# TEST REPORT
# EN 50549-1:2019/AC:2019
## TÜV SÜD 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. ..... : | 64.290.24.31527.01 |
| Date of issue ..... : | 2024-12-10 |
| Project handler ..... : | Luke Lu |
| Name of Testing Laboratory preparing the Report ..... : | TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch |
| Address ..... : | 5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou 510656, China |
| Client ..... : | Huawei Digital Power Technologies Co., Ltd. |
| Client number ..... : | 114387 |
| Address ..... : | Office 01, 39th Floor, Block A, Antuoshan Headquarters Towers, 33 Antuoshan 6th Road, Futian District, 518043 Shenzhen, PEOPLE'S REPUBLIC OF CHINA |
| Standard ..... : | This TÜV SÜD 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.00/2019-04 |
| TRF originated by ..... : | TÜV SÜD 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 TÜV SÜD Product Service.<br>TÜV SÜD 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 ..... : | ☐ TUV Mark ☒ Type verification of conformity<br>☐ GS Mark ☐ NRTL Mark ☐ other:<br>☐ AoC/CoC for EU-Directive / EU-Regulation: |
| Non-standard test method ..... : | ☒ No ☐ Yes, see details under Summary of testing |
| National deviations ..... : | Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Type A rev.0/2018-12, PTPiREE:2021 |
| Number of pages (*Report*) ..... : | 86 |
| Number of pages (*Attachments*) ..... : | N/A |
| Compiled by (name, function, signature) ..... : | Luke Lu<br>(Project Handler) |
| Approved by (name, function, function, signature) ..... : | Kennen Wang<br>(Designated Reviewer) |



Telephone : +86 20 38320668
Telefax : +86 20 38320478
www.tuvsud.com

TÜV SÜD Certification and Testing (China) Co., Ltd.
Guangzhou Branch
5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou 510656, China

| | |
|---|---|
| Test sample .....: | PV Inverter |
| Trademark .....: |  |
| Model and/ or type reference.....: | SUN2000-3K-LB0, SUN2000-3.68K-LB0, SUN2000-4K-LB0, SUN2000-4.6K-LB0, SUN2000-5K-LB0, SUN2000-6K-LB0, SUN5000-3K-LB0, SUN5000-6K-LB0 |
| Rating(s) .....: | See ratings on pages 6-7 |
| Manufacturer.....: | Huawei Digital Power Technologies Co., Ltd. |
| Manufacturer number .....: | 114387 |
| Address.....: | 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) .....: | N/A |
| Name .....: | N/A |
| Order description… .....: | ☒ Complete test according to TRF |
| | ☐ Partial test according to manufacturer's specifications |
| | ☐ Preliminary test |
| | ☐ Spot check |
| | ☐ Others: |
| Date of order.....: | 2024-09-20 |
| Date of receipt of test item.....: | 2024-09-24 |
| Date(s) of performance of test.....: | 2024-09-24 to 2024-11-27 |

Test item particulars:

All the tests' results confirmed to the requirements of the standard.

**General remarks:**

"(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.
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**Revision History:**

N/A



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| **Test item particulars:** | |
|---|---|
| Equipment mobility..... : | ☐ movable ☐ hand-held ☒ stationary<br>☒ fixed ☐ transportable ☐ for building-in |
| Connection to the mains ..... : | ☐ pluggable equipment ☐ direct plug-in<br>☒ permanent connection ☐ for building-in |
| Environmental 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<br>☐ Not classified |
| Mass of equipment (kg) ..... : | 15 |
| Pollution degree..... : | External (PD3), Internal (PD2) |
| IP protection class ..... : | IP66 |
| **Additional information on non-standard test method(s):** | |
| Sub clause ..... : | N/A |
| Page ..... : | N/A |
| Rational..... : | N/A |
| **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 was not evaluated for the requirement..... : | N/E (Not evaluated) |
| Test object does not meet the requirement.... : | F (Fail) |
| **Name and address of factory (ies)** (only if certification is provided)**:** | |
| Name: Huizhou Huazhi New Energy Technology Co., Ltd.<br>Address: No.8, Xinhua Avenue, Chenjiang Street, Zhongkai High-tech Zone, 516032 Huizhou, PEOPLE'S REPUBLIC OF CHINA | |



Telephone : +86 20 38320668
Telefax : +86 20 38320478

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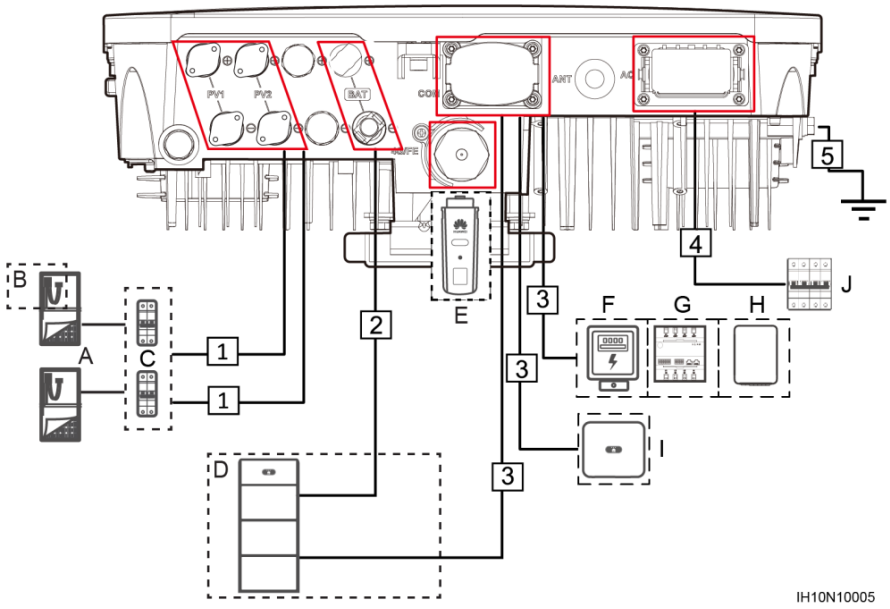
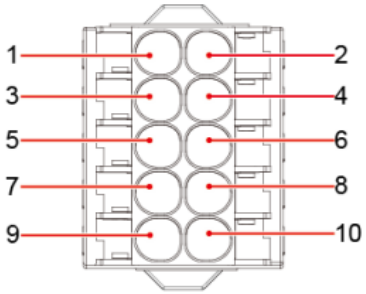
5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou 510656, China

**Purpose of the product** (description of intended use)**:**

1. This unit is non-isolated (transformerless) PV inverter for connection with public low voltage grid.
2. This unit is classified as the type A power-generating module according to the Regulation (EU) 2016/631 (NC RfG). The balancing devices must be used at the time of final installation to ensure that the asymmetry of generated power ≤ 3.68 kW.
3. If certain functions are not permitted by local regulation, the function shall be disabled by hardware or software setting (if applicable) by the manufacturer before putting into the market. For example, it's not permissible to draw electricity from the grid and then feed it back in order to claim statutory reimbursement in some nations.
4. Low voltage electrical installations shall comply with national and local regulation. Only qualified electricians are allowed to install and maintain the converter.
5. 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.
6. COM port as the logical interface of the unit, can be used to implement remote control functions.



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| Pin | Definition | Function | Description |
|---|---|---|---|
| 1 | 485B1 | RS485B, RS485 differential signal– | Used for cascading inverters or connecting to the RS485 signal port of the EMMA or SmartGuard. When cascaded inverters and the EMMA coexist, they share the 485B1 and 485A1 ports.<br>**NOTE**<br>Inverters cannot be cascaded in the SmartGuard networking. |
| 2 | 485A1 | RS485A, RS485 differential signal+ | |
| 3 | 485B2 | RS485B, RS485 differential signal– | Used to connect to the RS485 signal ports on the batteries and power meters. When batteries and power meters coexist, they share the 485B2 and 485A2 ports. |
| 4 | 485A2 | RS485A, RS485 differential signal+ | |
| 5 | GND | GND | Used to connect to the GND of the enable signal/DI1/DI2 of the battery. |
| 6 | EN+ | Enable signal | Used to connect to the enable signal of the battery. |
| 7 | DI1 | Digital input signal 1+ | Used to connect to the positive terminal of DI1. It can connect to the DRM0 scheduling signal or serve as a port for rapid shutdown signals. |
| 8 | DI2 | Digital input signal 2+ | Used to connect to the positive terminal of DI2. It serves as the feedback signal port of the SmartGuard. |
| 9 | GND | GND | Used to connect to the GND of the enable signal/DI1/DI2 of the battery. |
| 10 | PE | Shield layer grounding | - |

7. Software version: V300R024, Firmware version: V300R024.

**Model difference:**

SUN2000-6K-LB0, SUN2000-5K-LB0, SUN2000-4K-LB0, SUN2000-3K-LB0, SUN2000-4.6K-LB0, SUN2000-3.68K-LB0 have same electric circuits topology design, enclosure structure design, main control circuits and firmware.

SUN5000-6K-LB0, SUN5000-3K-LB0 have same electric circuits topology design, enclosure structure design, main control circuits and firmware.

The different output power and current are limited by software.

External optimizer which connected to PV side is optional for SUN2000 series inverters, but mandatory for SUN5000 series inverters. Internal for grid software control is same for this two series.



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**Characteristic data** (not shown on the marking plate)**:**

| Model | SUN2000-3K-LB0 | SUN2000-3.68K-LB0 | SUN2000-4K-LB0 |
|---|---|---|---|
| PV terminal parameters | | | |
| Maximum PV voltage [$V_{DC}$] | 600 | | |
| Rated voltage [$V_{DC}$] | 360 | | |
| MPPT voltage range [$V_{DC}$] | 40 ÷ 560 | | |
| MPPT voltage range (full load) [$V_{DC}$] | 120 ÷ 480 | 140 ÷ 480 | 155 ÷ 480 |
| Maximum input current [$A_{DC}$] | 16/16 | | |
| Isc PV [$A_{DC}$] | 20/20 | | |
| MPPT tracker number | 2 | | |
| Maximum input power [W] | 4500 | 5520 | 6000 |
| Grid terminal output parameters | | | |
| Rated output voltage [$V_{AC}$] | 1P+N+PE, 230 | | |
| Rated output frequency [Hz] | 50 | | |
| Rated output current [$A_{AC}$] | 13.0 | 16.0 | 17.4 |
| Maximum continuous output current [$A_{AC}$] | 15.0 | 16.0 | 20.0 |
| Rated output active power [W] | 3000 | 3680 | 4000 |
| Maximum output active power [W] | 3300 | 3680 | 4400 |
| Maximum output apparent power [VA] | 3300 | 3680 | 4400 |
| Power factor range | 0.8 inductive ÷ 0.8 capacitive | | |

| Model | SUN2000-4.6K-LB0 | SUN2000-5K-LB0 | SUN2000-6K-LB0 |
|---|---|---|---|
| PV terminal parameters | | | |
| Maximum PV voltage [$V_{DC}$] | 600 | | |
| Rated voltage [$V_{DC}$] | 360 | | |
| MPPT voltage range [$V_{DC}$] | 40 ÷ 560 | | |
| MPPT voltage range (full load) [$V_{DC}$] | 180 ÷ 530 | 190 ÷ 530 | 230 ÷ 530 |
| Maximum input current [$A_{DC}$] | 16/16 | | |
| Isc PV [$A_{DC}$] | 20/20 | | |
| MPPT tracker number | 2 | | |
| Maximum input power [W] | 6900 | 7500 | 9000 |
| Grid terminal output parameters | | | |
| Rated output voltage [$V_{AC}$] | 1P+N+PE, 230 | | |
| Rated output frequency [Hz] | 50 | | |
| Rated output current [$A_{AC}$] | 20.0 | 21.7 | 26.1 |
| Maximum continuous output current [$A_{AC}$] | 23.0 | 25.0 | 30.0 |
| Rated output active power [W] | 4600 | 5000 | 6000 |
| Maximum output active power [W] | 5000 | 5500 | 6600 |
| Maximum output apparent power [VA] | 5000 | 5500 | 6600 |
| Power factor range | 0.8 inductive ÷ 0.8 capacitive | | |



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| Model | SUN5000-3K-LB0 | SUN5000-6K-LB0 |
|---|---|---|
| PV terminal parameters | | |
| Maximum PV voltage [$V_{DC}$] | 600 | |
| Rated voltage [$V_{DC}$] | 360 | |
| MPPT voltage range [$V_{DC}$] | 40 ÷ 560 | |
| MPPT voltage range (full load) [$V_{DC}$] | 120 ÷ 480 | 230 ÷ 530 |
| Maximum input current [$A_{DC}$] | 16/16 | |
| Isc PV [$A_{DC}$] | 20/20 | |
| MPPT tracker number | 2 | |
| Maximum input power [W] | 4500 | 9000 |
| Grid terminal output parameters | | |
| Rated output voltage [$V_{AC}$] | 1P+N+PE, 230 | |
| Rated output frequency [Hz] | 50 | |
| Rated output current [$A_{AC}$] | 13.0 | 26.1 |
| Maximum continuous output current [$A_{AC}$] | 15.0 | 30.0 |
| Rated output active power [W] | 3000 | 6000 |
| Maximum output active power [W] | 3300 | 6600 |
| Maximum output apparent power [VA] | 3300 | 6600 |
| Power factor range | 0.8 inductive ÷ 0.8 capacitive | |

**Attachments:**

N/A

**If additional information is necessary, please provide:**

N/A



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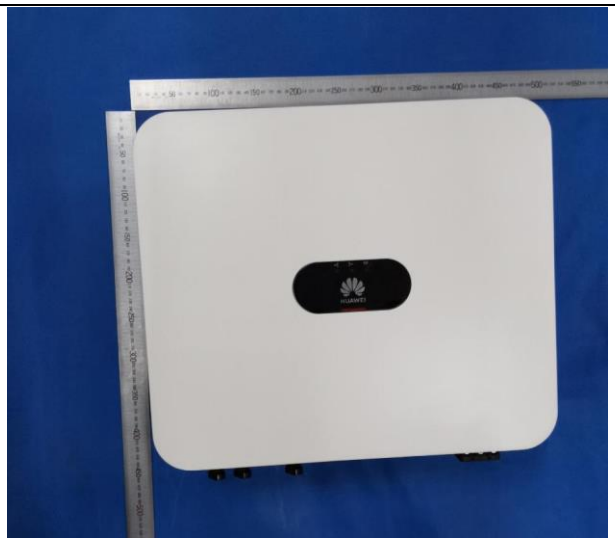
**Pictures of the product:**



Front view



Rear view



Left side view



Right side view



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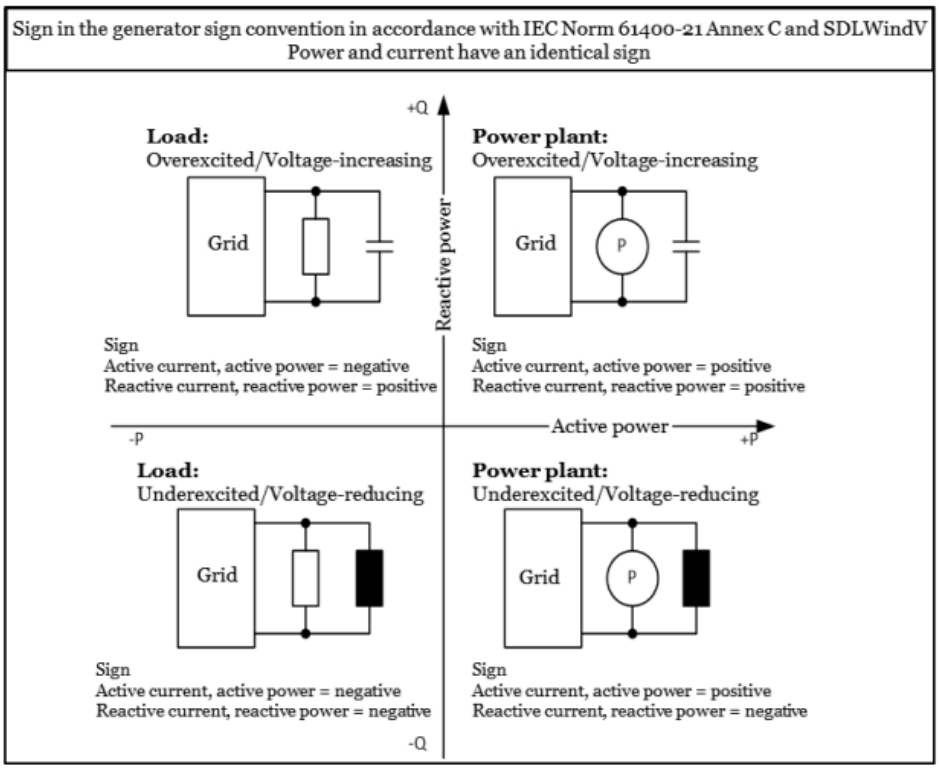
**Summary of testing:**

1. EN 50549-1:2019/AC:2019
2. Regulation (EU) 2016/631 (NC RfG) – Article 13 General requirements for Type A power-generating modules
3. Poland Deviation of Regulation (EU) 2016/631 (NC RfG) rev.0/2018-12 – 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<br>P > 0, the equipment supplies active power to the mains (Discharge mode)<br>Q < 0, the equipment draws reactive power from the mains (Inductive behavior) | I. Quadrant<br>P > 0, the equipment supplies active power to the mains (Discharge mode)<br>Q > 0, the equipment supplies reactive power to the mains (Capacitive behavior) |
| Consumer (Charge mode) | III. Quadrant<br>P < 0, the equipment draws active power from the mains (Charge mode)<br>Q < 0, the equipment draws reactive power from the mains (Inductive behavior) | II. Quadrant<br>P < 0, the equipment draws active power from the mains (Charge mode)<br>Q > 0, the equipment supplies reactive power to the mains (Capacitive behavior) |

Remark: For PV Inverter only consider Generator (PV generation) with Inductive (under-excited) or Capacitive(over-excited) behavior in this report.

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**Tests performed (name of test and test clause):**

| Clause of RfG:2016 | Clause of NC RfG:2018 | Clause of EN 50549-1 | Requirement + Test |
|---|---|---|---|
| Article 13.1 (a) | Article 13.1 (a) (i) | 4.4.2 | Frequency range |
| Article 13.1 (b) | Article 13.1 (b) | 4.5.2 | Ability to withstand the rate of change of frequency (RoCoF) df/dt |
| Article 13.2(*) | Article 13.2 (a) (b) (f) | 4.6.1 | Power generating module operating mode in which the generated active power decreases in response to an increase in system frequency above a specified value (LFSM-O) |
| Article 13.4 & 13.5 | Article 13.4 | 4.4.3 | Maximum power capability reduction with falling frequency |
| Article 13.6 | Article 13.6 | 4.11.1 | Remote ceasing active power generation |
| Article 13.7 & 14.4 | Article 13.7 & 14.4 (a) | - | Automatic connection to the network |
| - | - | 4.7.2.3.3 | Voltage support by reactive power - Voltage related control mode & Q set control mode & PF set control mode ** |
| - | - | 4.7.2.3.4 | Power related Control mode (cos φ (P) controls) ** |
| - | - | 4.9 | Interface protection ** |

Remark:

If no specify, all the tests were conducted on model SUN2000-6K-LB0.

* Article 13.2 lit. b) only applies to PPM type A according to the RfG:2016.

