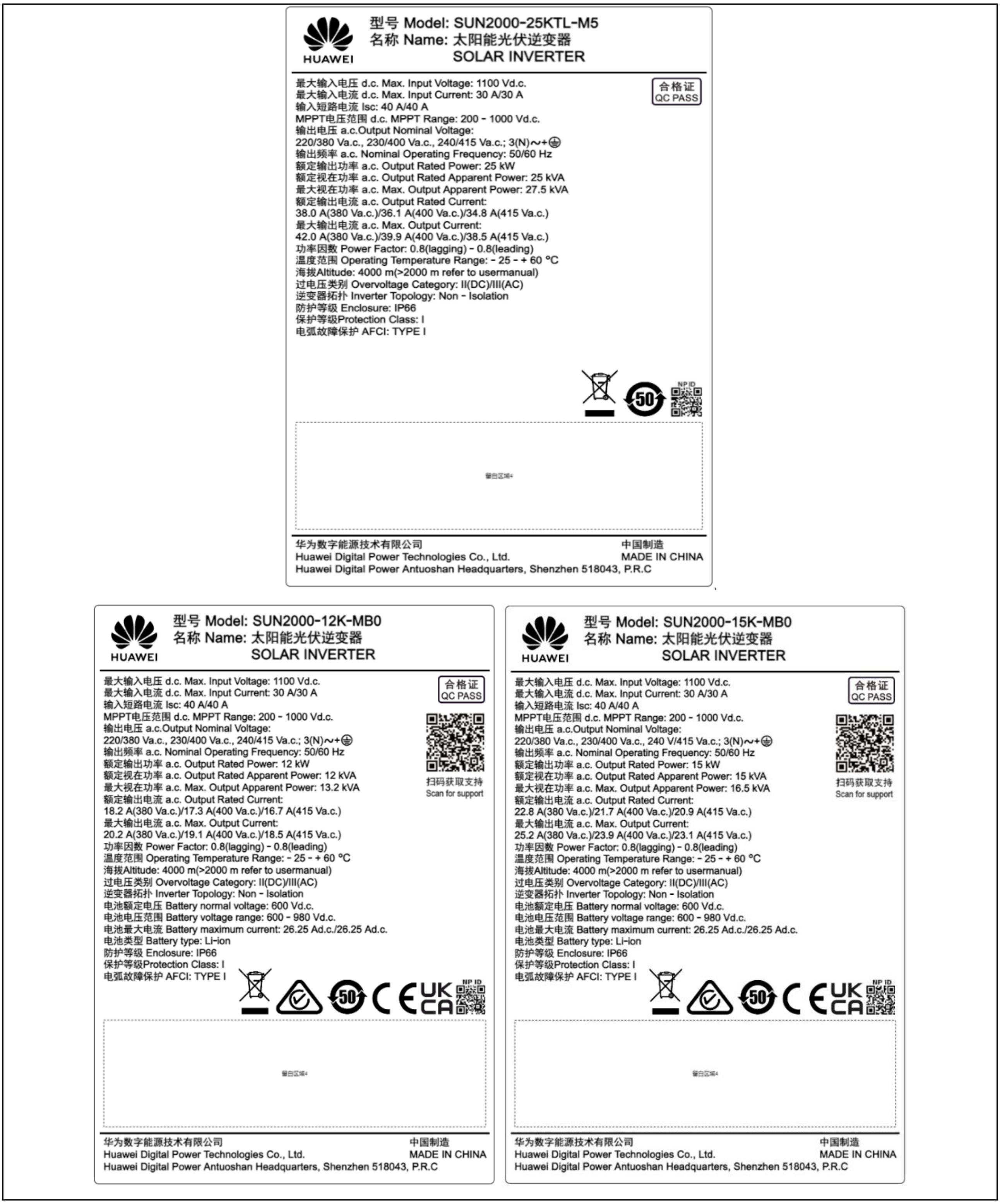

型号 Model: SUN2000-25KTL-M5
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER
HUAWEI

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 25 kW
额定视在功率 a.c. Output Rated Apparent Power: 25 kVA
最大视在功率 a.c. Max. Output Apparent Power: 27.5 kVA
额定输出电流 a.c. Output Rated Current:
38.0 A(380 Va.c.)/36.1 A(400 Va.c.)/34.8 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
42.0 A(380 Va.c.)/39.9 A(400 Va.c.)/38.5 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

合格证 QC PASS

NP ID

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Huawei Digital Power Antuoshan Headquarters, Shenzhen 518043, P.R.C
中国制造
MADE IN CHINA

型号 Model: SUN2000-12K-MB0
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER
HUAWEI

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 12 kW
额定视在功率 a.c. Output Rated Apparent Power: 12 kVA
最大视在功率 a.c. Max. Output Apparent Power: 13.2 kVA
额定输出电流 a.c. Output Rated Current:
18.2 A(380 Va.c.)/17.3 A(400 Va.c.)/16.7 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
20.2 A(380 Va.c.)/19.1 A(400 Va.c.)/18.5 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
电池额定电压 Battery normal voltage: 600 Vd.c.
电池电压范围 Battery voltage range: 600 - 980 Vd.c.
电池最大电流 Battery maximum current: 26.25 Ad.c./26.25 Ad.c.
电池类型 Battery type: Li-ion
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

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华为数字能源技术有限公司
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中国制造
MADE IN CHINA

型号 Model: SUN2000-15K-MB0
名称 Name: 太阳能光伏逆变器
SOLAR INVERTER
HUAWEI

最大输入电压 d.c. Max. Input Voltage: 1100 Vd.c.
最大输入电流 d.c. Max. Input Current: 30 A/30 A
输入短路电流 Isc: 40 A/40 A
MPPT电压范围 d.c. MPPT Range: 200 - 1000 Vd.c.
输出电压 a.c.Output Nominal Voltage:
220/380 Va.c., 230/400 Va.c., 240 V/415 Va.c.; 3(N)~+⏚
输出频率 a.c. Nominal Operating Frequency: 50/60 Hz
额定输出功率 a.c. Output Rated Power: 15 kW
额定视在功率 a.c. Output Rated Apparent Power: 15 kVA
最大视在功率 a.c. Max. Output Apparent Power: 16.5 kVA
额定输出电流 a.c. Output Rated Current:
22.8 A(380 Va.c.)/21.7 A(400 Va.c.)/20.9 A(415 Va.c.)
最大输出电流 a.c. Max. Output Current:
25.2 A(380 Va.c.)/23.9 A(400 Va.c.)/23.1 A(415 Va.c.)
功率因数 Power Factor: 0.8(lagging) - 0.8(leading)
温度范围 Operating Temperature Range: - 25 - + 60 °C
海拔Altitude: 4000 m(>2000 m refer to usermanual)
过电压类别 Overvoltage Category: II(DC)/III(AC)
逆变器拓扑 Inverter Topology: Non - Isolation
电池额定电压 Battery normal voltage: 600 Vd.c.
电池电压范围 Battery voltage range: 600 - 980 Vd.c.
电池最大电流 Battery maximum current: 26.25 Ad.c./26.25 Ad.c.
电池类型 Battery type: Li-ion
防护等级 Enclosure: IP66
保护等级Protection Class: I
电弧故障保护 AFCI: TYPE I

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Note: For application of this standard, the nominal voltage is 230/400 Va.c., nominal frequency is 50Hz, dafault power factor range: 0.9 inductive(under-excited) to 0.9 capacitive(over-excited), add test verification power factor adjustable range up to 0.8 inductive(under-excited) to 0.8 capacitive(over-excited).

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Characteristic data:

Model	SUN2000-12KTL-M5	SUN2000-15KTL-M5	SUN2000-17KTL-M5	SUN2000-20KTL-M5	SUN2000-25KTL-M5
PV terminal parameters					
Maximum DC input voltage	1100 Vd.c.				
Rated input voltage	600 Vd.c.				
MPPT range	200~1000 Vd.c.				
MPPT range (full load)	370~800 Vd.c.	410~800 Vd.c.	440~800 Vd.c.	480~800 Vd.c.	530~800 Vd.c.
Maximum input current	2*30 Ad.c.				
Isc PV	2*40 Ad.c.				
Maximum input power	18000 W	22500 W	25500 W	30000 W	37500 W
Grid terminal parameters					
Rated AC voltage	230/400 Va.c., 3W+N+PE				
Rated AC output current	17.3 Aa.c.	21.7 Aa.c.	24.5 Aa.c.	28.9 Aa.c.	36.1 Aa.c.
Maximum AC output current	20.2 Aa.c.	25.2 Aa.c.	28.6 Aa.c.	33.6 Aa.c.	42.0 Aa.c.
Rated output active power	12000 W	15000 W	17000 W	20000 W	25000 W
Maximum continuous output apparent power	13200 VA	16500 VA	18700 VA	22000 VA	27500 VA
Rated AC frequency	50 Hz				
Power factor	0.8 inductive(under-excited) to 0.8 capacitive(over-excited)				

Model	SUN2000-12K-MB0	SUN2000-15K-MB0	SUN2000-17K-MB0	SUN2000-20K-MB0	SUN2000-25K-MB0
Battery input/output parameters					
Battery type	Li-ion				
Rated voltage	600 Vd.c.				
Battery voltage range	600-980 Vd.c.				
Maximum charge/discharge current	26.25 Ad.c./26.25 Ad.c.				
Maximum charge power	25000 W	25000 W	25000 W	25000 W	25000 W
Maximum discharge power	13200 W	16500 W	18700 W	22000 W	25000 W
Maximum charge power from grid to battery	13200 W	15000 W	15000 W	15000 W	15000 W
PV terminal parameters					
Maximum DC input voltage	1100 Vd.c.				
Rated input voltage	600 Vd.c.				
MPPT Range	200~1000 Vd.c.				
MPPT Range (full load)	370~800 Vd.c.	410~800 Vd.c.	440~800 Vd.c.	480~800 Vd.c.	530~800 Vd.c.
Maximum Input Current	2*30 Ad.c.				
Isc PV	2*40 Ad.c.				

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Maximum Input Power	18000 W	22500 W	25500 W	30000 W	37500 W
Grid terminal parameters					
Rated AC voltage	230/400 Va.c., 3W+N+PE				
Maximum continuous input current	19.1 Aa.c.	21.7 Aa.c.			
Maximum continuous input power	13200 W	15000 W			
Rated AC output current	17.3 Aa.c.	21.7 Aa.c.	24.5 Aa.c.	28.9 Aa.c.	36.1 Aa.c.
Maximum AC output current	20.2 Aa.c.	25.2 Aa.c.	28.6 Aa.c.	33.6 Aa.c.	42.0 Aa.c.
Rated output active power	12000 W	15000 W	17000 W	20000 W	25000 W
Maximum continuous output apparent power	13200 VA	16500 VA	18700 VA	22000 VA	27500 VA
Rated AC frequency	50 Hz				
Power factor	0.8 inductive(under-excited) to 0.8 capacitive(over-excited)				

Remark: The maximum AC output current is the maximum current that can be withstood at low voltages.

Possible test case verdicts:

test case does not apply to the test object:	N/A (not applicable / not included in the order)
test object does meet the requirement:	P (Pass)
test object does not meet the requirement:	F (Fail)

Possible suffixes to the verdicts:

suffix for detailed information for the client:	C (Comment)
suffix for important information for factory inspection:	M (Manufacturing)

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Picture of the product:

(M5 Series)

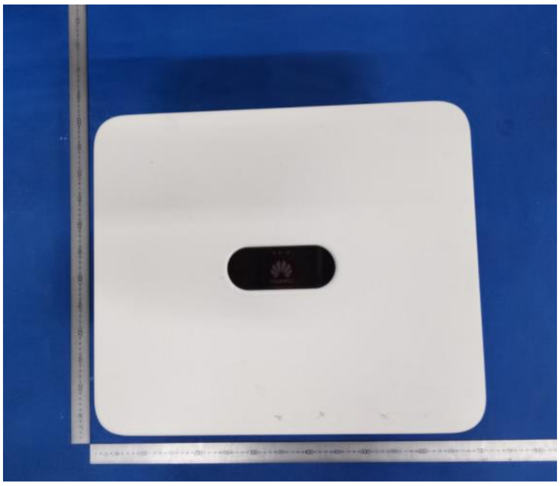
Over view

Internal view

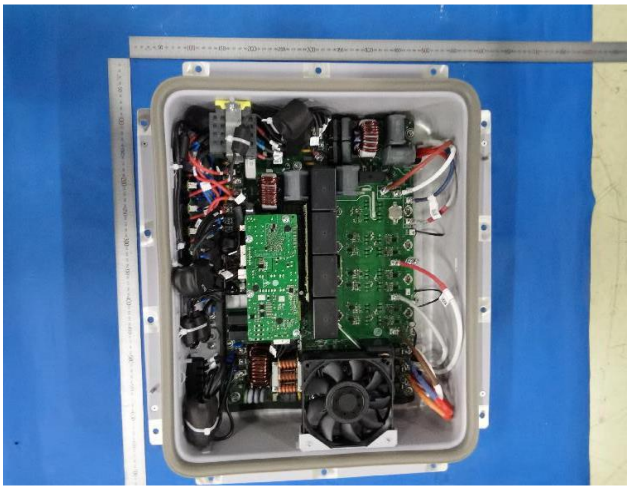
Left side DC switch view

External view

(MB0 Series)



Overall view



Internal view

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Left side DC switch view

External view

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Clause	Requirement + Test	result – Remark	Verdict
4	**Requirements on generating plants**		P
4.1	**General**		P
	This clause defines the requirements on generating plants to be operated in parallel with the distribution network. Where settings or a range of configurability is provided and respecting the legal framework the configurations and settings may be provided by the DSO. Where no settings are provided by the DSO, the specified default settings shall be used; if no default settings are provided, the producer shall propose settings and inform the DSO.	EN 50549-1:2019/AC:2019 is considerd.	P
	The requirements of Clause 4 apply during normal operation of the generating units and do not apply in case of maintenance or units out of operation. The provisions apply to EESS in generation mode. In charging mode EESS should have the same characteristics, unless stated otherwise in the clauses of this European Standard.		P
	The applicability is independent of the duration the generating unit operates in parallel with the distribution network. It is the responsibility of the DSO to relax, if deemed appropriate, the requirements for an individual generating unit or plant whose operation in parallel only lasts for a short time (temporary operation in parallel). The relaxed requirements shall be agreed between the DSO and the producer, along with the maximum allowable duration of the temporary operation in parallel. For the short-term parallel operation an appropriate device shall automatically disconnect the generating unit or plant as soon as the maximum allowable duration has elapsed.		P
	If different requirements on the generating plant interfere with each other, the following hierarchy in descending order shall be applied: 1. Generating unit protection, including regarding the prime mover; 2. interface protection (see 4.9) and protection against faults within the generating plant; 3. voltage support during faults and voltage steps (see 4.7.4); 4. the lower value of: remote control command on active power limitation for distribution grid security (see 4.11) and local response to overfrequency (see 4.6.1); 5. local response to underfrequency if applicable (see 4.6.2);	See the respective clause for detail	P

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Clause	Requirement + Test	result – Remark	Verdict
	6. reactive power (see 4.7.2) and active power (P(U) see 4.7.2) controls; 7. other control commands on active power set point for e.g. market, economic reasons, self-consumption optimization.		
	The system shall be so designed that under foreseeable conditions no self-protection trips prior to the fulfilment of the requirements of this European Standard and all settings provided by the DSO or responsible party.	Designed according to Regulation (EU) 2016/631, article Type A	P
	For cogeneration plants embedded in industrial sites, active power requirements shall be agreed between the responsible party and the producer. In such a case the priority list is adapted accordingly.		N/A
	Besides the requirements of Clause 4, additional requirements apply for connecting a generating plant to the distribution network, e.g. assessment of the point of connection. However, this is excluded from the scope of this European Standard but some guidance is provided in the informative Annex A.	Consider in final installation.	P
4.2	**Connection scheme**		P
	The connection scheme of the generating plant shall be in compliance with the requirements of the DSO. Different requirements may be subject to agreement between the producer and the DSO depending on the power system needs.		P
	Inter alia, the generating plant shall ensure the follow		P
	• synchronization, operation and disconnection under normal network operating conditions, i.e. in the absence of faults or malfunctions;		P
	• faults and malfunctions within the generating plant shall not impair the normal functioning of the distribution network;		P
	• coordinated operation of the interface switch with the generating unit switch, the main switch and switches in the distribution network, for faults or malfunctions within the generating plant or the DSO network during operation in parallel with the distribution network; and	Approved relay used	P
	• disconnection of the generating plant from the distribution network by tripping the interface switch according to 4.9.		P
	In order to satisfy the above functions, coordinated but independent switches and protection equipment may be applied in the generating plant, as shown in the example in Figure 2.		P

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Clause	Requirement + Test	result – Remark	Verdict
4.3	**Choice of switchgear**		P
4.3.1	General		P
	Switches shall be chosen based on the characteristics of the power system in which they are intended to be installed. For this purpose, the short circuit current at the installation point shall be assessed, taking into account, inter alia, the short circuit current contribution of the generating plant.	Refer to TÜV Rheinland safety report: CN221HFC 002	P
4.3.2	Interface switch	Refer to TÜV Rheinland safety report: CN221HFC 002	P
	Switches shall be power relays, contactors or mechanical circuit breakers each having a breaking and making capacity corresponding to the rated current of the generating plant and corresponding to the short circuit contribution of the generating plant.		P
	The short-time withstand current of the switching devices shall be coordinated with rated short circuit power at the point of connection.		P
	In case of loss of auxiliary supply power to the switchgear, a secure disconnection of the switch is required immediately.		P
	Where means of isolation (according to HD 60364-5-551) is not required to be accessible to the DSO at all times, automatic disconnection with single fault tolerance according to 4.13 shall be provided. NOTE 1 For PV-inverters, further requirements are stated in EN 62109–1 and EN 62109–2 with respect to the interface switch.		P
	The function of the interface switch might be combined with either the main switch or the generating unit switch in a single switching device. In case of a combination, the single switching device shall be compliant to the requirements of both, the interface switch and the combined main switch or generating unit switch. As a consequence, at least two switches in series shall be present between any generating unit and the POC. NOTE 2 This does not refer to the number of series-connected switches in order to ensure single fault tolerance as required in 4.13 but to the number of different switching devices itself.		P
4.4	**Normal operating range**		P
4.4.1	General		P
	Generating plants when generating power shall have the capability to operate in the operating ranges		P

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Clause	Requirement + Test	result – Remark	Verdict
	specified below regardless the topology and the settings of the interface protection.		
4.4.2	Operating frequency range	See below table	P
	The generating plant shall be capable to operate continuously when the frequency at the point of connection stays within the range of 49 Hz to 51 Hz.		P
	In the frequency range from 47 Hz to 52 Hz the generating plant should be capable of operating until the interface protection trips. Therefore, the generating plant shall at least be capable of operating in the frequency ranges, for the duration and for the minimum requirement as indicated in Table 1.		P
	Respecting the legal framework, it is possible that for some synchronous areas more stringent time periods and/or frequency ranges will be required by the DSO and the responsible party. Nevertheless, they are expected to be within the boundaries of the stringent requirement as indicated in Table 1 unless producer, DSO, TSO and responsible party agree on wider frequency ranges and longer durations. NOTE 1 For small isolated distribution networks (typically on islands) even more stringent time periods and frequency ranges may be required.		P
	As long as generating modules with linear Sterling engines are recognized as emerging technology according to COMMISSION REGULATION (EU) 2016/631 Title 6, they are permitted to disconnect below 49,5 Hz and above 50,5 Hz.		N/A
	This permission does not affect the requirements for interface protection according to clause 4.9. In this case over and under frequency machine protection might trip prior to interface protection. If an integrated interface protection device is used, the reduction of the configuration range of the interface protection in clause 4.9 is acceptable. NOTE 2: The status of emerging technology in COMMISSION REGULATION (EU) 2016/631 Title 6 depends on the cumulative maximum capacity of this technology. Once the threshold in cumulative maximum capacity is reached the status will be withdrawn		P
4.4.3	Minimal requirement for active power delivery at underfrequencies	See below table	P
	A generating plant shall be resilient to reductions of frequency at the point of connection while reducing the maximum active power as little as possible.		P

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Clause	Requirement + Test	result – Remark	Verdict
	The admissible active power reduction due to underfrequency is limited by the full line in Figure 5 and is characterized by a maximum allowed reduction rate of 10 % of Pmax per 1 Hz for frequencies below 49,5 Hz.		P
	It is possible that a more stringent power reduction characteristic is required by the responsible party. Nevertheless this requirement is expected to be limited to an admissible active power reduction represented by the dotted line in Figure 5 which is characterised by a reduction rate of 2 % of the maximum power Pmax per 1 Hz for frequencies below 49 Hz.		P
	If any technologies intrinsic design or ambient conditions have influence on the power reduction behaviour of the system, the manufacturer shall specify at which ambient conditions the requirements can be fulfilled and eventual limitations. The information can be provided in the format of a graph showing the intrinsic behaviour of the generating unit for example at different ambient conditions. The power reduction and the ambient conditions shall comply with the specification given by the responsible party. If the generating unit does not meet the power reduction at the specified ambient conditions, the producer and the responsible party shall agree on acceptable ambient conditions.		P
4.4.4	Continuous operating voltage range	See below table	P
	When generating power, the generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85 % Un to 110 % Un. Beyond these values the under and over voltage ride through immunity limits as specified in clause 4.5.3 and 4.5.4 shall apply.		P
	In case of voltages below Un, it is allowed to reduce the apparent power to maintain the current limits of the generating plant. The reduction shall be as small as technically feasible.		P
	For this requirement all phase to phase voltages and in case a neutral is connected, additionally all phase to neutral voltages shall be evaluated. NOTE The specified accepted reduction of output power is an absolute minimum requirement. Further power system aspects might require maintained output power in the entire continuous operation voltage range.		P

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Clause	Requirement + Test	result – Remark	Verdict
	The producer shall take into account the typical voltage rise and voltage drop within the generating plant.		P
4.5	**Immunity to disturbances**		P
4.5.1	General		P
	In general, generating plants should contribute to overall power system stability by providing immunity towards dynamic voltage changes unless safety standards require a disconnection.		P
	The following clauses describe the required immunity for generating plants taking into account the connection technology of the generating modules.		P
	The following withstand capabilities shall be provided regardless of the settings of the interface protection. NOTE An event on the HV and EHV transmission network can affect numerous small scale units on MV and LV level. Depending on the penetration of dispersed generation, a significant loss of active power provision can be caused.		P
4.5.2	Rate of change of frequency (ROCOF) immunity	See below table	P
	ROCOF immunity of a power generating plant means that the generating modules in this plant stay connected with the distribution network and are able to operate when the frequency on the distribution network changes with a specified ROCOF. The generating units and all elements in the generating plant that might cause their disconnection or impact their behaviour shall have this same level of immunity.		P
	The generating modules in a generating plant shall have ROCOF immunity for a ROCOF equal or exceeding the value specified by the responsible party. If no ROCOF immunity value is specified, the following ROCOF immunity shall apply, making distinction between generating technologies: • Non-synchronous generating technology: at least 2 Hz/s • Synchronous generating technology: at least 1 Hz/s		P
	The ROCOF immunity is defined with a sliding measurement window of 500 ms.		P
4.5.3	Under-voltage ride through (UVRT)	Not suitable for Type A unit	N/A
4.5.3.1	General		N/A
	Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.5.3.2 and 4.5.3.3. Generating modules classified as type A and		N/A

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Clause	Requirement + Test	result – Remark	Verdict
	smaller according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of type A modules and smaller shall be specified in the connection agreement. NOTE 1 Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of under voltage.		
	The requirements apply to all kinds of faults (1ph, 2ph and 3ph). NOTE 2 A more distinctive differentiation for 1ph, 2ph and 3ph faults is under consideration. NOTE 3 These requirements are independent of the interface protection settings. Disconnection settings of the interface protection relay always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings. NOTE 4 The FRT curves in Figure 6, Figure 7 and Figure 8 describe the minimum requirements for continued connection of the generating plant to the grid. They are not designed for parameterising the interface protection.		N/A
4.5.3.2	Generating plant with non-synchronous generating technology		N/A
	Generating modules shall be capable of remaining connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 6. The voltage is relative to Un. The smallest phase to neutral voltage, or if no neutral is present, the smallest phase to phase voltage shall be evaluated.		N/A
	The responsible party may define a different UVRT characteristic. Nevertheless, this requirement is expected to be limited to the most stringent curve as indicated in Figure 6.		N/A
	This means that the whole generating module has to comply with the UVRT requirement. This includes all elements in a generating plant: the generating units and all elements that might cause their disconnection.		N/A
	For the generating unit, this requirement is considered to be fulfilled if it stays connected to the distribution grid as long as the voltage at its terminals remains above the defined voltage-time diagram.		N/A
	After the voltage returns to continuous operating voltage range, 90 % of pre-fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 1 s unless the DSO and the responsible party requires another value.		N/A

Clause	Requirement + Test	result – Remark	Verdict
4.5.3.3	Generating plant with synchronous generating technology		N/A
	Generating modules shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 7. The voltage is relative to Un. The smallest phase to neutral voltage or if no neutral is present the smallest phase to phase voltage shall be evaluated.		N/A
	The responsible party may define a different UVRT characteristic. Nevertheless, this requirement is expected to be limited to the most stringent curve, indicated in Figure 7.		N/A
	This means that the whole generating module has to comply with the UVRT requirement. This includes all elements in a generating plant: the generating units and all elements that might cause its disconnection.		N/A
	For the generating unit, this requirement is considered to be fulfilled if it stays connected to the distribution grid as long as the voltage at its terminals remains above the defined voltage-time diagram.		N/A
	After the voltage returns to continuous operating voltage range, 90 % of pre-fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 3 s unless the DSO and the responsible party requires another value.		N/A
4.5.4	Over-voltage ride through (OVRT)	Not suitable for Type A unit	N/A
	Generating modules, except for micro-generating plants, shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains below the voltage-time curve of Figure 8.		N/A
	The highest phase to neutral voltage or if no neutral is present the highest phase to phase voltage shall be evaluated.		N/A
	This means that not only the generating units shall comply with this OVRT requirement but also all elements in a generating plant that might cause its disconnection. NOTE 1 Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of over voltage. NOTE 2 These requirements are independent of the interface protection settings. Disconnection settings of the		N/A

