NB/T 32004-2013

Energy Industrial Standard
of the People’s Republic of China

Technical specification of grid-connected PV inverter
光伏发电并网逆变器技术规范

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Introduction

This Standard is drafted according to the rules provided by GB/T 1.1-2009 *Standard Operations Guidelines Part 1: Structure and Compilation of Standard.*

This Standard is proposed by National Energy Administration.

This Standard is administered by China Electrical Equipment Industrial Association (CEEIA).

Principal organizations participated in the drafting of this Standard: Shanghai Testing & Inspection Institute for Electric Motor, Engineering Industry Beijing Electro-technics Institute of Economics.


Technical specification of grid-connected PV inverter

1 Scope
This Standard specifies the product classification, technical requirements and test methods of the inverters used for photovoltaic (PV) grid-connected system.
This Standard is applicable to grid-connected PV inverter connected to PV source circuit’s voltage not higher than DC 1500 V or AC 1000V.

2 Referenced and quoted standards
The following documents are indispensable for the application of this document. For quoted documents noted with dates, only versions with noted dates are applicable to this document. For quotation documents without noted dates, their latest version (including all modifications) are applicable to this document.

GB/T 1408.1-2006 Insulating material electric strength test method Part 1: Test under power frequency (IEC 60243-1: 1998, IDT)
GB/T 2828.1-2012 Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection (ISO 2859-1: 1999, IDT)
GB/T 3805-2008 Extra Low Voltage (Elv) Limit
GB/T 4207 Measuring Method of Solid Insulating material Proof Tracking Index and Comparative Tracing Index (IEC 60112, IDT)
GB/T 5465.2-2008 Electrical Equipment Graphic Symbol Part 2: Graphic Symbol (IEC 60695-11-20: 2003, IDT)
GB/T 14549-1993 Power Quality Harmonics in Public Supply Network
GB/T 15543-2008 Power Quality Three-Phase Voltage Unbalance
GB/T 16935.1-2008 Equipment’s Insulation Coordination in Low-Voltage System Part 1: Theory, Requirements and Test (IEC60664-1: 2007, IDT)
GB/T 17625.2-2007 Electromagnetic Compatibility Limiting Value Limit of Voltage Change, Voltage Fluctuation And Flicker of Per Rated Current Less Than or Equal to 16A and Unconditional Connected Equipment in Public Low-Voltage System (IEC61000-3-3: 2005, IDT)
GB/T 17626.2-2006 Electromagnetic Compatibility Test and Measuring Technique Electrostatic Discharge (IEC61000-4-2: 2001, IDT)
GB/T 17626.3-2006 Electromagnetic Compatibility Test and Measuring Technique Radiofrequency Electromagnetic Field Radiated Susceptibility Test (IEC61000-4-3: 2002, IDT)
GB/T 17626.4-2008 Electromagnetic Compatibility Test and Measuring Technique Electrical Fast Transient Immunity Test (IEC 61000-4-4: 2004, IDT)
GB/T 17626.5-2008 Electromagnetic Compatibility Test and Measuring Surge (Impact) Immunity Test (IEC 61000-4-5: 2005, IDT)
GB/T 17626.6-2008 Electromagnetic Compatibility Test and Measuring Conduction Harass
Immunity of Radio-Frequency Field Reaction (IEC61000-4-6: 2006, IDT)
GB/T 17626.8-2006 Electromagnetic Compatibility Test and Measuring Power Frequency Magnetic Field Immunity Test (IEC61000-4-8: 2001, IDT)
GB/T 17626.11-2008 Electromagnetic Compatibility Test and Measuring Immunity Test of Voltage Sags, Short Intermittent and Changes (IEC61000-4-11: 2004, IDT)
GB/T 19939-2005 Photovoltaic System Grid-Connection Technical Requirements
GB/T 25919.2-2010 Modbus Test Specification Part 2: Modbus Serial Link Interoperability Testing Specification

3 Terms and definitions

3.1 Photovoltaic grid-connected PV inverter
Equipment which can convert DC generated from PV array to AC and then feed the electricity into the power system.
Note 1: Inverters mentioned in this Standard all refer to grid-connected PV inverters.
Note 2: Technical requirements and test methods in this Standard are not applicable to inverters of AC MODULE.

3.2 Photovoltaic array simulator
Power source which converts simulated static and dynamic current, voltage of photovoltaic array.

3.3 Inverter AC output terminal
Connection point of output power at the AC side of inverter.
3.4 Maximum power point tracking; MPPT
Automatic adjustment action which track and control output voltage and current changes, that are resulted from photovoltaic array surface temperature changes and solar irradiance changes, so that the array can keep the maximum output operating condition, and achieve maximum power output.

3.5 Maximum power point tracking efficiency
In specified testing period Tm, the ratio of achieved DC electric energy of measured inverter AND electric energy provided by theoretical photovoltaic array simulator (or photovoltaic battery array), in the working period at the maximum power point. And the calculation formula is:

\[ \eta_{MPPT} = \frac{\int_0^T P_{DC}(t) \, dt}{\int_0^T P_{MPP}(t) \, dt} \]

In the formula:
P_{DC} (t) -- transient value of the inverter at DC port input power
P_{MPP} (t) -- transient maximum power-point power provided by photovoltaic array simulator (or photovoltaic battery array) in theory.

3.6 Conversion efficiency
In specified testing period Tm, the ratio of output electric energy at the inverter’s AC port AND input electric energy at DC port. And the computational formula is:

\[ \eta_{conv} = \frac{\int_0^T P_{AC}(t) \, dt}{\int_0^T P_{DC}(t) \, dt} \]

In the formula:
P_{AC} (t) -- transient value of the inverter’s output power at the AC port;
P_{DC} (t) -- transient value of the inverter’s input power at the DC port.

3.7 Overall (total) efficiency
In specified testing period Tm, the ratio of output electric energy at the inverter’s AC port AND electric energy provided by theoretical photovoltaic array simulator (or photovoltaic battery array) in the period. And the computational formula is:

\[ \eta = \frac{\int_0^T P_{AC}(t) \, dt}{\int_0^T P_{MPP}(t) \, dt} = \eta_{conv} \eta_{MPPT} \]
When the temperature is +40°C, air relative humidity shall not be higher than 50%. Comparatively high relative humidity is allowed when the temperature is comparatively low, for example, relative humidity can reach 100% when the temperature is +25°C. Occasional condensation resulted from temperature changes shall be dealt with specially.

6.1.1.3.2 Pollution degree
a) Pollution degree is related to the surrounding environment conditions of the inverter.

Note: Micro environment of electric clearance or creepage distance has impact on electrical apparatus insulation, rather than vise versa. Micro environment of electric clearance or creepage distance may be better or worse than the product’s environment. Micro environment includes all elements that influence the insulation, such as climate condition, electromagnetic condition, generation of pollution and so on.
b) For electric appliance used in the enclosure or in electric appliance with enclosure, their pollution degree can select and use the environment pollution degree in the enclosure.
c) In order to confirm electric clearance or creepage distance more conveniently, micro environment can be classified into four pollution degrees.