**The parameter setting of EN 50549-1 is according to Appendix I of IRiESD.

**Testing location:**

TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch

B1F&2F of A4, D1 Buildings, No. 63 Chuangqi Road, Shilou Town, Panyu District, Guangzhou 511447, China



Telephone : +86 20 38320668
Telefax : +86 20 38320478

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| EN 50549-1:2019/AC:2019 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |

| | | | |
|---|---|---|---|
| **4** | **Requirements on generating plants** | | P |
| **4.1** | **General** | | P |
| **4.2** | **Connection scheme** | | P |
| **4.3** | **Choice of switchgear** | | P |
| 4.3.1 | General | | P |
| 4.3.2 | Interface switch | | P |
| **4.4** | **Normal operating range** | | P |
| 4.4.1 | General | Evaluated with Article 13.1 (a) according to Poland Deviation of Regulation (EU) 2016/631 (NC RfG) | P |
| 4.4.2 | Operating frequency range | See table below, Test from 47.5Hz to 51.5Hz | P |
| 4.4.3 | Minimal requirement for active power delivery at underfrequencies | See table below | P |
| 4.4.4 | Continuous operating voltage range | Evaluated with Article 13.4 & 13.5 according to Poland Deviation of Regulation (EU) 2016/631 (NC RfG) | P |
| **4.5** | **Immunity to disturbances** | | P |
| 4.5.1 | General | Evaluated with Article 13.1 (b) according to Poland Deviation of Regulation (EU) 2016/631 (NC RfG) | P |
| 4.5.2 | Rate of change of frequency (ROCOF) immunity | See below table.<br>Test under the rate of 2.0 Hz/s | P |
| 4.5.3 | Under-voltage ride through (UVRT) | No suit for type A | N/A |
| 4.5.4 | Over-voltage ride through (OVRT) | | N/A |
| **4.6** | **Active response to frequency deviation** | | |
| 4.6.1 | Power response to overfrequency | Evaluated with Article 13.2 according to Poland Deviation of | P |



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| EN 50549-1:2019/AC:2019 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | | Regulation (EU) 2016/631 (NC RfG)<br>The default threshold setting is of 50.2 Hz, statism capacity is 5% | |
| 4.6.2 | Power response to underfrequency | | P |
| **4.7** | **Power response to voltage changes** | | P |
| 4.7.1 | General | | P |
| 4.7.2 | Voltage support by reactive power | | P |
| 4.7.2.1 | General | See table below | P |
| 4.7.2.2 | Capabilities | 0.8 inductive to 0.8 capacitive | P |
| 4.7.2.3 | Control modes | PF set, Q(U), Cosφ(P) modes | P |
| 4.7.2.3.1 | General | | P |
| 4.7.2.3.2 | Setpoint control modes | PF setting is 0.8 inductive to 0.8 capacitive for the test | P |
| 4.7.2.3.3 | Voltage related control modes | Q(U) control mode, voltage setting is 1.06Un to 1.08Un for Qmin for single phase inverter. | P |
| 4.7.2.3.4 | Power related Control mode | Cosφ(P) | P |
| 4.7.3 | Voltage related active power reduction | | N/A |
| 4.7.4 | Short circuit current requirements on generating plants | | N/A |
| 4.7.4.1 | General | | 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 |
| 4.7.4.2.2 | Zero current mode for converter connected generating technology | | N/A |
| 4.7.4.2.3 | Induction generator based units | | N/A |
| 4.7.4.3 | Generating plant with synchronous generating technology - Synchronous generator based units | | N/A |
| 4.8 | EMC and power quality | | N/A |
| **4.9** | **Interface protection** | | P |


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| EN 50549-1:2019/AC:2019 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| 4.9.1 | General | | P |
| 4.9.2 | Voltage transformer | | N/A |
| 4.9.3 | Requirements on voltage and frequency protection | See table below | P |
| 4.9.3.1 | General | | P |
| 4.9.3.2 | Undervoltage protection [27] | 0.85Un, 1.2-1.5s | P |
| 4.9.3.3 | Overvoltage protection [59] | 1.15Un, 0.1-0.2s | P |
| 4.9.3.4 | Overvoltage 10 min mean protection | 1.1Un, 3s | P |
| 4.9.3.5 | Underfrequency protection [81<] | 47.5Hz, 0.3-0.5s | P |
| 4.9.3.6 | Overfrequency protection [81>] | 52.0Hz, 0.3-0.5s | P |
| 4.9.3.7 | Positive sequence undervoltage protection [27D] | | N/A |
| 4.9.3.8 | Negative sequence overvoltage protection [47] | | N/A |
| 4.9.3.9 | Zero sequence overvoltage protection [59N] | | N/A |
| 4.9.4 | Means to detect island situation | | P |
| 4.9.4.1 | General | | P |
| 4.9.4.2 | Active methods tested with a resonant circuit | See table below | P |
| 4.9.4.3 | Switch to narrow frequency band (see Annex E and Annex F) | | N/A |
| 4.9.5 | Digital input to the interface protection | | N/A |
| **4.10** | **Connection and starting to generate electrical power** | | P |
| 4.10.1 | General | See table below | P |
| 4.10.2 | Automatic reconnection after tripping | Reconnection point is 49.00Hz and 50.05Hz, default delay time is 60s | P |
| 4.10.3 | Starting to generate electrical power | | P |
| 4.10.4 | Synchronization | | N/A |
| **4.11** | **Ceasing and reduction of active power on set point** | | P |
| 4.11.1 | Ceasing active power | See table below | P |
| 4.11.2 | Reduction of active power on set point | | N/A |
| **4.12** | **Remote information exchange** | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| Article 13.1 | Type A power-generating modules shall fulfil the following requirements relating to frequency stability: | | P |
| | (a) With regard to frequency ranges: | See table below | P |
| | (i) a power-generating module shall be capable of remaining connected to the network and operate within the frequency ranges and time periods specified in Table 2; | | P |
| | (ii) the relevant system operator, in coordination with the relevant TSO, and the power-generating facility owner may agree on wider frequency ranges, longer minimum times for operation or specific requirements for combined frequency and voltage deviations to ensure the best use of the technical capabilities of a power-generating module, if it is required to preserve or to restore system security; | | P |
| | (iii) the power-generating facility owner shall not unreasonably withhold consent to apply wider frequency ranges or longer minimum times for operation, taking account of their economic and technical feasibility. | | P |
| | (b) With regard to the rate of change of frequency withstand capability, a power-generating module shall be capable of staying connected to the network and operate at rates of change of frequency up to a value specified by the relevant TSO, unless disconnection was triggered by rate-of-change-of-frequency-type loss of mains protection. The relevant system operator, in coordination with the relevant TSO, shall specify this rate-of-change-of-frequency-type loss of mains protection. | See table below | P |
| Article 13.2 | With regard to the limited frequency sensitive mode — overfrequency (LFSM-O), the following shall apply, as determined by the relevant TSO for its control area in coordination with the TSOs of the same synchronous area to ensure minimal impacts on neighboring areas: | See table below | P |
| | (a) the power-generating module shall be capable of activating the provision of active power frequency response according to figure 1 at a frequency threshold and droop settings specified by the relevant TSO; | | P |
| | (b) instead of the capability referred to in paragraph (a), the relevant TSO may choose to allow within its control area automatic disconnection and reconnection of power-generating modules of Type A at randomized frequencies, ideally uniformly distributed, above a frequency threshold, as determined by the relevant TSO where it is able to demonstrate to the relevant regulatory authority, and with the cooperation of power-generating facility owners, that this has a limited cross-border impact and maintains the same level of operational security in all system states; | | P |


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| Clause | Requirement + Test | Result – Remark | Verdict |
| | (c) the frequency threshold shall be between 50,2 Hz and 50,5 Hz inclusive; | | P |
| | (d) the droop settings shall be between 2 % and 12 %; | | P |
| | (e) the power-generating module shall be capable of activating a power frequency response with an initial delay that is as short as possible. If that delay is greater than two seconds, the power-generating facility owner shall justify the delay, providing technical evidence to the relevant TSO; | | P |
| | (f) the relevant TSO may require that upon reaching minimum regulating level, the power-generating module be capable of either:<br>(i) continuing operation at this level; or<br>(ii) further decreasing active power output; | | P |
| | (g) the power-generating module shall be capable of operating stably during LFSM-O operation. When LFSM-O is active, the LFSM-O setpoint will prevail over any other active power setpoints. | | P |
| | $P_{ref}$ is the reference active power to which ΔP is related and may be specified differently for synchronous power-generating modules and power park modules. ΔP is the change in active power output from the power-generating module. $f_n$ is the nominal frequency (50 Hz) in the network and Δf is the frequency deviation in the network. At overfrequencies where Δf is above $\Delta f_1$, the power-generating module has to provide a negative active power output change according to the droop $S_2$. | | P |
| Article 13.3 | The power-generating module shall be capable of maintaining constant output at its target active power value regardless of changes in frequency, except where output follows the changes specified in the context of paragraphs 2 and 4 of this Article or points (c) and (d) of Article 15(2) as applicable. | | N/A |
| Article 13.4 | The relevant TSO shall specify admissible active power reduction from maximum output with falling frequency in its control area as a rate of reduction falling within the boundaries, illustrated by the full lines in Figure 2: | See table below | P |
| | (a) below 49 Hz falling by a reduction rate of 2 % of the maximum capacity at 50 Hz per 1 Hz frequency drop; | | P |
| | (b) below 49,5 Hz falling by a reduction rate of 10 % of the maximum capacity at 50 Hz per 1 Hz frequency drop. | | P |
| Article 13.5 | The admissible active power reduction from maximum output shall: | See table below | P |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | (a) clearly specify the ambient conditions applicable;<br>(b) take account of the technical capabilities of power-generating modules. | | |
| Article 13.6 | The power-generating module 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. The relevant system operator shall have the right to specify requirements for equipment to make this facility operable remotely. | See table below | P |
| Article 13.7 | The relevant TSO shall specify the conditions under which a power-generating module is capable of connecting automatically to the network. Those conditions shall include: | See table below | P |
| | (a) frequency ranges within which an automatic connection is admissible, and a corresponding delay time; and | | P |
| | (b) maximum admissible gradient of increase in active power output. | | P |
| | Automatic connection is allowed unless specified otherwise by the relevant system operator in coordination with the relevant TSO. | | P |
| Article 14.1 | Type A & B power-generating modules shall fulfil the requirements set out in Article 13, except for Article 13(2)(b). | Type A power-generating module | N/A |
| Article 14.2 | Type A & B power-generating modules shall fulfil the following requirements in relation to frequency stability:<br>(a) to control active power output, the power-generating module shall be equipped with an interface (input port) in order to be able to reduce active power output following an instruction at the input port; and<br>(b) the relevant system operator shall have the right to specify the requirements for further equipment to allow active power output to be remotely operated. | | N/A |
| Article 14.3 | Type A & B power-generating modules shall fulfil the following requirements in relation to robustness: | | N/A |
| (a) | with regard to fault-ride-through capability of power-generating modules: | | N/A |
| | (i) each TSO shall specify a voltage-against-time-profile in line with Figure 3 at the connection point for fault conditions, which describes the conditions in which the power-generating module is capable of staying connected to the network and continuing to operate stably after the power system has been disturbed by secured faults on the transmission system; | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | (ii) the voltage-against-time-profile shall express a lower limit of the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, as a function of time before, during and after the fault; | | N/A |
| | (iii) the lower limit referred to in point (ii) shall be specified by the relevant TSO using the parameters set out in Figure 3, and within the ranges set out in Tables 3.1 and 3.2; | | N/A |
| | (iv) each TSO shall specify and make publicly available the pre-fault and post-fault conditions for the fault-ride- through capability in terms of:<br>— the calculation of the pre-fault minimum short circuit capacity at the connection point,<br>— pre-fault active and reactive power operating point of the power-generating module at the connection point and voltage at the connection point, and<br>— calculation of the post-fault minimum short circuit capacity at the connection point; | | N/A |
| | (v) at the request of a power-generating facility owner, the relevant system operator shall provide the pre-fault and post-fault conditions to be considered for fault-ride-through capability as an outcome of the calculations at the connection point as specified in point (iv) regarding:<br>— pre-fault minimum short circuit capacity at each connection point expressed in MVA,<br>— pre-fault operating point of the power-generating module expressed in active power output and reactive power output at the connection point and voltage at the connection point, and<br>— post-fault minimum short circuit capacity at each connection point expressed in MVA.<br>Alternatively, the relevant system operator may provide generic values derived from typical cases;<br>The diagram represents the lower limit of a voltage-against-time profile of the voltage at the connection point, expressed as the ratio of its actual value and its reference 1 pu value before, during and after a fault. Uret is the retained voltage at the connection point during a fault, tclear is the instant when the fault has been cleared. Urec1, Urec2, trec1, trec2 and trec3 specify certain points of lower limits of voltage recovery after fault clearance. | | N/A |
| | (vi) the power-generating module shall be capable of remaining connected to the network and continuing to operate stably when the actual course of the phase-to-phase voltages on the network voltage level at the | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | connection point during a symmetrical fault, given the pre-fault and post-fault conditions in points (iv) and (v) of paragraph 3(a), remain above the lower limit specified in point (ii) of paragraph 3(a), unless the protection scheme for internal electrical faults requires the disconnection of the power-generating module from the network. The protection schemes and settings for internal electrical faults must not jeopardize fault-ride- through performance; | | |
| | (vii) without prejudice to point (vi) of paragraph 3(a), undervoltage protection (either fault-ride-through capability or minimum voltage specified at the connection point voltage) shall be set by the power-generating facility owner according to the widest possible technical capability of the power-generating module, unless the relevant system operator requires narrower settings in accordance with point (b) of paragraph 5. The settings shall be justified by the power-generating facility owner in accordance with this principle; | | N/A |
| (b) | fault-ride-through capabilities in case of asymmetrical faults shall be specified by each TSO. | | N/A |
| Article 14.4 | Type A & B power-generating modules shall fulfil the following requirements relating to system restoration:<br>(a) the relevant TSO shall specify the conditions under which a power-generating module is capable of reconnecting to the network after an incidental disconnection caused by a network disturbance; and<br>(b) installation of automatic reconnection systems shall be subject both to prior authorization by the relevant system operator and to the reconnection conditions specified by the relevant TSO. | | N/A |
| Article 14.5 | Type A & B power-generating modules shall fulfil the following general system management requirements: | | N/A |
| (a) | with regard to control schemes and settings:<br>(i) the schemes and settings of the different control devices of the power-generating module that are necessary for transmission system stability and for taking emergency action shall be coordinated and agreed between the relevant TSO, the relevant system operator and the power-generating facility owner; | | N/A |
| | (ii) any changes to the schemes and settings, mentioned in point (i), of the different control devices of the power-generating module shall be coordinated and agreed between the relevant TSO, the relevant system operator and the power-generating facility owner, in particular if they apply in the circumstances referred to in point (i) of paragraph 5(a); | | N/A |


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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| (b) | with regard to electrical protection schemes and settings: | | N/A |
| | (i) the relevant system operator shall specify the schemes and settings necessary to protect the network, taking into account the characteristics of the power-generating module. The protection schemes needed for the power-generating module and the network as well as the settings relevant to the power-generating module shall be coordinated and agreed between the relevant system operator and the power-generating facility owner. The protection schemes and settings for internal electrical faults must not jeopardize the performance of a power-generating module, in line with the requirements set out in this Regulation; | | N/A |
| | (ii) electrical protection of the power-generating module shall take precedence over operational controls, taking into account the security of the system and the health and safety of staff and of the public, as well as mitigating any damage to the power-generating module; | | N/A |
| | (iii) protection schemes may cover the following aspects:<br>— external and internal short circuit,<br>— asymmetric load (negative phase sequence),<br>— stator and rotor overload,<br>— over-/under-excitation,<br>— over-/undervoltage at the connection point,<br>— over-/undervoltage at the alternator terminals,<br>— inter-area oscillations,<br>— inrush current,<br>— asynchronous operation (pole slip),<br>— protection against inadmissible shaft torsions (for example, sub synchronous resonance),<br>— power-generating module line protection,<br>— unit transformer protection,<br>— back-up against protection and switchgear malfunction,<br>— over fluxing (U/f),<br>— inverse power,<br>— rate of change of frequency, and<br>— neutral voltage displacement. | | N/A |
| | (iv) changes to the protection schemes needed for the power-generating module and the network and to the settings relevant to the power-generating module shall be agreed between the system operator and the power-generating facility owner, and agreement shall be reached before any changes are made; | | N/A |


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| Clause | Requirement + Test | Result – Remark | Verdict |
| (c) | the power-generating facility owner shall organize its protection and control devices in accordance with the following priority ranking (from highest to lowest):<br>(i) network and power-generating module protection;<br>(ii) synthetic inertia, if applicable;<br>(iii) frequency control (active power adjustment);<br>(iv) power restriction; and<br>(v) power gradient constraint; | | N/A |
| (d) | with regard to information exchange:<br>(i) power-generating facilities shall be capable of exchanging information with the relevant system operator or the relevant TSO in real time or periodically with time stamping, as specified by the relevant system operator or the relevant TSO;<br>(ii) the relevant system operator, in coordination with the relevant TSO, shall specify the content of information exchanges including a precise list of data to be provided by the power-generating facility. | | N/A |
| Article 15.1 | Type C power-generating modules shall fulfil the requirements laid down in Articles 13 and 14, except for Article 13(2)(b) and (6) and Article 14(2). | Type A power-generating module | N/A |
| Article 15.2 | Type C power-generating modules shall fulfil the following requirements relating to frequency stability: | | N/A |
| (a) | with regard to active power controllability and control range, the power-generating module control system shall be capable of adjusting an active power setpoint in line with instructions given to the power-generating facility owner by the relevant system operator or the relevant TSO. | | N/A |
| | The relevant system operator or the relevant TSO shall establish the period within which the adjusted active power setpoint must be reached. The relevant TSO shall specify a tolerance (subject to the availability of the prime mover resource) applying to the new setpoint and the time within which it must be reached; | | N/A |
| (b) | Manual local measures shall be allowed in cases where the automatic remote control devices are out of service. | | N/A |
| | The relevant system operator or the relevant TSO shall notify the regulatory authority of the time required to reach the setpoint together with the tolerance for the active power; | | N/A |
| (c) | In addition to Article 13(2), the following requirements shall apply to type C power-generating modules with regard to | | N/A |



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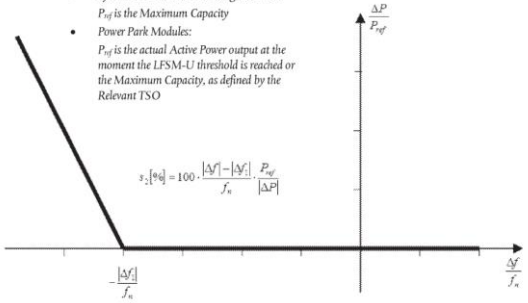
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | limited frequency sensitive mode — underfrequency (LFSM-U): | | |
| | (i) the power-generating module shall be capable of activating the provision of active power frequency response at a frequency threshold and with a droop specified by the relevant TSO in coordination with the TSOs of the<br>same synchronous area as follows:<br>— the frequency threshold specified by the TSO shall be between 49,8 Hz and 49,5 Hz inclusive,<br>— the droop settings specified by the TSO shall be in the range 2-12 %.<br>This is represented graphically in Figure 4; | | N/A |
| | (ii) the actual delivery of active power frequency response in LFSM-U mode shall take into account:<br>— ambient conditions when the response is to be triggered,<br>— the operating conditions of the power-generating module, in particular limitations on operation near maximum capacity at low frequencies and the respective impact of ambient conditions according to paragraphs 4 and 5 of Article 13, and<br>— the availability of the primary energy sources. | | N/A |
| | (iii) the activation of active power frequency response by the power-generating module shall not be unduly delayed.<br>In the event of any delay greater than two seconds, the power-generating facility owner shall justify it to the relevant TSO; | | N/A |
| | (iv) in LFSM-U mode the power-generating module shall be capable of providing a power increase up to its maximum capacity; | | N/A |
| | (v) stable operation of the power-generating module during LFSM-U operation shall be ensured; | | N/A |
| | Figure 4<br>**Active power frequency response capability of power-generating modules in LFSM-U**<br>• *Synchronous Power Generating Modules:* $P_{ref}$ *is the Maximum Capacity*<br>• *Power Park Modules:* $P_{ref}$ *is the actual Active Power output at the moment the LFSM-U threshold is reached or the Maximum Capacity, as defined by the Relevant TSO*<br>$s_2[\%] = 100 \cdot \frac{\lvert\Delta f\rvert - \lvert\Delta f_2\rvert}{f_n} \cdot \frac{P_{ref}}{\lvert\Delta P\rvert}$<br><br> | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | Pref is the reference active power to which ΔP is related and may be specified differently for synchronous power-generating modules and power park modules. ΔP is the change in active power output from the power- generating module. fn is the nominal frequency (50 Hz) in the network and Δf is the frequency deviation in the network. At underfrequencies where Δf is below Δf1 the power-generating module has to provide a positive active power output change according to the droop S2. | | |
| (d) | in addition to point (c) of paragraph 2, the following shall apply cumulatively when frequency sensitive mode ('FSM') is operating: | | N/A |
| | (i) the power-generating module shall be capable of providing active power frequency response in accordance with the parameters specified by each relevant TSO within the ranges shown in Table 4. In specifying those parameters, the relevant TSO shall take account of the following facts:<br>— in case of overfrequency, the active power frequency response is limited by the minimum regulating level,<br>— in case of underfrequency, the active power frequency response is limited by maximum capacity,<br>— the actual delivery of active power frequency response depends on the operating and ambient conditions of the power-generating module when this response is triggered, in particular limitations on operation near maximum capacity at low frequencies according to paragraphs 4 and 5 of Article 13 and available primary energy sources; | | N/A |
| | *Table 4*<br>**Parameters for active power frequency response in FSM (explanation for Figure 5)**<br>Active power range related to maximum capacity $\frac{\lvert\Delta P_1\rvert}{P_{max}}$: 1,5-10 %<br>Frequency response insensitivity: $\lvert\Delta f_1\rvert$: 10-30 mHz; $\frac{\lvert\Delta f_1\rvert}{f_n}$: 0,02-0,06 %<br>Frequency response deadband: 0-500 mHz<br>Droop $s_1$: 2-12 % | | N/A |