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Clause	Requirement + Test	result – Remark	Verdict
	interface protection relay will always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings. NOTE 3 This is a minimum requirement. Further power system stability aspects might be relevant. The technical discussion is still ongoing. A voltage jump of +10 % of Un from any stable point of operation is considered. In case of steady state voltages near the maximum voltage before the event, this will result in an over voltage situation for many seconds. In later editions of this document, more stringent immunity might be required.		
4.6	**Active response to frequency deviation**		P
4.6.1	Power response to overfrequency	See below table	P
	Generating plants shall be capable of activating active power response to overfrequency at a programmable frequency threshold f_1 at least between and including 50,2 Hz and 52 Hz with a programmable droop in a range of at least s=2 % to s=12 %. The droop reference is P_{ref} . Unless defined differently by the responsible party: • $P_{ref} = P_{max}$, in the case of synchronous generating technology and electrical energy storage systems. • $P_{ref} = P_M$, the actual AC output power at the instant when the frequency reaches the threshold f 1 , in the case of all other non-synchronous generating technology		P
	The power value calculated according to the droop is a maximum power limit. If e.g. the available primary power decreases during a high frequency period below the power defined by the droop function, lower power values are permitted.		P
	The maximum power limit is: $P_{max-limit} = P_M + \Delta P$ with $\Delta P = \frac{1}{s} \cdot \frac{(f_1 - f)}{f_n} \cdot P_{ref}$ with f the actual frequency NOTE 1 In other documents power response to overfrequency can also be described as frequency control or Limited Frequency Sensitive Mode - Overfrequency (LFSM-O). NOTE 2 The active power droop relative to the reference power might also be defined as an active power gradient relative to the reference power. A droop in the range of 2 % to 12 % represents a gradient of 100 % to 16,7 % P_{ref}/Hz so with g defined by $g\left[\frac{P}{P_{ref}}/Hz\right] = \frac{1}{s \cdot f_n}$ we get $\Delta P = g \cdot P_{ref} \cdot (f_1 - f)$.		P

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	The generating plant shall be capable of activating active power response to overfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s, unless another value is defined by the relevant party. An intentional delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s. NOTE 3 The following response times are considered feasible, for PV and battery inverters below 1 s for ΔP of 100 % P_{max} and for wind turbines 2 s for ΔP < 50 % P_{max} .		P
	After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power (see Figure 9). The resolution of the frequency measurement shall be ± 10 mHz or less. The accuracy is evaluated with a 1 min average value. At POC, loads if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant. NOTE 4 With the provision above, the intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed. NOTE 5 The option of an intentional delay is required since a very fast and undelayed active power frequency response in case of loss of mains would correct any excess of generation leading to a generation-consumption balance. In these circumstances, an unintended islanding situation with stable frequency would take place, in which the correct behaviour of any loss of mains detection based on frequency might be hindered. NOTE 6 The intentional delay is considered relevant for power system stability. For that reason, legal regulations might require a mutual agreement on the setting between DSO, responsible party and TSO.		P
	Generating plants reaching their minimum regulating level shall, in the event of further frequency increase, maintain this power level constant unless the DSO and the responsible party requires to disconnect the complete plant or if the plant consists of multiple units by disconnecting individual units.		P
	The active power frequency response is only deactivated if the frequency falls below the frequency threshold f_1.		P
	If required by the DSO and the responsible party an additional deactivation threshold frequency fstop shall		N/A

Clause	Requirement + Test	result – Remark	Verdict
	be programmable in the range of at least 50 Hz to f_1 . If f_{stop} is configured to a frequency below f_1 there shall be no response according to the droop in case of a frequency decrease (see Figure 10). The output power is kept constant until the frequency falls below f_{stop} for a configurable time t_{stop} .		
	If at the time of deactivation of the active power frequency response the momentary active power P_M is below the available active power P_A, the active power increase of the generating plant shall not exceed the gradient defined in 4.10.2.		P
	Settings for the threshold frequency f_1 , the droop and the intentional delay are provided by the DSO and the responsible party. If no settings are provided, the default settings in Table 2 should be applied. NOTE 7 When applying active power response to overfrequency, the frequency threshold f_1 should be set to a value from 50,2 Hz up to 50,5 Hz. Setting the frequency threshold f_1 to 52 Hz is considered as deactivating this function.	Frequency threshold can be 50.2Hz to 50.5Hz, 50.2Hz is selected and tested.	P
	The enabling and disabling of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party. NOTE 8 PV generating units are considered to have the ability to reduce power over the full droop range. NOTE 9 Protection setting overrules this behaviour.		P
	Alternatively for the droop function described above, the following procedure is allowed for generating modules if permitted by the DSO and the responsible party: • the generating units shall disconnect at randomized frequencies, ideally uniformly distributed between the frequency threshold f 1 and 52 Hz; NOTE 10 The usage of a disconnection limit above 51,5Hz does not necessarily imply the requirement to operate at this frequency. Operating range is defined in clause 4.4.4. If the randomized disconnection value is above the operating range and interface protection setting, the unit is disconnected according to chapter 4.9 at the value set by the interface protection. • in case the frequency decreases again, the generating unit shall start its reconnection procedure once the frequency falls below the specific frequency that initiated the disconnection; for this procedure, the connection conditions described in 4.10 do not apply; • the randomization shall either be at unit level by changing the threshold over time, or on plant level by		P

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	choosing different values for each unit within a plant, or on distribution system level if the DSO specifies a specific threshold for each plant or unit connected to its distribution system. NOTE 11 This procedure could be applied for generating modules for which it is technically not feasible to reduce power with the required accuracy in the required time or for reasons within the distribution network for example to prevent unintentional island operation. NOTE 12 The behaviour will, for a part of the network with many such units, result in a similar droop as specified above for controllable generating units and hence will provide for the necessary power system stability. Due to its fast reaction capability it contributes significantly to the avoidance of a frequency overshoot.		
	EES units that are in charging mode at the time the frequency passes the threshold f_1 shall not reduce the charging power below PM until frequency returns below f_1 . Storage units should increase the charging power according to the configured droop. In case the maximum charging capacity is reached or to prevent any other risk of injury or damage of equipment, a reduction of charging power is permitted.		P
4.6.2	Power response to underfrequency	See below table	P
	EES units shall be capable of activating active power response to underfrequency. Other generating units/plants should be capable of activating active power response to underfrequency. If active power to underfrequency is provided by a generating plant/unit, the function shall comply with the requirements below. NOTE 1: In other documents power response to underfrequency is also described as frequency control or Limited Frequency Sensitive Mode - Underfrequency (LFSM-U).		P
	Active power response to underfrequency shall be provided when all of the following conditions are met: • when generating, the generating unit is operating at active power below its maximum active power P_{max} ; • when generating, the generating unit is operating at active power below the available active power P_A ; NOTE 2 In case of EES units, the available power includes the state of charge of the storage. • the voltages at the point of connection of the generating plant are within the continuous operating voltage range; and • when generating, the generating unit is operating with currents lower than its current limit. NOTE 3 These conditions apply to each generating unit individually since the specified conditions need to be met by		P

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	each generating unit individually to allow the unit to increase power.		
	In the case of EES units, active power frequency response to underfrequency shall be provided in charging and generating mode. NOTE 4 In the case of EES units, the charging is regarded as a point of operation with negative active power. In charging mode the active power consumption is reduced according to the configured droop. Depending on the depth of the underferquency event a change to generating mode will happen. In this case the state of charge of the storage is part of the conditions above. NOTE 5 This clause provides additional detail to the network code on emergency and restoration (Regulation (EU) 2017/2196) and more precisely on its Article 15 3 (a).		P
	The active power response to underfrequency shall be delivered at a programmable frequency threshold f_1 at least between and including 49,8 Hz and 46,0 Hz with a programmable droop in a range of at least 2 % to 12 %. The droop reference P_{ref} is P_{max} . If the available primary power or a local set value increases during an underfrequency period above the power defined by the droop function, higher power values are permitted. The power value calculated according to the droop is therefore a minimum limit.		P
	The minimum power limit is, $P_{min-limit} = P_M + \Delta P$ With $\Delta P = \frac{1}{s} \times \frac{(f1-f)}{fn} \times Pref$ with f the actual frequency NOTE 6 In the case of active power response to underfrequency, P_{max} is used as P_{ref} to allow for system support even in case of low power output in the moment the event begins. NOTE 7 The active power droop relative to the reference power might also be defined as an active power gradient relative to the reference power. A droop in the range of 2 % to 12 % represents a gradient of 100 % to 16,7 % P_{ref} /Hz so with g defined by $g\left[\frac{P}{P_{ref}}/Hz\right] = \frac{1}{s \cdot f_n}$ we get $\Delta P = g \cdot P_{ref} \cdot (f_1 - f)$ NOTE 8 In the case of an increase of active power generation, the hierarchy of requirements in clause 4.1 apply.		P
	The generating unit shall be capable of activating active power response to underfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s unless another value is defined by the relevant party.		P

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	An intentional initial delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.		P
	After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power. The accuracy is evaluated with a 1 min average value. The resolution of the frequency measurement shall be ± 10 mHz or less. At POC loads, if present in the producer's network, might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant. NOTE 9 With the provision above, the intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed. NOTE 10 The option of an intentional delay is required since a very fast and undelayed active power frequency response in case of loss of mains would correct any shortage of generation leading to a generation-consumption balance. In these circumstances, an unintended islanding situation with stable frequency would take place, in which the correct behaviour of any loss of mains detection based on frequency might be hindered. NOTE 11 The intentional delay is considered relevant for power system stability. For that reason, legal regulations might require a mutual agreement on the setting between DSO, responsible party and TSO.		P
	Generating modules reaching any of the conditions above during the provision of active power frequency response shall, in the event of further frequency decrease, maintain this power level constant.		P
	The active power frequency response is only deactivated if the frequency increases above the frequency threshold f_1 .		P
	Settings for the threshold frequency f1, the droop and the intentional delay are defined by the DSO and the responsible party, if no settings are provided, the function shall be disabled. NOTE 12 When applying active power response to underfrequency, the frequency threshold f1 should be set to a value from 49,8 Hz up to 49,5 Hz. Setting the frequency threshold f1 to 46 Hz is considered as deactivating this function.	Frequency threshold can be 49.5Hz to 49.8Hz, 49.8Hz is selected and tested.	P
	The activation and deactivation of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted		N/A

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	interference (e.g. password or seal) if required by the DSO and the responsible party.		
4.7	**Power response to voltage changes**		P
4.7.1	General		P
	When the contribution to voltage support is required by the DSO and the responsible party, the generating plant shall be designed to have the capability of managing reactive and/or active power generation according to the requirements of this clause.		P
4.7.2	Voltage support by reactive power		P
4.7.2.1	General		P
	Generating plants shall not lead to voltage changes out of acceptable limits. These limits should be defined by national regulation. Generating units and plants shall be able to contribute to meet this requirement during normal network operation.		P
	Throughout the continuous operating frequency (see 4.4.2) and voltage (see 4.4.4) range, the generating plant shall be capable to deliver the requirements stipulated below. Outside these ranges, the generating plant shall follow the requirements as good as technically feasible although there is no stated accuracy required.		P
4.7.2.2	Capabilities	See below table	P
	Figure 12 gives a graphical representation of the minimum and optional capabilities at nominal voltage.		P
	Unless specified differently below, for specific generating technologies, generating plants shall be able to operate with active factors as defined by the DSO and the responsible party from active factor = 0,90underexcited to active factor= 0,90overexcited		P
	The reactive power capability shall be evaluated at the terminals of the/each generating unit		P
	CHP generating units with a capacity ≤ 150 kVA shall be able to operate with active factors as defined by the DSO from cos φ = 0,95underexcited to cos φ = 0,95overexcited		N/A
	Generating units with an induction generator coupled directly to the grid and used in generating plants above micro generating level, shall be able to operate with active factors as defined by the DSO from cos φ = 0,95underexcited to cos φ = 1 at the terminals of the unit. Deviating from 4.7.2.3 only the cos φ set point mode is required. Deviating from the accuracy		N/A

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	requirements below, the accuracy is only required at active power PD.		
	Generating units with an induction generator coupled directly to the grid and used in micro generating plants shall operate with an active factor above 0,95 at the terminals of the generating unit. A controlled voltage support by reactive power is not required from this technology.		N/A
	Generating units with linear generators, coupled directly and synchronously to the grid shall operate with an active factor above 0,95 at the terminals of the generating unit, and therefore a controlled voltage support by reactive power is not required from this technology.		N/A
	In case of different generating technologies with different requirements in one generating plant, each unit shall provide voltage support by reactive power as required for its specific technology. A compensation of one technology to reach the general plant requirement is not expected.		P
	The DSO and the responsible party may relax the above requirements. This relaxation might be general or specific for a certain generating plant or generating technology. NOTE 1 The generating unit manufacturer has a certain freedom in the sizing of the output side of the generating unit considering the advantages and drawbacks in the practical use of the generating unit when evaluating the need to reduce active output power (e.g. due to voltage changes or reactive power exchange) in order to respond to the requirements of this European Standard. This is indicated by the Design freedom area in Figure 12.		N/A
	All involved parties can expect to have access to information documenting the actual choices regarding active power capabilities relative to reactive power requirements and related to the power rating in the operating voltage range (see further in this clause). A P-Q Diagram shall be included in the product documentation of a generating unit. NOTE 2 For additional network support an optional extended reactive power capability according to Figure 12 might be provided by the generating plant, if agreed on between the DSO and the producer and is generally required in some countries for some technologies by legal regulations. NOTE 3 Additional requirements (e.g. continuous Var compensation or continuous reactive power operation disregarding the availability of the primary energy) might be provided by the generating plant, if agreed between the DSO and the producer. NOTE 4 In case of overvoltage, additional reactive power might be exchanged up to the rated current (increasing the		N/A

Clause	Requirement + Test	result – Remark	Verdict
	apparent power as a consequence), if agreed on between the DSO and the producer.		
	When operating above the apparent power threshold Smin equal to 10 % of the maximum apparent power Smax or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % Smax. Up to this apparent power threshold Smin, deviations above 2 % are permissible; nevertheless the accuracy shall always be as good as technically feasible and the exchange of uncontrolled reactive power in this low-power operation mode shall not exceed 10 % of the maximum apparent power Smax. At POC loads, if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.		P
	For generating units with a reactive power capability according Figure 12 the reactive power capability at active power PD shall be at least according Figure 13. For generating units with a reduced reactive power capability Figure 13 is only applicable up to the maximum reactive power capability. NOTE 5 Depending on the P-Q characteristic of the generating plant/unit, the reactive power at active powers below PD might be lower respecting the requirements above. If no or less than 0,484 Q/PD reactive power is required, the active power might increase above PD as indicated in Figure 12		P
	For voltages below U_n it is allowed to reduce apparent power according to 4.4.4		P
4.7.2.3	Control modes		P
4.7.2.3.1	General		P
	Where required, the form of the contribution to voltage control shall be specified by the DSO. The control shall refer to the terminals of the generating units		P
	The generating plant/unit shall be capable of operating in the control modes specified below within the limits specified in 4.7.2.2. The control modes are exclusive; only one mode may be active at a time.		P
	• Q setpoint mode		P
	• Q (U)		P
	• Cos φ setpoint mode		P
	• Cos φ (P)		P

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	For mass market products, it is recommended to implement all control modes. In case of site specific generating plant design, only the control modes required by the DSO need to be implemented.		P
	The configuration, activation and deactivation of the control modes shall be field adjustable. For field adjustable configurations and activation of the active control mode, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO. Which control modes are available in a product and how they are configured shall be stated in the product documentation.		P
4.7.2.3.2	Setpoint control modes	See below table	P
	Q setpoint mode and cos φ setpoint mode control the reactive power output and the cos φ of the output respectively, according to a set point set in the control of the generating plant/unit.		P
	In the case of change of the set point local or by remote control the settling time for the new set point shall be less than one minute.		P
4.7.2.3.3	Voltage related control modes	See below table	P
	The voltage related control mode Q (U) controls the reactive power output as a function of the voltage.	Q(U) control mode, voltage setting is 0.93Un ~ 0.97Un, 0.93Un for Qmax, 1.03Un ~ 1.07Un, 1.07Un for Qmin	P
	There is no preferred state of the art for evaluating the voltage. Therefore it is the responsibility of the generating plant designer to choose a method. One of the following methods should be used: • the positive sequence component of the fundamental; • the average of the voltages measured independently for each phase to neutral or phase to phase; • phase independently the voltage of every phase to determine the reactive power for every phase.		P
	For voltage related control modes, a characteristic with a minimum and maximum value and three connected lines according to Figure 16 shall be configurable.		P
	In addition to the characteristic, further parameters shall be configurable: • The dynamics of the control shall correspond with a first order filter having a time constant that is configurable in the range of 3 s to 60 s. NOTE 1 The time to perform 95 % of the changed set point due to a change in voltage will be 3 times the time constant.	The dynamics of control time set is 10 s	P

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	NOTE 2 The dynamic response of the generating units to voltage changes is not considered here. The response to disturbances as in 4.5 and short circuit current equirements as in 4.7.4 is not included in this clause. NOTE 3 An intentional delay is under consideration.		
	To limit the reactive power at low active power two methods shall be configurable: • a minimal cos φ shall be configurable in the range of 0-0,95; • two active power levels shall be configurable both at least in the range of 0 % to 100 % of PD. The lock-in value turns the Q(U) mode on, the lock-out value turns Q(U) off. If lock-in is larger than lock-out a hysteresis is given. See also Figure 14.	Lock-in value setting: 20%Pn. Lock-out value setting: 5%Pn	P
	The static accuracy shall be in accordance with 4.7.2.2. The dynamic accuracy shall be in accordance with Figure 15 with a maximum tolerance of +/- 5% of PD plus a time delay of up to 3 seconds deviating from an ideal first order filter response.		P
4.7.2.3.4	Power related Control mode:	See below table	P
	The power related control mode cos φ (P) controls the cos φ of the output as a function of the active power output.		P
	For power related control modes, a characteristic with a minimum and maximum value and three connected lines shall be configurable in accordance with Figure 16.		P
	Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached. The static accuracy of each cos φ set point shall be according to 4.7.2.2.		P
4.7.3	Voltage related active power reduction	See below table	P
	In order to avoid disconnection due to overvoltage protection (see 4.9.2.3 and 4.9.2.4), generating plants/units are allowed to reduce active power output as a function of this rising voltage. The final implemented logic can be chosen by the manufacturer. Nevertheless, this logic shall not cause steps or oscillations in the output power. The power reduction caused by such a function may not be faster than an equivalent of a time constant tau = 3 s (=	The overvoltage derating setting and response time setting: 1.10Un and 600 s	P

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	33%/s at a 100% change). The enabling and disabling of the function shall be field adjustable and means have to be provided to protect the setting from unpermitted interference (e.g. password or seal) if required by the DSO.		
4.7.4	Short circuit current requirements on generating plants		N/A
4.7.4.1	General		N/A
	The following clauses describe the required short circuit current contribution for generating plants taking into account the connection technology of the generating modules.		N/A
	Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.7.4.2 and 4.7.4.3. Generating modules classified as type A according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of type A modules shall be specified in the connection agreement. NOTE Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A if connected to medium voltage distribution grids. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of under voltage.		N/A
4.7.4.2	Generating plant with non-synchronous generating technology		N/A
4.7.4.2.1	Voltage support during faults and voltage steps		N/A
	In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN 50549-2 applies.		N/A
4.7.4.2.2	Zero current mode for converter connected generating technology		N/A
	If UVRT capability (see 4.5.3) is provided additional to the requirements of 4.5, generating units connected to the grid by a converter shall have the capability to reduce their current as fast as technically feasible down to or below 10 % of the rated current when the voltage is outside of a static voltage range. Generating units based on a doubly fed induction machine can only reduce the positive sequence current below 10 % of the rated current. Negative sequence current shall		N/A

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	be tolerated during unbalanced faults. In case this current reduction is not sufficient, the DSO should choose suitable interface protection settings.		
	The static voltage range shall be adjustable from 20 % to 100 % of Un for the undervoltage boundary and from 100 % to 130 % of Un for the overvoltage boundary. The default setting shall be 50% of Un for the undervoltage boundary and 120% of Un for the overvoltage boundary. Each phase to neutral voltage or if no neutral is present each phase to phase voltage shall be evaluated. At voltage re-entry into the voltage range, 90% of pre-fault power or available power, whichever is the smallest, shall be resumed as fast as possible, but at the latest according to 4.5.3 and 4.5.4.		N/A
	All described settings are defined by the DSO and the responsible party. If no settings are provided, the function shall be disabled.		N/A
	The enabling and disabling and the settings shall be field adjustable and means have to be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO.		N/A
4.7.4.2.3	Induction generator based units		N/A
	In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.		N/A
4.7.4.3	Generating plant with synchronous generating technology - Synchronous generator based units		N/A
	In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.		N/A
4.8	EMC and power quality	Refer to EMC report, report No.: SYBH(E)10301990EA	P
	Similar to any other apparatus or fixed installation, generating units shall comply with the requirements on electromagnetic compatibility established in Directive 2014/30/EU or 2014/53/EU, whichever applies.		P

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Clause	Requirement + Test	result – Remark	Verdict
	EMC limits and tests, described in EN 61000 series, have been traditionally developed for loads, without taking into account the particularities of generating units, such as their capability to create over-voltages or high frequency disturbances due to the presence of power converters, which were either impossible or less frequent in case of loads.		P
	• Harmonic emissions;		P
	• Flicker and voltage fluctuations;		P
	• DC injection;		P
	• Short and long duration overvoltages emission;		N/A
	• Switching frequency emission;		N/A
	• Immunity to voltage dips and short interruptions;		N/A
	• Immunity to frequency variation;	See clause 4.5.2	P
	• Immunity to harmonics and inter-harmonics;		P
	• Unbalance.		P
	As long as specific tests for generating units are not available for immunity and/or emission, generic EMC standards and/or any relevant EU harmonized EMC standard, should be applied. NOTE 2 Besides the compliance with EN61000 Series, in most countries power quality characteristic according to standards such as for example EN 61400–21 or VDE V 0124–100 are required as part of the connection agreement	Harmonic, Flicker, DC injection, Frequency variation, Three-phase unbalance were tested	P
	Additional phenomena need to be addressed specifically to generating plants and their integration in the power system.		P
	• ROCOF: See 4.5.2		P
	• UVRT: See 4.5.3	Not suitable for Type A unit	N/A
	• OVRT: See 4.5.4	Not suitable for Type A unit	N/A
	• DC injection: Generating plants shall not inject direct currents. NOTE 3 The DC injection clause is considered to be passed when for all generating units within the generating plant the measured DC injection of a type-tested unit is below the testing threshold.		P
	Generating plants can also disturb mains signalling (ripple control or power line carrier systems). EMC requirements on inter-harmonics and on conducted disturbances in the frequency range between 2 kHz and 150 kHz are under development. In case of electromagnetic interferences to mains signalling systems due to the connection of a generating plant, mitigation measures should be taken and national requirements may apply.		N/A

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Clause	Requirement + Test	result – Remark	Verdict
	Generating units are also expected to be compatible with voltage characteristics at the point of connection, as described in EN 50160 or in national regulations; however no compliance test is required due to the scope of EN 50160.		N/A
4.9	**Interface protection**		P
4.9.1	General		P
	According to HD 60364-5-551:2010, 551.7.4, means of automatic switching shall be provided to disconnect the generating plant from the distribution network in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values declared for normal supply.		P
	This automatic means of disconnection has following main objectives: • prevent the power production of the generating plant to cause an overvoltage situation in the distribution network it is connected to. Such overvoltages could result in damages to the equipment connected to the distribution network as well as the distribution network itself; • detect unintentional island situations and disconnect the generating plant in this case. This is contributing to prevent damage to other equipment, both in the producers' installations and the distribution network due to out of phase re-closing and to allow for maintenance work after an intentional disconnection of a section of the distribution network; NOTE 1 It is pointed out that checking the absence of voltage on all the live conductors is anyway mandatory before accessing a site for (maintenance) work. • assist in bringing the distribution network to a controlled state in case of voltage or frequency deviations beyond corresponding regulation values.		P
	It is not the purpose of the interface protection system to: • disconnect the generating plant from the distribution network in case of faults internal to the power generating plant. Protection against internal faults (short-circuits) shall be coordinated with network protection, according to DSO protection criteria. Protection against e.g. overload, electric shock and against fire hazards shall be implemented additionally according to HD 60364-1 and local requirements;		P

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Clause	Requirement + Test	result – Remark	Verdict
	• prevent damages to the generating unit due to incidents (e.g. short circuits) on the distribution network		
	Interface protections may contribute to preventing damage to the generating units due to out-of-phase reclosing of automatic reclosing which may happen after some hundreds of ms. However, in some countries some technologies of generating units are explicitly required to have an appropriate immunity level against the consequences of out-of-phase reclosing.		P
	The type of protection and the sensitivity and operating times depend upon the protection and the characteristics of the distribution network.		P
	A wide variety of approaches to achieve the above mentioned objectives is used throughout Europe. Besides the passive observation of voltage and frequency other active and passive methods are available and used to detect island situations. The requirements given in this clause are intended to provide the necessary functions for all known approaches as well as to give guidance in their use. Which functions are available in a product shall be stated in the product documentation.		P
	The interface protection system shall comply with the requirements of this European Standard, the available functions and configured settings shall comply with the requirements of the DSO and the responsible party. In any case, the settings defined shall be understood as the values for the interface protection system, i.e. where there is a wider technical capability of the generation module, it shall not be withheld by the settings of the protections (other than the interface protection).		P
	For micro generating plants, the interface protection system and the point of measurement might be integrated into the generating units. For generating plants with nominal current above 16 A the DSO may define a threshold above which the interface protection system shall be realized as a dedicated device and not integrated into the generating units. NOTE 2 Example thresholds are 11,08 kW per generating plant (Italy), 30 kVA per generating plant (Germany, Austria) and 50 kW per generating unit (GB) NOTE 3 Integrated interface protection systems might not be possible for two different reasons: • to place the protection system as close to the point of connection as possible, to avoid tripping due to		P