1) Pollution degree 1: there is no pollution or there is only dry non-electroconductibility pollution.

2) Pollution degree 2: generally there is only non-electroconductibility pollution, but transient electroconductibility pollution resulted from occasional condensation must be taken into consideration.

3) Pollution degree 3: there is electroconductibility pollution, or electroconductibility pollution that turned from dry non-electroconductibility pollution because of condensation.

4) Pollution degree 4: durable electroconductibility pollution, for example, pollution resulted from conductive dust or sleet.

Outdoor inverter and indoor type II inverters generally are applicable to environment of pollution degree 3; indoor type I inverter generally is applicable to environment of pollution degree 2. However, for special purpose and micro environment, other pollution degrees can be used. For example, inverter predetermined to be used in environment of pollution degree 4, some measures need to be taken so as to reduce the pollution degree of micro environment to grade 1, 2, 3.

If the inverter itself can generate pollution or moist (for example, conductive pollution generated by electromotor carbon brush, or condensation resulted from cooling system), then pollution degree of the inverter’s specific area will be increased.

6.1.1.4 Impact vibration
The inverter may suffer from impact vibration during production, transportation, installation,
Graph 1 Relation curve that the current capacity changes with altitude

6.2.2.3 Atmospheric conditions
Relative humidity of atmosphere of the inverter’s installation site is higher than rated value in 6.1.3, or there are excess dust, acidic material, corrosive gas and so on in the air. For example, the inverter is installed near to ocean.

6.2.2.4 Installation conditions
The inverter is installed in mobile device, or is installed on electric appliance of oblique position for a long term or short term (i.e., installed on a steamer), or the inverter suffered abnormal impact or vibration during using process.

6.2.2.5 Other conditions
Other abnormal conditions are in consideration.

7 Structure and performance requirements

7.1 Structural material
7.1.1 Temperature

a) Under the effect of electricity, the inverter will be influenced by the thermal stress, resulting in the probable decrease of the structure’s security. Meanwhile, it may generate influence unfavorable for security. Positions which abnormal temperature may give rise to and call for protection:

1) Contactable positions higher than safe temperature.

2) Components, parts, insulation and plastic materials which temperature is higher than specific temperature. When the inverter in its expected service life and in normal use, if the temperature is higher than the specific temperature, electric, mechanic and other
<table>
<thead>
<tr>
<th>Voltage</th>
<th>5000</th>
<th>6300</th>
<th>8000</th>
<th>10 000</th>
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<tbody>
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<td>20</td>
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<td>32</td>
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<td>80</td>
<td>100</td>
<td>125</td>
<td>160</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Row 2 and 3 are not only applicable to components and parts on PWB, but also applicable to creepage of other components and parts of considerate tolerance control.

Note 2: Row 2 and 4 are applicable to all material groups.

Note 3: Row 3 is applicable to all other material groups except IIIb.

Note 4: Interpolation is permitted.

a: For those with pollution degree of 3, and over 630V of voltage, generally insulation material in Group IIIb is recommended.

b: For those which voltage is over 1250V, appropriate values from Row 4 to Row 11 are adopted.

7.2.4.7.5 Creepage determination of functional insulation

Creepage distance of functional insulation shall be determined according to the corresponding practical working voltage bridging on the two ends of creepage distance in Chart 4.

When practical working voltage is used to determine creepage distance, interposition is permitted to use to determine the creepage distance of intermediate voltage. Linear interpolation shall be used to get the interpolation value, and digit of the obtained value shall be predetermined to the same significant digit in Chart 4.

7.2.4.7.6 Creepage determination of basic insulation, supplementary insulation and reinforced insulation

Creepage distance of basic insulation and supplementary insulation shall be determined from Chart 4. Interpolation is permitted to use to determine the creepage distance of intermediate voltage. Linear interpolation shall be used to get the interpolation value, and digit of the obtained value shall be predetermined to the same significant digit in the chart.

Since double insulation is made up of basic insulation and supplementary insulation, therefore, creepage distance of double insulation is the total of the creepage distance of basic insulation and supplementary insulation.

Creepage distance of reinforced insulation shall be twice of the determined value of basic insulation in Chart 4.

7.2.4.8 Solid insulation

7.2.4.8.1 Introduction

Since the electric strength of solid insulation is far stronger than that of air, so it may not be paid due attention when designing low-voltage insulation system. On the one hand, insulation
distance passing solid insulation material usually is far shorter than clearance, thus resulting in high electrical stress. On the other hand, practically material of high electric strength is rarely used. In insulation system, clearance may be generated between the electrode and insulation or different insulating layer, or there is clearance in the insulation material. In these clearances or air gaps, even if the voltage is far less than the breakdown standard, partial discharge may still happen, which will influence the service life of solid insulation.

Many negative influences will be accumulated during the service life of the solid insulation, thus resulting in complicated process, and finally leading to insulation aging. Superposition of electrical stress and other stresses (such as heat, environment) will result in insulation aging. Short-period test together with appropriate condition processing (refer to 8.6) can be used to simulate long-term performance of solid insulation.

The thickness of the solid insulation has some relation with its failure mechanism. When thickness of solid insulation decreases, the electric field intensity increases accordingly, and risk of failure will rise too. Since required thickness of the solid insulation cannot be calculated, only test can be used to test its performance.

7.2.4.8.2 Stress

7.2.4.8.2.1 Voltage frequency

Voltage frequency will greatly influence the electric strength, probability of medium radiation and thermal instability is basically in direct proposition to frequency. According to GB/T 1408.1-2006, when measuring under power frequency, for solid insulation with 3mm of thickness, its breakdown electric field intensity is 10 kV/mm~40kV/mm. Enhancing inflicted voltage frequency will reduce electric intensity of most insulation material.

Note: Influence of frequency higher than 30k Hz on electric intensity, please refer to IEC 60664-4: 2005.

7.2.4.8.2.2 Heating

Heating will give rise to:

-- Mechanical transformation because of elimination of inner stress;
-- Thermoplastic material softening under comparatively low temperature rising which is higher than environment temperature (for example, the temperature is higher than 60 ºC);
-- Embrittlement of some material because of plasticizer loss;
-- If the temperature is higher than the material’s glass-transition temperature, some crosslinking material will soften;
-- To increase dielectric loss will lead to thermal instability and damage.

7.2.4.8.2.3 Mechanical shock

If the material does not possess enough striking-resistance intensity, mechanical shock will
cause insulation damage. Therefore, when specifying transportation, storage, installation and using environment conditions, such condition must be taken into consideration.

7.2.4.8.2.4 Partial discharge (PD)
If the repetitive value of working voltage stridden on insulating parts is higher than 700V, and voltage stress on insulating parts is higher than 1 kV/mm, then partial discharge is needed. Partial discharge property is influenced by applied voltage frequency. To conduct accelerated life test when increasing frequency, it can prove that failure time is in inversely proportional to frequency of applied voltage. But practical experience only includes frequency equal to and under 5kHz, since in higher frequency, it may also have some other failure mechanisms, for example, dielectric medium heating.
Note: For influence of frequency higher than 30kHz on partial discharge, please refer to IEC 60664-4: 2005.