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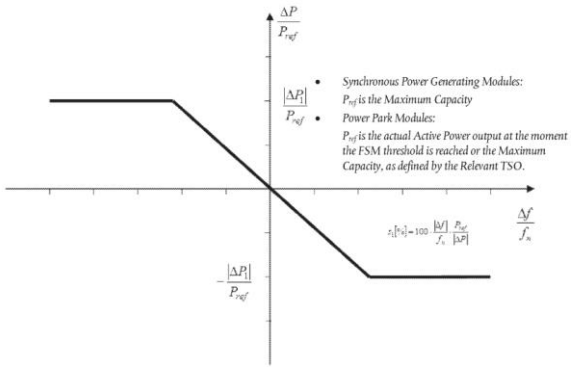
| Clause | Requirement + Test | Result – Remark | Verdict |
| | Figure 5<br>Active power frequency response capability of power-generating modules in FSM illustrating the case of zero deadband and insensitivity<br><br><br>Pref is the reference active power to which ΔP is related. ΔP is the change in active power output from the power-generating module. fn is the nominal frequency (50 Hz) in the network and Δf is the frequency deviation in the network. | | N/A |
| | (ii) the frequency response deadband of frequency deviation and droop must be able to be reselected repeatedly; | | N/A |
| | (iii) in the event of a frequency step change, the power-generating module shall be capable of activating full active power frequency response, at or above the full line shown in Figure 6 in accordance with the parameters specified by each TSO (which shall aim at avoiding active power oscillations for the power-generating module) within the ranges given in Table 5. The combination of choice of the parameters specified by the TSO shall take possible technology-dependent limitations into account; | | N/A |
| | (iv) the initial activation of active power frequency response required shall not be unduly delayed.<br>If the delay in initial activation of active power frequency response is greater than two seconds, the power-generating facility owner shall provide technical evidence demonstrating why a longer time is needed.<br>For power-generating modules without inertia, the relevant TSO may specify a shorter time than two seconds.<br>If the power-generating facility owner cannot meet this requirement they shall provide technical evidence demonstrating why a longer time is needed for the initial activation of active power frequency response; | | N/A |



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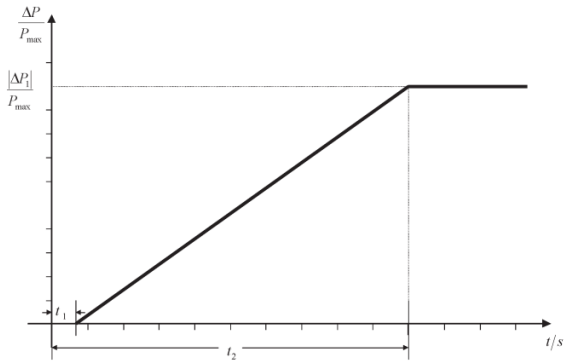
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | *Figure 6*<br>**Active power frequency response capability**<br><br><br>Pmax is the maximum capacity to which ΔP relates. ΔP is the change in active power output from the power-generating module. The power-generating module has to provide active power output ΔP up to the point ΔP1 in accordance with the times t1 and t2 with the values of ΔP1, t1and t2 being specified by the relevant TSO according to Table 5. t1 is the initial delay. t2 is the time for full activation. | | N/A |
| | (v) the power-generating module shall be capable of providing full active power frequency response for a period of between 15 and 30 minutes as specified by the relevant TSO. In specifying the period, the TSO shall have regard to active power headroom and primary energy source of the power-generating module; | | N/A |
| | (vi) within the time limits laid down in point (v) of paragraph 2(d), active power control must not have any adverse impact on the active power frequency response of power-generating modules; | | N/A |
| | (vii) the parameters specified by the relevant TSO in accordance with points (i), (ii), (iii) and (v) shall be notified to the relevant regulatory authority. The modalities of that notification shall be specified in accordance with the applicable national regulatory framework; | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | *Table 5*<br>**Parameters for full activation of active power frequency response resulting from frequency step change (explanation for Figure 6)**<br>Parameters: Active power range related to maximum capacity (frequency response range) $\frac{\lvert\Delta P_1\rvert}{P_{max}}$ — Ranges or values: 1,5-10 %<br>For power-generating modules with inertia, the maximum admissible initial delay $t_1$ unless justified otherwise in line with Article 15(2)(d)(iv) — 2 seconds<br>For power-generating modules without inertia, the maximum admissible initial delay $t_1$ unless justified otherwise in line with Article 15(2)(d)(iv) — as specified by the relevant TSO.<br>Maximum admissible choice of full activation time $t_2$, unless longer activation times are allowed by the relevant TSO for reasons of system stability — 30 seconds | | N/A |
| | (e) with regard to frequency restoration control, the power-generating module shall provide functionalities complying with specifications specified by the relevant TSO, aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values; | | N/A |
| | (f) with regard to disconnection due to underfrequency, power-generating facilities capable of acting as a load, including hydro pump-storage power-generating facilities, shall be capable of disconnecting their load in case of underfre-quency. The requirement referred to in this point does not extend to auxiliary supply; | | N/A |
| | (g) with regard to real-time monitoring of FSM: | | N/A |
| | (i) to monitor the operation of active power frequency response, the communication interface shall be equipped to transfer in real time and in a secured manner from the power-generating facility to the network control center of the relevant system operator or the relevant TSO, at the request of the relevant system operator or the relevant TSO, at least the following signals:<br>— status signal of FSM (on/off),<br>— scheduled active power output,<br>— actual value of the active power output,<br>— actual parameter settings for active power frequency response,<br>— droop and deadband;<br>(ii) the relevant system operator and the relevant TSO shall specify additional signals to be provided by the power-generating facility by monitoring and recording devices in order to verify the performance of the active power frequency response provision of participating power-generating modules. | | N/A |
| | (ii) the relevant system operator and the relevant TSO shall specify additional signals to be provided by the power- | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | generating facility by monitoring and recording devices in order to verify the performance of the active power frequency response provision of participating power-generating modules. | | |
| Article 15.3 | With regard to voltage stability, type C power-generating modules shall be capable of automatic disconnection when voltage at the connection point reaches levels specified by the relevant system operator in coordination with the relevant TSO. | | N/A |
| | The terms and settings for actual automatic disconnection of power-generating modules shall be specified by the relevant system operator in coordination with the relevant TSO. | | N/A |
| Article 15.4 | Type C power-generating modules shall fulfil the following requirements relating to robustness:<br>(a) in the event of power oscillations, power-generating modules shall remain steady-state stability when operating at any operating point of the P-Q-capability diagram; | | N/A |
| | (b) without prejudice to paragraph 4 and 5 of Article 13, power-generating modules shall be capable of remaining connected to the network and operating without power reduction, as long as voltage and frequency remain within the specified limits pursuant to this Regulation; | | N/A |
| | (c) power-generating modules shall be capable of remaining connected to the network during single-phase or three- phase auto-reclosures on meshed network lines, if applicable to the network to which they are connected. The details of that capability shall be subject to coordination and agreements on protection schemes and settings as referred to in point (b) of Article 14(5). | | N/A |
| Article 15.5 | Type C power-generating modules shall fulfil the following requirements relating to system restoration: | | N/A |
| (a) | with regard to black start capability:<br>(i) black start capability is not mandatory without prejudice to the Member State's rights to introduce obligatory rules in order to ensure system security; | | N/A |
| | (ii) power-generating facility owners shall, at the request of the relevant TSO, provide a quotation for providing black start capability. The relevant TSO may make such a request if it considers system security to be at risk due to a lack of black start capability in its control area; | | N/A |
| | (iii) a power-generating module with black start capability shall be capable of starting from shutdown without any external electrical energy supply within a time frame | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | specified by the relevant system operator in coordination with the relevant TSO; | | |
| | (iv) a power-generating module with black start capability shall be able to synchronize within the frequency limits laid down in point (a) of Article 13(1) and, where applicable, voltage limits specified by the relevant system operator or in Article 16(2); | | N/A |
| | (v) a power-generating module with black start capability shall be capable of automatically regulating dips in voltage caused by connection of demand; | | N/A |
| | (vi) a power-generating module with black start capability shall:<br>— be capable of regulating load connections in block load,<br>— be capable of operating in LFSM-O and LFSM-U, as specified in point (c) of paragraph 2 and Article 13(2),<br>— control frequency in case of overfrequency and underfrequency within the whole active power output range between minimum regulating level and maximum capacity as well as at house load level,<br>— be capable of parallel operation of a few power-generating modules within one island, and<br>— control voltage automatically during the system restoration phase; | | N/A |
| (b) | with regard to the capability to take part in island operation:<br>(i) power-generating modules shall be capable of taking part in island operation if required by the relevant system operator in coordination with the relevant TSO and:<br>— the frequency limits for island operation shall be those established in accordance with point (a) of<br>Article 13(1),<br>— the voltage limits for island operation shall be those established in accordance with Article 15(3) or Article 16(2), where applicable; | | N/A |
| | (ii) power-generating modules shall be able to operate in FSM during island operation, as specified in point (d) of paragraph 2. | | N/A |
| | In the event of a power surplus, power-generating modules shall be capable of reducing the active power output from a previous operating point to any new operating point within the P-Q-capability diagram. In that regard, the power-generating module shall be capable of reducing active power output as much as inherently technically feasible, but to at least 55 % of its maximum capacity; | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | (iii) the method for detecting a change from interconnected system operation to island operation shall be agreed between the power-generating facility owner and the relevant system operator in coordination with the relevant TSO. The agreed method of detection must not rely solely on the system operator's switchgear position signals; | | N/A |
| | (iv) power-generating modules shall be able to operate in LFSM-O and LFSM-U during island operation, as specified in point (c) of paragraph 2 and Article 13(2); | | N/A |
| (c) | with regard to quick re-synchronization capability: | | N/A |
| | (i) in case of disconnection of the power-generating module from the network, the power-generating module shall be capable of quick re-synchronization in line with the protection strategy agreed between the relevant system operator in coordination with the relevant TSO and the power-generating facility; | | N/A |
| | (ii) a power-generating module with a minimum re-synchronization time greater than 15 minutes after its disconnection from any external power supply must be designed to trip to house load from any operating point in its P-Q-capability diagram. In this case, the identification of house load operation must not be based solely on the system operator's switchgear position signals; | | N/A |
| | (iii) power-generating modules shall be capable of continuing operation following tripping to house load, irrespective of any auxiliary connection to the external network. The minimum operation time shall be specified by the relevant system operator in coordination with the relevant TSO, taking into consideration the specific characteristics of prime mover technology. | | N/A |
| Article 15.6 | Type C power-generating modules shall fulfil the following general system management requirements: | | N/A |
| (a) | with regard to loss of angular stability or loss of control, a power-generating module shall be capable of disconnecting automatically from the network in order to help preserve system security or to prevent damage to the power-generating module. The power-generating facility owner and the relevant system operator in coordination with the relevant TSO shall agree on the criteria for detecting loss of angular stability or loss of control; | | N/A |
| (b) | with regard to instrumentation: | | N/A |
| | (i) power-generating facilities shall be equipped with a facility to provide fault recording and monitoring of dynamic | | N/A |



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| | system behavior. This facility shall record the following parameters:<br>— voltage,<br>— active power,<br>— reactive power, and<br>— frequency.<br>The relevant system operator shall have the right to specify quality of supply parameters to be complied with on condition that reasonable prior notice is given; | | |
| | (ii) the settings of the fault recording equipment, including triggering criteria and the sampling rates shall be agreed between the power-generating facility owner and the relevant system operator in coordination with the relevant TSO; | | N/A |
| | (iii) the dynamic system behavior monitoring shall include an oscillation trigger specified by the relevant system operator in coordination with the relevant TSO, with the purpose of detecting poorly damped power<br>oscillations; | | N/A |
| | (iv) the facilities for quality of supply and dynamic system behavior monitoring shall include arrangements for the power-generating facility owner, and the relevant system operator and the relevant TSO to access the information. The communications protocols for recorded data shall be agreed between the power-generating facility owner, the relevant system operator and the relevant TSO; | | N/A |
| (c) | with regard to the simulation models: | | N/A |
| | (i) at the request of the relevant system operator or the relevant TSO, the power-generating facility owner shall<br>provide simulation models which properly reflect the behavior of the power-generating module in both steadystate and dynamic simulations (50 Hz component) or in electromagnetic transient simulations.<br>The power-generating facility owner shall ensure that the models provided have been verified against the results of compliance tests referred to in Chapters 2, 3 and 4 of Title IV, and shall notify the results of the verification to the relevant system operator or relevant TSO. Member States may require that such verification be carried out by an authorized certifier; | | N/A |
| | (ii) the models provided by the power-generating facility owner shall contain the following sub-models, depending on the existence of the individual components:<br>— alternator and prime mover, | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | — speed and power control,<br>— voltage control, including, if applicable, power system stabilizer ('PSS') function and excitation control<br>system,<br>— power-generating module protection models, as agreed between the relevant system operator and the power-generating facility owner, and<br>— converter models for power park modules; | | |
| | (iii) the request by the relevant system operator referred to in point (i) shall be coordinated with the relevant TSO. It shall include:<br>— the format in which models are to be provided,<br>— the provision of documentation on a model's structure and block diagrams,<br>— an estimate of the minimum and maximum short circuit capacity at the connection point, expressed in<br>MVA, as an equivalent of the network; | | N/A |
| | (iv) the power-generating facility owner shall provide recordings of the power-generating module's performance to the relevant system operator or relevant TSO if requested. The relevant system operator or relevant TSO may make such a request, in order to compare the response of the models with those recordings; | | N/A |
| (d) | with regard to the installation of devices for system operation and devices for system security, if the relevant system operator or the relevant TSO considers that it is necessary to install additional devices in a power-generating facility in order to preserve or restore system operation or security, the relevant system operator or relevant TSO and the<br>power-generating facility owner shall investigate that matter and agree on an appropriate solution; | | N/A |
| (e) | the relevant system operator shall specify, in coordination with the relevant TSO, minimum and maximum limits on rates of change of active power output (ramping limits) in both an up and down direction of change of active power output for a power-generating module, taking into consideration the specific characteristics of prime mover technology; | | N/A |
| (f) | earthing arrangement of the neutral-point at the network side of step-up transformers shall comply with the specifications of the relevant system operator. | | N/A |
| Article 16.1 | In addition to fulfilling the requirements listed in Article 13, except for Article 13(2)(b), (6) and (7), Article 14, | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | except for Article 14(2), and Article 15, except for Article 15(3), type D power-generating modules shall fulfil the requirements set out in this Article. | | |
| Article 16.2 | Type D power-generating modules shall fulfil the following requirements relating to voltage stability: | | N/A |
| (a) | with regard to voltage ranges: | | N/A |
| | (i) without prejudice to point (a) of Article 14(3) and point (a) of paragraph 3 below, a power-generating module shall be capable of staying connected to the network and operating within the ranges of the network voltage at the connection point, expressed by the voltage at the connection point related to the reference 1 pu voltage, and for the time periods specified in Tables 6.1 and 6.2; | | N/A |
| | (ii) the relevant TSO may specify shorter periods of time during which power-generating modules shall be capable of remaining connected to the network in the event of simultaneous overvoltage and underfrequency or simultaneous undervoltage and overfrequency; | | N/A |
| | (iii) notwithstanding the provisions of point (i), the relevant TSO in Spain may require power-generating modules to be capable of remaining connected to the network in the voltage range between 1,05 pu and 1,0875 pu for an unlimited period; | | N/A |
| | (iv) for the 400 kV grid voltage level (or alternatively commonly referred to as 380 kV level), the reference 1 pu value is 400 kV; for other grid voltage levels, the reference 1 pu voltage may differ for each system operator in the same synchronous area; | | N/A |
| | (v) notwithstanding the provisions of point (i), the relevant TSOs in the Baltic synchronous area may require power-generating modules to remain connected to the 400 kV network in the voltage range limits and for the time periods that apply in the Continental Europe synchronous area; | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | *Table 6.1*<br>The table shows the minimum time periods during which a power-generating module must be capable of<br>operating for voltages deviating from the reference 1 pu value at the connection point without disconnecting<br>from the network, where the voltage base for pu values is from 110 kV to 300 kV. | | N/A |
| | *Table 6.2*<br>The table shows the minimum time periods during which a power-generating module must be capable of<br>operating for voltages deviating from the reference 1 pu value at the connection point without disconnecting<br>from the network where the voltage base for pu values is from 300 kV to 400 kV. | | N/A |

| Synchronous area | Voltage range | Time period for operation |
|---|---|---|
| Continental Europe | 0,85 pu-0,90 pu | 60 minutes |
| | 0,90 pu-1,118 pu | Unlimited |
| | 1,118 pu-1,15 pu | To be specified by each TSO, but not less than 20 minutes and not more than 60 minutes |
| Nordic | 0,90 pu-1,05 pu | Unlimited |
| | 1,05 pu-1,10 pu | 60 minutes |
| Great Britain | 0,90 pu-1,10 pu | Unlimited |
| Ireland and Northern Ireland | 0,90 pu-1,118 pu | Unlimited |
| Baltic | 0,85 pu-0,90 pu | 30 minutes |
| | 0,90 pu-1,118 pu | Unlimited |
| | 1,118 pu-1,15 pu | 20 minutes |

| Synchronous area | Voltage range | Time period for operation |
|---|---|---|
| Continental Europe | 0,85 pu-0,90 pu | 60 minutes |
| | 0,90 pu-1,05 pu | Unlimited |
| | 1,05 pu-1,10 pu | To be specified by each TSO, but not less than 20 minutes and not more than 60 minutes |
| Nordic | 0,90 pu-1,05 pu | Unlimited |
| | 1,05 pu-1,10 pu | To be specified by each TSO, but not more than 60 minutes |
| Great Britain | 0,90 pu-1,05 pu | Unlimited |
| | 1,05 pu-1,10 pu | 15 minutes |
| Ireland and Northern Ireland | 0,90 pu-1,05 pu | Unlimited |
| Baltic | 0,88 pu-0,90 pu | 20 minutes |
| | 0,90 pu-1,097 pu | Unlimited |
| | 1,097 pu-1,15 pu | 20 minutes |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| (b) | wider voltage ranges or longer minimum time periods for operation may be agreed between the relevant system operator and the power-generating facility owner in coordination with the relevant TSO. If wider voltage ranges or longer minimum times for operation are economically and technically feasible, the power-generating facility owner shall not unreasonably withhold an agreement; | | N/A |
| (c) | without prejudice to point (a), the relevant system operator in coordination with the relevant TSO shall have the right to specify voltages at the connection point at which a power-generating module is capable of automatic disconnection. The terms and settings for automatic disconnection shall be agreed between the relevant system operator and the power-generating facility owner. | | N/A |
| Article 16.3 | Type D power-generating modules shall fulfil the following requirements in relation to robustness: | | N/A |
| (a) | with regard to fault-ride-through capability: | | N/A |
| | (i) power-generating modules shall be capable of staying connected to the network and continuing to operate stably after the power system has been disturbed by secured faults. That capability shall be in accordance with a voltage-against-time profile at the connection point for fault conditions specified by the relevant TSO.<br>The voltage-against-time-profile shall express a lower limit of the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, as a function of time before, during and after the fault.<br>That lower limit shall be specified by the relevant TSO, using the parameters set out in Figure 3 and within the<br>ranges set out in Tables 7.1 and 7.2 for type D power-generating modules connected at or above the 110 kV level.<br>That lower limit shall also be specified by the relevant TSO, using parameters set out in Figure 3 and within the ranges set out in Tables 3.1 and 3.2 for type D power-generating modules connected below the 110 kV level; | | N/A |
| | (ii) each TSO shall specify the pre-fault and post-fault conditions for the fault-ride-through capability referred to in point (iv) of Article 14(3)(a). The specified pre-fault and post-fault conditions for the fault-ride-through capability shall be made publicly available; | | N/A |



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| Clause | Requirement + Test | Result – Remark | Verdict |
| | *Table 7.1*<br>**Parameters for Figure 3 for fault-ride-through capability of synchronous power-generating modules**<br>Voltage parameters (pu) / Time parameters (seconds)<br>$U_{ret}$: 0 — $t_{clear}$: 0,14-0,15 (or 0,14-0,25 if system protection and secure operation so require)<br>$U_{clear}$: 0,25 — $t_{rec1}$: $t_{clear}$-0,45<br>$U_{rec1}$: 0,5-0,7 — $t_{rec2}$: $t_{rec1}$-0,7<br>$U_{rec2}$: 0,85-0,9 — $t_{rec3}$: $t_{rec2}$-1,5 | | N/A |
| | **Parameters for Figure 3 for fault-ride-through capability of power park modules**<br>Voltage parameters (pu) / Time parameters (seconds)<br>$U_{ret}$: 0 — $t_{clear}$: 0,14-0,15 (or 0,14-0,25 if system protection and secure operation so require)<br>$U_{clear}$: $U_{ret}$ — $t_{rec1}$: $t_{clear}$<br>$U_{rec1}$: $U_{clear}$ — $t_{rec2}$: $t_{rec1}$<br>$U_{rec2}$: 0,85 — $t_{rec3}$: 1,5-3,0 | | N/A |
| (b) | at the request of a power-generating facility owner, the relevant system operator shall provide the pre-fault and post- fault conditions to be considered for fault-ride-through capability as an outcome of the calculations at the connection point as specified in point (iv) of Article 14(3)(a) regarding:<br>(i) pre-fault minimum short circuit capacity at each connection point expressed in MVA;<br>(ii) pre-fault operating point of the power-generating module expressed as active power output and reactive power output at the connection point and voltage at the connection point; and<br>(iii) post-fault minimum short circuit capacity at each connection point expressed in MVA; | | N/A |
| (c) | fault-ride-through capabilities in case of asymmetrical faults shall be specified by each TSO. | | N/A |
| Article 16.4 | Type D power-generating modules shall fulfil the following general system management requirements: | | N/A |
| (a) | with regard to synchronization, when starting a power-generating module, synchronization shall be performed by the power-generating facility owner only after authorization by the relevant system operator; | | N/A |
| (b) | the power-generating module shall be equipped with the necessary synchronization facilities; | | N/A |
| (c) | synchronization of power-generating modules shall be possible at frequencies within the ranges set out in Table 2; | | N/A |
| (d) | the relevant system operator and the power-generating facility owner shall agree on the settings of synchronization | | N/A |