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Clause	Requirement + Test	result – Remark	Verdict
	overvoltages resulting from the voltage rise within the producer's network; • to allow for periodic field tests. In some countries periodic field tests are not required if the protection system meets the requirements of single fault safety.		
	The interface protection relay acts on the interface switch. The DSO may require that the interface protection relay acts additionally on another switch with a proper delay in case the interface switch fails to operate.		P
	In case of failure of the power supply of the interface protection, the interface protection shall trigger the interface switch without delay. An uninterruptible power supply may be required by the DSO, for instance in case of UVRT capability, delay in protection etc.		P
	In case of field adjustable settings of threshold and operation time, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.9.2	Void		N/A
4.9.3	Requirements on voltage and frequency protection		P
4.9.3.1	General		P
	Part or all of the following described functions may be required by the DSO and the responsible party. NOTE 1 In the following the headings of the clause sections contain ANSI device numbers according to IEEE/ANSI C37.2 in square brackets e.g. [27].		P
	The protection functions shall evaluate at least all phases where generating units, covered by this protection system, are connected to.	Three phases are evaluated the protection functions	P
	In case of three phase generating units/plants and in all cases when the protection system is implemented as an external protection system in a three phase power supply system, all phase to phase voltages and, if a neutral conductor is present, all phase to neutral voltages shall be evaluated. NOTE 2 It is possible to calculate the phase to phase voltages based on phase-neutral measurements.		P
	The frequency shall be evaluated on at least one of the voltages.		P
	If multiple signals (e.g. 3 phase to phase voltages) are to be evaluated by one protection function, this function shall evaluate all of the signals separately. The output of each evaluation shall be OR connected, so that if one signal passes the threshold of a function,	3 phase to neutral voltages were evaluated separately	P

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Clause	Requirement + Test	result – Remark	Verdict
	the function shall trip the protection in the specified time.		
	The minimum required accuracy for protection is: • for frequency measurement ± 0,05 Hz; • for voltage measurement ± 1 % of Un. • The reset time shall be ≤50ms • The interface protection relay shall not conduct continuous starting and disengaging operations of the interface protection relay. Therefore a reasonable reset ratio shall be implemented which shall not be zero but be below 2% of nominal value for voltage and below 0,2Hz for frequency. NOTE 3 If the interface protection system is external to the generating unit, it is preferably located as close as possible to the point of connection. The voltage rise between the point of connection and the measurement input of the interface protection system is then kept as small as possible to avoid nuisance tripping of the overvoltage protection.		P
4.9.3.2	Undervoltage protection [27]	See below table	P
	The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed. Undervoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P
	Undervoltage threshold stage 1 [27 <]: • Threshold (0,2 – 1) Un adjustable by steps of 0,01 Un • Operate time (0,1 – 100) s adjustable in steps of 0,1 s	0.85 Un is set and tested respectively setting time: 0.1 s	P
	Undervoltage threshold stage 2 [27 < <]: • Threshold (0,2 – 1) Un adjustable by steps of 0,01 Un • Operate time (0,1 – 5) s adjustable in steps of 0,05 s	0.80 Un is set and tested respectively setting time: 0.1 s	P
	The undervoltage threshold stage 2 is not applicable for micro-generating plants		P
4.9.3.3	Overvoltage protection [59]	See below table	P
	The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed. Overvoltage protection may be implemented with two completely independent protection thresholds, each		P

Clause	Requirement + Test	result – Remark	Verdict
	one able to be activated or not. The standard adjustment ranges are as follows.		
	Overvoltage threshold stage 1 [59 >]: • Threshold (1,0 – 1,2) Un adjustable by steps of 0,01 Un • Operate time (0,1 – 100) s adjustable in steps of 0,1 s	1.15 Un is set and tested respectively setting time: 0.1 s	P
	Overvoltage threshold stage 2 [59 > >]: • Threshold (1,0 – 1,30) Un adjustable by steps of 0,01 Un • Operate time (0,1 – 5) s adjustable in steps of 0,05 s	1.20 Un is set and tested respectively setting time: 0.1 s	P
4.9.3.4	Overvoltage 10 min mean protection	See below table	P
	The calculation of the 10 min value shall comply with the 10 min aggregation of EN 61000-4-30 Class S, but deviating from EN 61000-4-30 as a moving window is used. Therefore the function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. The calculation of a new 10 min value at least every 3 s is sufficient, which is then to be compared with the threshold value.		P
	• Threshold (1,0 – 1,15) Un adjustable by steps of 0,01 Un • Start time ≤ 3s not adjustable • Time delay setting = 0 ms NOTE 1 This function evaluates the r.m.s value. NOTE 2 More information can be found in EN 50160.	1.10 Un is set and tested respectively	P
4.9.3.5	Underfrequency protection [81<]	See below table	P
	Underfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P
	Underfrequency threshold stage 1 [81 <]: • Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 – 100) s adjustable in steps of 0,1 s	47.5 Hz is set and tested respectively setting time: 0.1 s	P
	Underfrequency threshold stage 2 [81 < <]: • Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 – 5) s adjustable in steps of 0,05 s	47.0 Hz is set and tested respectively setting time: 0.1 s	P
	In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to		P

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Clause	Requirement + Test	result – Remark	Verdict
	have the ability to activate and deactivate a stage by an external signal.		
	The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.		P
	Under 0,2 U_n the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.		P
4.9.3.6	Overfrequency protection [81>]	See below table	P
	Overfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P
	Overfrequency threshold stage 1 [81 >]: • Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 – 100) s adjustable in steps of 0,1 s	51.5 Hz is set and tested respectively setting time: 0.1 s	P
	Overfrequency threshold stage 2 [81 > >]: • Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 - 5) s adjustable in steps of 0,05 s	52.0 Hz is set and tested respectively setting time: 0.1 s	P
	In order to use narrow frequency thresholds for islanding detection (see4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.		N/A
	The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.		P
4.9.4	Means to detect island situation		P
4.9.4.1	General		P
	Besides the passive observation of voltage and frequency further means to detect an island may be required by the DSO. Detecting islanding situations shall not be contradictory to the immunity requirements of 4.5.	See below table	P
	Commonly used functions include: • Active methods tested with a resonant circuit; • ROCOF tripping; • Switch to narrow frequency band;		P

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Clause	Requirement + Test	result – Remark	Verdict
	• Vector shift • Transfer trip.		
	Only some of the methods above rely on standards. Namely for ROCOF tripping and for the detection of a vector shift, also called a vector jump, currently no European Standard is available.		P
4.9.4.2	Active methods tested with a resonant circuit		P
	These are methods which pass the resonant circuit test for PV inverters according to EN 62116.		P
4.9.4.3	Switch to narrow frequency band (see Annex E and Annex F)		N/A
	In case of local phenomena (e.g. a fault or the opening of circuit breaker along the line) the DSO in coordination with the responsible party may require a switch to a narrow frequency band to increase the interface protection relay sensitivity. In the event of a local fault it is possible to enable activation of the restrictive frequency window (using the two underfrequency/overfrequency thresholds described in 4.9.2.5 and 4.9.2.6) correlating its activation with another additional protection function.		N/A
	If required by the DSO, a digital input according to 4.9.4 shall be available to allow the DSO the activation of a restrictive frequency window by communication. NOTE An additional gateway to ensure communication with the DSO communication system might be required.		N/A
4.9.5	Digital input to the interface protection		N/A
	If required by the DSO, the interface protection shall have at least two configurable digital inputs. These inputs can for example be used to allow transfer trip or the switching to the narrow frequency band.		N/A
4.10	**Connection and starting to generate electrical power**		P
4.10.1	General		P
	Connection and starting to generate electrical power is only allowed after voltage and frequency are within the allowed voltage and frequency ranges for at least the specified observation time. It shall not be possible to overrule these conditions.		P
	Within these voltage and frequency ranges, the generating plant shall be capable of connecting and starting to generate electrical power.		P
	The setting of the conditions depends on whether the connection is due to a normal operational start-up or an automatic reconnection after tripping of the		P

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Clause	Requirement + Test	result – Remark	Verdict
	interface protection. In case the settings for automatic reconnection after tripping and starting to generate power are not distinct in a generating plant, the tighter range and the start-up gradient shall be used.		
	The setting of the conditions depends on whether the connection is due to a normal operational start-up or an automatic reconnection after tripping of the interface protection. In case the settings for automatic reconnection after tripping and starting to generate power are not distinct in a generating plant, the tighter range and the start-up gradient shall be used.		P
	For field adjustable settings, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.10.2	Automatic reconnection after tripping	See below table	P
	The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 3 column 2. If no settings are specified by the DSO and the responsible party, the default settings for the reconnection after tripping of the interface protection are according to Table 3 column 3.	The reconnect time is set to 60 s.	P
	After reconnection, the active power generated by the generating plant shall not exceed a specified gradient expressed as a percentage of the active nominal power of the unit per minute. If no gradient is specified by the DSO and the responsible party, the default setting is 10 % Pn/min. Generating modules for which it is technically not feasible to increase the power respecting the specified gradient over the full power range may connect after 1 min to 10 min (randomized value, uniformly distributed) or later.		P
4.10.3	Starting to generate electrical power	See below table	P
	The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 4 column 2. If no settings are specified by the DSO and the responsible party, the default settings for connection or starting to generate electrical power due to normal operational start-up or activity are according to Table 4 column 3.		P
	If applicable, the power gradient shall not exceed the maximum gradient specified by the DSO and the responsible party. Heat driven CHP generating units do not need to keep a maximum gradient, since the start up is randomized by the nature of the heat demand.	10% of rated power per minute	P

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Clause	Requirement + Test	result – Remark	Verdict
	For manual operations performed on site (e.g. for the purpose of initial start-up or maintenance) it is permitted to deviate from the observation time and ramp rate.		N/A
4.10.4	Synchronization		P
	Synchronizing a generating plant/unit with the distribution network shall be fully automatic i.e. it shall not be possible to manually close the switch between the two systems to carry out synchronization.		P
4.11	**Active power reduction on set point**		P
4.11.1	Ceasing active power		P
	Generating plants with a maximum capacity of 0,8 kW or more shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port. If required by the DSO and the responsible party, this includes remote operation.		P
4.11.2	Reduction of active power on set point	See below table	P
	For generating modules of type B, a generating plant shall be capable of reducing its active power to a limit value provided remotely by the DSO. The limit value shall be adjustable in the complete operating range from the maximum active power to minimum regulating level.		P
	The adjustment of the limit value shall be possible with a maximum increment of 10% of nominal power.		P
	A generation unit/plant shall be capable of carrying out the power output reduction to the respective limit within an envelope of not faster than 0,66 % Pn/ s and not slower than 0,33 % Pn/ s with an accuracy of 5 % of nominal power. Generating plants are permitted to disconnect from the network at a limit value below it minimum regulating level. If required by the DSO, this includes remote operation. NOTE Besides the requirements of this clause there might be other systems in place to control active power for reasons of market participation or local optimisation.		P
4.12	Remote information exchange		N/A
	Generating plants whose power is above a threshold to be determined by the DSO and the responsible party shall have the capacity to be monitored by the DSO or TSO control centre or control centres as well as receive operation parameter settings for the functions specified in this European Standard from the DSO or TSO control centre or control centres.		N/A

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Clause	Requirement + Test	result – Remark	Verdict
	This information exchange is aimed at allowing the DSO and/or the TSO to improve, optimize and make safer the operation of their respective networks.		N/A
	The remote monitoring and operation parameter settings system that may be used by the DSO is not aimed at replacing the manual and automatic control means implemented by the generating plant operator to control the operation of the generating plant. It should not interact directly with the power generation equipment and the switching devices of the generating plant. It should interact with the operation and control system of the generating plant.		N/A
	In principle, standardized communication should be used. It is recommended that in case of using protocols for signal transmission used between the DSO or TSO control centre or control centres and the generating plant, relevant technical standards (e.g. EN 60870-5-101, EN 60870-5-104, EN 61850 and in particular EN 61850-7-4, EN 61850-7-420, IEC/TR 61850-90-7, as well as EN 61400-25 for wind turbines and relevant parts of IEC 62351 for relevant security measures) are recognized.		N/A
	Alternative protocols can be agreed between the DSO and the producer. These protocols include hardwired digital input/output and analogue input/output provided locally by DSO. The information needed for remote monitoring and the setting of configurable parameters are specific to each distribution network and to the way it is operated.		N/A
	Signal transmission times between the DSO and/or the TSO control centre and the generating plant will depend on the means of transmission used between the DSO and/or TSO control centre and the generating plant.		N/A
	Informative Annex B of EN50549-2 can be used as guidance regarding the monitoring information and the remote operation parameter setting.		N/A
4.13	**Requirements regarding single fault tolerance of interface protection system and interface switch**		P
	If required in 4.3.2, the interface protection system and the interface switch shall meet the requirements of single fault tolerance.		P
	A single fault shall not lead to a loss of the safety functions. Faults of common cause shall be taken into account if the probability for the occurrence of such a fault is significant. Whenever reasonably practical, the	Refer to safety report: CN221HFC 002	P

Clause	Requirement + Test	result – Remark	Verdict
	individual fault shall be displayed and lead to the disconnection of the power generating unit or system. NOTE This requirement for the detection of individual faults does not mean that all faults are detected. Accumulation of undetected faults can therefore lead to an unintentional output signal and result in a hazardous condition.		
	Series-connected switches shall each have a independent breaking capacity corresponding to the rated current of the generating unit and corresponding to the short circuit contribution of the generating unit.		P
	The short-time withstand current of the switching devices shall be coordinated with maximum short circuit power at the connection point.		P
	At least one of the switches shall be a switch-disconnector suitable for overvoltage category 2. For single-phase generating units, the switch shall have one contact of this overvoltage category for both the neutral conductor and the line conductor. For poly-phase generating units, it is required to have one contact of this overvoltage category for all active conductors. The second switch may be formed of electronic switching components from an inverter bridge or another circuit provided that the electronic switching components can be switched off by control signals and that it is ensured that a failure is detected and leads to prevention of the operation at the latest at the next reconnection.		P
	For PV-inverters without simple separation between the network and the PV generating unit (e.g. PV-Inverter without transformer) both switches mentioned in the paragraph above shall be switch-disconnectors with the requirements described therein, although one switching device is permitted to be located between PV array and PV inverter.		P

4.4.2 & 4.4.4	Operating frequency range & Continuous operating voltage range		P
Setting (Minimum requirement)		Can operate according to minimum requirement?	
Test #1	47.5 Hz at least operate 30 min	Yes	
Test #2	51.5 Hz at least operate 30 min	Yes	
Setting (Most stringent requirement)		Can operate according to minimum requirement?	
Test #1	47.0 Hz at least operate 20 s	Yes	
Test #2	47.5 Hz at least operate 90 min	Yes	
Test #3	51.5 Hz at least operate 90 min	Yes	
Test #4	52.0 Hz at least operate 15 min	Yes	

Setting Voltage	85% Un*	110% Un
U_{L1-L2} (Va.c.)	339.77	431.26
U_{L2-L3} (Va.c.)	342.20	434.36
U_{L3-L1} (Va.c.)	340.95	432.77
U_{L1-N} (Va.c.)	196.17	248.99
U_{L2-N} (Va.c.)	197.57	250.78
U_{L3-N} (Va.c.)	196.85	249.86
I_{L1} (Aa.c.)	41.92	33.84
I_{L2} (Aa.c.)	42.00	33.96
I_{L3} (Aa.c.)	41.96	33.90
P (W)	24815.10	25362.63
Q (Var)	800.20	536.78
S (VA)	24828.33	25368.42

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4.4.3	Minimal requirement for active power delivery at underfrequencies			P
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{minimum}$ (W)	Deviation of P_{shall} (W) less than $P_{measure}$? (Yes/No)
1	50.00	25048.61	25000	Yes
2	49.50	25047.37	25000	Yes
3	49.00	25047.18	25000	Yes
4	48.50	25046.95	24750	Yes
5	48.00	25047.09	24500	Yes
6	47.50	25046.64	24250	Yes
Supplementary information: N/A				

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4.5.2	**Rate of change of frequency (ROCOF) immunity**		**P**
RoCoF operation test, +/-2.0Hz/s for smooth time window of 0.5s			
	Setting	Disconnection during RoCoF	
Test #1	47.0Hz to 49.0Hz, enhance 2Hz/s, 100% Un, cosφ=1	No disconnection	
Test #2	49.0Hz to 51.0Hz, enhance 2Hz/s, 100% Un, cosφ=1	No disconnection	
Test #3	52.0Hz to 50.0Hz, enhance 2Hz/s, 100% Un, cosφ=1	No disconnection	
Test #4	50.0Hz to 48.0Hz, enhance 2Hz/s, 100% Un, cosφ=1	No disconnection	
Test #5	47.0Hz to 49.0Hz, enhance 2Hz/s, 85% Un, cosφ=1	No disconnection	
Test #6	49.0Hz to 51.0Hz, enhance 2Hz/s, 85% Un, cosφ=1	No disconnection	
Test #7	52.0Hz to 50.0Hz, enhance 2Hz/s, 85% Un, cosφ=1	No disconnection	
Test #8	50.0Hz to 48.0Hz, enhance 2Hz/s, 85% Un, cosφ=1	No disconnection	
Test #9	47.0Hz to 49.0Hz, enhance 2Hz/s, 110% Un, cosφ=1	No disconnection	
Test #10	49.0Hz to 51.0Hz, enhance 2Hz/s, 110% Un, cosφ=1	No disconnection	
Test #11	52.0Hz to 50.0Hz, enhance 2Hz/s, 110% Un, cosφ=1	No disconnection	
Test #12	50.0Hz to 48.0Hz, enhance 2Hz/s, 110% Un, cosφ=1	No disconnection	
Supplementary information: N/A			

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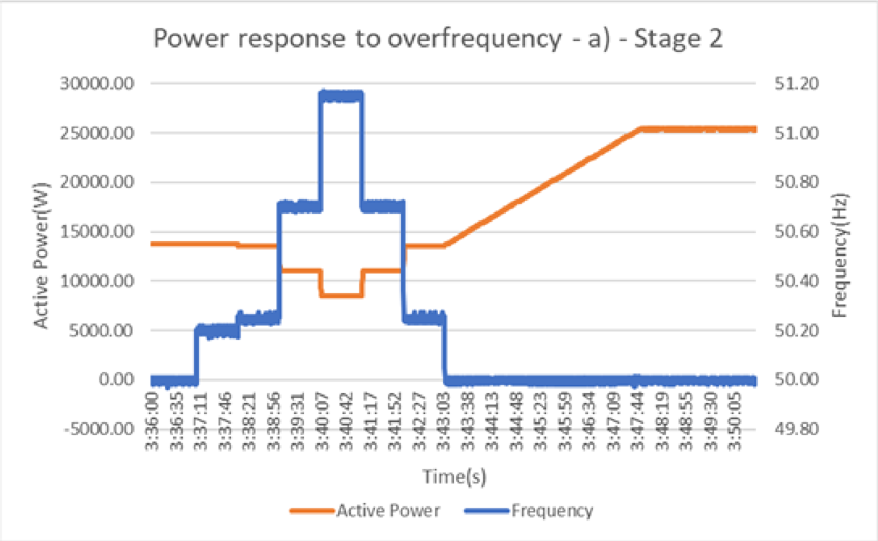
4.6.1	Power response to overfrequency				P
a) For Type 2 generation unit (PV or PV+ESS), over-frequency regulation, with active power reduction frequency start point=50.2Hz, gradient s=5%					
Stage 1: TYPE 2 inverter DC input power is set to 100% of rated active output power till the end of the test. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n. P_M = 25452.90W, 10% P_n= 2500W, intentional delay time: 0.2 s (should ≤2s)					
Model	SUN2000-25KTL-M5				
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	25467.26	--	--	--
2.	50.20	25452.90	--	--	--
3.	50.25	24966.81	24943.84	22.97	Yes
4.	50.70	20475.34	20362.32	113.02	Yes
5.	51.15	15882.06	15780.80	101.26	Yes
6.	50.70	20121.14	20362.32	241.18	Yes
7.	50.25	24771.08	24943.84	172.76	Yes
8.	50.00	25465.97	--	--	--
Stage 2: TYPE 2 inverter DC input power is set to 50% of rated active output power first. After the TYPE 2 inverter step into frequency range above 50.2Hz, the TYPE 2 inverter available input power is set to 100% of maximum active output. The output active power should not be changed. When the TYPE 2 inverter step back below the frequency 50.2Hz, the output active power should arise with a gradient of 10 % Pn/min. P_M = 13781.20W, 10% P_n= 2500W, intentional delay time: 0.2 s (should ≤2s)					
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	13781.21	--	--	--
2.	50.20	13781.20	--	--	--
3.	50.25	13513.50	13505.58	7.92	Yes
4.	50.70	11031.44	11024.96	6.48	Yes
5.	51.15	8553.14	8544.34	8.80	Yes
6.	50.70	11032.56	11024.96	7.60	Yes
7.	50.25	13510.79	13505.58	5.21	Yes
8.	50.00	See below table	--	--	--
Test sequence	Freq (Hz)	Time after step back from 50.2Hz t (min)	Measured active output power $P_{measure}$ (W)	ΔP Arise during next 1 min	Gradient of arising powerΔP/t under 10% P_{Emax}

					(Yes/No)
9.	50.00	0.0 min	13776.61	2483.76	Yes
10.	50.00	0.5 min	14900.43	2459.83	Yes
11.	50.00	1.0 min	16260.37	2439.75	Yes
12.	50.00	1.5 min	17360.26	2492.70	Yes
13.	50.00	2.0 min	18700.12	2476.20	Yes
14.	50.00	2.5 min	19852.96	2492.52	Yes
15.	50.00	3.0 min	21176.32	2473.33	Yes
16.	50.00	3.5 min	22345.48	2498.29	Yes
17.	50.00	4.0 min	23649.65	1350.35	Yes
18.	50.00	4.5 min	24843.77	--	Yes
19.	50.00	5.0 min	25000.00	--	Yes



b) For Type 2 generation unit (PV or PV+ESS), over-frequency regulation, with active power reduction frequency start point=50.2Hz, gradient s=12%

Stage 1: TYPE 2 inverter DC input power is set to 100% of rated active output power till the end of the test. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n.

P_M = 25489.04W, 10% P_n= 2500W, intentional delay time: 0.2 s (should ≤2s)

Model	SUN2000-25KTL-M5				
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	25500.00	--	--	--
2.	50.20	25489.04	--	--	--

3.	50.25	25207.97	25276.63	68.66	Yes
4.	50.70	23337.21	23364.95	27.74	Yes
5.	51.15	21441.86	21453.28	11.42	Yes
6.	50.70	23264.45	23364.95	100.5	Yes
7.	50.25	25151.83	25276.63	124.8	Yes
8.	50.00	25499.67	--	--	--
Stage 2: TYPE 2 inverter DC input power is set to 50% of rated active output power first. After the TYPE 2 inverter step into frequency range above 50.2Hz, the TYPE 2 inverter available input power is set to 100% of maximum active output. The output active power should not be changed. When the TYPE 2 inverter step back below the frequency 50.2Hz, the output active power should arise with a gradient of 10 % Pn/min. P_M = 13800.00W, 10% P_n= 2500W, intentional delay time: 0.2 s (should ≤2s)					
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	13800.00	--	--	--
2.	50.20	13800.00	--	--	--
3.	50.25	13700.00	13685.00	15.00	Yes
4.	50.70	12600.00	12650.00	50.00	Yes
5.	51.15	11600.00	11615.00	15.00	Yes
6.	50.70	12600.00	12650.00	50.00	Yes
7.	50.25	13700.00	13685.00	15.00	Yes
8.	50.00	See below table	--	--	--
Test sequence	Freq (Hz)	Time after step back from 50.2Hz t (min)	Measured active output power $P_{measure}$ (W)	ΔP Arise during next 1 min	Gradient of arising powerΔP/t under 10% P_{Emax} (Yes/No)
9.	50.00	0.0 min	13800.00	2441.87	Yes
10.	50.00	0.5 min	14999.94	2483.85	Yes
11.	50.00	1.0 min	16241.87	2483.85	Yes
12.	50.00	1.5 min	17483.79	2483.86	Yes
13.	50.00	2.0 min	18725.72	2483.85	Yes
14.	50.00	2.5 min	19967.65	2483.85	Yes
15.	50.00	3.0 min	21209.57	2483.85	Yes
16.	50.00	3.5 min	22451.50	2483.85	Yes
17.	50.00	4.0 min	23693.42	1306.58	Yes
18.	50.00	4.5 min	24935.35	--	Yes

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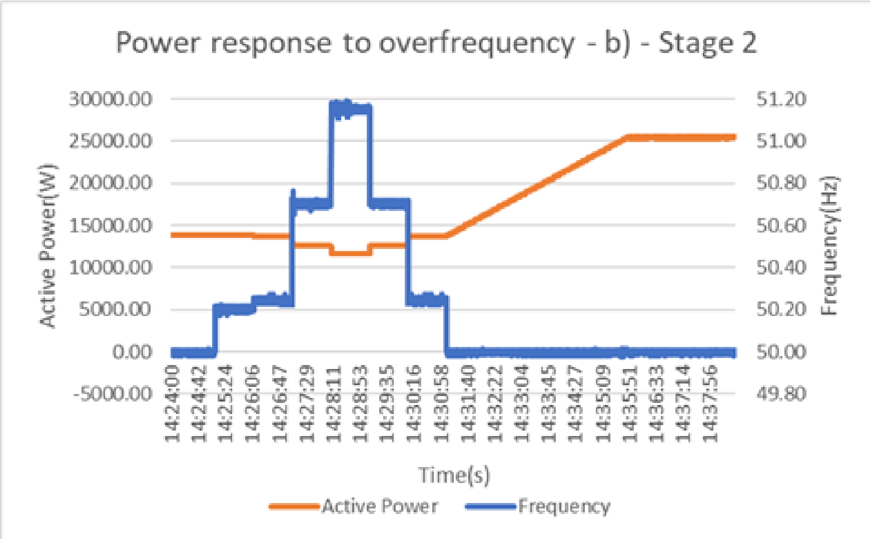
19.	50.00	5.0 min	25000.00	--	Yes



c) For Type 2 generation unit (PV or PV+ESS), over-frequency regulation, with active power reduction frequency start point=50.2Hz, gradient s=2%

Stage 1: TYPE 2 inverter DC input power is set to 100% of rated active output power till the end of the test. The active power value shall not be deviated from the required value calculated from the feature curve 10% P_n.