7.2.4.8.2.3 Humidity
Vapor may influence insulation resistance and discharge quenching, intensify surface contamination, and corrode the appearance. For some materials, high humidity will greatly reduce its electric strength. Under some circumstances, low humidity maybe unfavorable. For example, it will increase the retention of electrostatic charge, and reduce the mechanical strength of some material (i.e., polyamide).

7.2.4.8.2.6 Other stresses
The influence of some stresses is not too significant or is very little, but still needs to be paid attention under some specific conditions. For example:
-- Ultraviolet radiation and ionization radiation;
-- Stress cracking or stress fracture resulted from exposed to solvent or active chemical agent;
-- Plasticizer migration effect;
-- Effect of mold such as fungus and bacteria.
-- Mechanical plastic deformation and so on.

7.2.4.8.3 Requirements
7.2.4.8.3.1 Introduction
Solid insulation of basic insulation, supplementary insulation and reinforced insulation shall be able to bear electric field intensity and mechanical stress permanently, and be able to bear possible heat effect and environment effect during the inverter’s service life.

7.2.4.8.3.2 Withstand voltage stress
Basic insulation and supplementary insulation shall be able to bear the following test voltage:
a) Determine impulse voltage according to 8.2.3.4.2;
b) Determine appropriate AC or DC voltage according to 8.2.3.4.3.
fracture, or fail in other forms.

7.3.5 Cast parts
Under malfunction conditions, the inverter shall not install any parts that may cause harm when cast away, and the energy must be limited when installed. The inverter’s protection measures against cast parts can only be removed with instruments.

7.3.6 Wiring terminal
7.3.6.1 General requirements
a) The wiring terminal’s structure shall guarantee to possess fine electrical contact and electric current-carrying capability, and enough mechanical strength. The wiring terminal shall be connected to the conductor with bolt, spring or other equivalent method to ensure maintaining necessary contact pressure.
b) The wiring terminal’s structure shall be able to compress the conductor in appropriate contact surface without causing any conspicuous damage to the conductor or wiring terminal.
c) The wiring terminal shall be designed to the requirements that the conductor is not allowed to move, or its movement will not be unfavorable to the inverter’s normal operation instead of reducing the insulation voltage lower than rated value.
d) The wiring terminal’s structure requirements shall be tested by test in 8.2.4.3.
e) The wiring terminal can also adopt photovoltaic connector which shall be tested to prove applicable.

7.3.6.2 General requirements conductive ability
The manufacturer shall connected wire types applicable to the wiring terminal (rigid line or flexible line, single core wire or multi-folded wire), maximum and minimum wire cross sectional area and number of wires which can connect to wiring terminal at the same time (if applicable). Maximum wire sectional area that can be connected by the wiring terminal shall not be smaller than wire sectional area specified in temperature rise test in 8.4.2, conductor that can be used to wiring terminal shall be the same type (rigid line or flexible line, single core wire or multi-folded wire), minimum sectional area with same wire type shall be smaller of 2 degrees than specified in temperature test (refer to listed value in corresponding row in Chart 5).
Round copper conductor (metric size and AWG/MCM size) standard sectional area, please refer to Chart 5. Chart 5 lists ISO metric size and similar relations of AWG/MCM size.

Chart 5 Standard sectional area of round copper conductor
regulation rate and other parameters can be long-distance set by the power grid dispatching agency.

7.10 Installation requirements

7.10.1 Array insulation resistance detection

7.10.1.1 Inverter connected to earth-free PV array

Inverter connected to earth-free PV array shall measure the DC insulation resistance between the PV array input terminal and the earth before the system starts. If the resistance is less than $U_{\text{maxpv}}/30\ \text{MA}$ ($U_{\text{maxpv}}$ refers to PV array maximum output voltage), then:

a) For inverters with electric isolation, it shall indicate malfunction. But during malfunction, other actions and operations can still be conducted. When insulation resistance satisfies the above requirements, it is allowed to stop alarming.

b) For non-isolated inverters or inverters with isolation but its leak current does not conform to requirements, it shall indicate malfunction, and be restricted from connecting to the grid. At this time, it is allowed to monitor the insulation resistance of the array, and when the insulation resistance satisfies the above requirements, it is allowed to stop alarming and connect to the grid.

7.10.1.2 Inverters requiring functional grounding

If the inverter needs an integral resistance to realize PV array functional grounding, then the inverter needs to satisfy this clause a) and c), or b) and c).

a) Including the preset resistance used for functional grounding, the total grounding resistance shall not be less than $U_{\text{maxpv}}/30\ \text{MA}$. Expectant insulation resistance can be calculated when the connected PV array area is known, and by insulation resistance $40\ \Omega$ each square meter. It can also be calculated by the inverter’s rated power and its worst connected PV array efficiency.

b) If the resistance is less than specified in a), then the inverter shall provide monitoring passing the resistance and any one of network line (e. g., measurement circuit) parallel to it during the operation process. If the inrush current’s response time exceeds restrictions in Chart 17, the resistance shall be disconnected or use other methods to limit the current. If it is non-isolated inverter, or inverter which cannot satisfy the minimum current allowed by leak current, then it must be disconnected from the grid.

7.10.2 Array residual current test

![Chart 4 The inverter’s reactive output range](image)
7.10.2.1 General requirements

a) Earth-free PV array working above the safe voltage degree may lead to electric shock hazard. If the inverter is not isolated, or has isolation measures but cannot guarantee the pick-up current in in some reasonable range, if the user contacts the lives and the earth at the same time, the connection of the grid and the earth will provide a loop for the pick-up current, thus resulting electric shock hazard. This kind of danger can be eliminated by protection way described in 7.10.2.4, or restricting the pick-up current within 30mA by methods specified in 7.10.2.5.

b) Whether the PV array is grounded or not, grounding fault will lead to those conductor parts or structures, which are not supposed to carry current, become carrying current, thus triggering fire danger. The danger can be eliminated by protection way described in 7.10.2.4, or restricting ignition leak current to the following range by methods specified in 7.10.2.5:

1) For inverters of which rated output is less than or equal to 30kVA, not larger than 300MA.

2) For inverters of which rated output is larger than 30kVA, not larger than 10mA/kVA.

7.10.2.2 30mA contact current

By contact test circuit shown in Chart 4 of IEC 60990, test the contact current between each terminal in PV array and the ground. If the measured value is larger than 30 mA limiting value, then extra protection shall be provided by measures in 7.10.2.4 or 7.10.2.5.

7.10.2.3 Ignition leak current

Ignition leak current shall not be larger than 300 mA (inverters $\leq$30kVA) or 10 mA/ /kVA (inverters $>30$/kVA). If the value is larger than this, then extra protection shall be provided by measures in 7.10.2.4 or 7.10.2.5.