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| | devices to be concluded prior to operation of the power-generating module. This agreement shall cover:<br>(i) voltage;<br>(ii) frequency;<br>(iii) phase angle range;<br>(iv) phase sequence;<br>(v) deviation of voltage and frequency. | | |
| Article 20.1 | Type A & B power park modules shall fulfil the requirements laid down in Articles 13, except for Article 13(2)(b), and Article 14. | | N/A |
| Article 20.2 | Type A & B power park modules shall fulfil the following additional requirements in relation to voltage stability: | | N/A |
| (a) | with regard to reactive power capability, the relevant system operator shall have the right to specify the capability of a power park module to provide reactive power; | | N/A |
| (b) | the relevant system operator in coordination with the relevant TSO shall have the right to specify that a power park module be capable of providing fast fault current at the connection point in case of symmetrical (3-phase) faults, under the following conditions: | | N/A |
| | (i) the power park module shall be capable of activating the supply of fast fault current either by:<br>— ensuring the supply of the fast fault current at the connection point, or<br>— measuring voltage deviations at the terminals of the individual units of the power park module and providing a fast fault current at the terminals of these units; | | N/A |
| | (ii) the relevant system operator in coordination with the relevant TSO shall specify:<br>— how and when a voltage deviation is to be determined as well as the end of the voltage deviation,<br>— the characteristics of the fast fault current, including the time domain for measuring the voltage deviation and fast fault current, for which current and voltage may be measured differently from the method specified in Article 2,<br>— the timing and accuracy of the fast fault current, which may include several stages during a fault and after its clearance; | | N/A |
| (c) | with regard to the supply of fast fault current in case of asymmetrical (1-phase or 2-phase) faults, the relevant system operator in coordination with the relevant TSO shall | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | have the right to specify a requirement for asymmetrical current injection. | | |
| Article 20.3 | Type A & B power park modules shall fulfil the following additional requirements in relation to robustness: | | N/A |
| (a) | the relevant TSO shall specify the post-fault active power recovery that the power park module is capable of providing and shall specify:<br>(i) when the post-fault active power recovery begins, based on a voltage criterion;<br>(ii) a maximum allowed time for active power recovery; and<br>(iii) a magnitude and accuracy for active power recovery; | | N/A |
| (b) | the specifications shall be in accordance with the following principles:<br>(i) interdependency between fast fault current requirements according to points (b) and (c) of paragraph 2 and active power recovery;<br>(ii) dependence between active power recovery times and duration of voltage deviations;<br>(iii) a specified limit of the maximum allowed time for active power recovery;<br>(iv) adequacy between the level of voltage recovery and the minimum magnitude for active power recovery; and<br>(v) adequate damping of active power oscillations. | | N/A |
| Article 21.1 | Type C power park modules shall fulfil the requirements listed in Articles 13, except for Article 13(2)(b) and (6), Article 14, except for Article 14(2), Article 15 and Article 20, except for Article 20(2)(a), unless referred to otherwise in point (v) of paragraph 3(d). | | N/A |
| Article 21.2 | Type C power park modules shall fulfil the following additional requirements in relation to frequency stability: | | N/A |
| (a) | the relevant TSO shall have the right to specify that power park modules be capable of providing synthetic inertia during very fast frequency deviations; | | N/A |
| (b) | the operating principle of control systems installed to provide synthetic inertia and the associated performance parameters shall be specified by the relevant TSO. | | N/A |
| Article 21.3 | Type C power park modules shall fulfil the following additional requirements in relation to voltage stability: | | N/A |
| (a) | with regard to reactive power capability, the relevant system operator may specify supplementary reactive power to be provided if the connection point of a power park module is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the | | N/A |


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Telefax : +86 20 38320478
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| Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 &15 & 16 & 20 & 21 & 22<br>General requirements for Type A & B & C & D power-generating modules | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | connection point nor at the convertor terminals, if no step-up transformer exists. This supplementary reactive power shall compensate the reactive power demand of the high-voltage line or cable between the high-voltage terminals of the step-up transformer of the power park module or its convertor terminals, if no step-up transformer exists, and the connection point and shall be provided by the responsible owner of that line or cable. | | |
| (b) | with regard to reactive power capability at maximum capacity: | | N/A |
| | (i) the relevant system operator in coordination with the relevant TSO shall specify the reactive power provision capability requirements in the context of varying voltage. To that end, it shall specify a U-Q/Pmax-profile that may take any shape within the boundaries of which the power park module shall be capable of providing reactive power at its maximum capacity; | | N/A |
| | (ii) the U-Q/Pmax-profile shall be specified by each relevant system operator in coordination with the relevant TSO in conformity with the following principles: | | N/A |
| | — the U-Q/Pmax-profile shall not exceed the U-Q/Pmax-profile envelope, represented by the inner envelope in Figure 8, | | N/A |
| | — the dimensions of the U-Q/Pmax-profile envelope (Q/Pmax range and voltage range) shall be within the values specified for each synchronous area in Table 9, | | N/A |
| | — the position of the U-Q/Pmax-profile envelope shall be within the limits of the fixed outer envelope set out in Figure 8, and | | N/A |
| | — the specified U-Q/Pmax profile may take any shape, having regard to the potential costs of delivering the capability to provide reactive power production at high voltages and reactive power consumption at low voltages; | | N/A |



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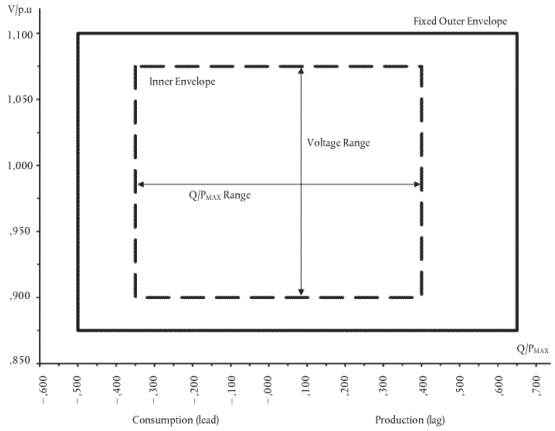
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | U-Q/$P_{max}$-profile of a power park module<br><br><br>The diagram represents boundaries of a U-Q/Pmax-profile by the voltage at the connection point, expressed by the ratio of its actual value and its reference 1 pu value, against the ratio of the reactive power (Q) and the maximum capacity (Pmax). The position, size and shape of the inner envelope are indicative. | | N/A |
| | *Table 9*<br>**Parameters for the inner envelope in Figure 8**<br>Synchronous area / Maximum range of $Q/P_{max}$ / Maximum range of steady-state voltage level in PU<br>Continental Europe: 0,75 / 0,225<br>Nordic: 0,95 / 0,150<br>Great Britain: 0,66 / 0,225<br>Ireland and Northern Ireland: 0,66 / 0,218<br>Baltic: 0,80 / 0,220 | | N/A |
| | (iii) the reactive power provision capability requirement applies at the connection point. For profile shapes other than rectangular, the voltage range represents the highest and lowest values. The full reactive power range is therefore not expected to be available across the range of steady-state voltages; | | N/A |
| (c) | with regard to reactive power capability below maximum capacity: | | N/A |
| | (i) the relevant system operator in coordination with the relevant TSO shall specify the reactive power provision capability requirements and shall specify a P-Q/Pmax-profile that may take any shape within the boundaries of which the power park module shall be capable of providing reactive power below maximum capacity; | | N/A |



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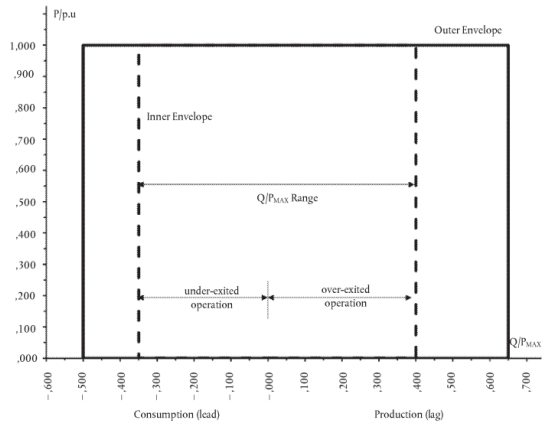
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | (ii) the P-Q/Pmax-profile shall be specified by each relevant system operator in coordination with the relevant TSO, in conformity with the following principles: | | N/A |
| | — the P-Q/Pmax-profile shall not exceed the P-Q/Pmax-profile envelope, represented by the inner envelope in Figure 9,<br>— the Q/Pmax range of the P-Q/Pmax-profile envelope is specified for each synchronous area in Table 9,<br>— the active power range of the P-Q/Pmax-profile envelope at zero reactive power shall be 1 pu,<br>— the P-Q/Pmax-profile can be of any shape and shall include conditions for reactive power capability at zero active power, and<br>— the position of the P-Q/Pmax-profile envelope shall be within the limits of the fixed outer envelope set out in Figure 9; | | N/A |
| | (iii) when operating at an active power output below maximum capacity (P<Pmax), the power park module shall be capable of providing reactive power at any operating point inside its P-Q/Pmax-profile, if all units of that power park module which generate power are technically available that is to say they are not out of service due to maintenance or failure, otherwise there may be less reactive power capability, taking into consideration the technical availabilities; | | N/A |
| | *Figure 9*<br>**P-Q/$P_{max}$-profile of a power park module**<br><br><br>The diagram represents boundaries of a P-Q/Pmax-profile at the connection point by the active power, expressed by the ratio of its actual value and the maximum capacity pu, against the ratio of the reactive power (Q) and the | | N/A |

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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | maximum capacity (Pmax). The position, size and shape of the inner envelope are indicative. | | |
| | (iv) the power park module shall be capable of moving to any operating point within its P-Q/Pmax profile in<br>appropriate timescales to target values requested by the relevant system operator; | | N/A |
| (d) | with regard to reactive power control modes: | | N/A |
| | (i) the power park module shall be capable of providing reactive power automatically by either voltage control mode, reactive power control mode or power factor control mode; | | N/A |
| | (ii) for the purposes of voltage control mode, the power park module shall be capable of contributing to voltage<br>control at the connection point by provision of reactive power exchange with the network with a setpoint<br>voltage covering 0,95 to 1,05 pu in steps no greater than 0,01 pu, with a slope having a range of at least 2 to 7 % in steps no greater than 0,5 %. The reactive power output shall be zero when the grid voltage value at the connection point equals the voltage setpoint; | | N/A |
| | (iii) the setpoint may be operated with or without a deadband selectable in a range from zero to ± 5 % of reference 1 pu network voltage in steps no greater than 0,5 %; | | N/A |
| | (iv) following a step change in voltage, the power park module shall be capable of achieving 90 % of the change in reactive power output within a time t1 to be specified by the relevant system operator in the range of 1 to 5 seconds, and must settle at the value specified by the slope within a time t2 to be specified by the relevant system operator in the range of 5 to 60 seconds, with a steady-state reactive tolerance no greater than 5 % of the maximum reactive power. The relevant system operator shall specify the time specifications; | | N/A |
| | (v) for the purpose of reactive power control mode, the power park module shall be capable of setting the reactive power setpoint anywhere in the reactive power range, specified by point (a) of Article 20(2) and by points (a) and (b) of Article 21(3), with setting steps no greater than 5 MVAr or 5 % (whichever is smaller) of full reactive power, controlling the reactive power at the connection point to an accuracy within plus or minus 5 MVAr or plus or minus 5 % (whichever is smaller) of the full reactive power; | | N/A |
| | (vi) for the purpose of power factor control mode, the power park module shall be capable of controlling the | | N/A |


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Telefax : +86 20 38320478
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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | power factor at the connection point within the required reactive power range, specified by the relevant system operator according to point (a) of Article 20(2) or specified by points (a) and (b) of Article 21(3), with a target power factor in steps no greater than 0,01. The relevant system operator shall specify the target power factor value, its tolerance and the period of time to achieve the target power factor following a sudden change of active power output. The tolerance of the target power factor shall be expressed through the tolerance of its corresponding reactive power. This reactive power tolerance shall be expressed by either an absolute value or by a percentage of the maximum reactive power of the power park module; | | |
| | (vii) the relevant system operator, in coordination with the relevant TSO and with the power park module owner, shall specify which of the above three reactive power control mode options and associated setpoints is to apply, and what further equipment is needed to make the adjustment of the relevant setpoint operable remotely; | | N/A |
| (e) | with regard to prioritizing active or reactive power contribution, the relevant TSO shall specify whether active power contribution or reactive power contribution has priority during faults for which fault-ride-through capability is required. If priority is given to active power contribution, this provision has to be established no later than 150 ms from the fault inception; | | N/A |
| (f) | with regard to power oscillations damping control, if specified by the relevant TSO a power park module shall be capable of contributing to damping power oscillations. The voltage and reactive power control characteristics of power park modules must not adversely affect the damping of power oscillations. | | N/A |
| Article 22 | Type D power park modules shall fulfil the requirements listed in Articles 13, except for Article 13(2)(b), (6) and (7), Article 14, except for Article 14(2), Article 15, except for Article 15(3), Article 16, Article 20 except for Article 20(2)(a) and Article 21. | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| Article 13(1) Article 1 (b) shall be replaced by the following (a) point (i) | Frequency parameters | See table below | P |
| | Minimum operating times of the energy generation module at frequencies deviating from the rated value:<br>Frequency range: 47.5 Hz – 48.5 Hz; Working time: 30 minutes<br>Frequency range: 48.5 Hz – 49.0 Hz; Working time: 30 minutes | | P |
| Article 13(1) Article 1 (b) shall be replaced by the following b) | Frequency change speed | See table below | P |
| | PGM's ability to stay at work at frequency change speeds of no greater than:<br>$\left\lvert\frac{df_{max}}{dt}\right\rvert = 2{,}0\left[\frac{Hz}{s}\right]$. , where this value would be measured as an average in a sliding measuring window of 500 ms.<br>Requirement $\left\lvert\frac{df_{max}}{dt}\right\rvert = 2{,}0\left[\frac{Hz}{s}\right]$ is a minimum requirement. Where the use of technology allows you to connect to the network and work at higher frequency change speed values, it is not permissible to limit the operation of the PGM module to the size defined above, unless this is due to the agreed security setting from network loss (Lost of Mains ( LOM). | | P |
| Article 13(1) Article 2 (b) shall be replaced by the following a) | Static parameters of LFSM-O mode | See table below | P |
| | Ability to set the LFSM-O frequency threshold in the range: 50.2 Hz-50.5 Hz, the default value of 50.2 Hz. | | P |
| | Ability to set LFSM-O statistics in range: 2-12%, default of 5%. | | P |
| | For energy park modules, the $P_{ref}$ value is the maximum active power. | | P |
| | You must provide the option to select the setting on the TSO command of the LFSM-O activation frequency threshold and the statistics within the required range. | | P |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | Regardless of the overriding value of the power settled lfsm-o mode, it is necessary to ensure: the ability to block LFSM-O mode and the ability to perform intervention work with the values indicated by the relevant OS. | | |
| Article 13(1) Article 2 (b) shall be replaced by the following (b) | Start-up pgm type A instead of LFSM-O mode | See table below | P |
| | It is not allowed to disable PGM Type A instead of providing lfsm-o capability.<br>The above decision does not preclude the adaptation of PGM Type A to LFSM-O mode by gradually disabling individual generation sources included in pgm, in particular PPM. | | P |
| Article 13(1) Article 2 (b) shall be replaced by the following (f) | LFSM-O regulatory minimum | See table below | P |
| | It is required that after reaching the minimum level of regulation in LFSM-O mode, the power generation module has the ability to work stable at this level. Work below the minimum level of regulation shall not be required unless such a requirement is determined individually in the framework of the adaptation of PGM to island work. | | P |
| | The reduction of the active power of PPM resulting from LFSM-O operation is realized from the starting point of the active power at the time of reaching the lfsm-o activation threshold to the power value resulting from the static characteristics of LFSM-O mode, unless reduce the power of the primary energy carrier below the level to achieve the required power level. | | P |
| Article 13(1) 4 | Permissible power reduction | See table below | P |
| | The permissible reduction of active power compared to the maximum power generated (defined at a frequency of 50 Hz), at a decreasing frequency shall be: | | P |
| | for synchronous energy generation modules excluding synchronous energy generation modules referred to in point b): 10% maximum power per 1 Hz, with a frequency drop below 49 Hz (fig. a); | | P |
| | for synchronous gas or gas-steam power generation modules: 4% maximum power per 1 | | P |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | Hz, with a frequency drop below a frequency of 49.5 Hz (fig b); | | |
| | for energy park modules: 2% maximum power per 1 Hz with a frequency drop below 49 Hz (fig. c). | | P |
| | Where the PGM may work with less power reduction, such work should be provided (applies in particular to PPM). | | P |
| | In accordance with Article 2(2) of Regulation (EC) No Whereas article 13(1) of Regulation (EC) No 1 5 the requirement for permissible reduction of active power is laid down for nominal ambient conditions which include, in particular, the following parameters:<br>Pressure<br>Temperature<br>relative humidity. | | P |
| | Where ambient parameters have a significant impact on the capacity to generation of maximum power, the owner of the energy generation plant shall provide the relevant OS with the relevant characteristics to identify those limitations. | | P |
| Article 13(1) 6 | PGM remote control | See table below | P |
| | PGM is required to be adapted to remote control by the relevant OS object in terms of discontinuation of the active power generation. Telecommunications standards are determined by the competent OS. | | P |
| Article 13(7) | Automatic connection to the network | See table below | P |
| | The conditions for automatic CONNECTION of PGM to the network (must be met together): | | P |
| | voltage frequency in the network ranges from 49.00 Hz to 50.05 Hz, and | | P |
| | time delay (understood as the time between the time when the frequency value returns to the interval defined above and the moment the power generation module is switched on to the grid) - at least 60 sec., and | | P |
| | The maximum permissible increase gradient of the generated active power is 10% of the maximum power per minute. | | P |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| Article 14(1) Article 2 (b) shall be replaced by the following (b) | B-type PGM remote control | | N/A |
| | Pgm capabilities are required to remotely control the object in terms of active power reduction at the command of the relevant OS. The reduction requirement also remains active if the primary energy source is insufficient to achieve the set value of the limitation.<br>In order to allow remote control generated active power through additional equipment, telecommunications standards set and published by the relevant OS should be met. | | N/A |
| Article 14(1) Article 3 (b) shall be replaced by the following (a) point (i) | FRT for symmetric allots | | N/A |
| | PGM may disconnect from the network during short circuit strain where the interphase voltage at the connection point decreases below the required short-circuit profile and the voltage values at the connection point immediately before the short circuit exceed the limit value set out in the relevant legal regulations. | | N/A |
| | • Synchronous energy generation modules must meet the requirements for the ability to stay at work during short circuits described in the following table and in the following figure.<br>Parameters in the range of synchronous capacity of energy generation modules to stay at work during short circuit:<br>The required short-circuit remain profile for the synchronous power generation module: | | N/A |
| | • Energy park modules must comply with the requirements for the ability to stay at work during short circuits described in the following table and in the following figure: | | N/A |

| Voltage parameters [pu] | | Time parameters [s] | |
|---|---|---|---|
| Uret: | 0,05 | tclear: | 0,15 |
| Uclear: | 0,70 | trec1: | 0,15 |
| Urec1: | 0,70 | trec2: | 0,70 |
| Urec2: | 0,85 | trec3: | 1,50 |



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<table>
<tr><td></td><td>Parameters in terms of the ability of energy park modules to stay at work during short circuit:<br><table><tr><td colspan="2">Voltage parameters [pu]</td><td colspan="2">Time parameters [s]</td></tr><tr><td>Uret:</td><td>0,05</td><td>tclear:</td><td>0,15</td></tr><tr><td>Uclear:</td><td>0,05</td><td>trec1:</td><td>0,15</td></tr><tr><td>Urec1:</td><td>0,05</td><td>trec2:</td><td>0,15</td></tr><tr><td>Urec2:</td><td>0,85</td><td>trec3:</td><td>2,50</td></tr></table></td><td></td><td></td></tr>
<tr><td>Article 14(1) Article 3 (b) shall be replaced by the following b)</td><td>FRT for unbalanced short circuits</td><td></td><td>N/A</td></tr>
<tr><td></td><td>The required PGM ability to stay at work during short circuits in the event of unsymmetric shorts relate to the course of the interphase voltage with the smallest amplitude.<br>PGM may disconnect from the network during an unbalanced short circuit where at least one of the interphase voltages at the connection point decreases below the required short-circuit profile and the voltage values at the point of connection immediately before short circuit, they exceed the limit value set out in the relevant legal regulations.</td><td></td><td>N/A</td></tr>
<tr><td></td><td>• Synchronous energy generation modules must meet the requirements for the ability to stay at work during short circuits described in the following table and in the following figure.<br>Parameters in the range of synchronous capacity of energy generation modules to stay at work during short circuit:<br>Required short-circuit remain profile for synchronous power generation module.<br><table><tr><td colspan="2">Voltage parameters [pu]</td><td colspan="2">Time parameters [s]</td></tr><tr><td>Uret:</td><td>0,05</td><td>tclear:</td><td>0,15</td></tr><tr><td>Uclear:</td><td>0,70</td><td>trec1:</td><td>0,15</td></tr><tr><td>Urec1:</td><td>0,70</td><td>trec2:</td><td>0,70</td></tr><tr><td>Urec2:</td><td>0,85</td><td>trec3:</td><td>1,50</td></tr></table></td><td></td><td>N/A</td></tr>
</table>