P_M = 25400.05W, 10% P_n= 2500W, intentional delay time: 0.2 s (should ≤2s)

Model	SUN2000-25KTL-M5

Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max-limit}$ (W)	Deviation of $P_{measure}$ and $P_{max-limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	25496.52	--	--	--
2.	50.20	25400.05	--	--	--
3.	50.25	24102.99	24130.05	27.06	Yes
4.	50.70	12700.00	12700.03	0.02	Yes
5.	51.15	1288.81	1270.00	18.81	Yes
6.	50.70	12700.00	12700.03	0.02	Yes
7.	50.25	24101.99	24130.05	28.06	Yes
8.	50.00	25479.10	--	--	--

Stage 2: TYPE 2 inverter DC input power is set to 50% of rated active output power first. After the TYPE 2 inverter step into frequency range above 50.2Hz, the TYPE 2 inverter available input power is set to 100% of maximum active output. The output active power should not be changed. When the TYPE 2 inverter step back below the frequency 50.2Hz, the output active power should arise with a gradient of 10 % Pn/min.

P_M = 13800.83W, 10% P_n= 2500W, intentional delay time: 0.2 s (should ≤2s)

Test	Freq (Hz)	Measured active output power	The calculated active output power as per	Deviation of $P_{measure}$ and	Deviation within

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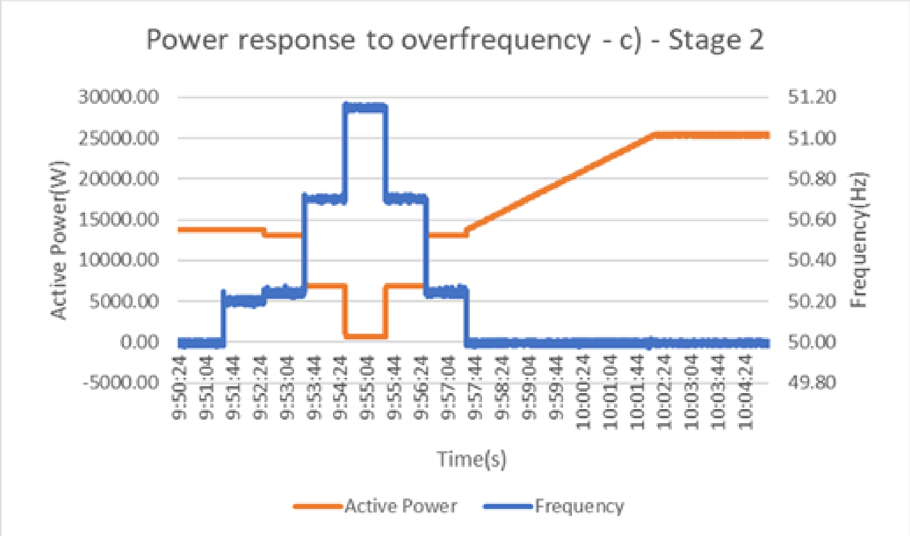
sequence		$P_{measure}$ (W)	feature curve $P_{max-limit}$ (W)	$P_{max-limit}$ (W)	10% P_n (Yes/No)
1.	50.00	13800.34	--	--	--
2.	50.20	13800.83	--	--	--
3.	50.25	13165.64	13110.79	54.85	Yes
4.	50.70	6880.25	6900.42	20.17	Yes
5.	51.15	703.97	690.04	13.93	Yes
6.	50.70	6880.43	6900.42	19.98	Yes
7.	50.25	13100.02	13110.79	10.77	Yes
8.	50.00	See below talbe	--	--	--
Test sequence	Freq (Hz)	Time after step back from 50.2Hz t (min)	Measured active output power $P_{measure}$ (W)	ΔP Arise during next 1 min	Gradient of arising powerΔP/t under 10% P_{Emax} (Yes/No)
9.	50.00	0.0 min	13843.65	2454.86	Yes
10.	50.00	0.5 min	15021.23	2471.64	Yes
11.	50.00	1.0 min	16298.51	2486.86	Yes
12.	50.00	1.5 min	17492.87	2490.38	Yes
13.	50.00	2.0 min	18785.37	2486.78	Yes
14.	50.00	2.5 min	19983.25	2476.44	Yes
15.	50.00	3.0 min	21272.15	2462.98	Yes
16.	50.00	3.5 min	22459.69	2490.15	Yes
17.	50.00	4.0 min	23735.13	1264.87	Yes
18.	50.00	4.5 min	24949.84	--	Yes
19.	50.00	5.0 min	25000.00	--	Yes



d) For Type 2 generation unit (ESS in charging mode), over-frequency regulation

Stage 1: TYPE 2 inverter EES units in charging mode is set to 100% of maximum charging power till the end of the test. The frequency passes the threshold f_1 shall not reduce the charging power below PM until frequency returns below f_1

$P_{max\text{-}charge}$ = -15000 , intentional delay time: 0.2 s (should ≤2s)

Model	SUN2000-25K-MB0				
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% $P_{max\text{-}charge}$ (Yes/No)
1.	50.00	-14670.12	-15000.00	329.88	Yes
2.	50.20	-14669.20	-15000.00	330.80	Yes
3.	50.25	-14663.23	-15000.00	336.77	Yes
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% $P_{max\text{-}charge}$ (Yes/No)
4.	50.00	-14661.74	-15000.00	338.26	Yes
5.	50.20	-14660.40	-15000.00	339.60	Yes
6.	50.25	-14648.36	-15000.00	351.64	Yes
7.	50.70	-14640.80	-15000.00	359.20	Yes
8.	51.15	-14640.08	-15000.00	359.92	Yes
9.	50.70	-14634.31	-15000.00	365.69	Yes
10.	50.25	-14633.13	-15000.00	366.87	Yes
11.	50.00	-14659.12	-15000.00	340.88	Yes

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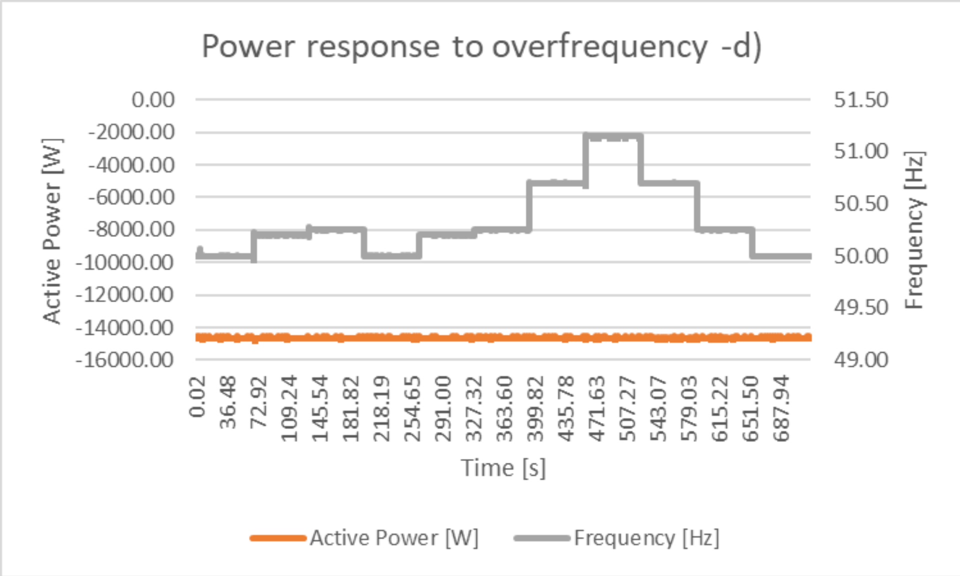

Active power reaction time Test with active power reduction frequency start point 50.20Hz, gradient s=5%, P=100%Pmax				
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	Instrinsic dead time (≤ 2s)	Response time (≤ 30s)
1.	50.00	24971.39	-	-
2.	50.20	24982.28	-	-
3.	50.70	20020.21	0.06s	1.54s

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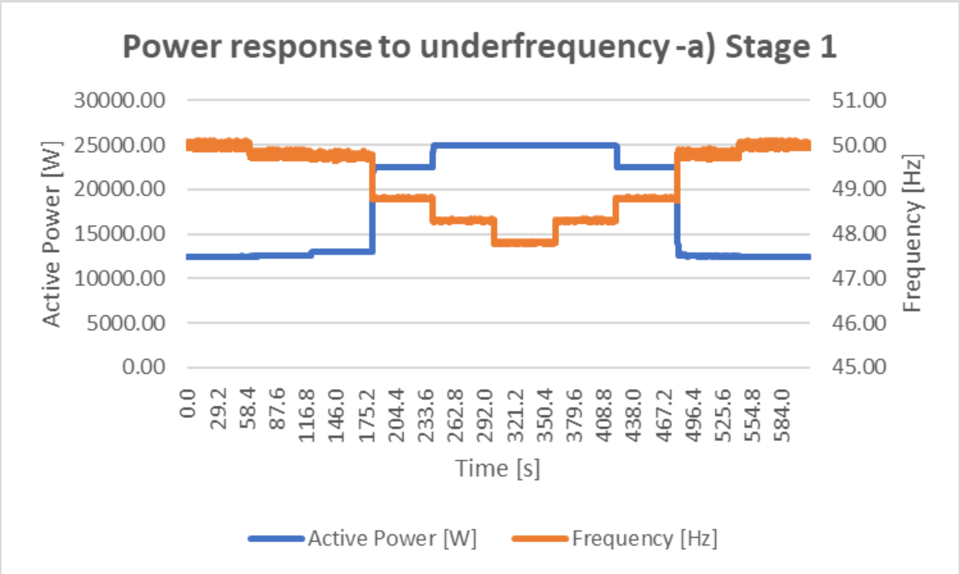
4.6.2	**Power response to underfrequency**				P
Model	SUN2000-25K-MB0				
a) under-frequency regulation, with active power reduction frequency start point=49.8Hz, gradient s=5%					
Stage 1: TYPE 2 inverter DC input power is set to 50% of maximum active output power first. After the TYPE 2 inverter step into frequency range under 49.8Hz, the TYPE 2 inverter available input power is set to 100% of maximum active output. The output active power should regulate the active power with gradient of 40% P_{max}/Hz till technical maximum power. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n. P_{Max} = 25000 W , 10% P_n= 2500 W , intentional delay time: 0.08 s (should ≤2s)					
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	12480	12500	-20	Yes
2.	49.80	12521	12500	21	Yes
3.	49.75	13005	13021	-16	Yes
4.	48.80	22497	22521	-24	Yes
5.	48.30	24962	25000	-38	Yes
6.	47.80	24939	25000	-61	Yes
7.	48.30	24929	25000	-71	Yes
8.	48.80	22452	22521	-69	Yes
9.	49.80	12499	12500	-1	Yes
10.	50.00	12458	12500	-42	Yes



Stage 2: TYPE 2 inverter EES units <u>in charging mode</u> is set to -50% of maximum discharging power first, After the TYPE 2 inverter EES units step into frequency range under 49.8Hz, the output active power

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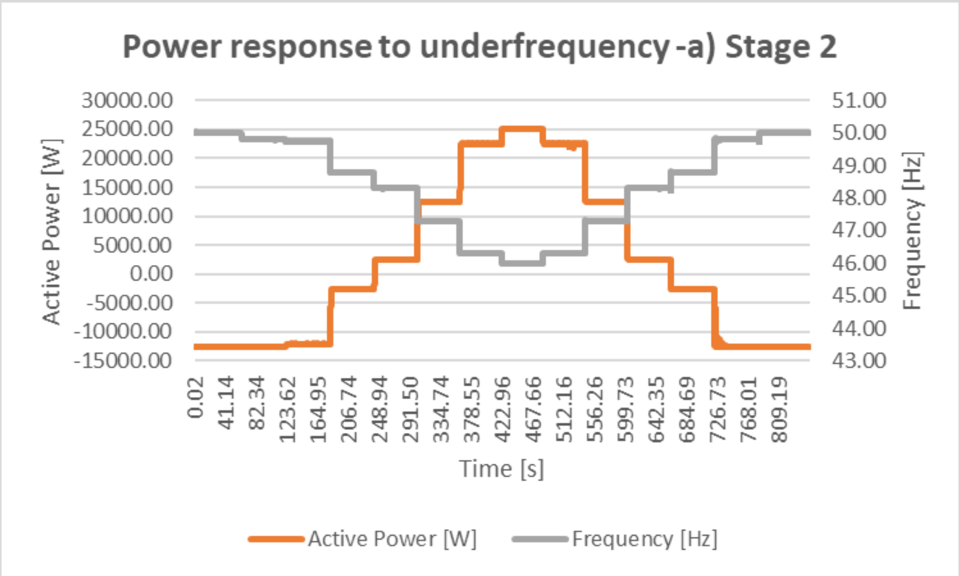
should regulate the active power with gradient of 40% P_{max}/Hz till technical maximum power. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n.
P_{max} = 25000 W , 10% P_n= 2500 W , intentional delay time: 0.10 s (should ≤2s)

Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max-limit}$ (W)	Deviation of $P_{measure}$ and $P_{max-limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	-12618	-12500	-118	Yes
2.	49.80	-12614	-12500	-114	Yes
3.	49.75	-12113	-12114	1	Yes
4.	48.80	-2543	-2614	71	Yes
5.	48.30	2469	2386	83	Yes
6.	47.30	12518	12386	132	Yes
7.	46.30	22522	22386	136	Yes
8.	46.00	25020	25000	20	Yes
9.	46.30	22191	22386	-195	Yes
10.	47.30	12504	12386	118	Yes
11.	48.30	2482	2386	96	Yes
12.	48.80	-2482	-2614	132	Yes
13.	49.80	-12632	-12500	-132	Yes
14.	50.00	-12628	-12500	-128	Yes



b) under-frequency regulation, with active power reduction frequency start point=49.8Hz, gradient s=12%

Stage 1: TYPE 2 inverter DC input power is set to 50% of maximum active output power first. After the TYPE 2 inverter step into frequency range under 49.8Hz, the TYPE 2 inverter available input power is set

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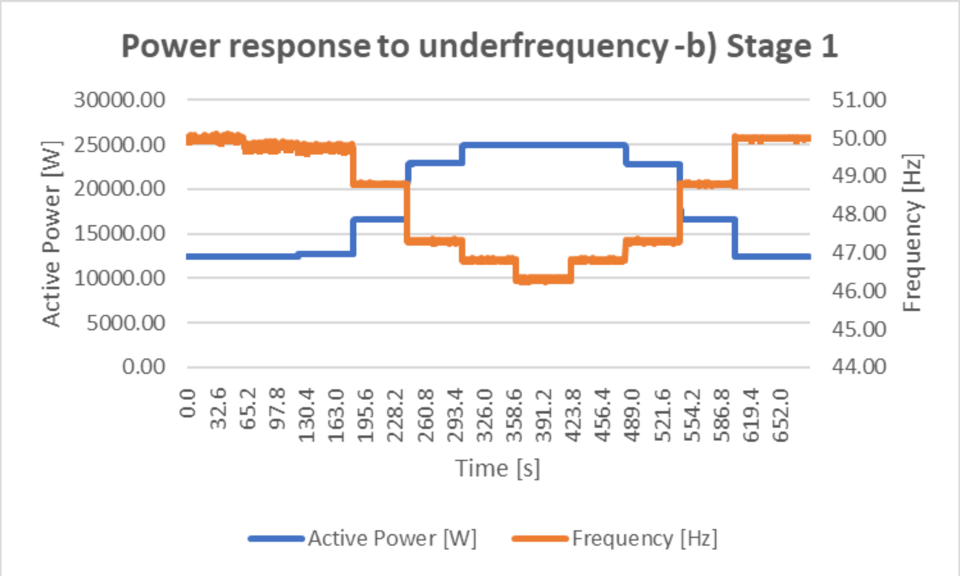
to 100% of maximum active output. The output active power should regulate the active power with gradient of 16.67% P_{max}/Hz till technical maximum power. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n.

P_{Max} = 25000 W , 10% P_n= 2500 W , intentional delay time: 0.08 s (should ≤2s)

Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max-limit}$ (W)	Deviation of $P_{measure}$ and $P_{max-limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	12471	12500	-29	Yes
2.	49.80	12475	12500	-25	Yes
3.	49.75	12681	12683	-2	Yes
4.	48.80	16636	16642	-6	Yes
5.	47.30	22861	22892	-31	Yes
6.	46.80	24930	24975	-45	Yes
7.	46.30	24912	25000	-88	Yes
8.	46.80	24896	24975	-79	Yes
9.	47.30	22818	22892	-74	Yes
10.	48.80	16600	16642	-42	Yes
11.	50.00	12442	12500	-58	Yes



Stage 2: TYPE 2 inverter EES units in charging mode is set to -50% of maximum discharging power first, After the TYPE 2 inverter EES units step into frequency range under 49.8Hz, the output active power should regulate the active power with gradient of 16.67% P_{max}/Hz till technical maximum power. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n.

P_{max} = 25000 W , 10% P_n= 2500 W , intentional delay time: 0.08 s (should ≤2s)

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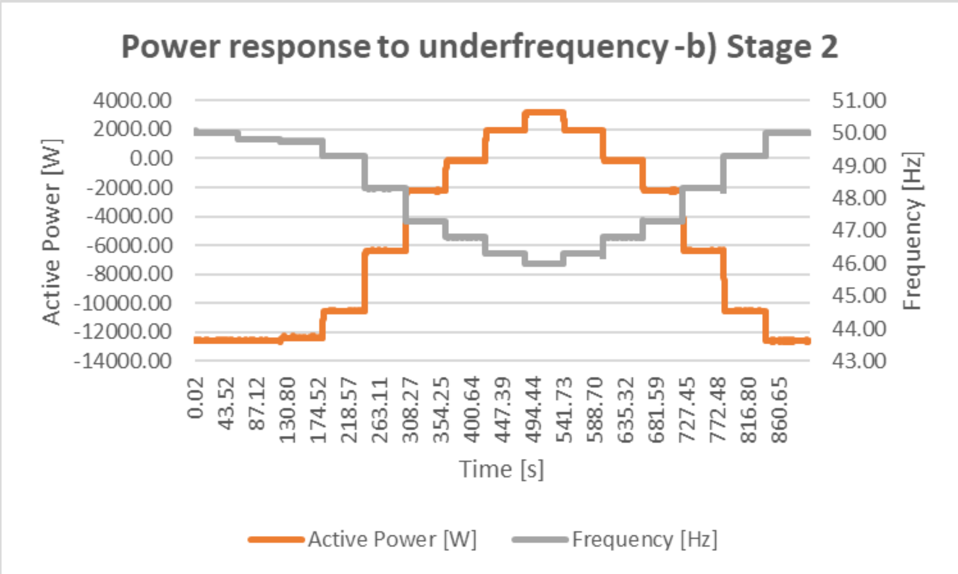
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max\text{-}limit}$ (W)	Deviation of $P_{measure}$ and $P_{max\text{-}limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	-12598	-12500	-98	Yes
2.	49.80	-12596	-12500	-96	Yes
3.	49.75	-12398	-12388	-10	Yes
4.	49.30	-10522	-10513	-9	Yes
5.	48.30	-6373	-6346	-27	Yes
6.	47.30	-2218	-2179	-39	Yes
7.	46.80	-141	-96	-45	Yes
8.	46.30	1922	1987	-65	Yes
9.	46.00	3168	3237	-69	Yes
10.	46.30	1918	1987	-69	Yes
11.	46.80	-143	-96	-47	Yes
12.	47.30	-2218	-2179	-39	Yes
13.	48.30	-6379	-6346	-33	Yes
14.	49.30	-10535	-10513	-22	Yes
15.	50.00	-12492	-12500	8	Yes



c) under-frequency regulation, with active power reduction frequency start point=49.8Hz, gradient s=2%

Stage 1: TYPE 2 inverter DC input power is set to 50% of maximum active output power first. After the TYPE 2 inverter step into frequency range under 49.8Hz, the TYPE 2 inverter available input power is set to 100% of maximum active output. The output active power should regulate the active power with gradient of 100% P_{max}/Hz till technical maximum power. The active power value shall not be deviated from the

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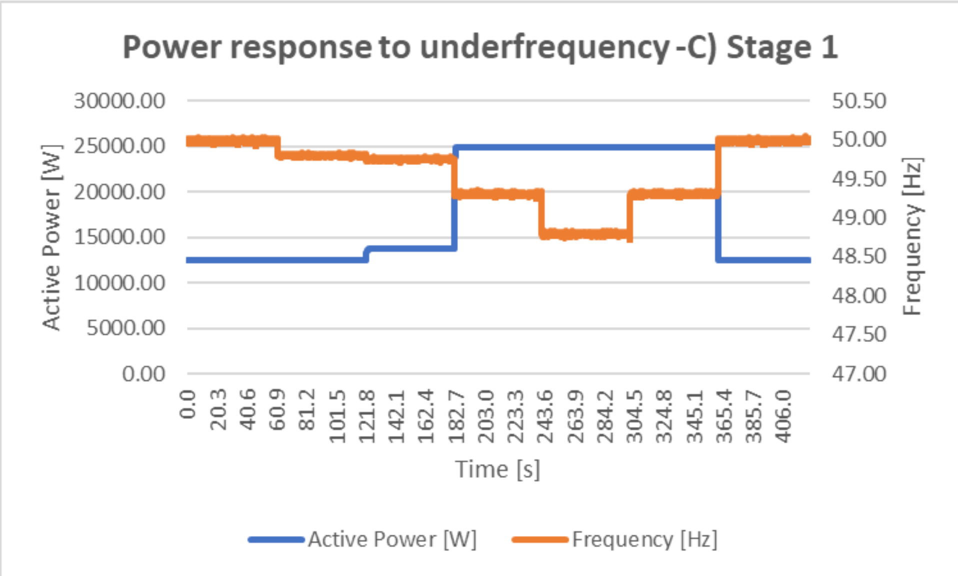
required value calculated from the feature curve for more than 10% P_n.

P_{Max} = 25000 W , 10% P_n= 2500 W , intentional delay time: 0.10 s (should ≤2s)

Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max-limit}$ (W)	Deviation of $P_{measure}$ and $P_{max-limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	12462	12500	-38	Yes
2.	49.80	12461	12500	-39	Yes
3.	49.75	13717	13711	6	Yes
4.	49.30	24921	24961	-40	Yes
5.	48.80	24908	25000	-92	Yes
6.	49.30	24884	24961	-77	Yes
7.	50.00	12442	12500	-58	Yes

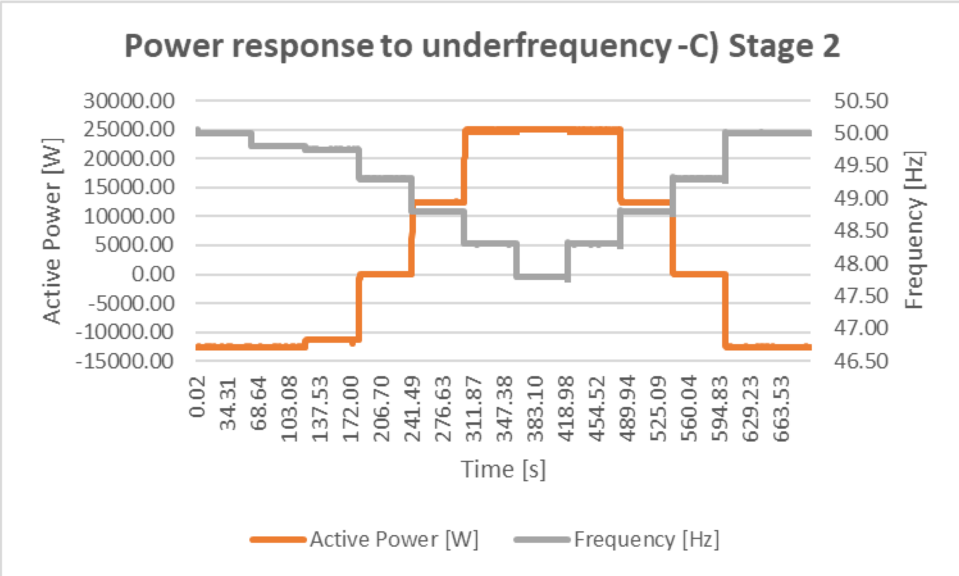


Stage 2: TYPE 2 inverter EES units in charging mode is set to -50% of maximum discharging power first, After the TYPE 2 inverter EES units step into frequency range under 49.8Hz, the output active power should regulate the active power with gradient of 100% P_{max}/Hz till technical maximum power. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% P_n.