7.10.2.4 Residual current detector (RCD) protection

Install RCD between the inverter and the AC grid to provide extra protection. RCD limit is set to 10mA, it must be type B rather than type A or AC type RCD (IEC 60755).

7.10.2.5 Residual current monitoring protection

When the inverter is connected to AC grid, AC circuit breaker is closed, the inverter shall conduct residual current detection. Residual current detection device shall be able to detect the total effective value current (including DC and AC components). Whether the inverter has isolation or not, the connected PV array is grounded or not, and isolation way adopts which degree (basic insulation isolation or reinforced insulation isolation), excess continue residual current and mutation of excess residual current must be monitored. The limiting values are as follows:

a) Continue residual current. If continue residual current exceeds the following limiting values, the inverter shall disconnect in 0.3s and send malfunction signal:

1) For inverters of which rated output is less than or equal to 30kVA, 300mA;

2) For inverters of which rated output is larger than 30kVA, 10 mA/kVA.
b) Mutation of residual current. If the mutation of residual current exceeds limiting values listed in Chart 17, then the inverter needs to disconnect in the time specified in Chart 17.

<table>
<thead>
<tr>
<th>Residual current mutation</th>
<th>Disconnection time of the inverter from the grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>mA</td>
<td>S</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>30</td>
<td>0.3</td>
</tr>
<tr>
<td>60</td>
<td>0.15</td>
</tr>
<tr>
<td>150</td>
<td>0.04</td>
</tr>
</tbody>
</table>

8 Test method

8.1 Test environmental conditions

Unless there is additional statement in this Standard, test site shall satisfy the following environment conditions:

-- Humidity 5 ºC–40 ºC;
-- Relative humidity 5%–75%;
-- Atmospheric pressure 75 kPa~106 kPa;
-- No frosting, condensation, water seepage, rain, sunlight and other phenomena.

8.2 Inverter’s safety

8.2.1 Appearance and structural inspection

The inverter shall conform to:

a) Adopted number of components and quality shall conform to design requirements; components arrangement and installation shall conform to respective technical requirements;

b) Oil paint or electroplate shall be firm and smooth without peeling-off, corrosion, crack and other phenomena;

c) Rack panel shall be smooth, characters and symbols shall be clear, orderly, standard and correct;

d) Name plate, symbol, and sign shall be complete and clear, and conform to requirements in 5.1.

e) Each kind of switch shall be convenient for operation, flexible and reliable;

f) Document and material shall conform to requirements in 5.2.

8.2.2 Structural material verification

8.2.2.1 Ultraviolet exposure
8.2.5 Fire protection requirements

8.2.5.1 Glowing filament test
Glowing filament test shall be conducted under conditions specified in 7.4 and GB/T 5169.10-2006 and GB/T5169.11-2006.

8.2.5.2 Heating wire ignition test
Heating wire ignition test shall be conducted under conditions specified in 7.4, and refer to Appendix I.

8.3 Basic functional verification

8.3.1 General requirements
a) Test platform shall be connected according to specifications in Appendix J.
b) If there is no specifications for permissible error during the test, please refer to specifications in Chart 25.

**Chart 25 Permissible error of test parameter**

<table>
<thead>
<tr>
<th>All tests</th>
<th>Test under under-loading, normal loading, overloading, short circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (DC/AC)±1%</td>
<td>Power factor</td>
</tr>
<tr>
<td>Voltage (DC/AC)±1%</td>
<td>Time constant</td>
</tr>
<tr>
<td></td>
<td>Frequency. ±5%</td>
</tr>
</tbody>
</table>

8.3.2 Electric parameter

8.3.2.1 Rated input, output
When operating under reference test conditions specified in 8.1, measured continue input, output current or power shall satisfy requirements in 7.5.1.
Start the inverter and set it in rated working condition, adjust the inverter’s input voltage (boost pressure or reduce the voltage), record the upper limit value and lower limit value of the voltage when the inverter stops working.

8.3.2.2 Efficiency
8.3.2.2.1 Maximum conversion efficiency
According to the inverter’s design principle, measured maximum conversion efficiency shall conform to specifications in 7.5.1.3.
Note 1: During the test, consuming electric energy to guarantee the inverter’s normal operation shall all be considered.
Note 2: During the test, maximum power point tracking function shall be turned off.

8.3.2.2.2 MPPT efficiency
MPPT efficiency includes dynamic MPPT efficiency and static MPPT efficiency. Measurement method shall be based on requirements in EN 50530-2010 or refer to Appendix K. Specific index (e.g., minimum threshold value of MPPT efficiency) is in consideration.

8.3.2.2.3 Conversion efficiency
Measure loading points which are 5%, 10%, 20%, 25%, 30%, 50%, 75%, 100% and conversion efficiency of input maximum power point, and given in test report with the form of graph. For measurement method, please refer to Appendix K.
In environment test, measure and record the inverter’s efficiency in high and low temperature, and record in test report.
Note: MPPT efficiency and the inverter’s efficiency curve do not need test during degree I and degree II assessment; but it needs efficiency curve during temperature rise and environment test for degree IIIa assessment; it needs to measure efficiency curve under specific environment for degree IIIb assessment.

8.3.3 Automatic switch
The inverter shall be able to switch automatically in manufacturer’s voltage range.
Connect according to requirements in 8.3.1, adjust DC input source, increase the input from the lower limit lower than the inverter’s permissible working range. When input is higher than the lower limit of working range, the inverter shall be able to start up automatically; when the inverter work smoothly, adjust the DC input source, reduce the input lower than the lower input of working range, and the inverter shall be able to power off automatically.

8.3.4 Soft start
When the inverter soft starts and operates, record the inverter’s power change curve with power analyzer, power quality analyzer or oscilloscope. Impulse phenomenon shall not happen according to requirements in 7.5.3.

8.3.5 Recover grid-connection
The inverter shall recover automatically and deliver power to the grid after starts or trouble removal. Recovery time shall conform to requirements in 7.5.4.

8.3.6 Communication
8.3.6.1 Communication protocol testing
8.3.6.1.1 Consistency test
Conduct communication protocol consistency test on the inverter, check whether it is consistent with the protocol.

8.3.6.1.2 Interoperability test

Conduct communication protocol interoperability test on the inverter, check whether it can conduct information exchange with other inverters in the system or communication equipment.

Note: The inverter’s communication adopts Modbus bus protocol, test according to GB/T 25192.2-2010.

8.3.6.2 Communication functional verification

8.3.6.2.1 General requirements

By connecting RS 485/RS 232 converter and PC, set the inverter can adopt exclusive monitoring and management software to verify the inverter’s telemetering, remote regulation, tele-commanding and remote control function under communication condition.

It shall guarantee that data transmission is correct, and it can conduct parameter settings without any fault information or obvious transmission delay.

Use the same method to verify the inverter’s communication function respectively under room temperature, extreme temperature (refer to 6.2.2.1) and electromagnetic compatibility test.