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| Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | • Energy park modules must comply with the requirements for the ability to stay at work during short circuits described in the following table and in the following figure:<br>Parameters in terms of the ability of energy park modules to stay at work during short circuit:<br>Voltage parameters [pu] / Time parameters [s]<br>Uret: 0,05 — tclear: 0,15<br>Uclear: 0,05 — trec1: 0,15<br>Urec1: 0,05 — trec2: 0,15<br>Urec2: 0,85 — trec3: 2,50 | | N/A |
| Article 14(1) Article 4 (b) shall be replaced by the following (a) | reconnecting PGM to the network | | N/A |
| | Conditions for reconnecting PGM to the network after its accidental disconnect due to network interference (must be met together):<br>• voltage frequency in the network ranges from 49.00 Hz to 50.05 Hz, and<br>• the voltage value at the connection point shall be within the range of the permissible tensions set out in the relevant legal regulations, and<br>• time delay (understood as the time between the time when the value of the parameters returns to the interval defined above and the moment the power generation module is switched on to the grid) - at least 60 sec.<br>If pgm disconnected from the network as a result of the opening of the switch on the power output track, its re-attachment for PGM type C and D may only take place with the consent or at the command of the competent OS. It is permissible for the relevant OS to use the delay time to block automatic reconnection depending on the location of the power station and the configuration of the network to which the power generation module is connected. | | N/A |
| Article 14 (1) Article 5 should be replaced by following d) point (i) | Data exchange | | N/A |
| | It is required that energy generation modules ensure the power generation plant's ability to exchange information in real time:<br>• Type A & B with the competent OS | | N/A |


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Telefax : +86 20 38320478
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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | • type C and D with the relevant OS and TSO. | | |
| Article 14(1) Article 5 (b) shall be replaced by the following (d) point (ii) | Exchange of real-time data | | N/A |
| | For entities connected to the OSD network, the scope of real-time data should include at least:<br>• position of linear connectors at the connection point; And<br>• active and passive power flow, current and voltage at the point of connection The competent OS, in agreement with the TSO, has the right to require a wider range of exchanged information in real time, necessary for the planning and operation of the system.<br>For entities connected to the TSO network, the scope of the real-time data should include at least:<br>• position of linear connectors at the connection point or at another point of interaction agreed with the TSO;<br>• the flow of active and passive power, current and voltage at the point of connection or at another point of interaction agreed with the TSO;<br>• in the case of an energy generation plant that consumes energy for non-own needs, net active power and net inactive power at the point of connection or at another point of interaction agreed with the TSO.<br>The TSO has the right to require a wider range of exchanged information in real time, necessary for the planning and operation of the system. | | N/A |
| Article 15 Article 2 (a) shall be replaced by the following (a) | Automatic power control | | N/A |
| | The period during which the modified active power setpoint must be reached must not exceed 15 minutes.<br>The accuracy of the regulation should not be less than 1% of the maximum power value for synchronous power generating modules and 2% of the set power for power park modules. | | N/A |
| Article 15 Article 2 (b) shall be replaced by the following (b) | Manual power control | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | The period during which the modified active power setting value must be reached, when the automatic control devices are inoperative, shall not be longer than 30 minutes from the moment of issuing the command by the relevant OS. The accuracy of the regulation should not be less than 2% of the maximum power value for synchronous power generating modules and 5% of the set power for power park modules. | | N/A |
| Article 15 Article 2 (c) shall be replaced by the following (c) point (i) | Static parameters of the LFSM-U mode | | N/A |
| | Ability to set the LFSM-U mode frequency threshold in the range: 49.5Hz - 49.8Hz, default 49.8Hz<br>Ability to set the LFSM-U mode droop in the range: 2-12%, default 5%.<br>For PPM power park modules, the $P_{ref}$ value is the maximum active power.<br>hall be possible to select a setting within the required range, at the request of the TSO:<br>• LFSM-U mode activation frequency threshold,<br>• Droop. | | N/A |
| | It shall be possible for the relevant OS to block the LFSM-U function in the event of real-time (rather than forecast-identified) network constraints. The use of LFSM-U mode lock should be limited to the area of the system where network restrictions have occurred. The relevant OS should inform the TSO about active LFSM-U locks. The network conditions enabling LFSM-U blocking should be agreed between the relevant OS and TSO. | | N/A |
| Article 15 Article 2 (d) shall be replaced by the following (d) point (i) | Static parameters of the FSM mode | | N/A |
| | The required parameters for active power frequency response in FSM. | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | <table><tr><th colspan="2">Parameters</th><th>Ranges or values</th></tr><tr><td colspan="2">Active power range related to maximum power $\frac{\lvert \Delta Pi \rvert}{P\,max}$</td><td>5%</td></tr><tr><td rowspan="2">Frequency response insensitivity</td><td>$\lvert \Delta f_i \rvert$</td><td>10 mHz</td></tr><tr><td>$\frac{\lvert \Delta f_i \rvert}{f_n}$</td><td>0.02%</td></tr><tr><td colspan="2">Frequency response dead zone</td><td>0–500 mHz</td></tr><tr><td colspan="2">Droop $s_1$</td><td>2–12%</td></tr></table> | | |
| Article 15 Article 2 (d) shall be replaced by the following (d) point (iii) | Dynamic parameters of the FSM mode | | N/A |
| | Parameters of the full activation of active power in response to a frequency change resulting from a frequency step change:<br><table><tr><th>Parameters</th><th>Ranges or values</th></tr><tr><td>Active power range related to maximum power (frequency response range) $\frac{\lvert \Delta Pi \rvert}{P\,ref}$</td><td>5%</td></tr><tr><td>For inertia power generating modules maximum allowable initial delay $t$ 1, unless otherwise justified in accordance with Art. 15 paragraph 2 lit. d) point (iv)</td><td>2 s</td></tr><tr><td>For power generating modules without inertia, the maximum allowable initial lag $t$ 1, unless otherwise justified in accordance with Art. 15 paragraph 2 lit. d) point (iv)</td><td>0.5 s</td></tr><tr><td>Maximum allowable selection of full activation time $t$ 2</td><td>30 s</td></tr></table> | | N/A |
| Article 15 Article 2 (d) shall be replaced by the following (d) point (iv) | Initial FSM delay | | N/A |
| | For power generating modules without inertia, the maximum allowable initial delay $t_1$ should be 0.5 s as per Table 5 of the NC RfG. | | N/A |
| Article 15 Article 2 (d) shall be replaced by the following (d) point (v) | FSM operation time | | N/A |
| | The power-generating module shall be capable of providing a full active power frequency response for at least 30 minutes, provided the primary energy source is available.<br>The frequency power correction signal must remain active as long as frequency conditions are present for FSM operation. It is not allowed to withdraw the power correction signal from the | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | frequency in the event of a temporary loss of the primary energy source. | | |
| Article 15 Article 2 (g) shall be replaced by the following (g) point (i) | Transmission of signals for FSM monitoring | | N/A |
| | If a given PGM module is involved in the FSM frequency control process, the signals for monitoring the FSM active power frequency response are to be sent to the TSO. | | N/A |
| Article 15 Article 2 (g) shall be replaced by the following (g) point (ii) | Signals for monitoring the FSM mode | | N/A |
| | Where a PGM is involved in the FSM frequency control process, additional signals to be provided by the power generating module using monitoring and recording equipment to verify the operation of the active power frequency response reserve shall include at least:<br>local frequency or speed;<br>PGM operating mode (i.e. LFSM-U / LFSM-O, PPW mode and island operation - if the PGM is adapted to it),<br>however, at the stage of connecting the facility to the network or when the TSO starts to use the PGM's ability to regulate the frequency in the system, the relevant OS, in consultation with the TSO, specifies additional signals necessary for monitoring, taking into account the generation technology. | | N/A |
| Article 15 Article 3 | Voltage protections | | N/A |
| | Conditions for the actual disconnection of PGMs:<br>If the relevant OS, in agreement with the TSO, decides to allow, for system reasons, the use of these protections, then the voltage thresholds at the connection point at which automatic disconnection of the facility may occur should be correlated with the voltage limits allowed by the relevant OS in the MV network. which it manages, i.e. .:<br>the undervoltage protection setting should be lower than the minimum voltage value at which the PGM should remain network-capable on the other hand, the overvoltage protection setting should be higher than the maximum voltage | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | value at which the PGM should remain network-capable.<br>Voltage protections at the connection point should not be active, unless they are used to prepare the unit for the defense / reconstruction of the KSE, e.g. by switching to the PPW in advance. They should not be used to protect the PGM against damage - this is the purpose of the protections installed directly on the device, referred to in Art. 14 paragraph 5 lit. b) point (iii).<br>The settings of the voltage levels of the protection operation are set individually as specific for the object. | | |
| Article 15 Article 5 (c) shall be replaced by the following (c) point (iii) | Work for own needs | | N/A |
| | The minimum required working time for the own needs of power generating modules incapable of quick resynchronization will be determined individually, taking into account the technology of execution, and this time may not be shorter than 2 hours.<br>Work for own needs may not be interrupted after exceeding the above-specified minimum 2-hour time limit, provided that its further work does not endanger the safety of people and devices.<br>Longer working time for own needs will be required, under separate arrangements, from the PGM modules intended for use in the process of defense and reconstruction of the PPS, in particular those adapted to island operation. | | N/A |
| Article 15 Article 6 (a) shall be replaced by the following (a) | Angular stability | | N/A |
| | Synchronous power-generating modules must be equipped with protection devices which respond to slip of the rotor poles, the criterion of which is impedance.<br>Another, equivalent safeguard may be used to detect any loss of angular stability. | | N/A |
| Article 15 Article 6 (b) shall be replaced by the following (b) point (i) | Short circuit recorder | | N/A |
| | Unless the relevant OS specifies otherwise, power generating plants must be equipped with | | N/A |


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| Clause | Requirement + Test | Result – Remark | Verdict |
| | an installation ensuring that the voltage and current waveforms during faults / short-circuits are recorded and the dynamic behavior of the system is monitored with accuracy (for nominal values in steady state):<br>voltage - accuracy 0.5%,<br>current - accuracy 0.5%,<br>active power - accuracy 1.0%,<br>reactive power - accuracy 1.0%,<br>frequency - accuracy 0.02%.<br>The instantaneous values of current and voltage should be recorded with the recording frequency and with the time synchronization required by the appropriate OS. | | |
| Article 15 Article 6 (b) shall be replaced by the following (b) point (ii) | The trigger criteria and sample sizes | | N/A |
| | Unless otherwise specified, it is proposed to agree with the owner of the generating facility the following threshold values for the registration:<br>for voltage (single-period RMS value updated every 10 ms in the measuring sliding window):<br>a) for networks with a voltage of 400 kV and above: $U_{RMS}$ <0.9 pu or $U_{RMS}$ > 1.05 pu,<br>b) for 220 kV and 110 kV networks: $U_{RMS}$ <0.9 pu or $U_{RMS}$ > 1.118 pu,<br>c) for networks below 110 kV: $U_{RMS}$ <0.9 pu or $U_{RMS}$ > 1.1 pu<br>for frequency: f <49.8 Hz or f> 50.2 Hz. | | N/A |
| Article 15 Article 6 (b) shall be replaced by the following (b) point (iii) | Oscillation alarm | | N/A |
| | As part of the detection of weakly damped power oscillations, it was assumed that the oscillations with a frequency of 0.1 Hz to 5 Hz were monitored, and at the same time the following thresholds were used to trigger the recording of oscillations (it is assumed that the thresholds of 2 values are exceeded simultaneously):<br>oscillation amplitude - Awzgl> 2%<br>where Awzgl = A / P, A - oscillation amplitude [MW], P - generator active power [MW] | | N/A |



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| | damping factor - ξ <5%<br>where: ξ = (A1-A2) / A1, A1, A2 - successive oscillation amplitudes<br>The above approach does not exclude the use of continuous recording, processed during which violations of the established thresholds will be identified. | | |
| Article 15 Article 6 (b) shall be replaced by the following (b) point (iv) | Communication protocols | | N/A |
| | Simulation models that adequately reflect the behavior of a power generating module both in steady state and for dynamic simulations (50 Hz component) or in short term electromagnetic simulations should comply with CGMES 2.4.15 or later, unless otherwise agreed between the generating facility owner energy and the relevant OS and TSO. | | N/A |
| Article 15 Article 6 (c) shall be replaced by the following (c) point (iii) | Simulation models | | N/A |
| | At the request of the relevant OS, the power generating facility owner must provide simulation models. Simulation models that adequately reflect the behavior of a power generating module both in steady state and for dynamic simulations (50 Hz component) or in short term electromagnetic simulations should comply with CGMES 2.4.15 or later, if the relevant OS in coordination with TSO he decided otherwise. | | N/A |
| Article 15 Article 6 (e) shall be replaced by the following (e) | Speed of power changes | | N/A |
| | Unless the relevant OS and the owner of a power-generating module in agreement with the TSO agree otherwise, the minimum and maximum limit values for the rate of change of active power output (change limit values) for both positive and negative change in the active power output of a power-generating module, taking into account the specifics of the primary drive technology are within the ranges given in the table below. | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | <table><tr><th>Type of power generating module</th><th>Limits of change rates of active power generated in the negative and positive directions [% of maximum power / minute]</th></tr><tr><td>thermal units (hard coal)</td><td>4 ÷ 6</td></tr><tr><td>thermal units (lignite)</td><td>3 ÷ 4</td></tr><tr><td>gas heat units (closed cycle)</td><td>5 ÷ 8</td></tr><tr><td>gas heat units (open circuit)</td><td>12 ÷ 20</td></tr><tr><td>thermal units powered by an internal combustion engine</td><td>80 ÷ 100</td></tr><tr><td>water units</td><td>40 ÷ 50</td></tr><tr><td>wind units</td><td>90 ÷ 100</td></tr><tr><td>photovoltaic units</td><td>90 ÷ 100</td></tr></table> The limit values of the active power change rate given in the table represent the average values of the base load change rate in the range from the technical minimum to the maximum power PGM. In technically justified cases, for thermal units in the range from 0.9 maximum power to 1.0 maximum power, lower limit active power change rates are allowed, which must be agreed with the relevant OS in consultation with the TSO. | | |
| Article 16 Article 2 (a) shall be replaced by the following (a) point (i) | Voltage conditions | | N/A |
| | The minimum time during which a power-generating module must be able to operate with voltages deviating from the reference 1 pu voltage at the connection point without disconnecting from the grid are:<br>• for base voltage from 110 kV to 300 kV:<br><table><tr><th>Voltage range</th><th>Working time</th></tr><tr><td>1.118 pu - 1.15 pu</td><td>60 minutes</td></tr></table><br>• for base voltage from 300 kV to 400 kV:<br><table><tr><th>Voltage range</th><th>Working time</th></tr><tr><td>1.05pu - 1.10pu</td><td>60 minutes</td></tr></table> | | N/A |
| Article 16 Article 2 (a) shall be replaced by the following (a) point (ii) | Voltage and frequency conditions | | N/A |
| | In the event of simultaneous overvoltage and frequency decrease or simultaneous overvoltage and frequency increase, the required operating | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | times will be shorter, resulting from separate frequency and voltage requirements. | | |
| Article 16 Article 2 (c) | voltage protections | | |
| | If the relevant OS, in consultation with the TSO, decides to allow, for system reasons, the use of protections, then the voltage thresholds at the connection point at which automatic disconnection of the facility may occur should be correlated with the limit values defined for undervoltage and overvoltage settings (based on Article 16 (2) (a) (i)) for PGMs connected to the 110 kV grid and above and specified by the relevant OS for PGMs connected to the grid with a voltage lower than 110 kV, i.e. .:<br>the undervoltage protection setting should be lower than the minimum voltage value at which the PGM should remain network-capable;<br>the overvoltage protection setting should be higher than the maximum voltage value at which the PGM should be able to work in the network. | | N/A |
| | Undervoltage protections at the connection point should not be active, unless they are used to prepare the PGM for the defense / reconstruction of the Polish Power System, e.g. by switching to the PPW in advance. They should not be used to protect the PGM against damage - this is the purpose of the protections installed directly on the device, referred to in Art. 14 (5) b) point (iii). The settings for automatic PGM disconnection are set individually as site-specific settings. | | N/A |
| Article 16 Article 3 (a) item (i) | FRT for symmetrical short-circuits | | N/A |
| | The PGM may disconnect from the network during a short-circuit in the event that the phase-to-phase voltage at the connection point drops below the required stay-in-service profile during the short-circuit, and the voltage at the connection point immediately before the short circuit exceeds:<br>the value specified in art. 16 paragraph 2 lit. a) (for 110 kV networks and above);<br>the limit value specified in the relevant legal regulations (for networks below 110 kV); | | N/A |
| | Type D synchronous PGMs must meet the fault-ride-through capability requirements described in the table below and in the figure below. | | N/A |



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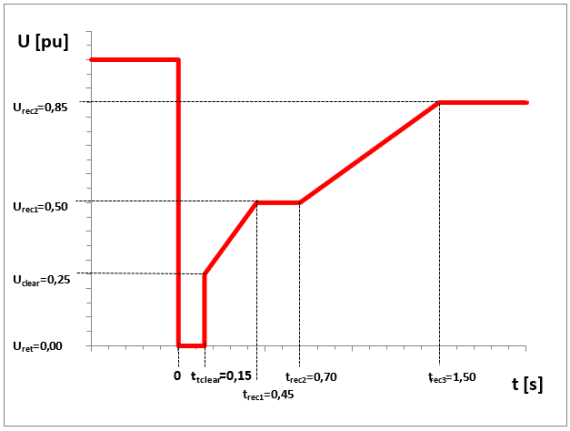
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | Parameters for the fault-ride-through ability of synchronous power generating modules.<br><table><tr><td>Voltage parameters [pu]</td><td></td><td>Time parameters [s]</td><td></td></tr><tr><td>Uret:</td><td>0.00</td><td>tclear:</td><td>0.15</td></tr><tr><td>Uclear:</td><td>0.25</td><td>trec1:</td><td>0.45</td></tr><tr><td>Urec1:</td><td>0.50</td><td>trec2:</td><td>0.70</td></tr><tr><td>Urec2:</td><td>0.85</td><td>trec3:</td><td>1.50</td></tr></table> | | |
| | Required fault-ride-through profile for a synchronous power generating module.<br> | | N/A |
| | Type D PPMs must meet the fault-ride-through capacity requirements described in the table below and in the figure below:<br>Parameters for the fault-ride-through ability of power park modules<br><table><tr><td>Voltage parameters [pu]</td><td></td><td>Time parameters [s]</td><td></td></tr><tr><td>Uret:</td><td>0.00</td><td>tclear:</td><td>0.15</td></tr><tr><td>Uclear:</td><td>0.00</td><td>trec1:</td><td>0.15</td></tr><tr><td>Urec1:</td><td>0.00</td><td>trec2:</td><td>0.15</td></tr><tr><td>Urec2:</td><td>0.85</td><td>trec3:</td><td>2.5</td></tr></table> | | N/A |
| | Required fault-ride-through profile for power park modules. | | N/A |



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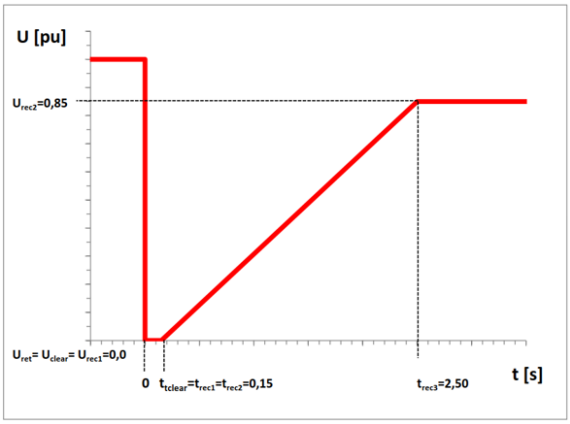
<table>
<tr><th colspan="4">Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21</th></tr>
<tr><th>Clause</th><th>Requirement + Test</th><th>Result – Remark</th><th>Verdict</th></tr>
<tr><td></td><td>
</td><td></td><td></td></tr>
<tr><td>Article 16 Article 3 (c)</td><td>FRT for asymmetrical short-circuits</td><td></td><td>N/A</td></tr>
<tr><td></td><td>The requirements for staying in service during asymmetrical short-circuits refer to the waveform of the phase-to-phase voltage with the smallest amplitude.<br>A power-generating module may disconnect from the grid during an asymmetrical short-circuit in the event that at least one of the phase-to-phase voltages at the connection point drops below the curve in the relevant figure below and the voltage at the connection point immediately before the fault exceeds:<br>the value specified in art. 16 paragraph 2 lit. a) (for 110 kV networks and above);<br>limit value specified in the relevant legal regulations (for networks below 110 kV)</td><td></td><td>N/A</td></tr>
<tr><td></td><td>Type D synchronous PGMs must meet the fault-rid-through capability requirements described in the table below and in the figure below.<br>Parameters for the fault-rid-through ability of synchronous power generating modules.
<table>
<tr><th colspan="2">Voltage parameters [pu]</th><th colspan="2">Time parameters [s]</th></tr>
<tr><td>Uret:</td><td>0.00</td><td>tclear:</td><td>0.15</td></tr>
<tr><td>Uclear:</td><td>0.25</td><td>trec1:</td><td>0.45</td></tr>
<tr><td>Urec1:</td><td>0.50</td><td>trec2:</td><td>0.70</td></tr>
<tr><td>Urec2:</td><td>0.85</td><td>trec3:</td><td>1.50</td></tr>
</table></td><td></td><td>N/A</td></tr>
<tr><td></td><td>Required fault-rid-through profile for a synchronous power generating module.</td><td></td><td>N/A</td></tr>
</table>