P_{max} = 25000 W , 10% P_n= 2500 W , intentional delay time: 0.08 s (should ≤2s)

Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	The calculated active output power as per feature curve $P_{max-limit}$ (W)	Deviation of $P_{measure}$ and $P_{max-limit}$ (W)	Deviation within 10% P_n (Yes/No)
1.	50.00	-12609	-12500	-109	Yes
2.	49.80	-12597	-12500	-97	Yes
3.	49.75	-12595	-11347	-1248	Yes
4.	49.30	-33	-97	64	Yes

5.	48.80	12471	12403	68	Yes
6.	48.30	24949	24903	46	Yes
7.	47.80	24932	25000	-68	Yes
8.	48.30	24924	24903	21	Yes
9.	48.80	12455	12403	52	Yes
10.	49.30	-33	-97	64	Yes
11.	50.00	-12598	-12500	-98	Yes



Active power reaction time Test with active power reduction frequency start point 49.80Hz, gradient s=5%,at 50%Pmax				
Test sequence	Freq (Hz)	Measured active output power $P_{measure}$ (W)	Instrinsic dead time (≤ 2s)	Response time (≤ 30s)
1	50.00	12512		-
2	49.80	12632		-
3	49.30	17701	0.06s	0.2s

Remark:

1. The battery pack model used in the test was: LUNA2000-5-E0&LUNA2000-5KW-C0 and LUNA2000-7-E1&LUNA2000-10KW-C1.

2. The maximum active output is 25000W when the inverter with only battery input.

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4.7.2.2	Capabilities									P
S_{max} (VA)	27375				P_{max}(W)	27288				
Case A: Tested at Nominal voltage 1.00Un										
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80	90	100
Q set value generation(Var)	11981	11981	11981	11981	11981	11981	11981	11981	11981	11981
Tested cosφ	0.219 cap	0.412 cap	0.561 cap	0.671 cap	0.749 cap	0.805 cap	0.845 cap	0.875 cap	0.897 cap	0.897 cap
Active power P (W)	2714	5459	8203	10949	13698	16446	19189	21921	24556	24558
Reactive power Q(Var)	12074	12080	12090	12098	12103	12113	12119	12112	12094	12095
Apparent power S (VA)	12376	13257	14610	16317	18279	20425	22695	25044	27373	27375
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80	90	100
Q set value generation(Var)	0	0	0	0	0	0	0	0	0	0
Tested cosφ	1.000 ind	1.000 ind	1.000 ind	1.000 ind	1.000 cap	1.000 cap	1.000 cap	1.000 cap	1.000 cap	1.000 cap
Active power P (W)	2743	5482	8221	10961	13697	16429	19156	21875	24588	27288
Reactive power Q(Var)	-9	-6	-4	-2	1	2	3	4	5	10
Apparent power S (VA)	2743	5482	8221	10961	13697	16429	19157	21876	24588	27288
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80	90	100
Q set value generation(Var)	-11981	-11981	-11981	-11981	-11981	-11981	-11981	-11981	-11981	-11981
Tested cosφ	0.223 ind	0.414 ind	0.564 ind	0.673 ind	0.751 ind	0.806 ind	0.846 ind	0.876 ind	0.897 ind	0.897 ind
Active power P (W)	2768	5514	8259	11006	13747	16486	19216	21935	24549	24550
Reactive power Q(Var)	-12089	-12090	-12089	-12091	-12088	-12086	-12076	-12071	-12047	-12047
Apparent power S (VA)	12402	13288	14641	16350	18306	20442	22696	25038	27346	27346
Deviation within	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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2% S_{max} (Yes/No)										

Case B Tested at Nominal voltage 1.10Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Q set value generation(Var)	11981	0	-11981
Tested cosφ	0.897 cap	1.000 cap	0.898 ind
Active power P (W)	24400	27211	24439
Reactive power Q(Var)	12002	12	-11985
Apparent power S (VA)	27192	27211	27220
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case C: Tested at Nominal voltage 1.05Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Q set value generation(Var)	11981	0	-11981
Tested cosφ	0.897 cap	1.000 cap	0.898 ind
Active power P (W)	24365	27180	24410
Reactive power Q(Var)	11995	14	-11973
Apparent power S (VA)	27157	27180	27189
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case D: Tested at Nominal voltage 0.95Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Q set value generation(Var)	11981	0	-11981
Tested cosφ	0.897 cap	1.000	0.897 ind
Active power P (W)	24338	27148 cap	24337
Reactive power Q(Var)	11989	12	11990
Apparent power S (VA)	27130	27148	27131
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case E: Tested at Nominal voltage 0.90Un*			
P/ S_{Emax} (%)	Max.	Max.	Max.
Q set value generation(Var)	11981	0	-11981
Tested cosφ	0.886 cap	1.000 cap	0.885 ind
Active power P (W)	22793	25650	22690

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Reactive power Q(Var)	11956	3	-11957
Apparent power S (VA)	25738	25650	25647
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case F: Tested at Nominal voltage 0.85Un*			
P/ S_{Emax} (%)	Max.	Max.	Max.
Q set value generation(Var)	11981	0	-11981
Tested cosφ	0.870 cap	1.000 cap	0.870 ind
Active power P (W)	21446	24589	21335
Reactive power Q(Var)	12131	8	-12105
Apparent power S (VA)	24639	24590	24530
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes

Case A: Tested at Nominal voltage 1.00Un										
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80	90	100
Cosφ set value generation	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.900 cap
Tested cosφ	0.900 cap	0.900 cap	0.900 cap	0.900 cap	0.899 cap	0.899 cap	0.899 cap	0.899 cap	0.899 cap	0.899 cap
Active power P (W)	2744	5485	8225	10961	13693	16419	19137	21847	24503	24503
Reactive power Q(Var)	1325	2657	3990	5323	6654	7981	9307	10623	11919	11919
Apparent power S (VA)	3047	6094	9142	12186	15224	18256	21281	24293	27248	27248
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80	90	100
Cosφ set value generation	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind
Tested cosφ	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind	0.900 ind
Active power P (W)	2744	5484	8223	10963	13701	16431	19155	21870	24536	24537
Reactive power Q(Var)	-1326	-2651	-3979	-5307	-6637	-7963	-9282	-10601	-11895	-11894
Apparent power S (VA)	3048	6091	9135	12180	15223	18259	21286	24304	27267	27267

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Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Case B Tested at Nominal voltage 1.10Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.900 cap	1.000	0.900 ind
Tested cosφ	0.899 cap	1.000 cap	0.900 ind
Active power P (W)	24484	27228	24501
Reactive power Q(Var)	11905	13	-11871
Apparent power S (VA)	27225	27228	27225
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case C: Tested at Nominal voltage 1.05Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.900 cap	1.000	0.900 ind
Tested cosφ	0.899 cap	1.000 cap	0.900 ind
Active power P (W)	24432	27186	24472
Reactive power Q(Var)	11878	14	-11859
Apparent power S (VA)	27167	27186	27194
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case D: Tested at Nominal voltage 0.95Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.900 cap	1.000	0.900 ind
Tested cosφ	0.899 cap	1.000 cap	0.900 ind
Active power P (W)	24370	27123	24398
Reactive power Q(Var)	11857	8	-11842
Apparent power S (VA)	27101	27123	27120
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case E: Tested at Nominal voltage 0.90Un*			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.900 cap	1.000	0.900 ind
Tested cosφ	0.899 cap	1.000 cap	0.900 ind

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Active power P (W)	23159	25706	23110
Reactive power Q(Var)	11264	2	-11222
Apparent power S (VA)	25753	25707	25691
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case F: Tested at Nominal voltage 0.85Un*			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.900 cap	1.000	0.900 ind
Tested cosφ	0.899 cap	1.000 ind	0.899 ind
Active power P (W)	21838	24227	21777
Reactive power Q(Var)	10641	-27	-10586
Apparent power S (VA)	24293	24227	24214
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes

Below table only to verify that inverter has the power factor adjustable range up to 0.8 leading to 0.8 lagging

Case A: Tested at Nominal voltage 1.00Un										
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80*	90*	100*
Cosφ set value generation	0.800 cap	0.800 cap	0.800 cap	0.800 cap	0.800 cap	0.800 cap	0.800 cap	0.800 cap	0.800 cap	0.800 cap
Tested cosφ	0.800 cap	0.800 cap	0.799 cap	0.799 cap	0.799 cap	0.799 cap	0.799 cap	0.799 cap	0.799 cap	0.799 cap
Active power P (W)	2758	5505	8249	10990	13729	16465	19194	21855	21854	21851
Reactive power Q(Var)	2065	4129	6199	8265	10328	12412	14462	16470	16467	16463
Apparent power S (VA)	3445	6881	10319	13751	17180	20619	24032	27366	27364	27359
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P/ S_{Emax} (%)	10	20	30	40	50	60	70	80*	90*	100*
Cosφ set value generation	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind
Tested cosφ	0.801 ind	0.801 ind	0.801 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind	0.800 ind
Active power P (W)	2760	5511	8260	11002	13738	16473	19196	21894	21883	21858
Reactive power	-2061	-4121	-6182	-8241	-10294	-12350	-14401	-16435	-16424	-16408

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Q(Var)										
Apparent power S (VA)	3444	6882	10317	13747	17167	20588	23998	27377	27361	27331
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Case B Tested at Nominal voltage 1.10Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.800 cap	1.000	0.800 ind
Tested cosφ	0.799 cap	1.000 cap	0.800 ind
Active power P (W)	21705	27204	21768
Reactive power Q(Var)	16342	12	-16329
Apparent power S (VA)	27169	27204	27212
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes

Case C: Tested at Nominal voltage 1.05Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.800 cap	1.000	0.800 ind
Tested cosφ	0.899 cap	1.000 cap	0.900 ind
Active power P (W)	24432	27186	24472
Reactive power Q(Var)	11878	14	-11859
Apparent power S (VA)	27167	27186	27194
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes

Case D: Tested at Nominal voltage 0.95Un			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.800 cap	1.000	0.800 ind
Tested cosφ	0.799 cap	1.000 cap	0.800 ind
Active power P (W)	21699	27193	21753
Reactive power Q(Var)	16337	15	-16340
Apparent power S (VA)	27162	27193	27206

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Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case E: Tested at Nominal voltage 0.90Un*			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.800 cap	1.000	0.800 ind
Tested cosφ	0.799 cap	1.000 cap	0.799 ind
Active power P (W)	20562	25659	20502
Reactive power Q(Var)	15487	2	-15409
Apparent power S (VA)	25742	25660	25647
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Case F: Tested at Nominal voltage 0.85Un*			
P/ S_{Emax} (%)	Max.	Max.	Max.
Cosφ set value generation	0.800 cap	1.000	0.800 ind
Tested cosφ	0.799 cap	1.000 cap	0.799 ind
Active power P (W)	19401	24227	19350
Reactive power Q(Var)	14604	1	-14551
Apparent power S (VA)	24284	24227	24211
Deviation within 2% S_{max} (Yes/No)	Yes	Yes	Yes
Remark:*This case limited by the maximum current, active power cannot reach rated power.			

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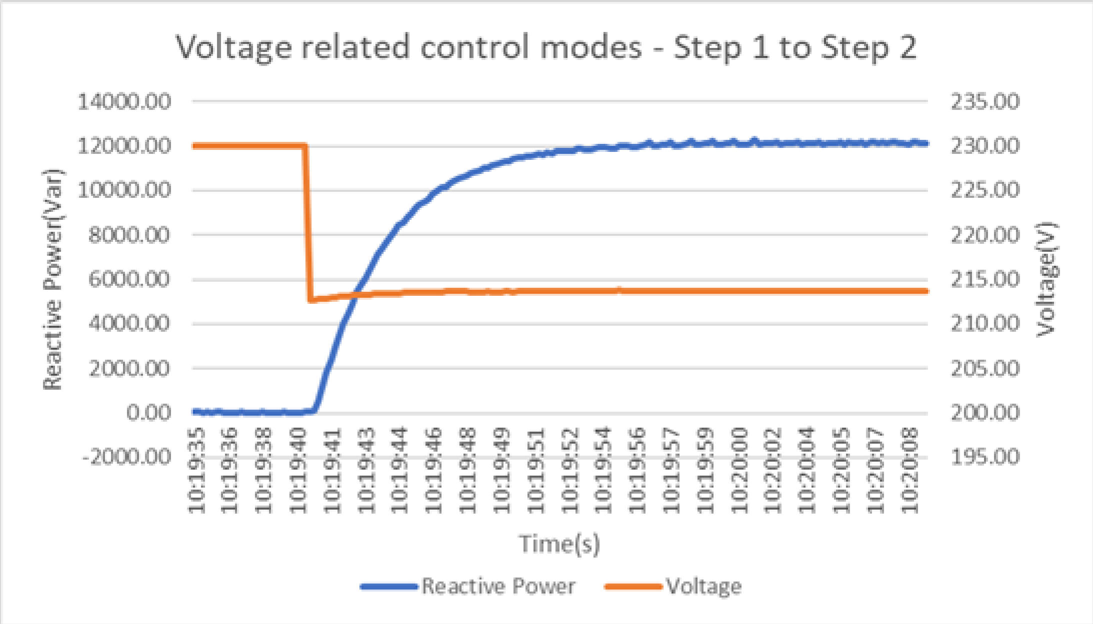
4.7.2.3.3	Voltage related control modes	P
The dynamics of the Response control time		

Set fixed P=0.5 S_{Emax}, the setting response time is __10__ s (the setting should within the range of 3s to 60s), change the voltage by steps:

1) 1.00 Un, stable operation
2) 0.93 Un, 30s
3) 1.07 Un, 30s
4) 1.00 Un, 30s

Step from 1) to 2)

Response curve:



Start reactive power Q_S (Var)	5.0
Target reactive power Q_T (Var)	11985.6
Required change of reactive power $\|Q_T-Q_S\|$ (Var)	11980.6
Step change of reactive power after the setting response time $\|Q_{srt}\|$ (Var)	11460.0
Percentage of step change of reactive power $\|Q_{srt}\| / \|Q_T-Q_S\|$ (%)	95.6
Step change of reactive power after 3 times the $\|Q_{srt}\|$ (Var)	12112.0
Percentage of step change of reactive power $\|Q_{srt}*3\| / \|Q_T-Q_S\|$ (%)	101.1

90%< $\|Q_{srt}\| / \|Q_T-Q_S\|$<100%	Yes	95%< $\|Q_{srt}\|*3/\|Q_T-Q_S\|$<105%	Yes

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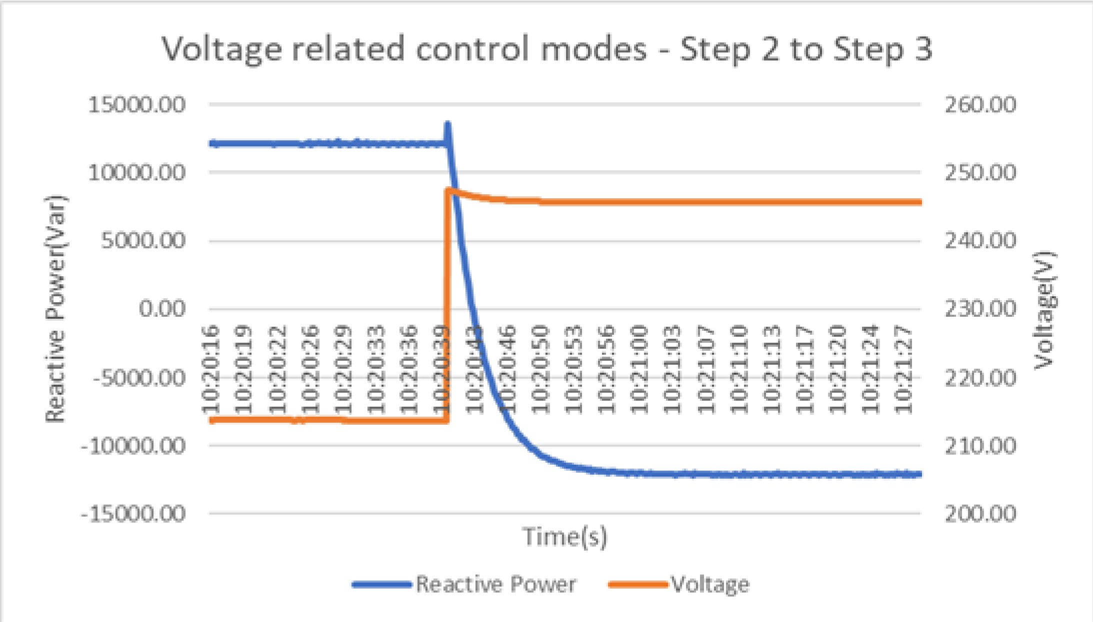
Product Service

Step from 2) to 3)			
Response curve: 			
Start reactive power Q_S (Var)		12088.0	
Target reactive power Q_T (Var)		-11873.2	
Required change of reactive power $\|Q_T-Q_S\|$ (Var)		23961.2	
Step change of reactive power after the setting response time $\|Q_{srt}\|$ (Var)		22859.0	
Percentage of step change of reactive power $\|Q_{srt}\|$ /$\|Q_T-Q_S\|$ (%)		95.4	
Step change of reactive power after 3 times the $\|Q_{srt}\|$ (Var)		24176.0	
Percentage of step change of reactive power $\|Q_{srt}*3\|$ /$\|Q_T-Q_S\|$ (%)		100.9	
90%< $\|Q_{srt}\|$ /$\|Q_T-Q_S\|$<100%	Yes	95%< $\|Q_{srt}\|*3/\|Q_T-Q_S\|$<105%	Yes

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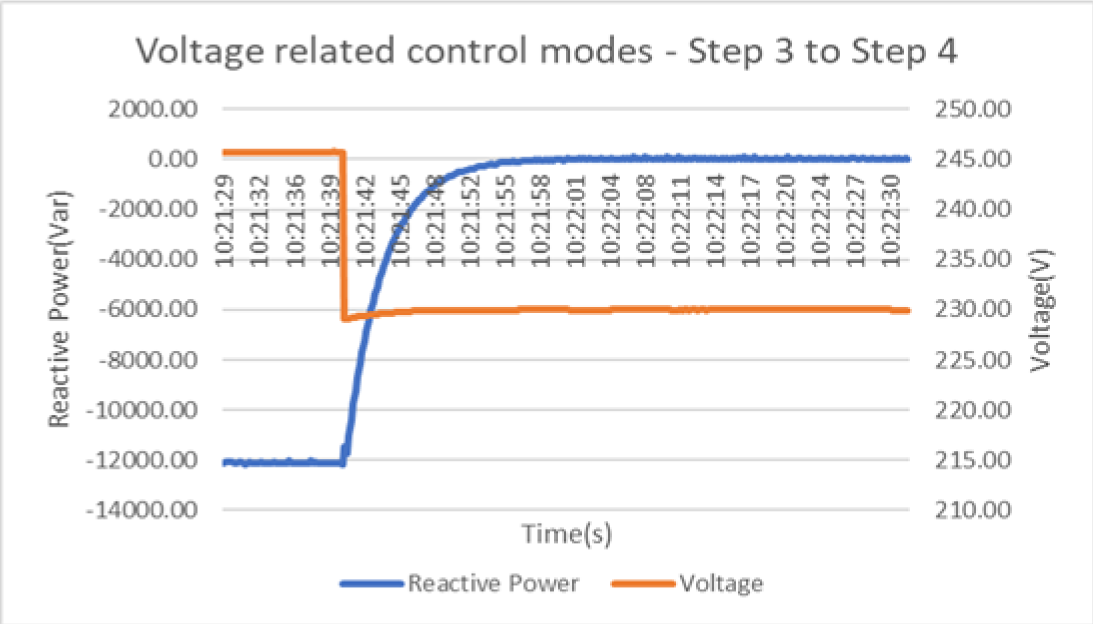
Step from 3) to 4)	
Response curve:	



Start reactive power Q_s (Var)	-12161.0
Target reactive power Q_T (Var)	-180.4
Required change of reactive power $\|Q_T-Q_S\|$ (Var)	11980.6
Step change of reactive power after the setting response time $\|Q_{srt}\|$ (Var)	11486.0
Percentage of step change of reactive power $\|Q_{srt}\| /\|Q_T-Q_S\|$ (%)	95.9
Step change of reactive power after 3 times the $\|Q_{srt}\|$ (Var)	12200.0
Percentage of step change of reactive power $\|Q_{srt}*3\| /\|Q_T-Q_S\|$ (%)	101.8

90%< $\|Q_{srt}\| /\|Q_T-Q_S\|$<100%	Yes	95%< $\|Q_{srt}\|*3/\|Q_T-Q_S\|$<105%	Yes

Remark: Q(U) control mode, voltage setting is 0.93Un for Qmax, 1.07Un for Qmin.

The voltage related control modes control the reactive power output

$-Q_{max}$ and Q_{max} is defined by testing in Cl.4.7.2. Fixed active power setting 0.5 S_{Emax}

Q_{max} at this active power (Var)	±11980.6

Grid simulator voltage (Un)	Measured Voltage U_{L-N} (V)	Measured active power P (W)	Measured apparent power S (VA)	Measured displacement factor cosφ	Measured reactive power Q(Var)	Required reactive power as to feature curve Q(Var)	Deviation of reactive power
0.91 Un	210.26 210.31	13680.93	18297.42	0.748 cap	12150.04	11980.6	169.44

	210.35						
	213.31						
0.93 Un	213.28	13684.47	18305.92	0.748 cap	12158.79	11980.6	178.19
	213.43						
	218.11						
0.95 Un	218.09	13701.08	15002.18	0.913 cap	6110.85	5990.3	120.55
	218.22						
	223.00						
0.97 Un	223.08	13703.74	13704.21	1.000	109.69	0	109.69
	223.11						
	229.99						
1.00 Un	230.06	13707.71	13707.78	1.000	-0.44	0	0.44
	230.11						
	236.29						
1.03 Un	236.21	13719.81	13719.87	1.000	0.92	0	0.92
	236.40						
	240.99						
1.05 Un	241.07	13715.60	15009.44	0.914 ind	-6096.18	-5990.3	105.88
	241.13						
	246.28						
1.07 Un	246.19	13723.30	18285.51	0.751 ind	-12084.22	-11980.6	103.62
	246.42						
	250.24						
1.09 Un	250.18	13734.40	18352.24	0.748 ind	-12172.53	-11980.6	191.93
	250.36						
	246.38						
1.07 Un	246.28	13732.15	18350.22	0.748 ind	-12172.00	-11980.6	191.4
	246.50						
	241.61						
1.05 Un	241.59	13722.03	15052.61	0.912 ind	-6187.51	-5990.3	197.21
	241.73						
	236.71						
1.03 Un	236.76	13717.20	13717.28	1.000	-3.13	0	3.13
	236.81						

Product Service

1.00 Un	230.00 230.06 230.10	13713.33	13713.38	1.000	-1.87	0	1.87
0.97 Un	222.99 223.06 223.10	13709.58	13709.61	1.000	-4.80	0	4.8
0.95 Un	218.13 218.07 218.22	13704.08	15013.81	0.913 cap	6132.83	5990.3	142.53
0.93 Un	213.31 213.30 213.42	13690.19	18292.74	0.748 cap	12132.63	11980.6	152.03
0.91 Un	210.25 210.33 210.33	13681.42	18300.89	0.748 cap	12154.71	11980.6	174.11

Limit the reactive power at low active power

Qmin

P/P_{SMAX} [%] Set-point	Vac [V] set-point	P/P_{SMAX} [%] Measured	Vac [V] measured	Q [Var] measured	Q [Var] expected	Δ Q (< ± 2 % Sn)
< 20 %	1.03 Vn	9.99	236.32 236.19 236.39	-3.72	0	3.72
< 20 %	1.05 Vn	10.03	241.54 241.38 241.61	-8.17	0	8.17
<20 % -> 30 %	1.05 Vn	29.98	241.34 241.29 241.46	-6079.54	-5990.3	89.24
50 %	1.05 Vn	49.86	241.45 241.44 241.58	-6081.21	-5990.3	90.91
100 %	1.05 Vn	97.12	241.24 241.30 241.38	-5998.57	-5990.3	8.27
100 %	1.07 Vn	89.30	246.51 246.50 246.62	-12087.90	-11980.6	107.30
100 % -> 10 %	1.07 Vn	10.06	246.20 246.08 246.28	-12145.02	-11980.6	164.42

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10 % -> ≤ 5 %	1.07 Vn	4.03	246.17 246.09 246.33	-39.28	0	39.28
Qmax						
P/PSMAX [%] Set-point	Vac [V] set-point	P/PSMAX [%] Measured	Vac [V] measured	Q [Var] measured	Q [Var] expected	Δ Q (< ± 2 % Sn)
< 20 %	0.97 Vn	10.01	222.90 222.81 222.99	-3.70	0	3.70
< 20 %	0.95 Vn	10.01	218.17 218.11 218.27	-4.35	0	4.35
<20 % -> 30 %	0.95 Vn	30.91	218.16 218.13 218.28	6104.75	5990.3	114.45
50 %	0.95 Vn	49.81	218.27 218.21 218.39	6144.75	5990.3	154.45
100 %	0.95 Vn	96.98	218.49 218.55 218.57	6141.31	5990.3	151.01
100 %*	0.93 Vn	86.79	213.25 213.29 213.39	12121.10	11980.6	140.50
100 % -> 10 %	0.93 Vn	9.90	212.89 212.77 212.99	12092.51	11980.6	111.91
10 % -> ≤ 5 %	0.93 Vn	4.03	212.85 212.75 212.94	230.23	0	230.23
Remark: 1.*This case limited by the maximum current, active power cannot reach the set point. 2.Lock-in value setting: 20%Pn, Lock-out value setting: 5%Pn.						

