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**Technical requirements and test methods for grid-connected
PV inverters**

并网光伏发电专用逆变器 技术要求和试验方法

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Technical requirements and test methods for grid-connected PV inverters

1 Scope

This Standard specifies the terms and definitions, product classification, technical requirements, test methods, inspection rules and marking, packaging, transportation and storage for grid-connected PV inverters.

This Standard applies to grid-connected PV inverters – hereinafter referred to as inverters – whose AC output terminal voltage does not exceed 0.4 kV.

Note: According to the *Technical rules for photovoltaic power station connected to power grid* formulated by the State Grid Corporation of China, considering the technical requirements of power transmission and distribution capacity and power quality of power grids of different voltage levels, photovoltaic power stations can be divided into small, medium or large photovoltaic power stations according to the voltage level of photovoltaic power stations connected to.

Small photovoltaic power station – photovoltaic power station connected to low-voltage power grid with a voltage level of 0.4 kV.

Medium photovoltaic power station – photovoltaic power station connected to power grid with a voltage level of 10 kV ~ 35 kV.

Large photovoltaic power station – photovoltaic power station connected to power grid with a voltage level of 66 kV or above.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies to this document. For undated references, the latest edition (including any amendment) applies to this document.

GB/T 191, Packaging - Pictorial marking for handling of goods

GB/T 2423.1-2008, Environmental testing for electric and electronic products - Part 2: Test methods - Tests A: Cold (IEC 60068-2-1: 2007, IDT)

GB/T 2423.2-2008, Environmental testing for electric and electronic products - Part 2: Test methods - Tests B: Dry heat (IEC 60068-2-2:2007, IDT)

GB/T 2423.3-2006, Environmental testing for electric and electronic products - Part 2: Testing method - Test Cab: Damp heat, steady state (IEC 60068-2-78:2001, IDT)

GB/T 3859.2-2013, Semiconductor converters - General requirements and line commutated converters - Part 1-2: Application guide (IEC/TR 60146-1-2:2011, MOD)

GB 4208-2008, Degrees of Protection Provided by Enclosure (IP Code) (IEC 60529:2001, IDT)

GB 7260.2-2009, Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements (IEC 62040-2:2005, IDT)

GB/T 13384-2008, General specifications for packing of mechanical and electrical product

GB/T 14549-1993, Quality of electric energy supply - Harmonics in public supply network

GB/T 15543-2008, Power quality - Three-phase voltage

GB/T 17626.2-2006, Electromagnetic compatibility (EMC) - Testing and measurement techniques - Electrostatic discharge immunity test (IEC 61000-4-2:2001, IDT)

GB/T 17626.3-2006, Electromagnetic compatibility - Testing and measurement techniques - Radiated radio-frequency electromagnetic field immunity test (IEC 61000-4-3:2002, IDT)

GB/T 17626.4-2008, Electromagnetic compatibility - Testing and measurement techniques - Electrical fast transient/burst immunity test (IEC 61000-4-4:2004, IDT)

GB/T 17626.5-2008, Electromagnetic compatibility - Testing and measurement techniques - Surge immunity test (IEC 61000-4-5:2005, IDT)

GB/T 17626.6-2008, Electromagnetic compatibility - Testing and measurement techniques - Immunity to conducted disturbances induced by radio-frequency fields (IEC 61000-4-6: 2006, IDT)

GB/T 17626.11-2008, Electromagnetic compatibility - Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests (IEC 61000-4-11: 2004, IDT)

GB/T 18479-2001, Terrestrial photovoltaic (PV) power generating systems - General and guide (idt IEC 61277:1995)

GB/T 20514-2006, Photovoltaic systems - Power conditioners - Procedure for measuring efficiency (IEC 61683:1999, IDT)

The output power rating of the single-phase inverter is preferably selected from the following values, in kilowatts (kW):

1, 1.5, 2, 2.5, 3, 4, 5, 6, 8.