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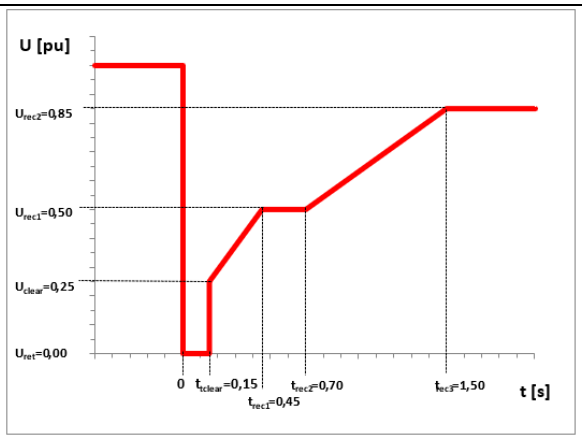
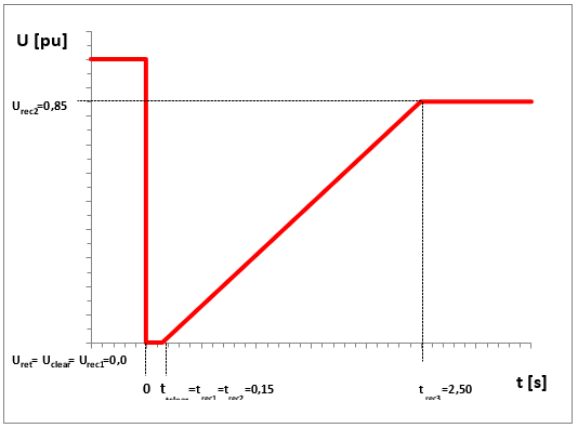
| |  | | |
| | Type D PPMs must meet the fault-rid-through capacity requirements described in the table below and in the figure below:<br>Parameters for the fault-rid-through ability of power park modules<br>Voltage parameters [pu] / Time parameters [s]<br>Uret: 0.00 — tclear: 0.15<br>Uclear: 0.00 — trec1: 0.15<br>Urec1: 0.00 — trec2: 0.15<br>Urec2: 0.85 — trec3: 2.5 | | N/A |
| | Required fault-rid-through profile for power park modules.<br> | | N/A |
| Article 16 Article 4 (d) | synchronization conditions | | N/A |



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| | Unless the relevant OS and the generating facility owner have agreed otherwise, the following requirements for synchronization with the grid shall be defined: | | N/A |
| | (i) voltage, the agreed voltage difference should be in the range from 0% to + 5% of the network voltage; | | N/A |
| | (ii) frequency, the agreed frequency difference should not be greater than 0.067 Hz; | | N/A |
| | (iii) range of the phase angle, the agreed difference of the phase angle should be in the range from 0 ° to + 10 °, the "+" sign being the phase advance of the generator in relation to the network; | | N/A |
| | (iv) phase sequence (checking the phase sequence before synchronization); | | N/A |
| | (v) voltage and frequency deviations - synchronization should be possible in the range of network frequencies resulting from the provisions of Art. 13 paragraph 1 lit. a) and in terms of tensions:<br>• as defined in art. 16.2.a. (i) (for PGMs connected to the 110 kV grid and above),<br>• determined by the relevant OS (for PGMs connected to the network with a voltage lower than 110 kV). | | N/A |
| Article 17 Article 2 (a) | reactive power | | N/A |
| | Unless the relevant OS specifies otherwise, the synchronous power generating module, with the maximum active power generated, must be able to provide (at the device terminals) reactive power with a power factor in the range of cosϕ = 0.85 in the direction of reactive power production and cosϕ = 0.95 in the direction of reactive power consumption. With active power output below maximum power (P <Pmax), the synchronous power-generating module shall be capable of generating reactive power (MVar) within the range resulting from the PQ capability pie of the synchronous power-generating module. | | N/A |
| Article 17 Article 3 | active power restoration after short-circuit | | N/A |



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Telefax : +86 20 38320478

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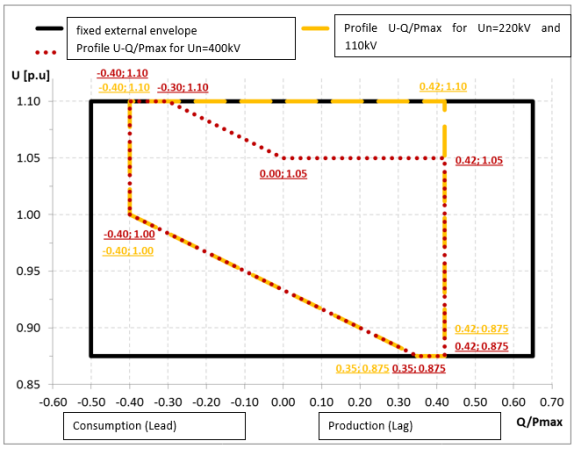
| | | | |
|---|---|---|---|
| | Post-fault recovery of active power by a synchronous PGM module should take place without undue delay, in accordance with the natural properties of the synchronous machine.<br>In the case of using fast valving automatics, post-fault active power recovery may take place with different characteristics than those resulting from the natural properties of the synchronous PGM module, agreed with the relevant OS in consultation with the TSO. | | N/A |
| Article 18 Article 2 (b) point (i) (ii) (iii) | reactive power | | N/A |
| | The ability of a Type D synchronous power generating module connected to a 110 kV grid and above to generate reactive power at maximum power is defined in the table below and in the figure below. | | N/A |
| | Parameters of the inner envelope<br>Rated voltage of the network / The maximum range of Q / Pmax / The maximum range of the steady state voltage level in relative units<br>400 kV / 0.82 / 0.225<br>220 kV and 110 kV / 0.82 / 0.225 | | N/A |
| | UQ / Pmax profile of a synchronous power generating module.<br><br><br>The diagram shows the boundaries of the U-Q/Pmax profile divided into the voltage values at the connection point, expressed as the ratio of its actual value and the reference voltage 1 pu, compared with the ratio of reactive power (Q) to maximum power (Pmax). The position, size and shape of the internal envelope have been marked separately for the 400 kV network voltage (red dotted line) and for the 220 kV and | | N/A |

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| Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | 110 kV networks (dashed orange line). The relevant OS has the right to modify the presented range of the U-Q/Pmax profile (within the maximum values and the fixed outer envelope provided for in the regulation) if such a need is demonstrated by the connection expertise. | | |
| | Unless the relevant OS specifies otherwise, a type C or D synchronous power generating module connected to a network below 110 kV, with the maximum active power generated, must be able to provide (at the device terminals) reactive power with a power factor in the range of cosϕ = 0.85 in the direction of reactive power production and cosϕ = 0.95 in the direction of reactive power consumption. | | N/A |
| Article 18 Article 2 (b) point (iv) | reactive power change rate | | N/A |
| | The synchronous power-generating module must be able to go to any operating point set by the appropriate OS within the U-Q/Pmax profile in up to 150 seconds.<br>The control time is determined individually in the event that a change of the operating point forces a change of the operating state of the static means for reactive power compensation or a change of the network transformer ratio of the synchronous generating module, if any.<br>The above requirement specifies the maximum capacity and does not exclude a slower activation of reactive power, if it results from the properties of the superordinate voltage regulation system or other network conditions. | | N/A |
| Article 18 Article 2 (b) point (v) | PSS | | N/A |
| | To ensure stable operation of the system, all synchronous PGMs type D with a maximum power equal to and above 20 MW must be equipped with the PSS function (power oscillation damping). | | N/A |
| Article 20(1) Article 2 (b) shall be replaced by the following (a) | Passive power | | N/A |
| | Unless otherwise decided by the OS, Type A & B PPM must have the ability to provide, at the point of connection, with maximum force, the passive power resulting from cosφ=0,95 towards the | | N/A |


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Telefax : +86 20 38320478
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| Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | collection and production of reactive power. With ppm load, operating power below the maximum power up to 0,1 maximum power must be made available all available passive power in accordance with technical capabilities, but not less than is apparent from cosφ=0,95 (for current active power), both in and passive power production. With ppm load, active power of less than 0,1 maximum power must be made available all available inactive power in accordance with technical capabilities, with detailed requirements for the energy generation module up to the generation of reactive power will be determined individually with the relevant OS. | | |
| Article 20(1) Article 2 (b) shall be replaced by the following (b) | fast short-circuit current (symmetrical short-circuits) | | N/A |
| | Unless the relevant OS in agreement with the TSO decides otherwise, the PPM should be capable of generating an additional, fast short-circuit current, in accordance with the following static characteristics with an adjustable value of the K factor in the range of 2-10 at a time:<br>(i) 90% additional reactive current at the terminals of basic generating installations in a time not exceeding 60 ms.<br>(ii) The target value of this current should be reached with an accuracy of -10% / + 20% within 100 ms from the moment of the voltage deviation.<br>In the event of short circuits resulting in voltage dips below 0.2 Un, no additional reactive current may be generated on the terminals of the basic generating unit. | | N/A |
| Article 20(1) Article 2 (b) shall be replaced by the following c) | fast short- circuit current (asymmetrical short circuits) | | N/A |
| | Unless otherwise decided by the relevant OS, the energy park module should be capable of a generation of high-speed short-circuit current during unbalanced short circuits in phases subject to voltage reduction. This capacity is to be ensured in compliance with the requirements for static and dynamic parameters as for symmetric alpacas and taking into account the limitations resulting from the unbalanced load of the basic manufacturing system. | | N/A |



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| Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| Article 20(1) Article 3 (b) shall be replaced by the following (a) | reconstruction of active power after short circuit | | N/A |
| | With regard to post-disruption of active power playback, PPM are to comply with the following requirements:<br>(i) Post-interference playback of active power begins when the post-interference voltage is recreated to a value of not less than 90% Un on the basic manufacturing system included in the PPM.<br>(ii) Maximum time for post-interference playback of active power (time counted from short-circuit removal): 5 seconds.<br>(iii) The amount of the reconstituted active power: 90% of pre-interference power, provided that the source of primary energy is available.<br>(iv) Active power restoration accuracy, understood as a repeal established: 10%<br>(v) Unsuppressed oscillations are not allowed after the restoration of active power. | | N/A |
| Article 21 Article 2 (a) | synthetic inertia | | N/A |
| | It is not required to use synthetic inertia, and thus does not define their operational parameters. | | N/A |
| Article 21 Article 3 (b) point (i) | reactive power at maximum power | | N/A |
| | The ability of the D-type PPM connected to the 110 kV grid and above to generate reactive power at maximum power is defined in the table below and in the figure below.<br>Parameters of the inner envelope:<br>Rated voltage of the network / The maximum range of Q/Pmax / The maximum range of the steady state voltage level in relative units<br>400 kV / 0.66 / 0.225<br>220 kV and 110 kV / 0.66 / 0.225 | | N/A |
| | U-Q/Pmax profile of a power park module | | N/A |



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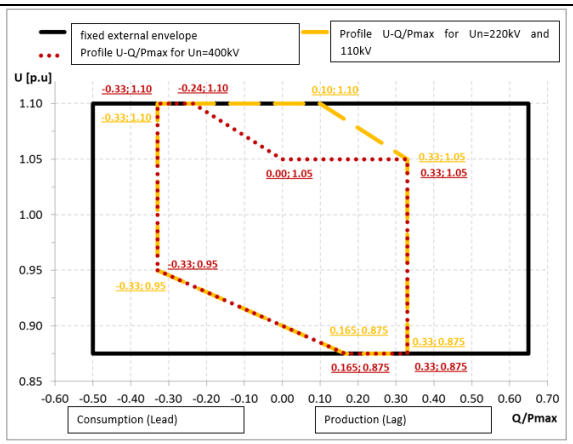
| Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | <br>The diagram shows the boundaries of the U-Q/Pmax profile divided into the voltage values at the connection point, expressed as the ratio of its actual value and the reference voltage 1 pu, compared with the ratio of reactive power (Q) to maximum power (Pmax). The position, size and shape of the internal envelope have been marked separately for the 400 kV network voltage (red dotted line) and for the 220 kV and 110 kV networks (dashed orange line). The relevant OS may modify the presented range of the UQ / Pmax profile (within the maximum values and the fixed outer envelope provided for in the Regulation) if the connection expertise demonstrates such a need. | | |
| | Unless the relevant OS decides otherwise, then a PPM of type C or D connected to a network below 110 kV must be capable of providing, at the connection point, at maximum power, reactive power resulting from cos $\phi$ = 0.95 in the direction of reactive power consumption and production. | | N/A |
| Article 21 Article 3 (c) point (i) | reactive power below maximum power | | N/A |
| | The required PPM capability to generate reactive power below maximum power is defined below:<br>Rated voltage of the network: The maximum range of Q / Pmax<br>400 kV: 0.75<br>220 kV and 110 kV: 0.75 | | N/A |



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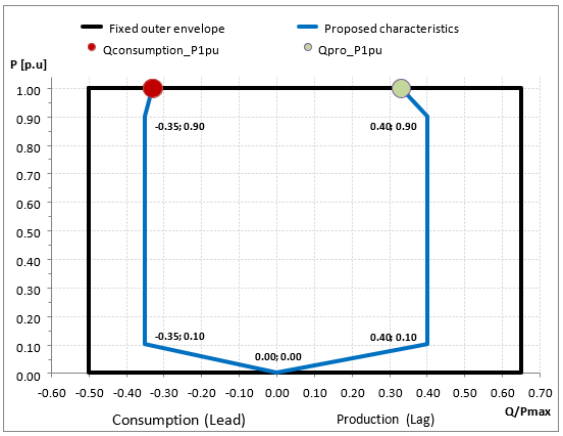
| Poland Deviation of Regulation (EU) 2016/631 (NC RfG) – Article 13 & 14 & 15 & 16 & 20 & 21 | | | |
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | P-Q/Pmax profile of a power park module<br><br><br>The diagram shows the limits of the P-Q/Pmax profile at the point of connection, expressed as the ratio of its actual active power to the maximum power in relative units (pu), against the ratio of reactive power (Q) to maximum power (Pmax). The relevant OS may modify the presented range of the P-Q/Pmax profile (within the maximum values and the fixed outer envelope provided for in the NC RfG), if such a need is demonstrated by the connection expertise. | | N/A |
| | Unless the relevant OS decides otherwise, PPM type C or D connected to the network below 110 kV must be capable of providing at the connection point, in the range below the maximum power to 0.1 of the maximum power of the total available reactive power, as technically possible, however, not less than it results from cos ϕ = 0.95 (for the actual active power), both in the direction of consumption and production of reactive power. When the PPM is loaded with active power in the range below 0.1 Pmax, all available reactive power should be made available, in accordance with the technical possibilities, and the detailed requirements for the power generating module for reactive power generation will be agreed individually with the appropriate OS. | | N/A |
| | PQ / Pmax profile of a type C or D grid-connected power park module below 110 kV | | N/A |



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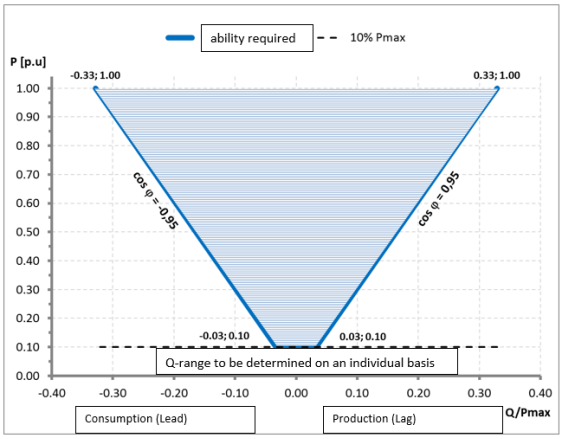
|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| |  | | |
| Article 21 Article 3 (c) point (iv) | reactive power regulation speed | | N/A |
| | The power park module shall be able to go to any operating point within the P- Q/Pmax profile defined in accordance with Art. 21 paragraph 3 lit. c) point (i) within 150 seconds, if for a given mode of regulation, in accordance with the requirements set out pursuant to Art. 21 paragraph 3 lit. d) not otherwise specified. | | N/A |
| | In the case of using static measures for reactive power control, a longer time of the transition between the extreme values of reactive power is allowed (but not longer than 15 min). A longer regulation time will be agreed between the relevant SA and the owner of the generating facility. | | N/A |
| | If the transition between two PGM operating points requires changing the gear position of the PGM transformer on-load tap changer, the indicated time should be extended by the time of adjusting the tap changer position. | | N/A |
| Article 21 Article 3 (d) point (iv) | dynamics of reactive power activation as a function of voltage | | N/A |
| | PPMs must meet the following additional requirements for a stable voltage level:<br>When operating in the voltage regulation mode ( according to the set static characteristic, individually parameterized in the scope resulting from Article 21 (3) (d) (ii), (iii)), as a result of a voltage step change, the power park module must be capable of to achieve 90% of the change in generated reactive power in no more than $t_1$ = 5 seconds, and must reach the value | | N/A |



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|---|---|---|---|
| Clause | Requirement + Test | Result – Remark | Verdict |
| | defined by the slope in no more than $t_2$ = 60 seconds. | | |
| Article 21 Article 3 (d) point (vi) | dynamics of power factor regulation | | N/A |
| | When operating in the power factor control mode, the accuracy of achieving the target power factor value following a sudden change in active power output is expressed by the tolerance for the corresponding reactive power change and should not be greater than 5% of the maximum reactive power or 5 MVAr (depending on whichever is smaller) and achieved in no more than 150 seconds. | | N/A |
| Article 21 Article 3 (d) point (vii) | reactive power control systems operation modes | | N/A |
| | In order to select the reactive power control mode and determine the related settings, the relevant OS should be able to remotely select one of the three regulation modes and set the operating point, unless the relevant OS decides otherwise in agreement with the power park module owner. | | N/A |
| Article 21 Article 3 (e) | priority of active or reactive power input | | N/A |
| | During faults where the ability to stay in service is required, reactive power takes priority. | | N/A |
| Article 21 Article 3 (f) | damping of oscillations | | N/A |
| | The PPM is not required to be capable of contributing to the damping of power oscillations. | | N/A |



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| 4.4.2 | **Frequency range** | **P** |
|---|---|---|
| Frequency range operation test | | |
| | Setting (Minimum requirement) | Can operate according to minimum requirement? |
| Test #1 | 47.5 Hz at least operate 30 min | Yes |
| Test #2 | 48.5 Hz at least operate 30 min | Yes |
| Test #3 | 51.5 Hz at least operate 30 min | Yes |

| 4.5.2 | **Ability to withstand the rate of change of frequency (RoCoF) df/dt** | **P** |
|---|---|---|
| RoCoF operation test, +/-2.0Hz/s for smooth time window of 0.5s | | |
| | Setting | Disconnection during RoCoF? |
| Test #1 | 47.5Hz to 51.5Hz, enhance 2Hz/s, cosφ=1 | No Disconnection |
| Test #2 | 51.5Hz to 47.5Hz, enhance 2Hz/s, cosφ=1 | No Disconnection |

| 4.6.1 | **Power generating module operating mode in which the generated active power decreases in response to an increase in system frequency above a specified value (LFSM-O)** | **P** |
|---|---|---|

a) For Type 2 generation unit, 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 maximum 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% $P_n$.