8.3.6.2.2 Telemetering (when applicable)

Telemeter the inverter’s electricity quantity parameter of each loop by PC:

a) Three-phase current, accuracy shall at least be 2.5;
b) Three-phase voltage, accuracy shall at least be 2.5;
c) Active power, reactive power, apparent power;
d) Grid frequency, harmonic and so on.

8.3.6.2.3 Remote regulating (when applicable)

Remote regulate the inverter’s every set value characteristic curve and so on by PC, and be able to conduct parameter setting.

8.3.6.2.4 Tele-commanding (when applicable)

Read the inverter’s information resources by PC, such as working conditions, malfunction conditions and operation time and so on.

8.3.6.2.5 Remote control (when applicable)

Send instructions to the inverter by PC, the inverter receives instructions successfully and can operate.

Note: Specific parameters and functions of the inverter’s telemetering, remote regulation, tele-commanding and remote control need the manufacturer to provide specific information for the convenience of measurement.

8.3.7 Cooling system
The inverter’s cooling system shall set malfunction according to the following requirements, can set one according to the inverter’s using conditions:

a) Block the air inlet completely or partially;

b) Block or disconnect the cooling fan, one for each time;

c) Circulating water or other cooling liquid shall stop or partially restrict.

The inverter can continually operate 7h without damage, or possesses Automatic temperature-detection function. When the temperature exceeds the permissible value, it will stop working automatically.

Note: Degree III equipment requires verifying the system’s malfunction test under high temperature.

8.3.8 Thunder prevention

Check whether the inverter is equipped with thunder prevention device.

8.3.9 Noise

Under the most rigorous working conditions, at the direction with strongest noise of the inverter, use sound level meter to measure the noise sent by the inverter at 1m from the equipment. Sound level meter adopts A weighting method.

When measuring, at least guarantee difference value between the measured noise and background noise is larger than 3dB; otherwise, some measures shall be taken to make testing environment satisfy testing conditions. When difference value between the measured noise and background noise is larger than 10 dB, the measured value does not need to be modified; when difference value between the measured noise and background noise is 3 dB~10dB, the noise value shall be modified according to Chart 26, and the value shall satisfy requirements in 7.5.8.

<table>
<thead>
<tr>
<th>Difference value dB</th>
<th>3</th>
<th>4~5</th>
<th>6~10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revised value dB</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
</tr>
</tbody>
</table>

8.4 Electrical performance

8.4.1 General requirements

a) Items that have not been noted with test circuit during test can be connected according to specifications in Appendix J.

b) If there is no specification for permissible error during electrical performance test, then
specifications in Chart 25 can be referred to.

8.4.2 Temperature rise

8.4.2.1 General requirements

Temperature rise test shall satisfy requirements in 7.1.1.

Conductor used in temperature rise tests shall be chosen by the following specifications according to the magnitude of test current:

a) Test current is no larger than 400A:

1) Connecting wire adopts single core PVC insulation copper wire, and its sectional area is shown in Chart 27.

2) Connecting wire shall be placed in the air. Distance between wires shall be equal to distance between the equipment terminals.

---

**Chart 27 Test copper wire of which test current is equal to or smaller than 400A**

<table>
<thead>
<tr>
<th>Test current range</th>
<th>Wire size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td><strong>mm²</strong></td>
</tr>
<tr>
<td>0≤I&lt;8</td>
<td>1.0</td>
</tr>
<tr>
<td>8≤I&lt;12</td>
<td>1.5</td>
</tr>
<tr>
<td>12≤I&lt;15</td>
<td>2.5</td>
</tr>
<tr>
<td>15≤I&lt;20</td>
<td>2.5</td>
</tr>
<tr>
<td>20≤I&lt;25</td>
<td>4.0</td>
</tr>
<tr>
<td>25≤I&lt;32</td>
<td>6.0</td>
</tr>
<tr>
<td>32≤I&lt;50</td>
<td>10</td>
</tr>
<tr>
<td>50≤I&lt;65</td>
<td>16</td>
</tr>
<tr>
<td>65≤I&lt;85</td>
<td>25</td>
</tr>
<tr>
<td>85≤I&lt;100</td>
<td>35</td>
</tr>
<tr>
<td>100≤I&lt;115</td>
<td>35</td>
</tr>
<tr>
<td>115≤I&lt;130</td>
<td>50</td>
</tr>
<tr>
<td>130≤I&lt;150</td>
<td>50</td>
</tr>
<tr>
<td>150≤I&lt;175</td>
<td>70</td>
</tr>
<tr>
<td>175≤I&lt;200</td>
<td>95</td>
</tr>
<tr>
<td>200≤I&lt;225</td>
<td>95</td>
</tr>
<tr>
<td>225≤I&lt;250</td>
<td>120</td>
</tr>
<tr>
<td>250≤I&lt;275</td>
<td>150</td>
</tr>
<tr>
<td>275≤I&lt;300</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>√</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---</td>
</tr>
<tr>
<td>Surge (impact) immunity</td>
<td></td>
</tr>
<tr>
<td>Induced conducted disturbance immunity of the radio-frequency field</td>
<td></td>
</tr>
<tr>
<td>Immunity of voltage dips, short interruptions and voltage variations</td>
<td></td>
</tr>
<tr>
<td>Power frequency magnetic field immunity</td>
<td>√</td>
</tr>
<tr>
<td>Damped oscillation immunity</td>
<td></td>
</tr>
<tr>
<td>Voltage fluctuation immunity</td>
<td></td>
</tr>
</tbody>
</table>

Note: “√” means that the corresponding EMC test shall be done at the port.

### 8.6 Environment Test

#### 8.6.1 Low temperature test
Test shall be done according to the “Test A” in GB/T 2423.1-2008. The inverter has no packaging. Under the test temperature of -20°C±3°C (indoor) or -25°C±3°C (outdoor), after energization, MAINTAIN for 2h with the rated loading; under the standard atmospheric condition, it is restored for two hours; the inverter shall be able to work properly.

#### 8.6.2 High temperature test
Test shall be done according to the “Test B” in GB/T 2423.2-2008. The inverter has no packaging. Under the test temperature of 40°C±2°C (indoor) or 60°C±2°C (outdoor), after energization, MAINTAIN for 2h with the rated loading; under the standard atmospheric condition, it is restored for two hours; the inverter shall be able to work properly.

#### 8.6.3 Damp heat test

a) Constant temperature damp heat rest: Test shall be done according to GB/T 2423.3-2006. The test temperature is 40°C±2°C (indoor) or 60°C±2°C (outdoor), under the constant damp heat condition of the relative humidity 90%±3%, no packaging, not energized, after 48h’s test, TAKE out the sample; under the standard atmospheric condition, it is restored for two hours; and the inverter shall be able to work properly.

b) Alternating temperature humidity test: the test shall be done according to GB/T 2423.4-2008. The inverter’s test temperature and relative humidity are under consideration.

#### 8.6.4 Vibration test
The vibration test of the inverter shall be done according to GB/T2423.10-2008.
Frequency range: 10Hz~150Hz.
Amplitude/acceleration recommendation: amplitude 0.075mm;
acceleration 1g.