4.2.2 Three-phase inverter

The output power rating of the three-phase inverter is preferably selected from the following values, in kilowatts (kW):

10, 20, 30, 50, 100, 250, 500, 1 000.

5 Conditions of use

5.1 Environmental conditions for normal use

The environmental conditions for the normal use of the inverter are specified as follows:

- a) operating environment temperature: $-10\text{ }^{\circ}\text{C} \sim +40\text{ }^{\circ}\text{C}$ for indoor type, $-25\text{ }^{\circ}\text{C} \sim +60\text{ }^{\circ}\text{C}$ for outdoor type (no direct sunlight); relative humidity not more than 95%, no condensation.
- b) altitude not greater than 1 000 m; when the altitude is greater than 1 000 m, it shall be derated according to the provisions of GB/T 3859.2-2013.
- c) no severe shock and impact; vertical inclination not greater than 5° .
- d) no corrosive and explosive particles and gases shall be contained in the air.

5.2 Grid conditions for normal use

Unless otherwise specified, inverters conforming to this Standard shall be able to operate in a normal manner under the following grid conditions:

- a) The harmonic voltage in public power grid shall not exceed the limit specified in Chapter 4 of GB/T 14549-1993, that is, the total harmonic distortion rate of the voltage shall not exceed 5%, the odd-order harmonic voltage content rate shall not exceed 4%, and the even-order harmonic voltage content rate shall not exceed 2%.
- b) The three-phase voltage unbalance shall not exceed the value specified in GB/T 15543-2008; the allowable value shall be 2%, and shall not exceed 4% for a short time.
- c) The allowable deviation of the single-phase voltage is +10% and -15% of the rated voltage; the allowable deviation of the three-phase voltage is $\pm 10\%$ of the rated voltage. If it exceeds this range, the user shall negotiate with the manufacturer. Grid rated voltage: 380 V for three-phase, 220 V for single-phase.

- d) The allowable range of frequency is 47 Hz ~ 51.5 Hz, and the rated frequency of the grid is 50 Hz.

5.3 Special conditions of use

If the inverter is used under conditions different from those stipulated in 5.1 and 5.2, the user shall propose it when ordering and obtain an agreement with the manufacturer or supplier.

6 Technical requirements

6.1 Body and structure quality

The body and structure of the inverter shall meet the following requirements:

- a) The components related to rack assembly shall meet their respective technical requirements;
- b) Paint electroplating shall be firm and smooth, without peeling, rust and cracks;
- c) The rack panel shall be flat, and the text and symbols shall be clear, neat, standardized and correct;
- d) Plates, marking and signs shall be complete and clear;
- e) Various switches shall be easy-to-operate, flexible and reliable.

6.2 Performance indicators

6.2.1 Inverter efficiency

The maximum efficiency of the inverter without transformer shall not be lower than 95%, and the maximum efficiency of the inverter with transformer shall not be lower than 94%.

6.2.2 Grid-connected current harmonics

During grid-connected operation, the inverter shall not cause excessive distortion of the grid voltage waveform and inject excessive harmonic current into the grid, so as to ensure that other equipment connected to the grid will not be adversely affected. The limit value of the total current harmonic distortion rate is 5%; the limit value of odd-order harmonic current content rate is shown in Table 1, and the limit value of even-order harmonic current content rate is shown in Table 2.

When the DC side voltage of the inverter is lower than the allowable operating range or the inverter is in shutdown state, there shall be no reverse current flowing through the DC side of the inverter.

6.4.3 Reverse polarity protection

When the polarity of the inverter input terminal is reversed, the inverter shall be able to protect without damage. After the polarity is positively connected, the inverter shall work normally.

6.4.4 Overload protection

When the output power of the photovoltaic array exceeds the maximum DC input power allowed by the inverter, the inverter shall automatically limit the current and work at the allowable maximum AC output power. In any case of continuous operation for 7 hours or temperature exceeding the allowable value, the inverter shall stop supplying power to the grid. After returning to normal, the inverter shall work normally.