$P_{MAX}$ = 6600 W, 10% $P_n$= 600 W, intentional delay time: 0.1 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 | 6575.34 | -- | -- | -- |
| 2 | 50.20 | 6576.00 | -- | -- | -- |
| 3 | 50.25 | 6440.03 | 6468.00 (98% $P_{MAX}$) | -27.97 | Yes |
| 4 | 50.70 | 5256.71 | 5280.00 (80% $P_{MAX}$) | -23.29 | Yes |
| 5 | 51.15 | 4075.59 | 4092.00 (62% $P_{MAX}$) | -16.41 | Yes |
| 6 | 50.70 | 5256.68 | 5280.00 (80% $P_{MAX}$) | -23.32 | Yes |
| 7 | 50.25 | 6436.73 | 6468.00 (98% $P_{MAX}$) | -31.27 | Yes |
| 8 | 50.00 | 6571.84 | -- | -- | -- |



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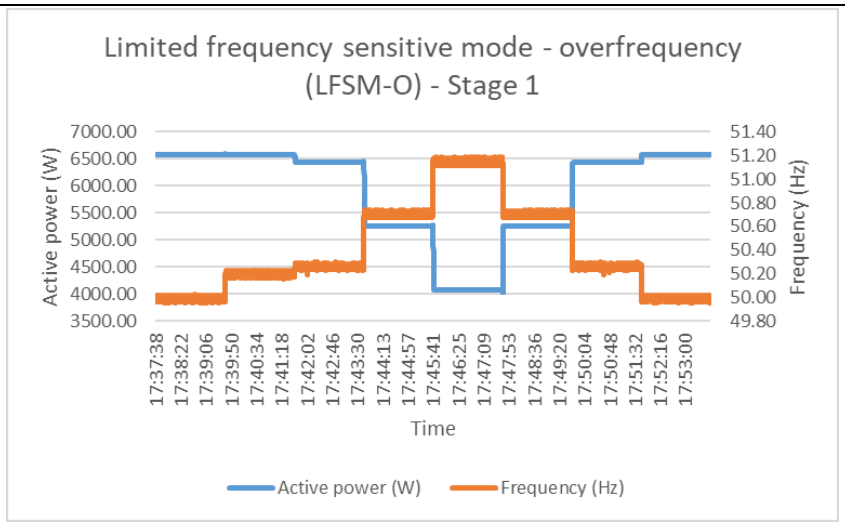
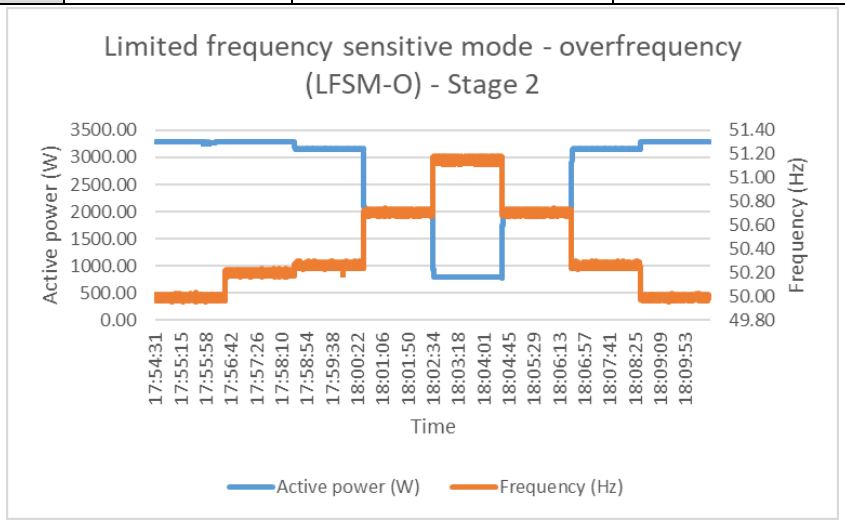



Stage 2: Inverter DC input power is set to 50% of maximum active output power till the end of the test. The active power value shall not be deviated from the required value calculated from the feature curve for more than 10% Pn.

$P_{MAX}$ = 6600 W, 10% $P_n$= 600 W, intentional delay time: 0.1 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 | 3285.76 | -- | -- | -- |
| 2 | 50.20 | 3288.06 | -- | -- | -- |
| 3 | 50.25 | 3156.62 | 3168.00 (48% $P_{MAX}$) | -11.38 | Yes |
| 4 | 50.70 | 1971.98 | 1980.00 (30% $P_{MAX}$) | -8.02 | Yes |
| 5 | 51.15 | 783.87 | 792.00 (12% $P_{MAX}$) | -8.13 | Yes |
| 6 | 50.70 | 1972.09 | 1980.00 (30% $P_{MAX}$) | -7.91 | Yes |
| 7 | 50.25 | 3156.98 | 3168.00 (48% $P_{MAX}$) | -11.02 | Yes |
| 8 | 50.00 | 3288.83 | -- | -- | -- |



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| Active power reaction time<br>Test with active power reduction frequency start point 50.20Hz, gradient s=5% | | | | |
|---|---|---|---|---|
| Test sequence | Freq (Hz) | Measured active output power $P_{measure}$ (W) | Response time (ms) (≤ 2s) | Settling time (ms) (≤ 30s) |
| 1 | 50.00 | 6571.83 | - | - |
| 2 | 50.20 | 6573.74 | - | - |
| 3 | 50.70 | 5259.54 | 0.05 | 0.40 |

The software setting droop can be set from 2% to 12%.

Droop=2%




Droop=12%




Droop=5% for testing







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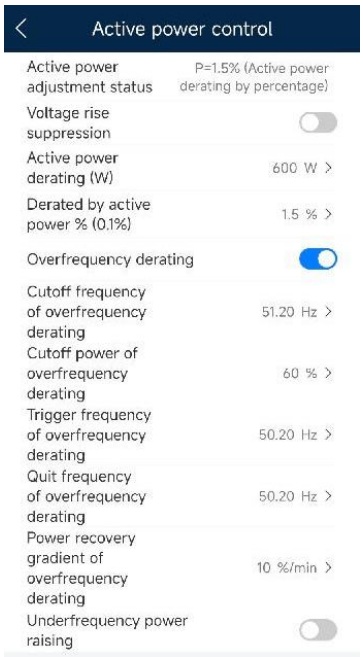
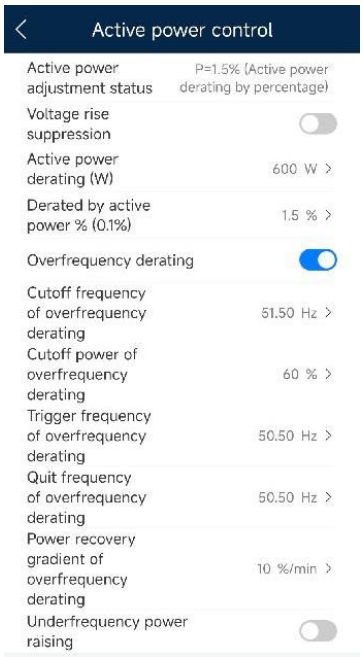
| | |
|---|---|
| | Remark:<br>The Trigger frequency of overfrequency derating is the value which the inverter enters the overfrequency derating;<br>The Quit frequency of overfrequency derating is the value which the inverter quits the overfrequency derating;<br>The Cutoff frequency of overfrequency derating means when the frequency goes up to this setting value, the output power must derating to the Cutoff power;<br>The Cutoff power of overfrequency derating means when the frequency goes up to the Cutoff frequency, the output power must derating to this setting value;<br>The droop can be calculated in the following way:<br>droop= -[(Trigger frequency-Cutoff frequency)/fn]/[(100%-Cutoff power)/100%], where fn is the nominal frequency 50 Hz. |
| The software setting frequency threshold can be set from 50.2 Hz to 50.5 Hz | 50.2 Hz<br><br><br>50.5 Hz<br><br> |



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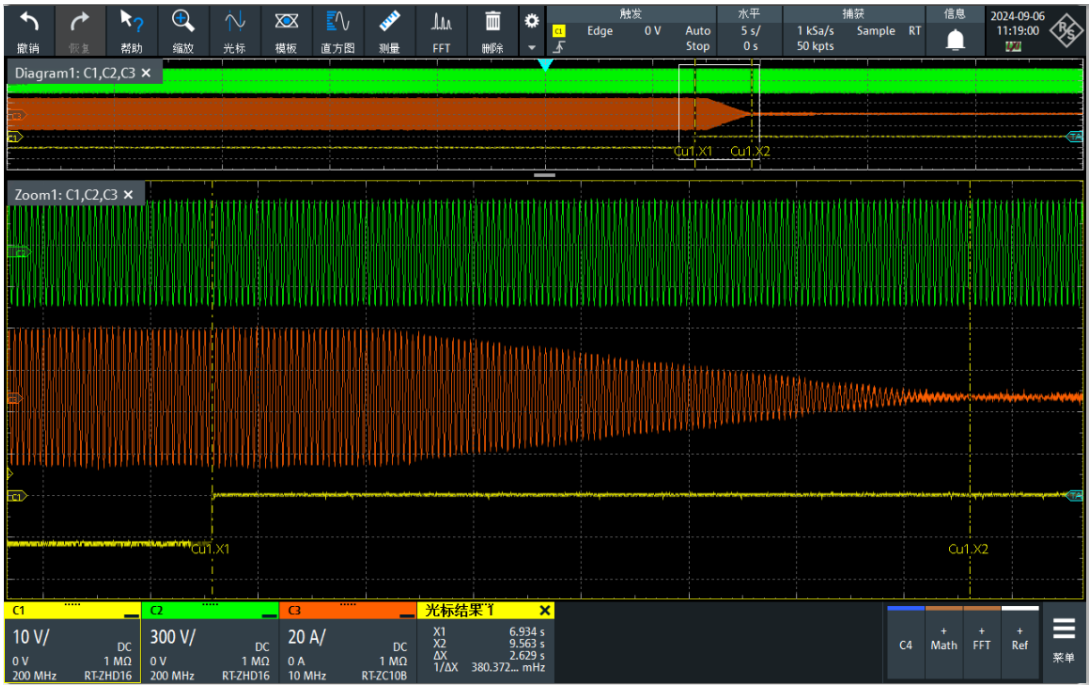
| 4.4.3 | Maximum power capability reduction with falling frequency | | | P |
|---|---|---|---|---|
| Test sequence | Freq (Hz) | Measured active output power $P_{measure}$ (W) | The calculated active output power as per feature curve $P_{minimum}$ (W) | $P_{measure}$ > $P_{minimum}$? (Yes/No) |
| 1 | 50.00 | 6574.51 | 6600.00 (100% $P_{MAX}$) | Yes |
| 2 | 49.50 | 6573.07 | 6600.00 (100% $P_{MAX}$) | Yes |
| 3 | 49.00 | 6571.53 | 6600.00 (100% $P_{MAX}$) | Yes |
| 4 | 48.50 | 6569.72 | 6534.00 (99% $P_{MAX}$) | Yes |
| 5 | 48.00 | 6567.96 | 6468.00 (98% $P_{MAX}$) | Yes |
| 6 | 47.50 | 6566.09 | 6402.00 (97% $P_{MAX}$) | Yes |

| Article 13.6 | Remote ceasing active power generation | P |
|---|---|---|
| Logic interface provided? | Yes | |
| Interface type | RS485 | |
| Expected signal type | Single-Ended signal | |
| Confirm that an input port is provided and can be used to shut down the module within 5 s | 2.629 s | |

Ceasing active power log: (with control signal and current curve)




Channel C1: RS485 command shut down signal;

Channel C2: Grid side voltage signal;

Channel C3: Inverter output current signal.

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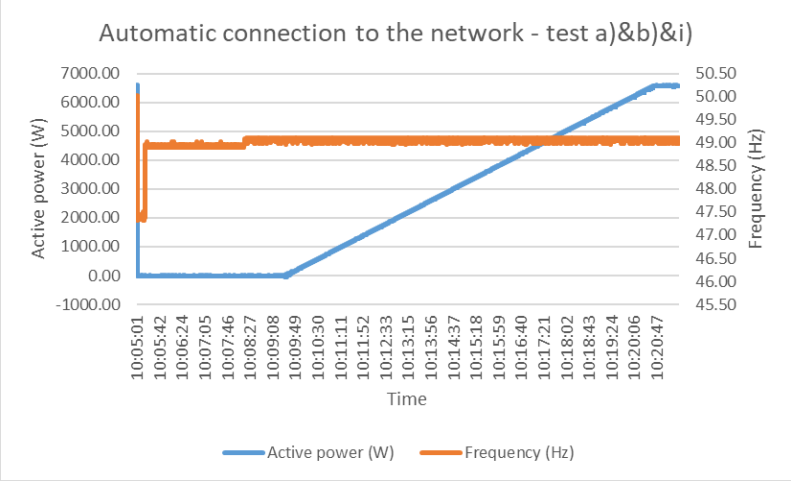
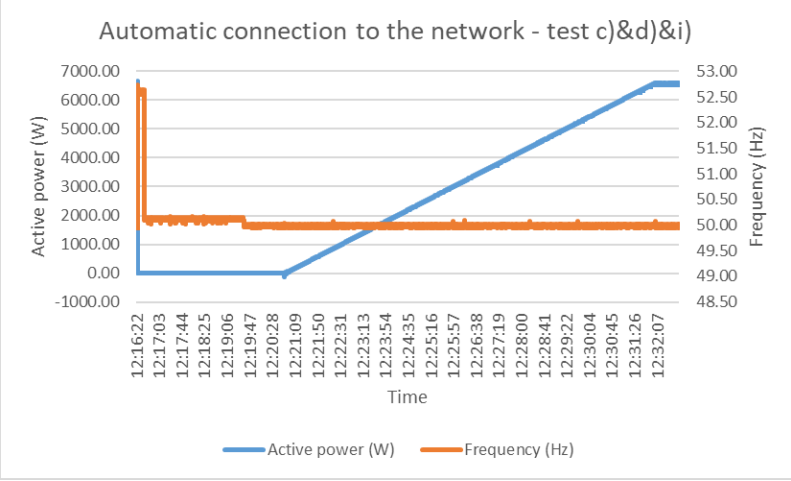
| Article 13.7 | Automatic connection to the network | P |
|---|---|---|
| Test procedure | a) f=48.95 Hz, no reconnection allowed, maintain at least 120 s | Yes |
| | b) f=49.05 Hz, reconnection allowed | Yes |
| | c) f=50.10 Hz, no reconnection allowed, maintain at least 120 s | Yes |
| | d) f=50.00 Hz, reconnection allowed | Yes |
| | e) U=84% Un, no reconnection allowed, maintain at least 120 s | Yes |
| | f) U=86% Un, reconnection allowed | Yes |
| | g) U=111% Un, no reconnection allowed, maintain at least 120 s | Yes |
| | h) U=109% Un, reconnection allowed | Yes |
| | i) After at least 60 s delay confirming that recovery of the system voltage and frequency at a maximum rate of 10 % of maximum power per minute | Yes |

Waveform diagram after underfrequency protection then to step a) to step b) to step i), the reconnection time is 74.35 s, the maximum gradient of increase in active power output is 9.14 %$P_{max}$/min.




Waveform diagram after overfrequency protection then to step c) to step d) to step i), the reconnection time is 74.40 s, the maximum gradient of increase in active power output is 9.05 %$P_{max}$/min.




Waveform diagram after undervoltage protection then to step e) to step f) to step i), the reconnection time

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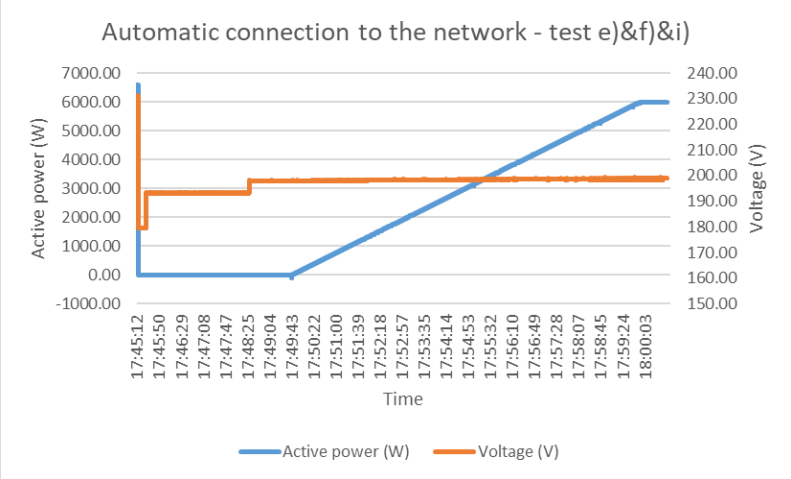
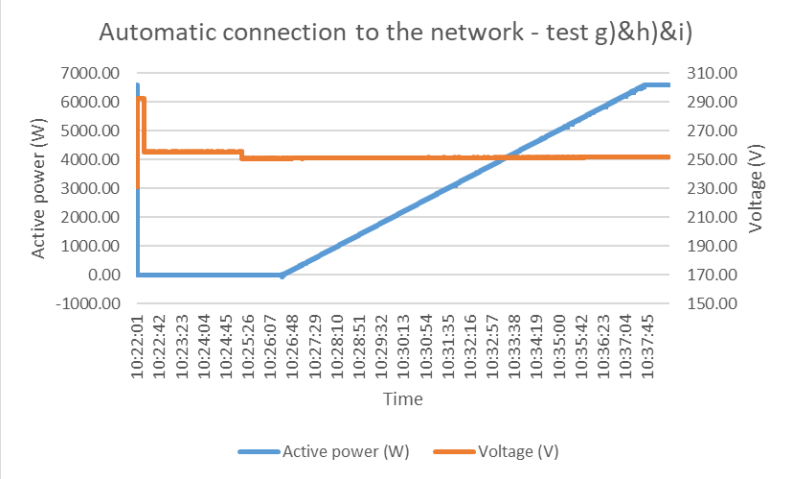
is 74.15 s, the maximum gradient of increase in active power output is 9.08 %$P_{max}$/min.




Waveform diagram after overvoltage protection then to step g) to step h) to step i), the reconnection time is 73.95 s, the maximum gradient of increase in active power output is 9.09 %$P_{max}$/min.




| 4.7.2.2 | Voltage support by reactive power - Capabilities | | | P |
|---|---|---|---|---|
| Test frequency (Hz) | 50.00 | Rated AC voltage (V) | 230.00 | |
| **Case A: Tested at voltage 0.85Un** | | | | |
| Maximum inductive reactive power (Var) | -3960 | | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.815 ind | 0.634 ind | 0.735 ind | 0.735 ind |
| Reactive Power Q (Var) | -466.11 | -3990.24 | -3997.83 | -3997.89 |
| Active power P (W) | 654.75 | 3267.13 | 4334.89 | 4332.66 |
| Apparent power S (VA) | 803.69 | 5157.15 | 5896.95 | 5895.35 |
| Deviation within 5% $Q_{max}$ | - | -0.76% | -0.96% | -0.96% |
| Maximum inductive power factor | Cosφ = 0.800 ind | | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |



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| | | | | |
|---|---|---|---|---|
| Tested cosφ | 0.814 ind | 0.795 ind | 0.795 ind | 0.795 ind |
| Reactive Power Q (Var) | -466.28 | -2499.88 | -3577.71 | -3577.81 |
| Active power P (W) | 654.38 | 3279.21 | 4683.91 | 4684.01 |
| Apparent power S (VA) | 803.53 | 4123.43 | 5894.00 | 5894.13 |
| Deviation within ±0.01 from cosφ-setting | - | -0.005 | -0.005 | -0.005 |
| Maximum capacitive reactive power (Var) | | 3960 | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.820 cap | 0.641 cap | 0.742 cap | 0.742 cap |
| Reactive Power Q (Var) | 460.10 | 3947.47 | 3946.24 | 3946.02 |
| Active power P (W) | 658.25 | 3299.91 | 4363.84 | 4363.99 |
| Apparent power S (VA) | 803.13 | 5145.20 | 5883.53 | 5883.49 |
| Deviation within 5% $Q_{max}$ | - | -0.32% | -0.35% | -0.35% |
| Maximum capacitive power factor | | Cosφ = 0.800 cap | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.820 cap | 0.801 cap | 0.801 cap | 0.801 cap |
| Reactive Power Q (Var) | 459.55 | 2463.07 | 3522.79 | 3523.56 |
| Active power P (W) | 658.06 | 3300.00 | 4716.54 | 4717.48 |
| Apparent power S (VA) | 802.65 | 4117.84 | 5886.91 | 5888.13 |
| Deviation within ±0.01 from cosφ-setting | - | 0.001 | 0.001 | 0.001 |
| **Case B: Tested at Nominal voltage 1.00Un** | | | | |
| Maximum inductive reactive power (Var) | | -3960 | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.803 ind | 0.626 ind | 0.790 ind | 0.790 ind |
| Reactive Power Q (Var) | -536.56 | -4049.50 | -4064.98 | -4064.96 |
| Active power P (W) | 645.47 | 3253.50 | 5229.57 | 5229.92 |
| Apparent power S (VA) | 848.71 | 5194.59 | 6623.63 | 6623.88 |
| Deviation within 5% $Q_{max}$ | - | -2.26% | -2.65% | -2.65% |
| Maximum inductive power factor | | Cosφ = 0.800 ind | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.804 ind | 0.791 ind | 0.791 ind | 0.791 ind |
| Reactive Power Q (Var) | -477.58 | -2521.85 | -4036.58 | -4036.94 |
| Active power P (W) | 646.84 | 3260.12 | 5212.14 | 5212.16 |
| Apparent power S (VA) | 804.09 | 4121.66 | 6592.44 | 6592.68 |
| Deviation within ±0.01 from cosφ-setting | - | -0.009 | -0.009 | -0.009 |