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4.7.2.3.4	Power related Control mode:					P
Maximal active power P_{Emax} with the tested displacement factor (W)					27500	
Percentage of output active power P/P_{Emax} (%)	Measured active power P (W)	Measured apparent power S (VA)	Measured displacement factor cosφ	Measured reactive power Q(Var)	Displacement factor as to feature curve	Whether the accuracy fulfill according to clause 4.7.2.2 (± 2% Smax)
Set point 1: P=0 P_{Emax}, cosφ=1 Set point 2: P=0.5 P_{Emax}, cosφ=1 Set point 3: P=1 P_{Emax}, cosφ=0.9 or $0.95_{under-excited}$						
10%	2753.34	2753.36	1.000	-10.67	1.000	Yes
20%	5499.51	5499.53	1.000	-6.39	1.000	Yes
30%	8244.33	8244.35	1.000	-3.70	1.000	Yes
40%	10988.16	10988.18	1.000	-0.76	1.000	Yes
50%	13727.66	13727.79	1.000	-43.12	1.000	Yes
60%	16465.63	16802.44	0.980 ind	-3347.09	0.980 ind	Yes
70%	19194.18	19995.31	0.960 ind	-5603.07	0.960 ind	Yes
80%	21913.02	23314.93	0.940 ind	-7962.67	0.940 ind	Yes
90%	24621.61	26768.83	0.920 ind	-10504.36	0.920 ind	Yes
100%	25038.23	27318.86	0.917 ind	-10927.33	0.915 ind	Yes
90%	24570.42	26712.27	0.920 ind	-10480.17	0.920 ind	Yes
80%	21831.84	23229.13	0.940 ind	-7934.75	0.940 ind	Yes
70%	19103.42	19900.08	0.960 ind	-5574.08	0.960 ind	Yes
60%	16380.35	16715.27	0.980 ind	-3328.95	0.980 ind	Yes
50%	13657.14	13657.27	1.000	-41.46	1.000	Yes
40%	10935.84	10935.86	1.000	-2.20	1.000	Yes
30%	8210.60	8210.62	1.000	-4.63	1.000	Yes
20%	5481.35	5481.36	1.000	-7.40	1.000	Yes
10%	2745.55	2745.59	1.000	-10.32	1.000	Yes
Supplementary information: N/A						

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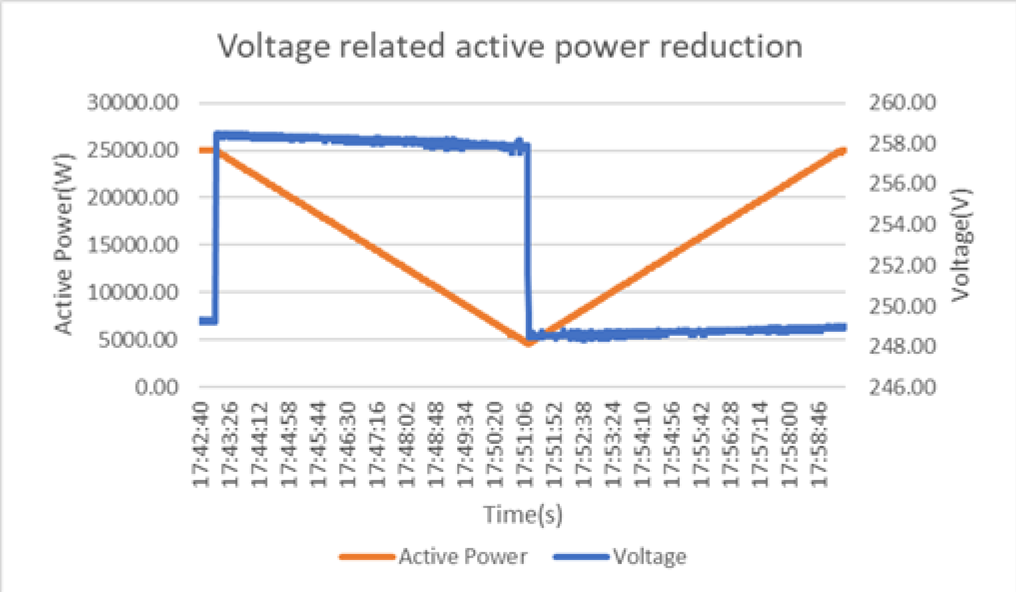
4.7.3	TABLE: Voltage related active power reduction									P
Step	Voltage set-point	Grid voltage [V]			Current [A]			Output active power [W]	Droop during power reduction [%P_n/s]	
		L1-N	L2-N	L3-N	L1	L2	L3			
1)	-2% of 110%U_n	249.33	249.38	249.22	33.49	33.52	33.44	25000.00	-	
2)	+2% of 110%U_n	257.88	257.91	257.85	6.55	6.54	6.54	5010.00	0.16	
3)	-2% of 110%U_n	249.01	249.14	248.91	33.53	33.57	33.48	25000.00	0.17	



4.8	Power quality - TABLE: Rapid voltage change								P
Test conditions: Case A: Switch on at any power level of primary energy Case B: Worst case of switching of generator level Case C: Switch on at the nominal power Case D: Switch off at the nominal power (not emergency, but normal operational switch off)									
Nominal current of PGU I_n (A)		36.1			The k_{imax} value:		1.02		
Test frequency (Hz)		50			--		--		
Switching action		Ia (A)			U(V)			ki	
A	--	L1	L2	L3	L1	L2	L3	--	
	#1	18.54	18.49	18.57	230.16	230.32	230.18	0.51	
	#2	18.47	18.63	18.57	230.18	230.34	230.20	0.52	
	#3	18.45	18.59	18.58	230.16	230.35	230.21	0.51	
A-with 0.33% rate	--	L1	L2	L3	L1	L2	L3	--	
	#1	18.17	18.18	18.16	230.14	230.25	230.18	0.50	
	#2	18.17	18.18	18.16	230.15	230.27	230.16	0.50	
	#3	18.17	18.18	18.15	230.13	230.24	230.16	0.50	
A-with 0.66% rate	--	L1	L2	L3	L1	L2	L3	--	
	#1	18.17	18.17	18.15	230.14	230.31	230.21	0.50	
	#2	18.16	18.18	18.15	230.13	230.26	230.17	0.50	
	#3	18.17	18.19	18.16	230.16	230.31	230.22	0.50	
B	--	L1	L2	L3	L1	L2	L3	--	
	#1	18.54	18.49	18.57	230.16	230.32	230.18	0.51	
	#2	18.47	18.63	18.57	230.18	230.34	230.20	0.52	
	#3	18.45	18.59	18.58	230.16	230.35	230.21	0.51	
C	--	L1	L2	L3	L1	L2	L3	--	
	#1	36.63	36.72	36.65	230.40	230.63	230.46	1.02	
	#2	36.62	36.76	36.64	230.43	230.70	230.50	1.02	
	#3	36.65	36.67	36.66	230.38	230.61	230.41	1.02	
C-with 0.33% rate	--	L1	L2	L3	L1	L2	L3	--	
	#1	36.62	36.76	36.64	230.31	230.48	230.35	1.02	
	#2	36.23	36.25	36.21	230.29	230.48	230.34	1.00	
	#3	36.23	36.28	36.21	230.27	230.45	230.31	1.00	
C-with 0.66% rate	--	L1	L2	L3	L1	L2	L3	--	
	#1	36.24	36.30	36.23	230.30	230.49	230.34	1.01	
	#2	36.24	36.27	36.22	230.29	230.47	230.34	1.00	
	#3	36.25	36.28	36.23	230.30	230.47	230.35	1.00	
D	--	L1	L2	L3	L1	L2	L3	--	
	#1	36.24	36.27	36.21	230.27	230.49	230.28	1.00	
	#2	36.23	36.26	36.21	230.28	230.48	230.31	1.00	
	#3	36.23	36.29	36.22	230.32	230.54	230.36	1.01	

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Supplementary information: Choose the applicable case for the tested EZE. Each case shall be measured for three times.

4.8	Power quality - TABLE: Flicker					P
Simulated network voltage (V)	L1 (P-N)	230	Network impedance	L1	--	
	L2 (P-N)	230		L2	--	
	L3 (P-N)	230		L3	--	
	--	--		N	--	
EZE operating current (A)	L1	36.1	EZE operating power (VA)	L1	--	
	L2	36.1		L2	--	
	L3	36.1		L3	--	
Simulated network frequency (Hz)	50		Short circuit power Sk (VA)	907500		
Plt (Maximum measured Pst)	L1	0.013	EZE nominal power (Pn)	25000		
	L2	0.013				
	L3	0.013				
Maximum flicker coefficient Cφk	L1	0.429	--	--		
	L2	0.429				
	L3	0.429				

Pst	#1	#2	#3	#4	#5	#6
L1	0.013	0.010	0.010	0.010	0.010	0.010
L2	0.013	0.010	0.010	0.010	0.010	0.010
L3	0.013	0.010	0.010	0.010	0.010	0.010
Pst	#7	#8	#9	#10	#11	#12
L1	0.010	0.010	0.010	0.010	0.010	0.010
L2	0.010	0.010	0.010	0.010	0.010	0.010
L3	0.013	0.010	0.010	0.010	0.010	0.010

Supplementary information:
The table is only applied to EZE with nominal current less than 75A.
The ratio of Sk,fic/Sn used for the analysis: 33.
Grid angle setting 32°for test

4.8	Power quality - TABLE: DC injection								P
Test level	33%			66%			100%		
Phase	L1	L2	L3	L1	L2	L3	L1	L2	L3
Test results (Amp)	0.030	0.077	0.043	0.031	0.087	0.043	0.037	0.098	0.043
Test results (% of rated output current)	0.08	0.21	0.12	0.09	0.24	0.12	0.10	0.27	0.12
Limit	≤0.5%			≤0.5%			≤0.5%		

Supplementary information: rated output current: 36.1A.
Arithmetic mean value used as test result in test duration of 5min.

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4.8	Power quality - TABLE: Harmonics and inter-harmonics											P
It is a design test referring to the test method and evaluation in IEC 61000-3-12 & IEC 61000-4-7.												
Phase L1												
Harmon. Nr.	P/P_{Emax}											Limit
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
1	0.06%	10.02 %	20.35 %	30.57 %	40.76 %	50.93 %	61.05 %	71.14 %	81.21 %	91.24 %	99.57 %	--
2	0.07%	0.05%	0.11%	0.10%	0.18%	0.15%	0.28%	0.25%	0.34%	0.25%	0.35%	8%
3	0.05%	0.04%	0.03%	0.04%	0.04%	0.05%	0.04%	0.05%	0.04%	0.06%	0.04%	--
4	0.07%	0.04%	0.05%	0.06%	0.07%	0.07%	0.09%	0.09%	0.11%	0.09%	0.14%	4%
5	0.07%	0.07%	0.05%	0.07%	0.06%	0.05%	0.09%	0.15%	0.17%	0.23%	0.34%	10.7%
6	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	2.6%
7	0.07%	0.05%	0.04%	0.07%	0.08%	0.07%	0.06%	0.05%	0.06%	0.06%	0.07%	7.2%
8	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.05%	0.06%	0.06%	0.07%	0.07%	2%
9	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
10	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.03%	0.04%	0.05%	0.06%	0.06%	1.6%
11	0.10%	0.09%	0.10%	0.10%	0.06%	0.13%	0.11%	0.12%	0.11%	0.14%	0.05%	3.1%
12	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.04%	1.3%
13	0.06%	0.13%	0.08%	0.08%	0.07%	0.13%	0.13%	0.17%	0.16%	0.21%	0.25%	2.0%
14	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.05%	0.05%	0.06%	0.05%	--
15	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.04%	--
16	0.03%	0.02%	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	--
17	0.05%	0.06%	0.05%	0.09%	0.05%	0.08%	0.09%	0.15%	0.15%	0.25%	0.18%	--
18	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	--
19	0.05%	0.15%	0.04%	0.08%	0.03%	0.08%	0.09%	0.13%	0.13%	0.21%	0.30%	--
20	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.04%	--
21	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	--
22	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.06%	--
23	0.06%	0.07%	0.09%	0.04%	0.06%	0.03%	0.04%	0.08%	0.09%	0.16%	0.16%	--
24	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	--
25	0.08%	0.16%	0.05%	0.05%	0.04%	0.04%	0.05%	0.06%	0.06%	0.07%	0.20%	--
26	0.03%	0.03%	0.03%	0.03%	0.04%	0.03%	0.03%	0.04%	0.04%	0.05%	0.04%	--
27	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	--
28	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.06%	--

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29	0.09%	0.05%	0.07%	0.10%	0.06%	0.05%	0.04%	0.06%	0.07%	0.10%	0.15%	--
30	0.02%	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
31	0.10%	0.10%	0.04%	0.05%	0.05%	0.05%	0.04%	0.04%	0.04%	0.05%	0.12%	--
32	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.06%	--
33	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	--
34	0.03%	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.06%	--
35	0.11%	0.07%	0.14%	0.14%	0.07%	0.07%	0.04%	0.05%	0.06%	0.10%	0.12%	--
36	0.02%	0.03%	0.01%	0.01%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%	--
37	0.11%	0.04%	0.05%	0.06%	0.04%	0.07%	0.05%	0.05%	0.04%	0.05%	0.09%	--
38	0.02%	0.02%	0.02%	0.03%	0.03%	0.02%	0.03%	0.03%	0.04%	0.05%	0.06%	--
39	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	--
40	0.02%	0.02%	0.02%	0.02%	0.03%	0.02%	0.03%	0.03%	0.04%	0.04%	0.05%	--
THC/ I_{ref}	0.33%	0.35%	0.30%	0.33%	0.31%	0.34%	0.42%	0.47%	0.54%	0.63%	0.79%	13%
PWHC/ I_{ref}	1.41%	1.45%	1.22%	1.33%	0.96%	1.01%	1.00%	1.28%	1.38%	2.03%	2.61%	22%
Phase L2												
Har mon. Nr.	P/P_{Emax}											Limit
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
1	0.07%	10.05 %	20.42 %	30.67 %	40.91 %	51.11 %	61.27 %	71.39 %	81.49 %	91.56 %	99.93 %	--
2	0.10%	0.04%	0.06%	0.07%	0.15%	0.13%	0.26%	0.24%	0.34%	0.26%	0.38%	8%
3	0.05%	0.03%	0.03%	0.04%	0.03%	0.04%	0.03%	0.04%	0.03%	0.03%	0.04%	--
4	0.07%	0.04%	0.05%	0.05%	0.07%	0.07%	0.09%	0.09%	0.11%	0.08%	0.12%	4%
5	0.06%	0.06%	0.05%	0.07%	0.07%	0.06%	0.10%	0.16%	0.17%	0.22%	0.34%	10.7%
6	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	2.6%
7	0.07%	0.05%	0.04%	0.07%	0.09%	0.07%	0.06%	0.05%	0.06%	0.06%	0.06%	7.2%
8	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.05%	0.06%	0.06%	0.07%	0.07%	2%
9	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	--
10	0.03%	0.02%	0.03%	0.03%	0.04%	0.04%	0.04%	0.04%	0.04%	0.06%	0.06%	1.6%
11	0.10%	0.10%	0.10%	0.10%	0.06%	0.13%	0.10%	0.12%	0.11%	0.14%	0.04%	3.1%
12	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	1.3%
13	0.06%	0.13%	0.08%	0.08%	0.07%	0.13%	0.13%	0.17%	0.16%	0.22%	0.26%	2.0%
14	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.05%	0.06%	0.05%	--
15	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.04%	--

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16	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.06%	--
17	0.04%	0.06%	0.04%	0.09%	0.05%	0.08%	0.09%	0.14%	0.14%	0.25%	0.18%	--
18	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
19	0.04%	0.15%	0.04%	0.08%	0.03%	0.08%	0.10%	0.14%	0.14%	0.22%	0.31%	--
20	0.03%	0.02%	0.03%	0.04%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.04%	--
21	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	--
22	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.06%	--
23	0.06%	0.07%	0.09%	0.04%	0.06%	0.03%	0.04%	0.07%	0.08%	0.14%	0.17%	--
24	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
25	0.08%	0.16%	0.05%	0.05%	0.04%	0.04%	0.05%	0.06%	0.06%	0.07%	0.21%	--
26	0.03%	0.03%	0.03%	0.04%	0.04%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	--
27	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	--
28	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.04%	0.07%	--
29	0.10%	0.05%	0.08%	0.10%	0.06%	0.05%	0.04%	0.05%	0.06%	0.09%	0.14%	--
30	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
31	0.10%	0.10%	0.04%	0.04%	0.04%	0.04%	0.04%	0.05%	0.05%	0.05%	0.12%	--
32	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	--
33	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
34	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.07%	--
35	0.11%	0.08%	0.14%	0.14%	0.07%	0.07%	0.04%	0.04%	0.05%	0.09%	0.11%	--
36	0.02%	0.02%	0.01%	0.01%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%	--
37	0.11%	0.05%	0.05%	0.06%	0.04%	0.06%	0.05%	0.05%	0.04%	0.05%	0.09%	--
38	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.05%	0.05%	--
39	0.02%	0.02%	0.01%	0.01%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%	--
40	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	0.04%	0.06%	--
THC/ I_{ref}	0.33%	0.35%	0.28%	0.32%	0.30%	0.33%	0.40%	0.46%	0.53%	0.62%	0.81%	13%
PWHC/ I_{ref}	1.42%	1.45%	1.22%	1.32%	0.97%	1.00%	1.00%	1.26%	1.34%	1.99%	2.64%	22%

Phase L3												
Har mon. Nr.	P/P_{Emax}											Limit
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
1	0.06%	10.05 %	20.42 %	30.67 %	40.90 %	51.09 %	61.24 %	71.37 %	81.46 %	91.54 %	99.86 %	--
2	0.08%	0.05%	0.09%	0.10%	0.18%	0.16%	0.27%	0.26%	0.36%	0.27%	0.37%	8%

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3	0.05%	0.03%	0.03%	0.04%	0.04%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	--
4	0.07%	0.04%	0.05%	0.05%	0.07%	0.06%	0.09%	0.09%	0.10%	0.08%	0.12%	4%
5	0.07%	0.06%	0.05%	0.08%	0.07%	0.06%	0.10%	0.16%	0.17%	0.23%	0.34%	10.7%
6	0.03%	0.02%	0.02%	0.02%	0.03%	0.03%	0.02%	0.03%	0.03%	0.03%	0.04%	2.6%
7	0.08%	0.05%	0.04%	0.08%	0.09%	0.07%	0.06%	0.05%	0.06%	0.06%	0.06%	7.2%
8	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.05%	0.05%	0.06%	0.07%	0.07%	2%
9	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
10	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	1.6%
11	0.10%	0.09%	0.10%	0.10%	0.07%	0.14%	0.11%	0.13%	0.11%	0.15%	0.05%	3.1%
12	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	1.3%
13	0.06%	0.13%	0.08%	0.08%	0.07%	0.13%	0.13%	0.17%	0.16%	0.22%	0.25%	2.0%
14	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.05%	0.06%	0.05%	--
15	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.04%	--
16	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	--
17	0.05%	0.06%	0.05%	0.09%	0.05%	0.08%	0.09%	0.14%	0.14%	0.25%	0.18%	--
18	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.04%	--
19	0.04%	0.15%	0.04%	0.08%	0.03%	0.08%	0.10%	0.14%	0.14%	0.22%	0.31%	--
20	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.04%	--
21	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.05%	--
22	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.06%	--
23	0.06%	0.07%	0.09%	0.04%	0.06%	0.03%	0.04%	0.07%	0.08%	0.15%	0.16%	--
24	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.04%	--
25	0.07%	0.16%	0.05%	0.05%	0.04%	0.04%	0.05%	0.06%	0.06%	0.07%	0.20%	--
26	0.03%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	--
27	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.04%	--
28	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.04%	0.07%	--
29	0.10%	0.05%	0.07%	0.10%	0.06%	0.05%	0.04%	0.06%	0.07%	0.09%	0.15%	--
30	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.04%	--
31	0.11%	0.10%	0.04%	0.04%	0.05%	0.04%	0.04%	0.04%	0.04%	0.05%	0.12%	--
32	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.05%	0.06%	--
33	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	--
34	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%	0.04%	0.04%	0.07%	--
35	0.11%	0.08%	0.14%	0.14%	0.07%	0.07%	0.04%	0.05%	0.06%	0.09%	0.12%	--
36	0.02%	0.02%	0.01%	0.01%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%	--

37	0.11%	0.05%	0.05%	0.06%	0.04%	0.06%	0.04%	0.04%	0.04%	0.05%	0.09%	--
38	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.03%	0.04%	0.05%	0.06%	--
39	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%	--
40	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%	0.03%	0.06%	--
THC/ I_{ref}	0.33%	0.35%	0.29%	0.33%	0.31%	0.34%	0.42%	0.48%	0.55%	0.63%	0.80%	13%
PWHC/ I_{ref}	1.42%	1.44%	1.22%	1.32%	0.96%	1.00%	0.99%	1.28%	1.36%	2.00%	2.64%	22%
Supplementary information: N/A												

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4.8	Power quality - TABLE: Calculation of the asymmetry of three-phase inverters					P
Simulated network voltage (V)	L1 (L-N)	230	Frequency (Hz)	50		
	L2 (L-N)	230				
	L3 (L-N)	230				

Test condition:
a) 100 % Rated power ± 5 % PEmax, cos φ = 1;
b) 100 % Rated power ± 5 % PEmax, cos φ = max. under excited;
c) 100 % Rated power ± 5 % PEmax, cos φ = max. over-excited;
d) 50% Rated power ± 5 % PEmax, cos φ = 1;
e) 50% Rated power ± 5 % PEmax, cos φ = max. under excited;
f) 50 % Rated power ± 5 % PEmax, cos φ = max. over-excited.
g) 100% of SEmax consumption power, cosφ=1, for ESS;
h) 50% of SEmax consumption power, cosφ=1, for ESS.

	The maximum unbalance under all condition: (VA)	35.35				
a)	Number	1	2	3	4	5
	L1	9082.95	9080.57	9078.45	9076.16	9072.99
	L2	9075.20	9072.48	9069.68	9067.30	9065.93
	L3	9096.49	9093.75	9091.71	9089.71	9086.63
	Calculation					
	|L1-L2|	7.75	8.09	8.77	8.86	7.06
	|L2-L3|	21.29	21.27	22.03	22.41	20.7
	|L3-L1|	13.54	13.18	13.26	13.55	13.64
	Unbalance	21.29	21.27	22.03	22.41	20.7
	Maximum unbalance	22.41				
b)	Number	1	2	3	4	5
	L1	9094.80	9086.38	9131.37	9138.71	9137.13
	L2	9082.41	9075.11	9165.94	9172.28	9171.25
	L3	9103.83	9095.36	9144.95	9151.63	9149.75
	Calculation					
	|L1-L2|	12.39	11.27	34.57	33.57	34.12
	|L2-L3|	21.42	20.25	20.99	20.65	21.5
	|L3-L1|	9.03	8.98	13.58	12.92	12.62
	Unbalance	21.42	20.25	34.57	33.57	34.12
	Maximum unbalance	34.57				
c)	Number	1	2	3	4	5

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	L1	9100.37	9147.06	9093.15	9145.49	9145.09
	L2	9086.66	9181.18	9079.30	9179.95	9180.44
	L3	9109.48	9161.90	9102.96	9160.16	9159.82
	Calculation					
	|L1-L2|	13.71	34.12	13.85	34.46	35.35
	|L2-L3|	22.82	19.28	23.66	19.79	20.62
	|L3-L1|	9.11	14.84	9.81	14.67	14.73
	Unbalance	22.82	34.12	23.66	34.46	35.35
	Maximum unbalance		35.35			
d)	Number	1	2	3	4	5
	L1	4538.30	4540.35	4542.80	4545.10	4547.66
	L2	4531.00	4533.51	4536.21	4537.80	4540.83
	L3	4542.70	4544.88	4546.95	4548.91	4551.16
	Calculation					
	|L1-L2|	7.30	6.84	6.59	7.30	6.83
	|L2-L3|	11.70	11.37	10.74	11.11	10.33
	|L3-L1|	4.40	4.53	4.15	3.81	3.50
	Unbalance	11.70	11.37	10.74	11.11	10.33
	Maximum unbalance		11.70			
e)	Number	1	2	3	4	5
	L1	5093.97	5092.63	5092.94	5090.61	5089.64
	L2	5106.68	5105.82	5105.42	5103.90	5103.72
	L3	5096.12	5095.47	5095.36	5093.96	5093.15
	Calculation					
	|L1-L2|	12.71	13.19	12.48	13.29	14.08
	|L2-L3|	10.56	10.35	10.06	9.94	10.57
	|L3-L1|	2.15	2.84	2.42	3.35	3.51
	Unbalance	12.71	13.19	12.48	13.29	14.08
	Maximum unbalance		14.08			
f)	Number	1	2	3	4	5
	L1	5093.92	5093.68	5093.76	5093.51	5093.07
	L2	5107.49	5107.35	5107.09	5107.39	5107.12
	L3	5097.32	5098.61	5097.55	5097.75	5097.59
	Calculation					

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	|L1-L2|	13.57	13.67	13.33	13.88	14.05
	|L2-L3|	10.17	8.74	9.54	9.64	9.53
	|L3-L1|	3.40	4.93	3.79	4.24	4.52
	Unbalance	13.57	13.67	13.33	13.88	14.05
	Maximum unbalance	14.05				
Supplementary information:N/A						

4.9.3.2 & 4.9.3.3	**Undervoltage protection & Overvoltage protection**						**P**
Undervoltage threshold stage 1 [27<] setting value				0.85 Un	Disconnect time	100 ms	
Undervoltage threshold stage 2 [27<<] setting value				0.80 Un	Disconnect time	100 ms	
Overvoltage threshold stage 1 [59>] setting value				1.15 Un	Disconnect time	100 ms	
Overvoltage threshold stage 2 [59>>] setting value				1.2 Un	Disconnect time	100 ms	
		1		2		3	
		Value (V)	Time (ms)	Value (V)	Time (ms)	Value (V)	Time (ms)
L1-N voltage	U<	195.13 230.66 230.54	81.16	195.10 230.68 230.55	88.45	195.11 230.63 230.56	70.69
	U<<	183.61 230.67 230.56	81.51	183.59 230.69 230.58	65.72	183.60 230.68 230.56	79.70
	U>	265.53 230.67 230.52	69.17	265.83 230.39 230.17	71.17	265.64 230.63 230.50	71.17
	U>>	276.74 230.65 230.51	81.51	276.74 230.63 230.52	65.72	276.76 230.65 230.53	79.70
L2-N voltage	U<	230.69 194.72 230.54	76.13	230.71 194.89 230.21	63.69	230.34 194.76 230.18	85.08
	U<<	230.69 183.59 230.55	72.54	230.68 183.07 230.53	76.29	230.68 183.59 230.54	66.39
	U>	230.37 265.81 230.20	77.29	230.26 265.87 230.17	64.65	230.45 265.67 230.51	81.37
	U>>	230.35	72.54	230.52	76.29	230.67	66.39

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		276.75 230.53		277.29 230.42		276.73 230.52	
L3-N voltage	U<	230.33 230.46 194.89	79.65	230.38 230.43 194.86	63.05	230.69 230.65 194.67	77.06
	U<<	230.71 230.69 183.49	76.11	230.67 230.67 183.48	76.62	230.80 230.66 183.41	77.90
	U>	230.19 230.31 265.75	78.88	230.46 230.58 265.46	78.64	230.21 230.31 265.75	67.97
	U>>	230.31 230.36 276.31	76.11	230.69 230.64 276.60	76.62	230.65 230.67 276.60	77.90
All voltage	U<	194.80 194.89 194.66	68.84	194.68 194.69 194.48	74.85	194.64 194.64 194.46	73.65
	U<<	183.66 183.62 183.52	73.12	183.95 183.96 183.82	58.01	183.97 183.97 183.92	78.94
	U>	264.72 264.74 264.59	71.39	264.67 264.71 264.57	69.87	264.85 264.89 264.74	70.36
	U>>	276.33 276.38 276.21	73.12	276.33 276.38 276.22	58.01	276.28 276.31 276.13	78.94

Undervoltage threshold stage 1 [27<] setting value	0.85 Un	Disconnect time	100 s
Undervoltage threshold stage 2 [27<<] setting value	0.80 Un	Disconnect time	5 s
Overvoltage threshold stage 1 [59>] setting value	1.15 Un	Disconnect time	100 s
Overvoltage threshold stage 2 [59>>] setting value	1.2 Un	Disconnect time	5 s