6.4.5 DC over/under voltage protection

When the DC side input voltage deviates from the allowable DC operating voltage range of the inverter, the inverter shall stop within 0.1 s and send out a warning signal at the same time. After the DC side voltage returns to the allowable range, the inverter shall work normally.

6.5 Communication

The inverter shall be equipped with a local communication interface.

6.6 Automatic power on/off

The inverter shall be able to automatically start and shut down according to the sunshine conditions of sunrise and sunset.

6.7 Start-up

For inverters with a power of not less than 100 kW, the current state of the photovoltaic system, instructions from the power system dispatch center and local measurement signals shall be considered when starting up, and the change in active power shall not exceed the set maximum power change rate.

6.8 Insulation and voltage resistance

6.8.1 Insulation resistance

The insulation resistance between the input circuit of the inverter and the ground, the output circuit and the ground, and between the input circuit and the output circuit shall

7.5.2.1 Electrostatic discharge immunity test

The test shall be carried out under rated operating conditions, and the test arrangement and measurement criteria shall comply with the provisions of GB/T 17626.2-2006. The test shall be carried out in the form of a single discharge, and 10 single discharges shall be applied at a preselected point.

7.5.2.2 Radiated radio-frequency electromagnetic field immunity test

The test shall be carried out under rated operating conditions, and the test arrangement and measurement criteria shall comply with the provisions of GB/T 17626.3-2006.

7.5.2.3 Electrical fast transient/burst immunity test

The test shall be carried out under rated operating conditions, and the test arrangement and measurement criteria shall comply with the provisions of GB/T 17626.4-2008.

7.5.2.4 Surge immunity test

The test shall be carried out under rated operating conditions, and the test arrangement and measurement criteria shall comply with the provisions of GB/T 17626.5-2008.

7.5.2.5 Immunity test to conducted disturbances induced by radio-frequency fields

The test shall be carried out under rated operating conditions, and the test arrangement and measurement criteria shall comply with the provisions of GB/T 17626.6-2008.

7.5.2.6 Voltage dips, short interruptions immunity test

The test shall be carried out under rated operating conditions, and the test arrangement and measurement criteria shall comply with the provisions of GB/T 17626.11-2008.

7.6 Protection function test**7.6.1 Grid fault protection test****7.6.1.1 Over/under voltage protection test**

Wire according to Figure 2; carry out the test, respectively, at the rated output power of the inverter and the minimum power point where it can work; set the output voltage of the utility simulator as the voltage trip point of the inverter; record the operating time of the inverter and the voltage when operating.

Note: This test can be carried out by means of signal simulation.

7.6.1.2 Over/under frequency protection test

rated input voltage of the inverter, and its output current does not exceed 1.5 times the rated input current of the inverter.

Connect the negative pole of the photovoltaic array or photovoltaic array simulator output to the positive pole of the inverter DC input, and the positive pole of the photovoltaic array or photovoltaic array simulator output to the negative pole of the inverter DC input. The inverter shall be able to protect automatically; after 1 minute, connect it correctly, and the inverter shall work normally.

7.6.4 Overload protection test

Wire according to Figure 2; adjust the DC input source so that the input current of the inverter is twice its rated value; adjust the output voltage of the grid simulator to the voltage lower limit value specified in c) in 5.2 (the inverter will not trip).

7.6.5 DC over/under voltage protection test

Wire according to Figure 2; adjust the voltage of the DC input source until the input voltage on the DC side of the inverter deviates from the allowable DC input voltage range.

7.7 Communication test

Connect the communication interface of the PC with the communication interface of the inverter, and the inverter shall be able to receive and send data normally according to the communication protocol.

7.8 Automatic power on/off test

Simulate the sunshine conditions of sunrise and sunset by changing the magnitude of the inverter input DC voltage.