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| | | | | |
|---|---|---|---|---|
| Maximum capacitive reactive power (Var) | | 3960 | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.818 cap | 0.638 cap | 0.799 cap | 0.799 cap |
| Reactive Power Q (Var) | 457.82 | 3985.17 | 3969.47 | 3969.27 |
| Active power P (W) | 651.92 | 3305.31 | 5278.25 | 5277.83 |
| Apparent power S (VA) | 796.60 | 5177.50 | 6604.28 | 6603.84 |
| Deviation within 5% $Q_{max}$ | - | 0.64% | 0.24% | 0.23% |
| Maximum capacitive power factor | | Cosφ = 0.800 cap | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.820 cap | 0.804 cap | 0.804 cap | 0.804 cap |
| Reactive Power Q (Var) | 457.96 | 2443.22 | 3910.15 | 3910.83 |
| Active power P (W) | 655.92 | 3306.75 | 5288.59 | 5289.35 |
| Apparent power S (VA) | 800.00 | 4111.44 | 6577.12 | 6578.13 |
| Deviation within ±0.01 from cosφ-setting | - | 0.004 | 0.004 | 0.004 |
| **Case C: Tested at voltage 1.10Un** | | | | |
| Maximum inductive reactive power | | -3960 Var | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.808 ind | 0.633 ind | 0.795 ind | 0.795 ind |
| Reactive Power Q (Var) | -473.22 | -3994.60 | -4005.47 | -4005.89 |
| Active power P (W) | 649.58 | 3266.03 | 5243.72 | 5243.82 |
| Apparent power S (VA) | 803.68 | 5159.82 | 6598.51 | 6598.85 |
| Deviation within 5% $Q_{max}$ | - | -0.87% | -1.15% | -1.16% |
| Maximum inductive power factor | | Cosφ = 0.800 ind | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.802 ind | 0.791 ind | 0.791 ind | 0.791 ind |
| Reactive Power Q (Var) | -480.59 | -2524.07 | -4037.25 | -4037.60 |
| Active power P (W) | 645.24 | 3260.79 | 5214.76 | 5215.11 |
| Apparent power S (VA) | 804.59 | 4123.56 | 6594.92 | 6595.40 |
| Deviation within ±0.01 from cosφ-setting | 0.002 | -0.009 | -0.009 | -0.009 |
| Maximum capacitive reactive power | | 3960 Var | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.818 cap | 0.638 cap | 0.799 cap | 0.799 cap |
| Reactive Power Q (Var) | 456.26 | 3988.17 | 3974.15 | 3973.67 |
| Active power P (W) | 649.70 | 3301.72 | 5280.57 | 5282.29 |
| Apparent power S (VA) | 793.89 | 5177.57 | 6608.96 | 6610.05 |



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| | | | | |
|---|---|---|---|---|
| Deviation within 5% $Q_{max}$ | - | 0.71% | 0.36% | 0.35% |
| Maximum capacitive power factor | | Cosφ = 0.800 cap | | |
| $P/P_{max}$ (%) | 10* | 50 | 90 | 100 |
| Tested cosφ | 0.822 cap | 0.805 cap | 0.804 cap | 0.804 cap |
| Reactive Power Q (Var) | 453.07 | 2441.70 | 3908.59 | 3909.34 |
| Active power P (W) | 654.24 | 3308.07 | 5292.01 | 5292.59 |
| Apparent power S (VA) | 795.80 | 4111.60 | 6578.94 | 6579.84 |
| Deviation within ±0.01 from cosφ-setting | - | 0.005 | 0.004 | 0.004 |
| Supplementary information:<br>* : No change in reactive power by more than 10% Pn when active power lower than 20% Pn, so the power factor will automatically respond to 0.8 in this area, exact compliance with the accuracy is not required. | | | | |

| **4.7.2.3.3** | **Voltage support by reactive power - Voltage related control mode** | | | | | **P** |
|---|---|---|---|---|---|---|
| Grid simulator voltage (Un) | Measured active power P (W) | Measured apparent power S (VA) | Measured displacement factor cosφ | Measured reactive power Q (VA) | Required reactive power as to feature curve Q (VA) | Deviation of reactive power |
| Fixed active power setting 0.5 $S_{max}$ | | | | | | |
| $Q_{max}$ at this active power (Var) | | 3960 | -$Q_{max}$ at this active power (Var) | | -3960 | |
| 0.85 Un | 3297.87 | 3297.90 | 1.000 | -15.08 | 0.00 | -15.08 |
| 0.90 Un | 3297.09 | 3297.13 | 1.000 | -15.86 | 0.00 | -15.86 |
| 0.92 Un | 3296.97 | 3297.02 | 1.000 | -16.19 | 0.00 | -16.19 |
| 0.93 Un | 3294.18 | 3294.23 | 1.000 | -16.49 | 0.00 | -16.49 |
| 0.94 Un | 3296.73 | 3296.77 | 1.000 | -16.60 | 0.00 | -16.60 |
| 0.96 Un | 3296.72 | 3296.76 | 1.000 | -17.23 | 0.00 | -17.23 |
| 1.00 Un | 3296.98 | 3297.02 | 1.000 | -17.75 | 0.00 | -17.75 |
| 1.04 Un | 3297.07 | 3297.13 | 1.000 | -18.48 | 0.00 | -18.48 |
| 1.06 Un | 3296.80 | 3296.84 | 1.000 | -18.70 | 0.00 | -18.70 |
| 1.07 Un | 3284.64 | 3849.40 | 0.853 ind | -2007.26 | -1980.00 | -27.26 |
| 1.08 Un | 3268.84 | 5163.48 | 0.633 ind | -3997.03 | -3960.00 | -37.03 |
| 1.10 Un | 3268.53 | 5163.31 | 0.633 ind | -3997.05 | -3960.00 | -37.05 |
| 1.08 Un | 3268.26 | 5163.11 | 0.633 ind | -3997.02 | -3960.00 | -37.02 |
| 1.07 Un | 3283.30 | 3848.48 | 0.853 ind | -2007.71 | -1980.00 | -27.71 |
| 1.06 Un | 3295.59 | 3295.65 | 1.000 | -19.59 | 0.00 | -19.59 |
| 1.04 Un | 3295.71 | 3295.78 | 1.000 | -19.69 | 0.00 | -19.69 |
| 1.00 Un | 3295.81 | 3295.86 | 1.000 | -18.97 | 0.00 | -18.97 |
| 0.96 Un | 3295.29 | 3295.34 | 1.000 | -18.52 | 0.00 | -18.52 |



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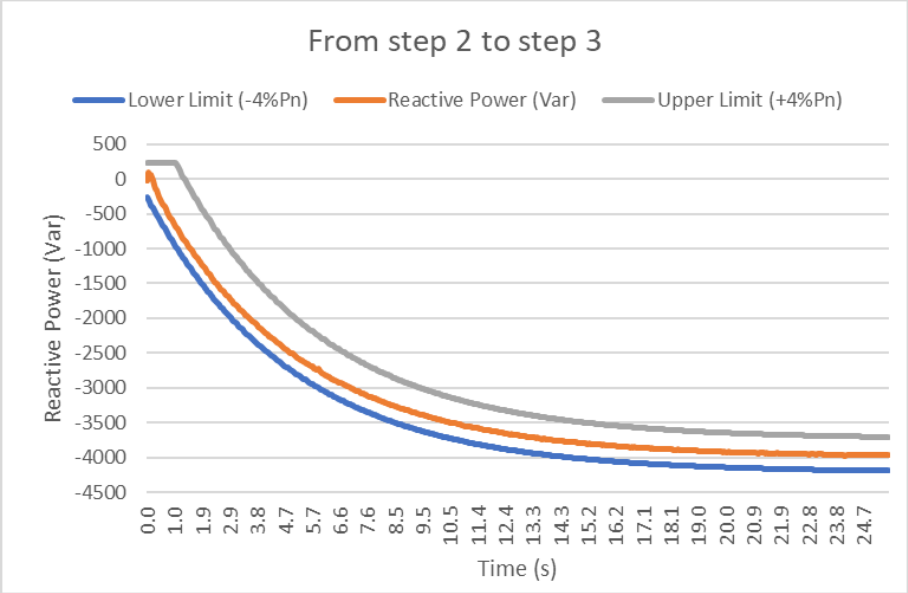
| | | | | | | |
|---|---|---|---|---|---|---|
| 0.94 Un | 3295.01 | 3295.05 | 1.000 | -18.04 | 0.00 | -18.04 |
| 0.93 Un | 3294.90 | 3294.95 | 1.000 | -18.21 | 0.00 | -18.21 |
| 0.92 Un | 3294.76 | 3294.80 | 1.000 | -18.08 | 0.00 | -18.08 |
| 0.90 Un | 3294.76 | 3294.80 | 1.000 | -17.73 | 0.00 | -17.73 |
| 0.85 Un | 3295.01 | 3295.06 | 1.000 | -17.42 | 0.00 | -17.42 |

Response time to the control system

| | Step | | $P_{0.2}$ [W] | $Q_{0.2}$ [Var] | $\cos\varphi_{0.2}$ | $U_{pos\ 0.2}$ [V] |
|---|---|---|---|---|---|---|
| 50% Pn | Step1, t1=0s | Starts at 1.00 $U_{pos}$ | 3294.69 | -19.39 | 1.000 | 230.30 |
| | Step2, t2= t1+120s | Step change to 0.92 $U_{pos}$ | 3294.08 | -18.40 | 1.000 | 211.80 |
| | Step3, t3= t2+120s | Step change to 1.08 $U_{pos}$ | 3266.08 | -3996.24 | 0.633 ind | 248.65 |
| | Step4, t4= t3+120s | Step change to 1.00 $U_{pos}$ | 3291.02 | -19.53 | 1.000 | 230.30 |
| | t5= t4+120s | Recording is stopped | -- | -- | -- | -- |

| Reactive power step | | | Point in time of setpoint change [s] | Point in time of settling [s] | Time difference [s] |
|---|---|---|---|---|---|
| 1.00 $U_{pos}$ | → | 0.92 $U_{pos}$ | 0.00 | 0.00 | 0.00 |
| 0.92 $U_{pos}$ | → | 1.08 $U_{pos}$ | 0.05 | 13.55 | 13.50 |
| 1.08 $U_{pos}$ | → | 1.00 $U_{pos}$ | 0.05 | 14.55 | 14.50 |

Supplementary information:







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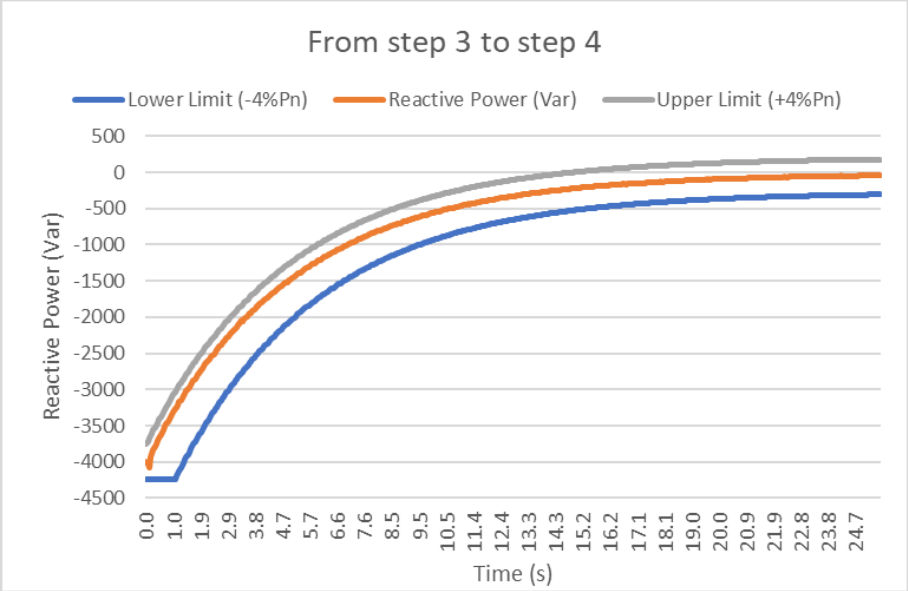


| 4.7.2.3.4 | **Power related Control mode (cos φ (P) controls)** | | | | | **P** |
|---|---|---|---|---|---|---|
| Maximal active power $P_{Emax}$ with the tested displacement factor (W) | | | | 6600 VA*0.9=5940 W | | |
| Percentage of output active power P/ $P_{Emax}$ (%) | Measured active power P (W) | Measured apparent power S (VA) | Measured displacement factor cosφ | Measured reactive power Q (Var) | Displacement factor as to feature curve | Deviation of displacement factor (±0.01) |
| Set point 1: P=0 $P_{Emax}$, cosφ=1<br>Set point 2: P=0.5 $P_{Emax}$, cosφ=1<br>Set point 3: P=1 $P_{Emax}$, cosφ=0.9 inductive | | | | | | |
| Trip #1 | | | | | | |
| 10% | 587.87 | 587.90 | 1.000 | -7.06 | 1.000 | 0.000 |
| 20% | 1183.76 | 1183.79 | 1.000 | -9.35 | 1.000 | 0.000 |
| 30% | 1779.18 | 1779.23 | 1.000 | -11.82 | 1.000 | 0.000 |
| 40% | 2374.08 | 2374.13 | 1.000 | -14.62 | 1.000 | 0.000 |
| 50% | 2968.57 | 2968.73 | 1.000 | -30.49 | 1.000 | 0.000 |
| 60% | 3559.90 | 3637.42 | 0.979 ind | -746.89 | 0.980 ind | -0.001 |
| 70% | 4151.25 | 4332.81 | 0.958 ind | -1241.16 | 0.960 ind | -0.002 |
| 80% | 4741.62 | 5057.20 | 0.938 ind | -1758.49 | 0.940 ind | -0.002 |
| 90% | 5331.14 | 5812.69 | 0.917 ind | -2316.55 | 0.920 ind | -0.003 |
| 100% | 5919.56 | 6601.41 | 0.897 ind | -2921.90 | 0.900 ind | -0.003 |
| Supplementary information: | | | | | | |



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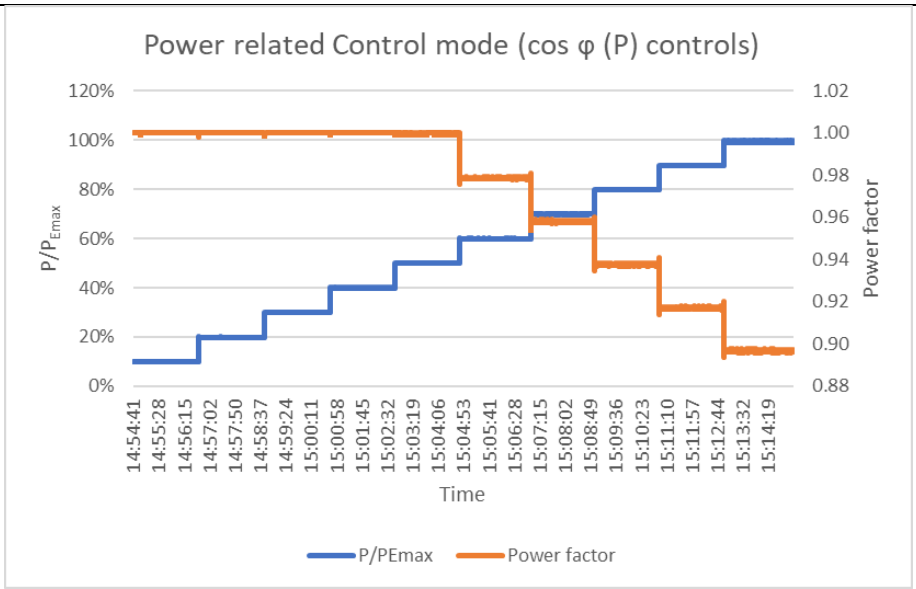


| 4.9 | **Interface protection** | | | | | | **P** |
|---|---|---|---|---|---|---|---|
| Voltage monitoring: Voltage reduction and Voltage increase grade 2 | | | | | | | |
| | | 1 | | 2 | | 3 | |
| | | Value (V) | Time (ms) | Value (V) | Time (ms) | Value (V) | Time (ms) |
| L1-N voltage | Voltage increases grade 2 | 264.00 | 161.78 | 264.10 | 171.61 | 263.50 | 169.34 |
| | Voltage reduction | 194.70 | 1475 | 194.60 | 1480 | 194.70 | 1465 |
| Voltage monitoring for 10-min-mean-value: Voltage increase grade 1 | | | | | | | |
| Test procedure (for U>) | a) The voltage is maintained at 100% Un for 600s, afterwards the voltage is raised to 112%, the switch off must be within 600s;<br>b) The voltage is maintained at Un for 600s, afterwards the voltage is raised to 108%. The switch off should not be activated;<br>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. | | | | | | |
| Applied phase | a) | | b) | | c) | | |
| | Switch off (Yes/No) | Time (s) | Switch off (Yes/No) | Time (s) | Switch off (Yes/No) | Time (s) | |
| L1-N | Yes | 452.01 | No | - | Yes | 226.56 | |
| Frequency monitoring | | | | | | | |
| Test procedure (for f>. f<) | For frequency protection. the frequency is changed with a speed of 1Hz/s.<br>• 48.50 → 47.50<br>• 51.00 → 52.00<br>All tests are repeated for three times.<br>The disconnection value shall not be deviated from the setting value for more than 0.1% fn.<br>Disconnection time shall within 0.3s to 0.5s. | | | | | | |
| | | 1 | | 2 | | 3 | |



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| | | Value (Hz) | Time (ms) | Value (Hz) | Time (ms) | Value (Hz) | Time (ms) |
|---|---|---|---|---|---|---|---|
| Test procedure (for f>. f<) | f> | 47.50 | 493.06 | 47.50 | 496.87 | 47.51 | 491.12 |
| | f< | 52.02 | 487.93 | 52.03 | 496.16 | 52.03 | 489.22 |

| Security from island work: Active | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test procedure | IEC 62116 | | | | | | | | |
| No. | $P_{EUT}$ (% of EUT rating) | Reactive Load (% of $Q_L$) | $P_{AC}$ (% of nominal) | $Q_{AC}$ (% of nominal) | Run on time (ms) | $P_{EUT}$ (W) | Actual $Q_f$ (L1) | $V_{DC}$ (V) | Remarks |
| 1. | 100 | 100 | 0 | 0 | 842 | 6590 | 1.000 | 400 | Test A at BL |
| 2. | 66 | 66 | 0 | 0 | 857 | 4350 | 1.000 | 330 | Test B at BL |
| 3. | 33 | 33 | 0 | 0 | 665 | 2180 | 1.000 | 250 | Test C at BL |
| 4. | 100 | 100 | -5 | -5 | 622 | 6590 | 1.026 | 400 | Test A at IB |
| 5. | 100 | 100 | -5 | 0 | 747 | 6590 | 1.053 | 400 | Test A at IB |
| 6. | 100 | 100 | -5 | 5 | 644 | 6590 | 1.079 | 400 | Test A at IB |
| 7. | 100 | 100 | 0 | -5 | 600 | 6590 | 0.975 | 400 | Test A at IB |
| 8. | 100 | 100 | 0 | 5 | 622 | 6590 | 1.025 | 400 | Test A at IB |
| 9. | 100 | 100 | 5 | -5 | 606 | 6590 | 0.928 | 400 | Test A at IB |
| 10. | 100 | 100 | 5 | 0 | 764 | 6590 | 0.952 | 400 | Test A at IB |
| 11. | 100 | 100 | 5 | 5 | 623 | 6590 | 0.976 | 400 | Test A at IB |
| 12. | 66 | 66 | 0 | -5 | 553 | 4350 | 0.975 | 330 | Test B at IB |
| 13. | 66 | 66 | 0 | -4 | 627 | 4350 | 0.980 | 330 | Test B at IB |
| 14. | 66 | 66 | 0 | -3 | 567 | 4350 | 0.985 | 330 | Test B at IB |
| 15. | 66 | 66 | 0 | -2 | 610 | 4350 | 0.990 | 330 | Test B at IB |
| 16. | 66 | 66 | 0 | -1 | 557 | 4350 | 0.995 | 330 | Test B at IB |
| 17. | 66 | 66 | 0 | 1 | 706 | 4350 | 1.005 | 330 | Test B at IB |
| 18. | 66 | 66 | 0 | 2 | 590 | 4350 | 1.010 | 330 | Test B at IB |
| 19. | 66 | 66 | 0 | 3 | 573 | 4350 | 1.015 | 330 | Test B at IB |
| 20. | 66 | 66 | 0 | 4 | 642 | 4350 | 1.020 | 330 | Test B at IB |
| 21. | 66 | 66 | 0 | 5 | 544 | 4350 | 1.025 | 330 | Test B at IB |
| 22. | 33 | 33 | 0 | -5 | 532 | 2180 | 0.975 | 250 | Test C at IB |
| 23. | 33 | 33 | 0 | -4 | 592 | 2180 | 0.980 | 250 | Test C at IB |
| 24. | 33 | 33 | 0 | -3 | 528 | 2180 | 0.985 | 250 | Test C at IB |
| 25. | 33 | 33 | 0 | -2 | 553 | 2180 | 0.990 | 250 | Test C at IB |
| 26. | 33 | 33 | 0 | -1 | 730 | 2180 | 0.995 | 250 | Test C at IB |
| 27. | 33 | 33 | 0 | 1 | 595 | 2180 | 1.005 | 250 | Test C at IB |
| 28. | 33 | 33 | 0 | 2 | 585 | 2180 | 1.011 | 250 | Test C at IB |



Telephone : +86 20 38320668
Telefax : +86 20 38320478

www.tuvsud.com

TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch
5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou 510656, China

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 29. | 33 | 33 | 0 | 3 | 549 | 2180 | 1.015 | 250 | Test C at IB |
| 30. | 33 | 33 | 0 | 4 | 575 | 2180 | 1.020 | 250 | Test C at IB |
| 31. | 33 | 33 | 0 | 5 | 520 | 2180 | 1.024 | 250 | Test C at IB |

…….. End of test report ……..



Telephone : +86 20 38320668
Telefax : +86 20 38320478

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5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou 510656, China