Vibration duration: at 3 axis-directions mutually perpendicular each other. [Translator: There is something mismatched in original text -- DURATION vs. DIRECTION]

Sweep frequency cycle time: 10 scan cycles/axis.

After the vibration test, the sample can work properly.

Note: large inverter vibration alternatives are under consideration.

**8.7 Power control**

8.7.1 Active power control test

USE PC simulation to send multiple sets of active power control signals to the inverter (including maximum output power and power variation rate and other parameters), the inverter shall be able to receive and execute, and COMPLY with the provisions of 7.9.1.

8.7.2 Voltage/reactive power adjustment test

USE PC simulation to send multiple sets of reactive power control signals to the inverter (including adjustment mode, reference voltage, voltage adjustable rate and other parameters), within the specified range of reactive power output range, the inverter shall adjust the reactive power output according to the network voltage level, with function of reactive power adjustment, and COMPLY with the provisions of 7.9.2.

**8.8 Installation requirements**

8.8.1 Photovoltaic array insulation resistance test

CONNECT the inverter to the test circuit, SET the DC voltage at lower than the startup voltage (power) value of the inverter. CONNECT a resistance of which impedance value is lower than the impedance value in 7.10.1 (about 90% of required impedance value) between the DC terminal of the inverter and the ground, the inverter response shall meet the requirements in 7.10.1.

8.8.2 Photovoltaic array residual current test

8.8.2.1 Continuous residual current test method

In the most severe conditions, and the DC terminal is not grounded, one pole of the AC terminal shall be grounded. During the test, the monitoring function of the insulation resistance in the
photovoltaic array can be turned off. Connect an adjustable resistance between the DC terminal and the ground. The starting value of the adjustable resistance shall ensure that the initial residual current is below the limits specified in 7.10.2.1. Then gradually lower the resistance, record the current value when the residual current protection activates. The test shall be repeated for five times and all test results shall not exceed the limits in a) of 7.10.2.1, otherwise the inverter shall cut off the power within 0.3s.

Note: if there are multiple inputs, and the circuit analysis has the same theory and possible test results, then no need to test one by one.

8.8.2.2 Fire leakage test method
In the most severe conditions, and the DC terminal is not grounded, one pole of the AC terminal shall be grounded. During the test, the monitoring function of the insulation resistance in the photovoltaic array can be turned off. Measure the leakage current between each photovoltaic array terminal and the ground, it shall comply with the specification in 7.10.2.3.

8.8.2.3 Residual current breaks test method
The inverter works under rated power, set an adjustable resistance between the DC terminal and the ground. Adjust the resistance to create leakage current of 30, 60, 150mA [Translator: respectively], the cut off time of the inverter shall not be longer than the limits specified in 7.10.2.5 b).

Note: if there are multiple inputs, and the circuit analysis has the same theory and possible test results, then no need to test one by one.

9 Inspection rules

9.1 General rules
9.1.1 The tests mentioned in this Standard shall be carried out by test agencies with certain qualifications.

9.1.2 The tests shall be in the same conditions with the actual working conditions, or in the conditions that the usage requirements of the inverter can be met.

9.2 Inspection classification
The tests to evaluate the inverter performance include:
a) Factory test. To test the inverter performance and ensure it is in line with this Standard and relevant requirements of type test, factory test shall be done to each inverter assembled. Those passed the factory test shall be given the conformity certification of the factory test.

If any item does not meet the requirements in the factory test, repair and retest will be allowed. Conformity certification of factory test will also be given if the retest is passed.

b) Type test is to fully validate whether the inverter performance indicator and quality meet the requirements in this Standard. Take following type test to evaluate the quality of the inverter:

-- Level I: the inverter performance can satisfy basic usage requirements.
-- Level II: the inverter passes all the test.
-- Level IIIa: the conversion efficiency of the inverter shall be no lower than 96.5% when without transformer isolation, and no lower than 94.5% when with the transformer isolation; measure the static MPPT efficiency, dynamic MPPT efficiency; the three-phase voltage imbalance, negative sequence voltage unbalance generally shall be no more than 1.3%, short term shall not exceed 2.6%.
-- Level IIIb: meet all the requirements in level IIIa and add the test of inverter working under abnormal conditions (such as high altitude, see 6.2)

c) On-site inspection. Test the performance of the inverter in actual working conditions.

d) Sampling test. If engineering and statistical analysis indicate the there is no need to take factory test on every inverter, then it can be replaced with sampling test. Relevant sampling test method can be specified in accordance with the specifications in IEC60410 or GB/T 2828.1-2012, and shall be reflected in the product quality control files of the manufacturer.

9.3 Test items
The test items of the inverter evaluation are shown in Chart 35.

| ID | Test item                          | Provision ID | Exit-Factory Test | Type test
|----|-----------------------------------|--------------|-------------------|-----------
<p>| 1  | Appearance and structural inspection | 8.2.1        | √                 | √         | √         | √         |
| 2  | Protection class                  | 8.2.2.2      | √                 | √         | √         | √         |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Specification</th>
<th>Checkmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Protection connection</td>
<td>8.2.3.2</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Contact current</td>
<td>8.2.3.3</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>Impulse withstand voltage verification</td>
<td>8.2.3.4.2</td>
<td>✓</td>
</tr>
<tr>
<td>6</td>
<td>Power frequency withstand</td>
<td>8.2.3.4.3</td>
<td>✓</td>
</tr>
<tr>
<td>7</td>
<td>Partial discharge test</td>
<td>8.2.3.4.6</td>
<td>✓</td>
</tr>
<tr>
<td>8</td>
<td>Electric clearance and creep distance</td>
<td>8.2.3.4.7</td>
<td>✓</td>
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<tr>
<td>9</td>
<td>Stability test</td>
<td>8.2.4.1</td>
<td>✓</td>
</tr>
<tr>
<td>10</td>
<td>Handling requirements</td>
<td>8.2.4.2</td>
<td>✓</td>
</tr>
<tr>
<td>11</td>
<td>Terminal requirements</td>
<td>8.2.4.3</td>
<td>✓</td>
</tr>
<tr>
<td>12</td>
<td>Glow-wire test</td>
<td>8.2.5.1</td>
<td>✓</td>
</tr>
<tr>
<td>13</td>
<td>Electric wire ignition test</td>
<td>8.2.5.2</td>
<td>✓</td>
</tr>
<tr>
<td>14</td>
<td>Rated input and output</td>
<td>8.3.2.1</td>
<td>✓</td>
</tr>
<tr>
<td>15</td>
<td>Switcher</td>
<td>8.3.3</td>
<td>✓</td>
</tr>
<tr>
<td>16</td>
<td>Soft start</td>
<td>8.3.4</td>
<td>✓</td>
</tr>
<tr>
<td>17</td>
<td>Recovery and network</td>
<td>8.3.5</td>
<td>✓</td>
</tr>
<tr>
<td>18</td>
<td>Communication consistency</td>
<td>8.3.6.1.1</td>
<td>✓</td>
</tr>
<tr>
<td>19</td>
<td>Communications interoperability</td>
<td>8.3.6.1.2</td>
<td>✓</td>
</tr>
<tr>
<td>20</td>
<td>Communication function verification</td>
<td>8.3.6.2</td>
<td>✓</td>
</tr>
<tr>
<td>21</td>
<td>Cooling system</td>
<td>8.3.7</td>
<td>✓</td>
</tr>
<tr>
<td>22</td>
<td>Lightning protection</td>
<td>8.3.8</td>
<td>✓</td>
</tr>
<tr>
<td>23</td>
<td>Noise</td>
<td>8.3.9</td>
<td>✓</td>
</tr>
<tr>
<td>24</td>
<td>Temperature rise</td>
<td>8.4.2</td>
<td>✓</td>
</tr>
<tr>
<td>25</td>
<td>Active power control test a</td>
<td>8.7.1</td>
<td>✓</td>
</tr>
<tr>
<td>26</td>
<td>Voltage/reactive power regulation test a</td>
<td>8.7.2</td>
<td>✓</td>
</tr>
<tr>
<td>27</td>
<td>Photovoltaic array insulation resistance test</td>
<td>8.8.1</td>
<td>✓</td>
</tr>
<tr>
<td>28</td>
<td>Photovoltaic array residual current test</td>
<td>8.8.2</td>
<td>✓</td>
</tr>
<tr>
<td>29</td>
<td>Maximum conversion efficiency</td>
<td>8.3.2.2.1</td>
<td>✓</td>
</tr>
<tr>
<td>30</td>
<td>MPPT efficiency</td>
<td>8.3.2.2.2</td>
<td>✓</td>
</tr>
<tr>
<td>31</td>
<td>Conversion efficiency</td>
<td>8, 3.2.2.3</td>
<td>✓</td>
</tr>
</tbody>
</table>
Appendix K – Inverter Efficiency Test
(Informative Appendix)
Inverter efficiency test