		1		2		3	
		Value (V)	Time (s)	Value (V)	Time (s)	Value (V)	Time (s)
L1-N voltage	U<	194.76 230.65 230.55	99.99	194.75 230.67 230.57	99.98	194.76 230.66 230.56	99.97
	U<<	182.83 230.87 230.70	4.97	182.92 230.84 230.70	4.98	182.98 230.86 230.70	4.98

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	U>	265.05 230.65 230.57	99.98	265.33 230.66 230.56	99.98	265.26 230.64 230.57	99.97
	U>>	277.79 230.64 230.52	4.97	277.77 230.64 230.54	4.97	277.73 230.66 230.52	4.97
L2-N voltage	U<	230.71 194.59 230.56	99.97	230.69 194.63 230.57	99.99	230.70 194.86 230.55	99.98
	U<<	230.91 182.44 230.72	4.98	230.91 182.50 230.72	4.99	230.91 182.38 230.71	4.99
	U>	230.70 265.72 230.55	99.97	230.68 265.21 230.54	99.97	230.71 265.49 230.55	99.97
	U>>	230.71 277.62 230.52	4.97	230.70 277.40 230.52	4.97	230.69 277.73 230.52	4.98
L3-N voltage	U<	230.72 230.67 194.80	99.96	230.68 230.67 194.73	99.98	230.70 230.67 194.51	99.98
	U<<	230.87 230.81 182.97	4.99	230.88 230.80 182.66	4.98	230.90 230.81 182.88	4.98
	U>	230.67 230.67 265.55	99.96	230.71 230.63 265.64	99.97	230.71 230.63 265.37	99.98
	U>>	230.69 230.66 277.60	4.98	230.68 230.64 277.56	4.98	230.69 230.62 277.59	4.97
All voltage	U<	195.28 195.13 195.07	99.97	195.23 195.14 195.00	99.98	195.24 195.14 195.01	99.97
	U<<	183.89 183.77 183.73	4.98	183.89 183.78 183.72	4.97	183.90 183.77 183.72	4.97
	U>	264.70 264.69 264.59	99.97	264.49 264.71 264.60	99.97	264.62 264.56 264.45	99.97
	U>>	276.71	4.97	276.71	4.97	276.73	4.96

		276.72 276.54		276.71 276.57		276.73 276.54		
Supplementary information: N/A								

4.9.3.4	Overvoltage 10 min mean protection				P
Test procedure	a) The voltage is maintained at 100% Un for 600s, afterwards the voltage is raised to 112%, the switch off must be within 600s; b) The voltage is maintained at Un for 600s, afterwards the voltage is raised to 108% . The 0switch off should not be activated; c) The voltage is maintained at 106% Un for 600s, afterwards the voltage is raised to 114%. The switch off should be within 225s-375s.				
Overvoltage threshold setting value			253 Va.c.		
L1-N					
a		b		c	
Switch off (Yes/No)	Time (s)	Switch off (Yes/ No)	Time (s)	Switch off (Yes/No)	Time (s)
Yes	497.4	No	/	Yes	296.0
L2-N					
a		b		c	
Switch off (Yes/No)	Time (s)	Switch off (Yes/ No)	Time (s)	Switch off (Yes/No)	Time (s)
Yes	509.6	No	/	Yes	300.8
L3-N					
a		b		c	
Switch off (Yes/No)	Time (s)	Switch off (Yes/ No)	Time (s)	Switch off (Yes/No)	Time (s)
Yes	490.2	No	/	Yes	297.8
All					
a		b		c	
Switch off (Yes/No)	Time (s)	Switch off (Yes/ No)	Time (s)	Switch off (Yes/No)	Time (s)
Yes	462.2	No	/	Yes	266.1
Supplementary information: N/A					

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4.9.3.5 & 4.9.3.6	Underfrequency protection & Overfrequency protectionc						P
underfrequency threshold protection [81<] setting value			47.5 Hz		Disconnect time	0.1 s	
underfrequency threshold protection [81<<] setting value			47.0 Hz		Disconnect time	0.1 s	
Overfrequency threshold protection [81>] setting value			51.5 Hz		Disconnect time	0.1 s	
Overfrequency threshold protection [81>>] setting value			52.0 Hz		Disconnect time	0.1 s	
1) 100%Un							
		1		2		3	
		Value (Hz)	Time (ms)	Value (Hz)	Time (ms)	Value (Hz)	Time (ms)
frequecy	F<	47.50	71.53	47.51	77.83	47.51	76.33
	F<<	47.01	76.59	46.99	67.42	47.01	71.47
	F>	51.50	68.14	51.49	70.76	51.50	67.97
	F>>	51.99	83.23	51.98	75.74	51.98	63.63
underfrequency threshold protection [81<] setting value			47.5 Hz		Disconnect time	100 s	
underfrequency threshold protection [81<<] setting value			47.0 Hz		Disconnect time	5 s	
Overfrequency threshold protection [81>] setting value			51.5 Hz		Disconnect time	100 s	
Overfrequency threshold protection [81>>] setting value			52.0 Hz		Disconnect time	5 s	
2) 100%Un							
		1		2		3	
		Value (Hz)	Time (s)	Value (Hz)	Time (s)	Value (Hz)	Time (s)
frequecy	F<	47.50	99.97	47.51	99.96	47.50	99.97
	F<<	47.01	4.98	47.01	4.97	47.01	4.98
	F>	51.51	99.98	51.52	99.97	51.51	99.97
	F>>	52.02	4.96	52.01	4.97	52.02	4.98
Supplementary information: N/A							

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4.9.4.2	Active methods tested with a resonant circuit										P
No.	P_{EUT} (% of EUT rating)	Reactive Load (% of Q_L)	P_{AC} (% of nominal)	Q_{AC} (% of nominal)	Run on time (ms)	P_{EUT} (kW)	Actual Q_f (L1)	Actual Q_f (L2)	Actual Q_f (L3)	V_{DC} (V)	Remarks
1	100	100	0	0	211.2	25.1	0.999	0.999	1.000	700	Test A at BL
2	66	66	0	0	183.3	16.6	1.001	0.999	1.001	545	Test B at BL
3	33	33	0	0	187.2	8.3	1.001	1.000	0.999	300	Test C at BL
4	100	100	-5	-5	175.8	25.1	1.029	1.028	1.025	700	Test A at IB
5	100	100	-5	0	176.4	25.1	1.052	1.048	1.050	700	Test A at IB
6	100	100	-5	5	175.8	25.1	1.081	1.075	1.075	700	Test A at IB
7	100	100	0	-5	175.2	25.1	0.990	0.985	0.979	700	Test A at IB
8	100	100	0	5	164.0	25.1	1.030	1.021	1.023	700	Test A at IB
9	100	100	5	-5	168.8	25.1	0.940	0.935	0.928	700	Test A at IB
10	100	100	5	0	187.4	25.1	0.958	0.951	0.953	700	Test A at IB
11	100	100	5	5	171.2	25.1	0.984	0.976	0.979	700	Test B at IB
12	66	66	0	-5	169.6	16.6	0.969	0.974	0.970	545	Test B at IB
13	66	66	0	-4	190.6	16.6	0.981	0.987	0.984	545	Test B at IB
14	66	66	0	-3	172.8	16.6	0.974	0.982	0.978	545	Test B at IB
15	66	66	0	-2	166.7	16.6	0.986	0.993	0.990	545	Test B at IB
16	66	66	0	-1	223.5	16.6	0.995	0.991	0.996	545	Test B at IB
17	66	66	0	1	283.3	16.6	0.996	0.993	0.996	545	Test B at IB
18	66	66	0	2	161.9	16.6	0.985	0.990	0.990	545	Test B at IB

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19	66	66	0	3	155.7	16.6	0.977	0.980	0.974	545	Test B at IB
20	66	66	0	4	181.9	16.6	0.980	0.988	0.984	545	Test B at IB
21	66	66	0	5	165.4	16.6	0.970	0.974	0.972	545	Test B at IB
22	33	33	0	-5	198.5	8.3	0.975	0.975	0.974	300	Test C at IB
23	33	33	0	-4	201.0	8.3	0.975	0.979	0.981	300	Test C at IB
24	33	33	0	-3	210.3	8.3	0.981	0.982	0.981	300	Test C at IB
25	33	33	0	-2	165.9	8.3	0.983	0.984	0.984	300	Test C at IB
26	33	33	0	-1	189.6	8.3	0.995	0.995	0.996	300	Test C at IB
27	33	33	0	1	222.9	8.3	1.004	1.003	1.005	300	Test C at IB
28	33	33	0	2	189.9	8.3	1.007	1.006	1.007	300	Test C at IB
29	33	33	0	3	184.4	8.3	1.014	1.014	1.012	300	Test C at IB
30	33	33	0	4	185.9	8.3	1.014	1.016	1.014	300	Test C at IB
31	33	33	0	5	181.2	8.3	1.021	1.022	1.020	300	Test C at IB
Supplementary information: N/A											

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4.10.2 & 4.10.3	Automatic reconnection after tripping & Starting to generate electrical power				P
Automatic reconnection after tripping					
Test 1)					
Test sequence	Freq (Hz)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)		
1.	49.45	0.5 min	No		
2.	49.45	1.0 min	No		
3.	49.45	1.5 min	No		
4.	49.45	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 49.55 Hz (min)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	49.55	0.0 min	--	Reconnection time (s)	66.3
After reconnection					
6.	49.55	0.0 min	46	2487	-
7.	49.55	0.5 min	1286	2491	Yes
8.	49.55	1.0 min	2533	2490	Yes
9.	49.55	1.5 min	3777	2490	Yes
10.	49.55	2.0 min	5023	2496	Yes
11.	49.55	2.5 min	6267	2486	Yes
12.	49.55	3.0 min	7519	2479	Yes
13.	49.55	3.5 min	8753	2489	Yes
14.	49.55	4.0 min	9998	2485	Yes
15.	49.55	4.5 min	11242	2484	Yes
16.	49.55	5.0 min	12483	2483	Yes
17.	49.55	5.5 min	13726	2478	Yes
18.	49.55	6.0 min	14966	2471	Yes
19.	49.55	6.5 min	16204	2462	Yes
20.	49.55	7.0 min	17437	2459	Yes
21.	49.55	7.5 min	18666	2458	Yes
22.	49.55	8.0 min	19896	2453	Yes
23.	49.55	8.5 min	21124	2464	Yes
24.	49.55	9.0 min	22349	2482	Yes
25.	49.55	9.5 min	23588	2480	Yes

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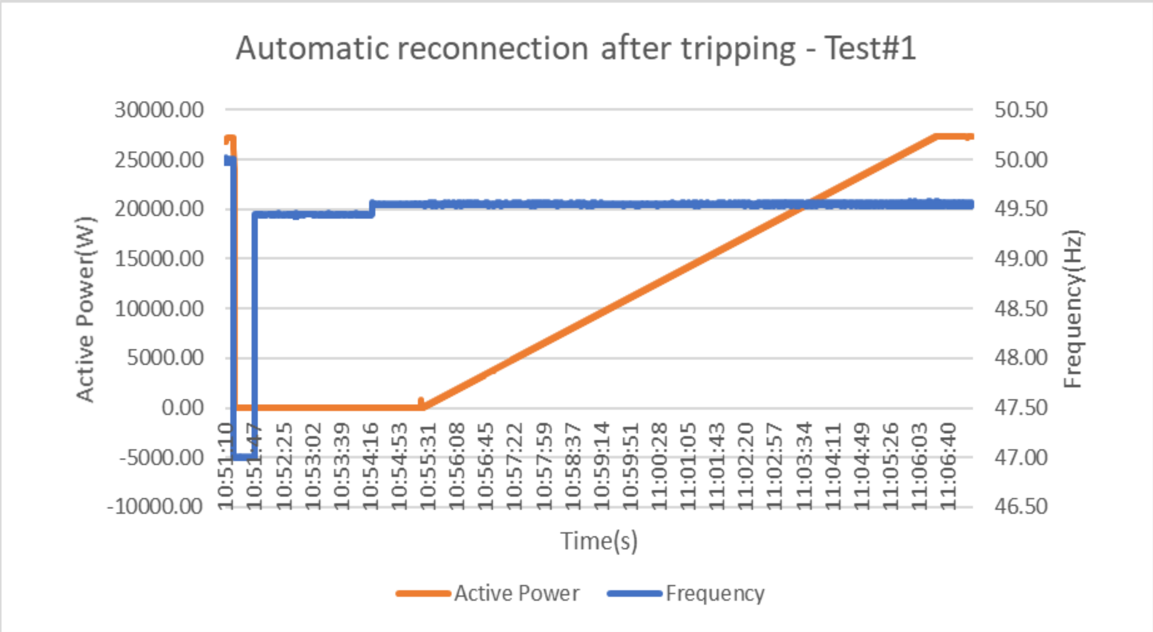
26.	49.55	10.0 min	24831	2448	Yes
27.	49.55	10.5 min	26068	1210	Yes
28.	49.55	11.0 min	27279	--	--
29.	49.55	11.5 min	27278	--	--

Response curve:



Test 2)					
Test sequence	Freq (Hz)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)		
1.	50.25	0.5 min	No		
2.	50.25	1.0 min	No		
3.	50.25	1.5 min	No		
4.	50.25	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 50.15 Hz (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	50.15	0.0 min	--	Reconnection time (s)	66.2
After reconnection					
6.	50.15	0.0 min	51	2494	Yes
7.	50.15	0.5 min	1297	2491	Yes
8.	50.15	1.0 min	2545	2489	Yes
9.	50.15	1.5 min	3788	2487	Yes

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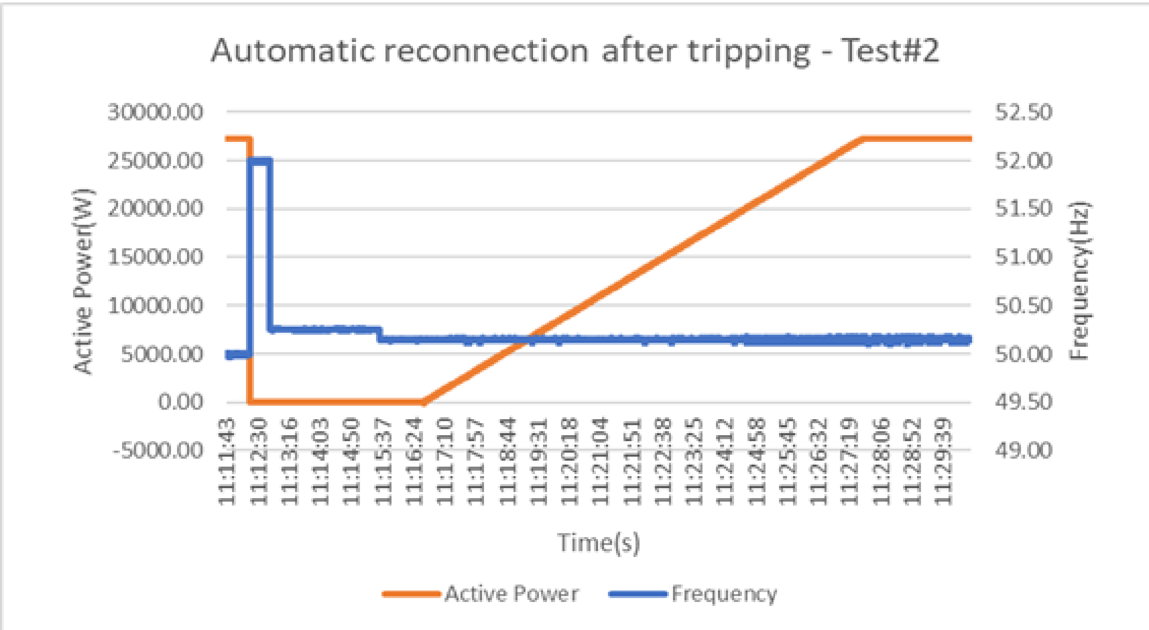
10.	50.15	2.0 min	5034	2483	Yes
11.	50.15	2.5 min	6275	2484	Yes
12.	50.15	3.0 min	7517	2486	Yes
13.	50.15	3.5 min	8759	2486	Yes
14.	50.15	4.0 min	10003	2490	Yes
15.	50.15	4.5 min	11245	2483	Yes
16.	50.15	5.0 min	12493	2478	Yes
17.	50.15	5.5 min	13728	2478	Yes
18.	50.15	6.0 min	14971	2462	Yes
19.	50.15	6.5 min	16206	2467	Yes
20.	50.15	7.0 min	17433	2468	Yes
21.	50.15	7.5 min	18673	2443	Yes
22.	50.15	8.0 min	19901	2445	Yes
23.	50.15	8.5 min	21116	2475	Yes
24.	50.15	9.0 min	22346	2489	Yes
25.	50.15	9.5 min	23591	2472	Yes
26.	50.15	10.0 min	24835	2434	Yes
27.	50.15	10.5 min	26063	1194	Yes
28.	50.15	11.0 min	27269	--	--
29.	50.15	11.5 min	27257	--	--

Response curve:



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Test 3)					
Test sequence	Vol. (V)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)		
1.	84%Un	0.5 min	No		
2.	84%Un	1.0 min	No		
3.	84%Un	1.5 min	No		
4.	84%Un	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 86% Un (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	86%Un	0.0 min	--	Reconnection time (s)	65.8
After reconnection					
6.	86%Un	0.0 min	74	2493	Yes
7.	86%Un	0.5 min	1324	2490	Yes
8.	86%Un	1.0 min	2567	2498	Yes
9.	86%Un	1.5 min	3814	2498	Yes
10.	86%Un	2.0 min	5065	2495	Yes
11.	86%Un	2.5 min	6312	2499	Yes
12.	86%Un	3.0 min	7560	2499	Yes
13.	86%Un	3.5 min	8811	2493	Yes
14.	86%Un	4.0 min	10059	2498	Yes
15.	86%Un	4.5 min	11304	2499	Yes
16.	86%Un	5.0 min	12557	2492	Yes
17.	86%Un	5.5 min	13803	2491	Yes
18.	86%Un	6.0 min	15049	2484	Yes
19.	86%Un	6.5 min	16294	2480	Yes
20.	86%Un	7.0 min	17533	2477	Yes
21.	86%Un	7.5 min	18774	2472	Yes
22.	86%Un	8.0 min	20010	2468	Yes
23.	86%Un	8.5 min	21246	2465	Yes
24.	86%Un	9.0 min	22478	2330	Yes
25.	86%Un	9.5 min	23711	1084	Yes
26.	86%Un	10.0 min	24808	--	--
27.	86%Un	10.5 min	24795	--	--

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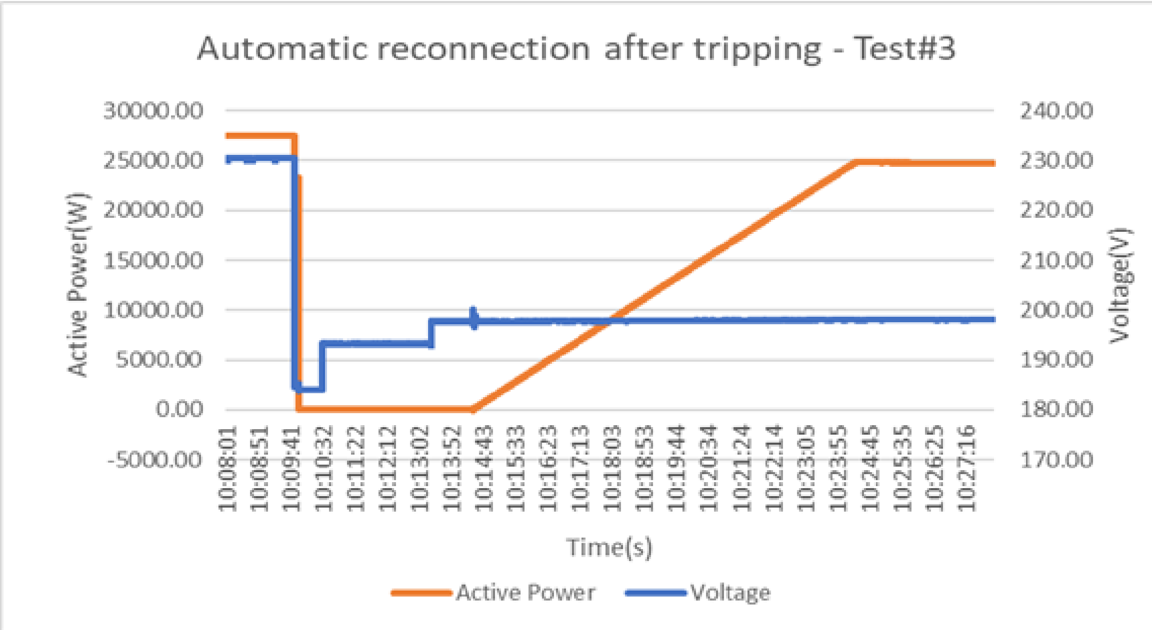
Response curve:



Test 4)					
Test sequence	Vol. (V)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)		
1.	111%Un	0.5 min	No		
2.	111%Un	1.0 min	No		
3.	111%Un	1.5 min	No		
4.	111%Un	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 109% Un (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	109%Un	0.0 min	--	Reconnection time (s)	66.4
After reconnection					
6.	109%Un	0.0 min	70	2488	Yes
7.	109%Un	0.5 min	1307	2499	Yes
8.	109%Un	1.0 min	2558	2499	Yes
9.	109%Un	1.5 min	3806	2500	Yes
10.	109%Un	2.0 min	5057	2497	Yes
11.	109%Un	2.5 min	6306	2497	Yes
12.	109%Un	3.0 min	7554	2496	Yes
13.	109%Un	3.5 min	8803	2494	Yes
14.	109%Un	4.0 min	10050	2496	Yes

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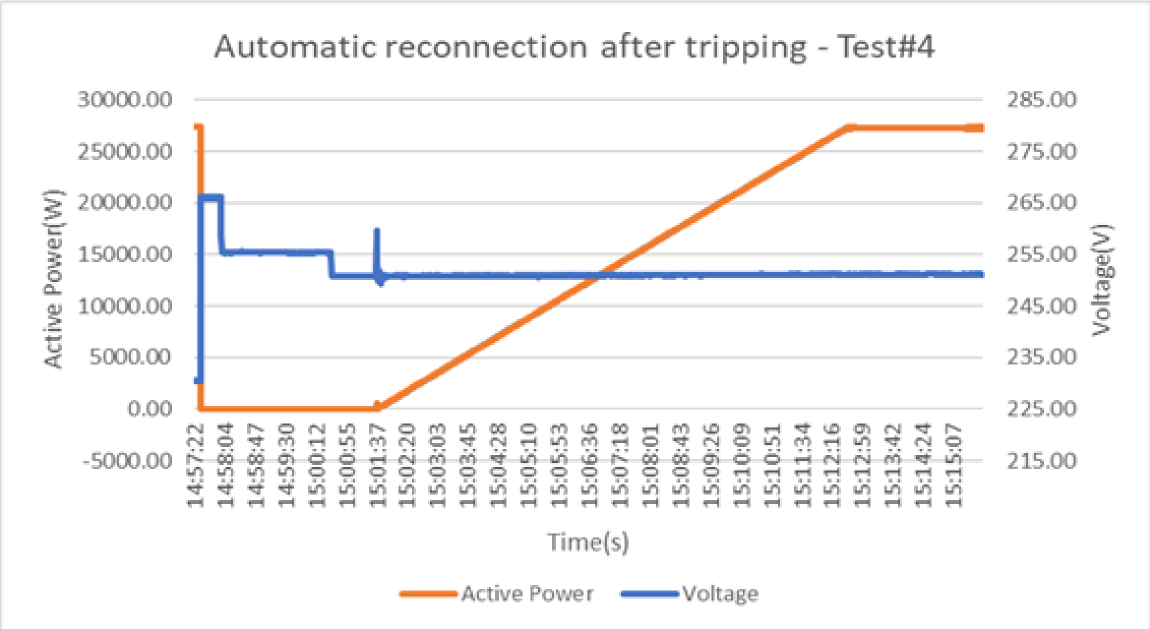
15.	109%Un	4.5 min	11297	2494	Yes
16.	109%Un	5.0 min	12546	2491	Yes
17.	109%Un	5.5 min	13791	2490	Yes
18.	109%Un	6.0 min	15037	2482	Yes
19.	109%Un	6.5 min	16281	2476	Yes
20.	109%Un	7.0 min	17519	2471	Yes
21.	109%Un	7.5 min	18757	2470	Yes
22.	109%Un	8.0 min	19990	2469	Yes
23.	109%Un	8.5 min	21227	2461	Yes
24.	109%Un	9.0 min	22459	2458	Yes
25.	109%Un	9.5 min	23688	2455	Yes
26.	109%Un	10.0 min	24917	2412	Yes
27.	109%Un	10.5 min	26143	1172	--
28.	109%Un	11.0 min	27329	--	--

Response curve:



Starting to generate electrical power			
Test 1)			
Test sequence	Freq (Hz)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)
1.	49.45	0.5 min	No
2.	49.45	1.0 min	No

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3.	49.45	1.5 min	No		
4.	49.45	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 49.55 Hz (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	49.55	0.0 min	--	Reconnection time (s)	66.0
After reconnection					
6.	49.55	0.0 min	62	2487	Yes
7.	49.55	0.5 min	1305	2490	Yes
8.	49.55	1.0 min	2549	2490	Yes
9.	49.55	1.5 min	3795	2487	Yes
10.	49.55	2.0 min	5039	2483	Yes
11.	49.55	2.5 min	6282	2483	Yes
12.	49.55	3.0 min	7522	2488	Yes
13.	49.55	3.5 min	8765	2489	Yes
14.	49.55	4.0 min	10010	2487	Yes
15.	49.55	4.5 min	11254	2487	Yes
16.	49.55	5.0 min	12497	2486	Yes
17.	49.55	5.5 min	13741	2483	Yes
18.	49.55	6.0 min	14983	2478	Yes
19.	49.55	6.5 min	16224	2474	Yes
20.	49.55	7.0 min	17461	2471	Yes
21.	49.55	7.5 min	18698	2466	Yes
22.	49.55	8.0 min	19932	2464	Yes
23.	49.55	8.5 min	21164	2461	Yes
24.	49.55	9.0 min	22396	2456	Yes
25.	49.55	9.5 min	23625	2456	Yes
26.	49.55	10.0 min	24852	2411	Yes