The specific steps are as follows: Wire according to Figure 2; adjust the DC input source so that the DC side voltage starts to increase from a voltage lower than the lower limit of the allowable DC voltage operating range of the inverter. When the DC side voltage is higher than the lower limit of the allowable range, the inverter shall be able to start automatically; after the inverter works stably, adjust the DC input source so that the DC side voltage drops below the lower limit of the allowable range, the inverter shall be able to automatically shut down.

7.9 Start-up test

Observe the working status of the inverter when it starts running.

7.10 Insulation and voltage resistance test

7.10.1 Insulation resistance measurement test

Use a megohmmeter or an insulation resistance tester to measure the insulation resistance values of the inverter's input circuit to ground, output circuit to ground, and input circuit to output circuit with a test voltage of 1 000 V. The dielectric strength test can only be carried out after the measured insulation resistance is qualified.

7.10.2 Dielectric strength measurement test

Use a withstand voltage tester to apply test voltages to the inverter's input circuit to ground, output circuit to ground, and input circuit to output circuit. The test voltage shall start from zero and rise to the specified value in a step-by-step adjustment method with each level being 5% of the specified value, and last for 1 min.

Note: During the insulation resistance and dielectric strength test, the low-voltage control circuit shall be excluded.

7.11 Enclosure protection grade test

Carry out the test according to the provisions of GB 4208-2008.

7.12 Power control and voltage regulation test

7.12.1 Active power control test

Use a PC to simulate the grid dispatching department to send active power output control signals (including parameters such as maximum output power and power change rate) to the inverter, and the inverter shall be able to receive and execute them.

7.12.2 Voltage/reactive adjusting test

Use a PC to simulate the power grid dispatching department to send reactive power output control signals (including parameters such as adjustment mode, reference voltage, and voltage difference rate) to the inverter. The inverter shall adjust the reactive power output according to the voltage level of the grid-connected point within the specified reactive power output range.

7.13 Environmental test

7.13.1 Low temperature operation test

The test method is carried out according to "Test A" in GB/T 2423.1-2008. The product has no packaging. Under the test temperature of $-10\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ (indoor type) or $-25\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ (outdoor type), keep it powered on for 2 hours with rated load, and recover for 2 hours under standard atmospheric conditions.

7.13.2 High temperature operation test

The test method is carried out according to "Test B" in GB/T 2423.2-2008. The product has no packaging. Under test temperature of $40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ (indoor type) or $60\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$

8.2 Ex-factory inspection

Each inverter shall be subject to the ex-factory inspection. If any failure occurs during the inspection, the inspection shall be stopped, the cause of the failure shall be found out, and after the failure is eliminated, a mark shall be marked and the ex-factory inspection shall be carried out again. If the failure still occurs, the inverter will be judged as unqualified. After passing the inspection, fill in the inspection record and issue a certificate before leaving the factory.

8.3 Type inspection

8.3.1 Type inspection conditions

In any of the following cases, type inspection shall be carried out:

- a) identification of new products;
- b) after formal production, when the structure, material and process have changed greatly, which is enough to affect the performance of the product;
- c) for mass-produced products, type inspection shall be carried out every two years;
- d) when the production of the product is resumed after two years of suspension;
- e) when the national quality supervision agency requests type inspection;
- f) when producing in different places.

8.3.2 Sampling method and judgment rules

During the type inspection, two samples shall be randomly selected from the products that have passed the ex-factory inspection. If any item is unqualified during the inspection, the cause shall be found out, the unqualified items shall be eliminated, and a comprehensive inspection shall be carried out again. If a certain item is unqualified again, judge that this batch of inverters have not passed the type inspection.

9 Marking, packaging, transportation and storage

9.1 Marking

9.1.1 Product marking

There shall be a nameplate in the appropriate position of the inverter. The content of the nameplate is as follows:

- a) product name.
- b) product model.

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