K.1 Inversion efficiency

The total inversion efficiency defined in this appendix $\eta_i$ includes the maximum power point tracking efficiency, conversion efficiency, and provides a more accurate description method of the inverter total efficiency $\eta_{\text{cont}}$ than giving a separate conversion efficiency. Based on different irradiation intensity $G$ and part temperature $T$, the maximum power point tracking efficiency guarantees to get the maximum output power $P_{\text{MPP}}$ from the PV array. The inverter conversion efficiency can effectively convert available DC power $P_{\text{DC}}$ to AV power $P_{\text{AC}}$.

K.1.1 Maximum power point tracking efficiency

a) General description. Maximum power point tracking efficiency reflects the set precision of the maximum power point on the PV power characteristic. The maximum power point tracking efficiency is divided into static maximum power point tracking efficiency and dynamic maximum power point tracking efficiency. The two efficiencies are both collected and measured by the momentary value of the voltage and current at the inverter input terminal.

b) The static maximum power point tracking efficiency. It is decided by the average value of the collected values:

$$\eta_{\text{MPP,sta}} = \frac{\sum U_{\text{DC},i}I_{\text{DC},i}\Delta T}{P_{\text{MPP,sys}}T_M} \quad (K.1)$$

$U_{\text{DC},i}$ - collected value of the input voltage of the inverter;
$I_{\text{DC},i}$ - collected value of the input current of the inverter;
$T_M$ - total collection cycle (no shorter than 10min);
$\Delta T$ - cycle of two continuous collected values (no greater than 20ms).

The static maximum power point tracking efficiency reflects the accuracy of the adjusted tracking maximum power point of the inverter on the given static PV component characteristic.

Note: $U_{\text{DC},i}$ and $I_{\text{DC},i}$ shall be values collected at the same time.

c) The dynamic maximum power point tracking efficiency. The static maximum power point tracking efficiency does not consider the change of irradiation intensity and the transit conversation of the inverter in different operation points and other factors. The dynamic
maximum power point tracking efficiency can be used to evaluate the efficiency characters in the transient process of the inverter. The calculation formula is as below:

$$\eta_{\text{MPPT, dyn}} = \frac{1}{\sum P_{\text{MPP, PVS}, j}} \sum U_{\text{DC}, i} I_{\text{DC}, i} \Delta T_j$$  \(\text{(K.2)}\)

\(\Delta T_j\) - the collection interval between \(P_{\text{MPP, PVS}, j}\)
\(\Delta T_i\) - the collection interval between \(U_{\text{DC}, i}, I_{\text{DC}, i}\)

K.1.2 Conversion efficiency

The test of the static conversion efficiency shall follow the test specifications in Chart K.1

If the tested inverter has multiple DC terminals, then the parameter configuration of each input terminal shall be the same as the requirements of the manufacturer. Unless otherwise specified by the manufacturer, the output power of the PV array simulator shall be equally distributed to each input terminal.

Note: the test of conversion efficiency and static maximum power point tracking efficiency shall be carried out at the same time.

### Chart K.1 Test specification of the dynamic conversion efficiency

<table>
<thead>
<tr>
<th>Maximum power point voltage of the PV array simulator</th>
<th>I/U character</th>
<th>ratio of the power in PV array simulator maximum power point and rated DC power (P_{\text{mpp, pvs}}/P_{\text{DC, N}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(U_{\text{MPP}}^\text{max} (0.8U_{\text{DC, max}}))(^a)</td>
<td>Crystalline silicon modules</td>
<td>0.05 0.10 0.20 0.25 0.30 0.50 0.75 1.00</td>
</tr>
<tr>
<td>(U_{\text{DC, N}})</td>
<td>Crystalline silicon modules</td>
<td></td>
</tr>
<tr>
<td>(U_{\text{MPPmin}})</td>
<td>Crystalline silicon modules</td>
<td></td>
</tr>
<tr>
<td>(U_{\text{MPP}}^\text{max} (0.7U_{\text{DC, max}}))(^a)</td>
<td>thin-film module(^b)</td>
<td></td>
</tr>
<tr>
<td>(U_{\text{DC, N}})</td>
<td>thin-film module(^b)</td>
<td></td>
</tr>
<tr>
<td>(U_{\text{MPPmin}})</td>
<td>thin-film module(^b)</td>
<td></td>
</tr>
</tbody>
</table>

a. the lower one shall be selected among the two values to ensure the inverter is not affected by the DC input voltage in the maximum power point tracking mode.

b. For the tested inverters which are not working with thin-film module, these measuring points cannot be measured.

c. \(N\) means rated, \(P_{\text{DC, N}}\) means rated direct current power

Adjust the output characteristics of the PV array simulator according to the specified test
condition mentioned above. Then the output of the tested inverter become stable, begin to measure following data, the record time is 10min.
- input DC voltage $U_{DC}$;
- input DC current $I_{DC}$;
- output AC voltage $U_{AC}$;
- output AC current $I_{AC}$.

No particular waiting time is specified in this Standard. The waiting time during the test of the inverter shall be taken down in the test report. If the output of the tested inverter is continuously unstable, then the waiting time shall be no shorter than 5min. Use the formula (K.2) to calculate the conversion efficiency and enter the results in the test report.