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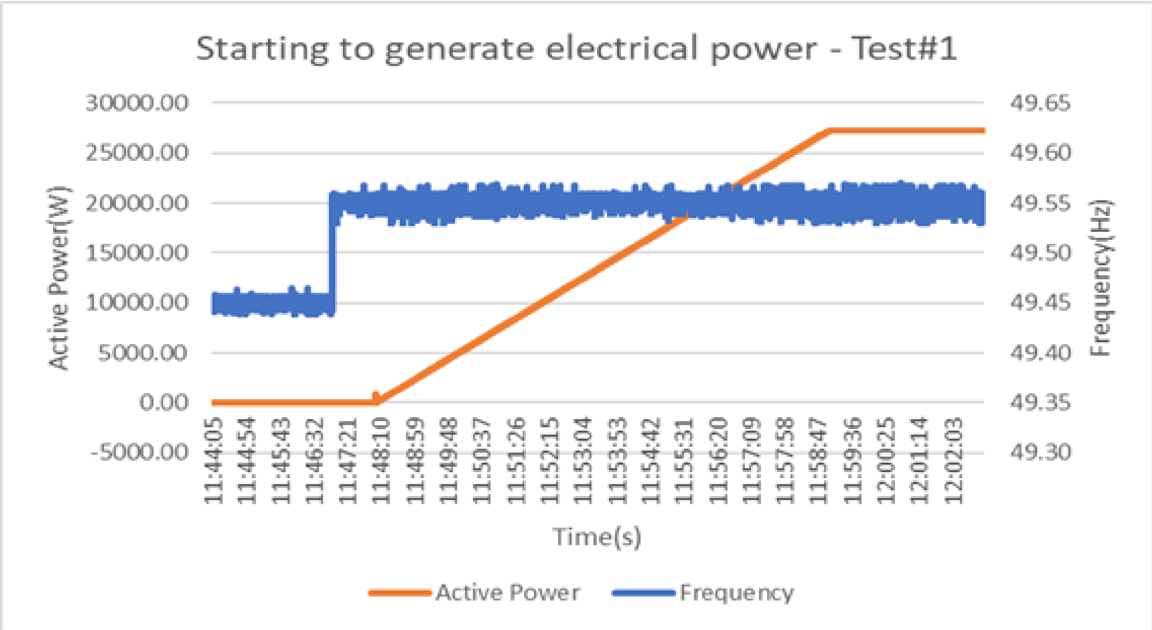
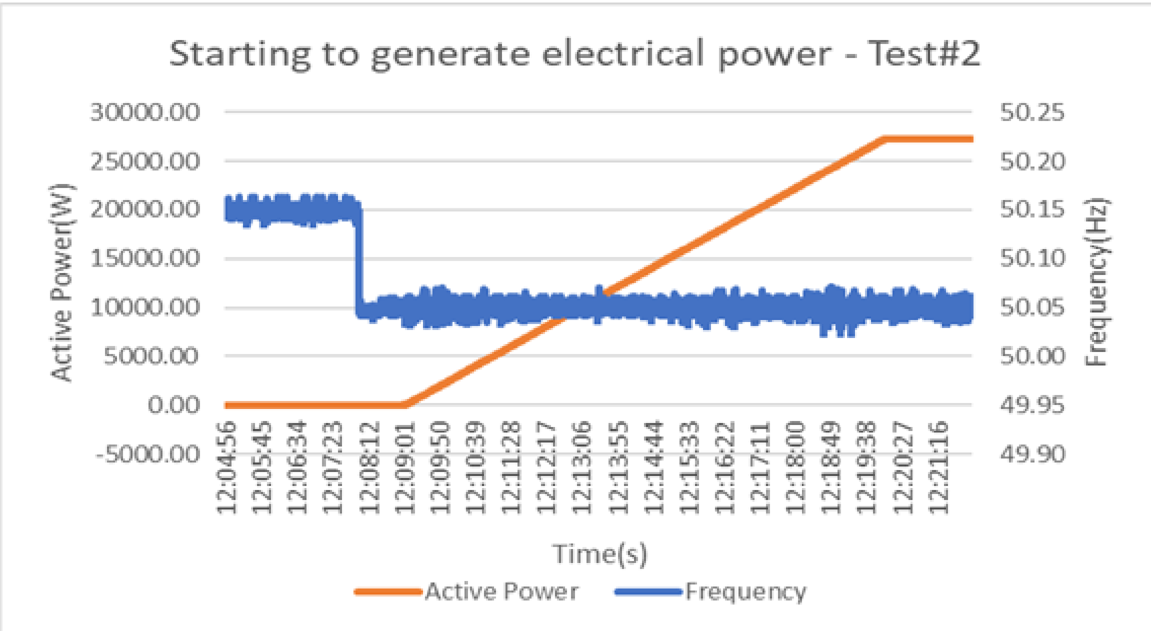
Response curve:



Test 2)					
Test sequence	Freq (Hz)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)		
1.	50.15	0.5 min	No		
2.	50.15	1.0 min	No		
3.	50.15	1.5 min	No		
4.	50.15	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 50.05 Hz (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	50.05	0.0 min	--	Reconnection time (s)	65.4
After reconnection					
6.	50.05	0.0 min	62	2486	Yes
7.	50.05	0.5 min	1301	2492	Yes
8.	50.05	1.0 min	2548	2491	Yes
9.	50.05	1.5 min	3793	2489	Yes
10.	50.05	2.0 min	5039	2484	Yes
11.	50.05	2.5 min	6282	2481	Yes
12.	50.05	3.0 min	7523	2484	Yes
13.	50.05	3.5 min	8763	2489	Yes
14.	50.05	4.0 min	10007	2488	Yes

15.	50.05	4.5 min	11252	2487	Yes
16.	50.05	5.0 min	12495	2486	Yes
17.	50.05	5.5 min	13739	2488	Yes
18.	50.05	6.0 min	14981	2483	Yes
19.	50.05	6.5 min	16227	2467	Yes
20.	50.05	7.0 min	17464	2470	Yes
21.	50.05	7.5 min	18694	2468	Yes
22.	50.05	8.0 min	19934	2458	Yes
23.	50.05	8.5 min	21162	2468	Yes
24.	50.05	9.0 min	22392	2461	Yes
25.	50.05	9.5 min	23630	2457	Yes
26.	50.05	10.0 min	24853	2417	Yes
27.	50.05	10.5 min	26087	1173	--
28.	50.05	11.0 min	27270	--	--

Response curve:



Test 3)*

Test sequence	Vol. (V)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)
1.	84%Un	0.5 min	No
2.	84%Un	1.0 min	No
3.	84%Un	1.5 min	No

4.	84%Un	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 86% Un (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	86%Un	0.0 min	--	Reconnection time (s)	65.8
After reconnection					
6.	86%Un	0.0 min	72	2497	Yes
7.	86%Un	0.5 min	1320	2495	Yes
8.	86%Un	1.0 min	2569	2491	Yes
9.	86%Un	1.5 min	3815	2489	Yes
10.	86%Un	2.0 min	5060	2488	Yes
11.	86%Un	2.5 min	6304	2488	Yes
12.	86%Un	3.0 min	7548	2492	Yes
13.	86%Un	3.5 min	8792	2495	Yes
14.	86%Un	4.0 min	10040	2491	Yes
15.	86%Un	4.5 min	11287	2490	Yes
16.	86%Un	5.0 min	12531	2489	Yes
17.	86%Un	5.5 min	13777	2484	Yes
18.	86%Un	6.0 min	15020	2478	Yes
19.	86%Un	6.5 min	16261	2472	Yes
20.	86%Un	7.0 min	17498	2467	Yes
21.	86%Un	7.5 min	18733	2463	Yes
22.	86%Un	8.0 min	19965	2457	Yes
23.	86%Un	8.5 min	21196	2452	Yes
24.	86%Un	9.0 min	22422	2324	Yes
25.	86%Un	9.5 min	23648	1099	Yes
26.	86%Un	10.0 min	24746	--	Yes
27.	86%Un	10.5 min	24747	--	Yes

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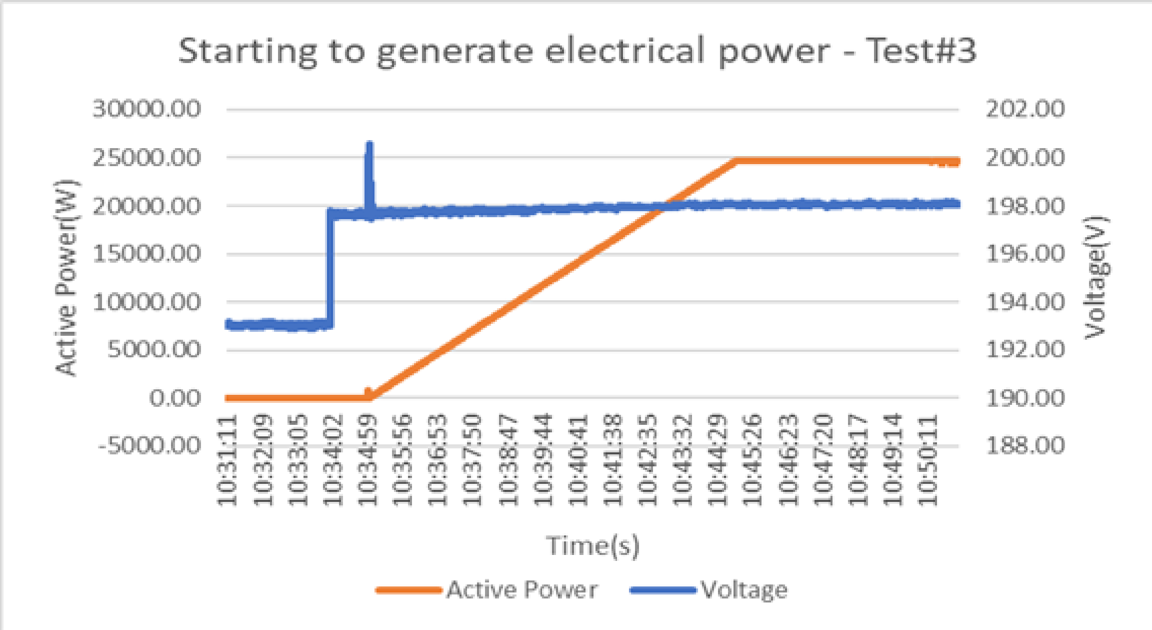
Response curve:



Test 4)					
Test sequence	Vol. (V)	Time stay in step (min.)	Whether reconnect to main and the active power generated? (Yes/No)		
1.	111%Un	0.5 min	No		
2.	111%Un	1.0 min	No		
3.	111%Un	1.5 min	No		
4.	111%Un	2.0 min	No		
Test sequence	Freq (Hz)	Time after reach 109% Un (min.)	Measured charge rate $P_{Measured}$ (W)	Arised charge rate ΔP during next 1 minute (W)	Deviation within 10% P_n (Yes/No)
5.	109%Un	0.0 min	--	Reconnection time (s)	65.4
After reconnection					
6.	109%Un	0.0 min	74	2490	Yes
7.	109%Un	0.5 min	1313	2493	Yes
8.	109%Un	1.0 min	2564	2487	Yes
9.	109%Un	1.5 min	3806	2488	Yes
10.	109%Un	2.0 min	5051	2485	Yes
11.	109%Un	2.5 min	6294	2490	Yes
12.	109%Un	3.0 min	7536	2489	Yes
13.	109%Un	3.5 min	8784	2492	Yes
14.	109%Un	4.0 min	10025	2493	Yes

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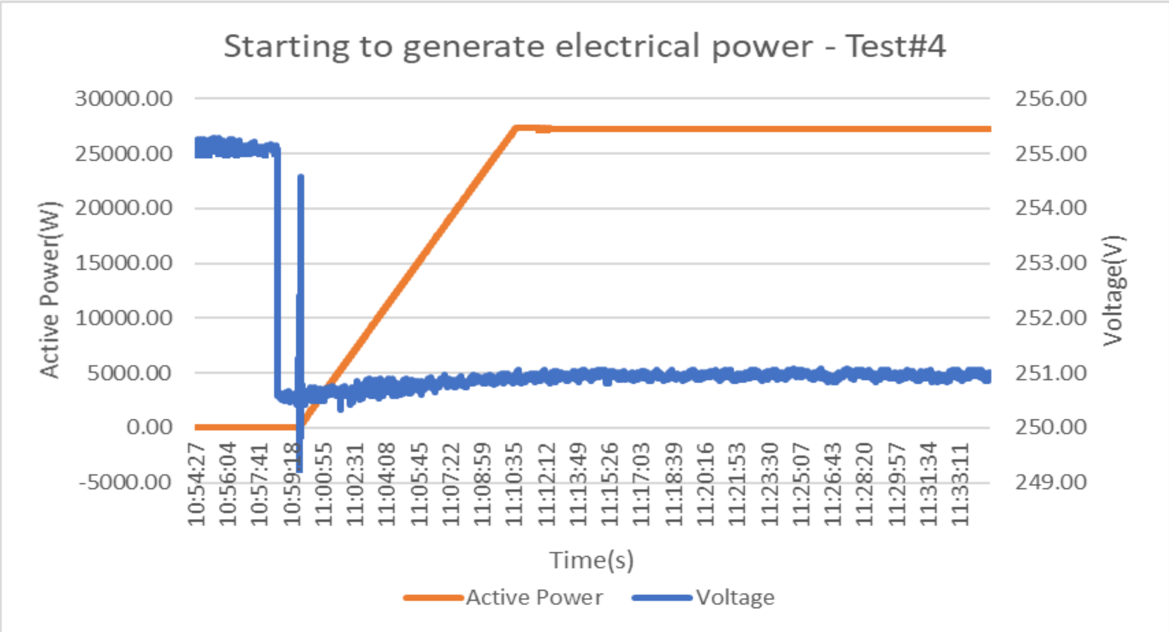
15.	109%Un	4.5 min	11276	2491	Yes
16.	109%Un	5.0 min	12518	2494	Yes
17.	109%Un	5.5 min	13767	2484	Yes
18.	109%Un	6.0 min	15012	2478	Yes
19.	109%Un	6.5 min	16251	2482	Yes
20.	109%Un	7.0 min	17490	2481	Yes
21.	109%Un	7.5 min	18733	2474	Yes
22.	109%Un	8.0 min	19971	2466	Yes
23.	109%Un	8.5 min	21207	2468	Yes
24.	109%Un	9.0 min	22437	2474	Yes
25.	109%Un	9.5 min	23675	2466	Yes
26.	109%Un	10.0 min	24911	2408	Yes
27.	109%Un	10.5 min	26141	1167	Yes
28.	109%Un	11.0 min	27319	--	Yes

Response curve:



Remark:*This case limited by the maximum current, active power cannot reach rated power.

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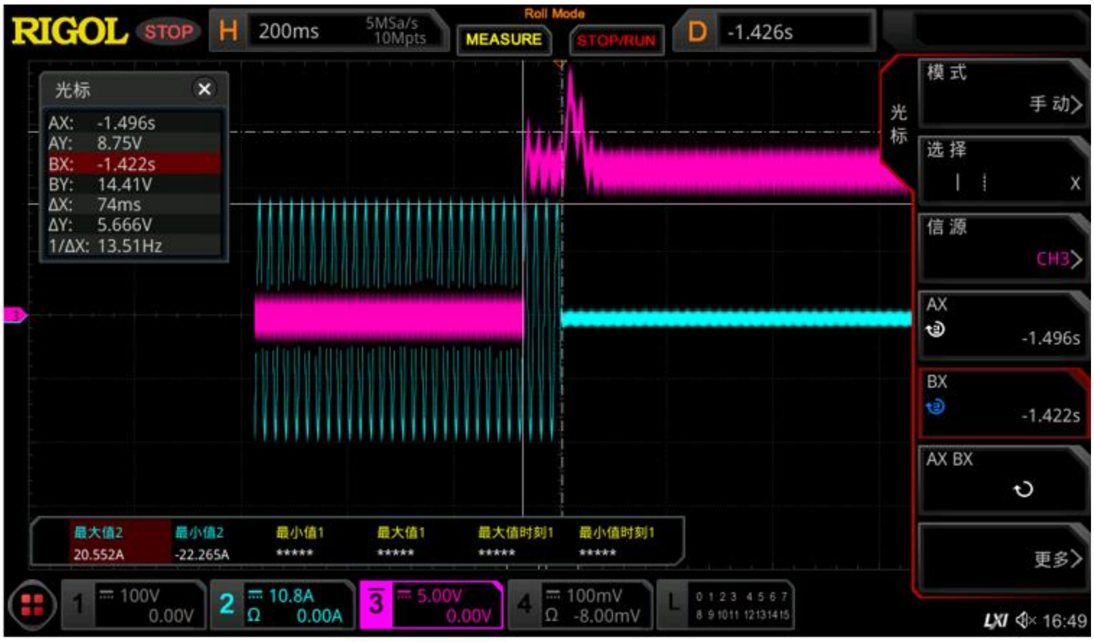
4.11.1	Ceasing active power	P

Result	
Logic interface provided?	Yes
Ceasing active power response time(s)	0.074
stop the generation of active power time(s)	0.074

Ceasing active power log:



CH2: A phase current
CH3: Signal

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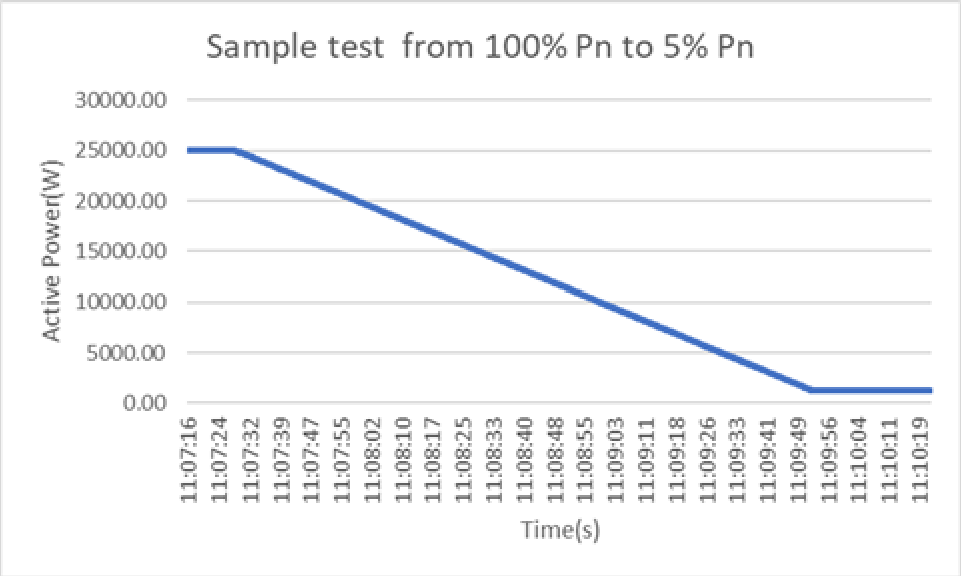
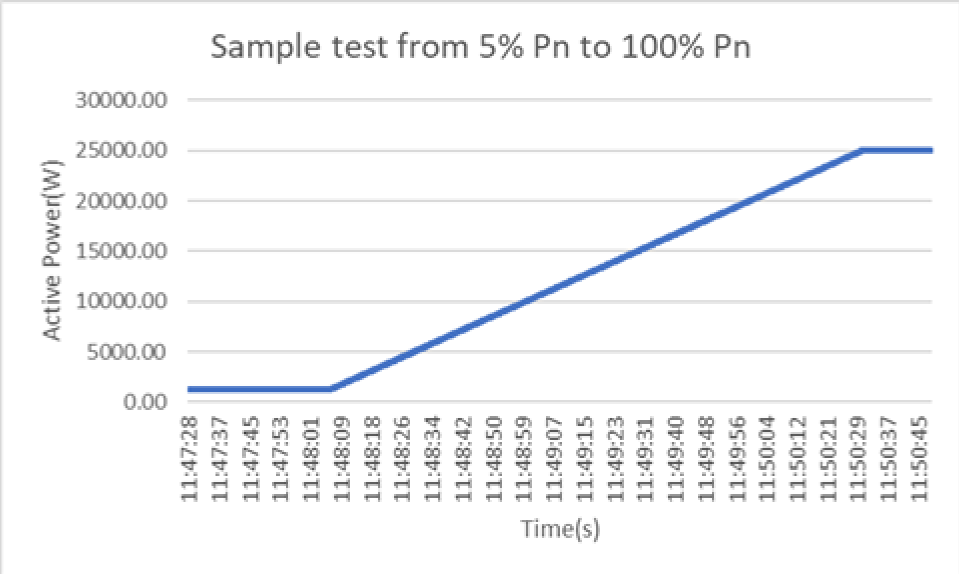
4.11.2	Reduction of active power on set point								P
P/P_{Emax} (%)	100	90	80	70	60	50	40	30	20	10
Setting value (W)	25000	22500	20000	17500	15000	12500	10000	7500	5000	2500
Measured value (W)	24914	22417	19928	17437	14950	12462	9972	7480	4985	2490
Deviation(%Pn)	0.34	0.33	0.29	0.25	0.20	0.15	0.11	0.08	0.06	0.04
Maximum active power gradient (0.66% Pn inst (or P controllable) per second)										
Sample test from 100% P_n to 5% P_n, settling time [s]						144.6				
Sample test from 100% P_n to 5% P_n Gradient [%P_n/s], (see the graphic below):						0.657				

Sample test from 100% Pn to 5% Pn Gradient:



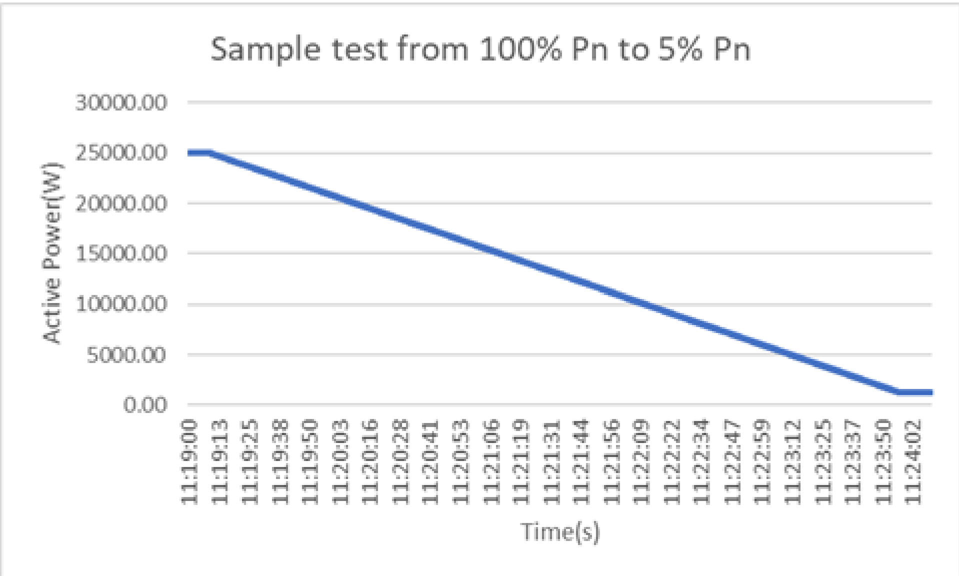
Sample test from 5% P_n to 100% P_n, settling time [s], (see the graphic below):	144.4
Sample test from 5% P_n to 100% P_n Gradient [%P_n/s], (see the graphic below):	0.658

Sample test from 5% Pn to 100% Pn Gradient:



Minimum active power gradient(0.33% Pn inst (or P controllable) per second)	
Sample test from 100% P_n to 5% P_n, settling time [s], (see the graphic below):	287.8
Sample test from 100% P_n to 5% P_n Gradient [%P_n/s], (see the graphic below):	0.330

Sample test from 100% Pn to 5% Pn Gradient:



Sample test from 5% P_n to 100% P_n, settling time [s], (see the graphic below):	286.4
Sample test from 5% P_n to 100% P_n Gradient [%P_n/s], (see the graphic below):	0.332

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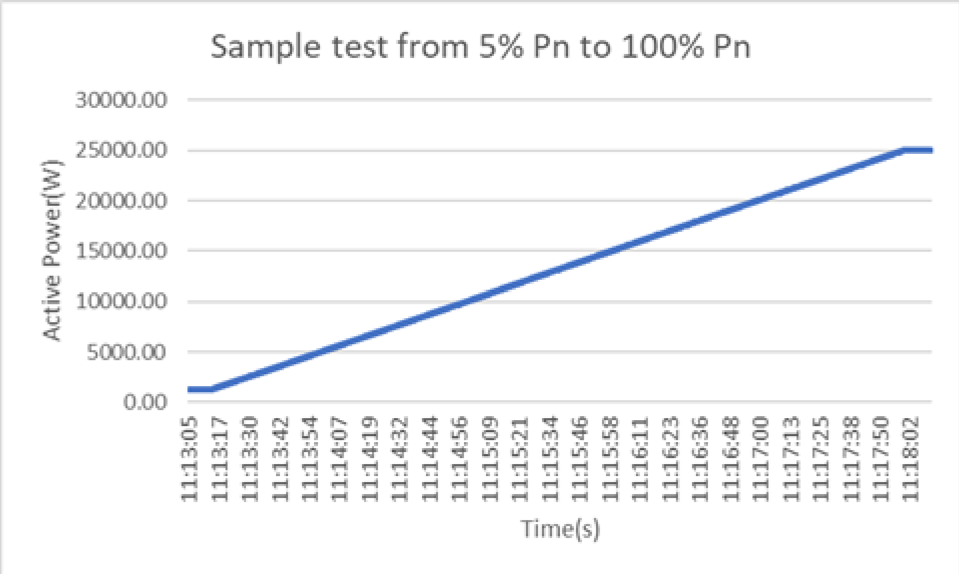
Sample test from 5% Pn to 100% Pn Gradient:		
		
During the active power regulation, the PGU disconnect from the grid or not?	No disconnection	
	Disconnection power level	-
Supplementary information: N/A		

. ……………………………….…………………End of test report……………………..……………………………..

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