If needed the parameters in Chart K.2 in the formula (K.3) to evaluate efficiency:

$$\eta = \alpha_1\eta_1 + \alpha_2\eta_2 + \alpha_3\eta_3 + \alpha_4\eta_4 + \alpha_5\eta_5 + \alpha_6\eta_6$$  
(K.3)

In the formula:
- $\alpha_1, \alpha_2, \alpha_3, \cdots, \alpha_6$ - weighting factor
- $\eta_1, \eta_2, \eta_3, \cdots, \eta_6$ - measured static maximum power point tracking efficiency or conversion rate under different power values.

### Chart K.2  Weighting factor and power

<table>
<thead>
<tr>
<th>Weighting factor</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$\alpha_3$</th>
<th>$\alpha_4$</th>
<th>$\alpha_5$</th>
<th>$\alpha_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{MPP, PIP} / P_{DC,N}$</td>
<td>0.03</td>
<td>0.06</td>
<td>0.13</td>
<td>0.1</td>
<td>0.48</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

K.2 Measuring method of dynamic maximum power point tracking efficiency

K.2.1 Test process

The test of dynamic maximum power point tracking (MPPT) efficiency shall follow the process below. The percentage of the normalized irradiation intensity and the irradiation intensity in standard test condition (STC), 100% of normalized irradiation intensity means the irradiation condition of 1000W/m² when the irradiation intensity is 25°C. The test process of the changes between low irradiation intensity and medium irradiation intensity is shown in Graph K.1. The test process of the changes between medium irradiation intensity and high irradiation intensity is shown in Graph K.2.
Appendix L – Wire Used in Temperature Test
(Normative Appendix)

Wire used in temperature-rise test

L.1 Test current value is greater than 400, but not exceed 800A

a) Connecting wire shall adopt single core polyvinyl chloride (PVC) insulate copper wire, the sectional area see Chart L.1, or use equivalent copper bar in Chart L.2 recommended by the manufacturer.

b) The distance between the connecting conductors shall be approximately the same with the distance between the terminals of the equipment. The copper bar shall be painted with black varnish. Each terminal shall have multiple parallel conductors connected and the interval distance shall be approximately the same as the thickness of the copper bar. If the copper bar in specified size is not suitable for the connecting terminal or hard to get, then can use copper bars in other size with approximately the same sectional area and approximately the same of smaller cooling area. Copper conductor or copper bar shall not be overlaid to get the specified size.

Chart L.1 test copper conductive wire with test current greater than 400A and not exceed 800A

<table>
<thead>
<tr>
<th>Test current range a</th>
<th>Conductive wire</th>
<th>Copper bar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pieces</td>
<td>Sectional area mm²</td>
</tr>
<tr>
<td>400≤I≤500</td>
<td>2</td>
<td>150 (16)</td>
</tr>
<tr>
<td>500≤I≤630</td>
<td>2</td>
<td>185 (18)</td>
</tr>
<tr>
<td>630≤I≤800</td>
<td>2</td>
<td>240 (21)</td>
</tr>
</tbody>
</table>

Note 1: the Chart lists the conversion of metric and AWG/MCM system sizes and the conversion of conductive wire and copper bar.

Note 2: for the convenience of the test, smaller test current conductors can be used with the permission of the manufacturer.

Note 3: within the specified test current range both types of conductors can be used.

Note 4: the value in the parentheses is the estimated value (represented in absolute temperature K) of temperature rise of the test conductive wire, for reference only.

a. The test current shall be greater than the first value in the first column and smaller than or equal to the second value.
L.2 Test current value greater than 800A and not exceed 2000A

a) the conductive wire shall use copper bar with the size in Chart L.2. If the design specifies that only cable connection can be used, then the sectional area and size shall be specified by the manufacturer.

b) The distance between the connecting conductors shall be approximately the same with the distance between the terminals of the equipment. The copper bar shall be painted with black varnish. Each terminal shall have multiple parallel conductors connected and the interval distance shall be approximately the same as the thickness of the copper bar. If the copper bar in specified size is not suitable for the connecting terminal or hard to get, then can use copper bars in other size with approximately the same sectional area and approximately the same of smaller cooling area. Copper conductor or copper bar shall not be overlaid to get the specified size.

**Chart L.2 Test current greater than 400A**

<table>
<thead>
<tr>
<th>Test current range</th>
<th>Copper bar^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Pieces</td>
</tr>
<tr>
<td>400≤I≤500</td>
<td>2</td>
</tr>
<tr>
<td>500≤I≤630</td>
<td>2</td>
</tr>
<tr>
<td>630≤I≤800</td>
<td>2</td>
</tr>
<tr>
<td>800≤I≤1000</td>
<td>2</td>
</tr>
<tr>
<td>1000≤I≤1250</td>
<td>2</td>
</tr>
<tr>
<td>1250≤I≤1600</td>
<td>2</td>
</tr>
<tr>
<td>1600≤I≤2000</td>
<td>3</td>
</tr>
</tbody>
</table>

Note 1: for the convenience of the test, smaller test current conductors can be used with the permission of the manufacturer.

Note 2: the value in the parentheses is the estimated value (represented in absolute temperature K) of temperature rise of the test conductive wire, for reference only.

A copper bar can be set with the longer side in vertical position. With the permission of the manufacturer, the copper bar can also be set with the longer side in horizontal position. When applying 4 pieces of copper bars, they shall be divided into 2 groups with 2 pieces in each group. The distance between each group center shall be no greater than 100mm.
Appendix M – Thermometry Measurement Adjustment

(Informative Appendix)

Thermometry measurement adjustment

For the coils, resistance variation method can be used for the measurement. The measuring adjustment formula is as follows:

\[ T = \frac{R_2}{R_1} (k + t_1) - (k + t_2) \]

In the formula:

- \( T \) -- temperature raised, °C
- \( R_1 \) -- resistance of the coil at the beginning of the test, Ω;
- \( t_1 \) -- room temperature at the beginning of the test, °C;
- \( R_2 \) -- resistance of the coil at the end of the test, Ω;
- \( t_2 \) -- room temperature at the end of the test, °C;
- \( k \) -- temperature constant, 234.5 for copper, 225.0 for aluminum. Other materials can be adjusted through usage.

Temperature limits are as follows:

a) For coils and their insulation system, see Chart 28.

b) For other parts, the test temperature shall not exceed following limits:
   1) The limits for the IEC standard parts;
   2) Part and material temperature limits specified by the manufactures.

c) If the above two don’t apply, see Chart 24.
Appendix N – Short-circuit Protection Verification
(Informative Appendix)

Short-circuit protection functional verification test

N.1 Direct power short circuit fault method

- Direct power short circuit fault method: when the inverter is operating at the maximum output power, A short circuits the inverter grid side in the closure Graph N.1, check whether the inverter meets the requirements in 7.7.5. After the fault is resolved check and take down if the inverter works appropriately.

a) In the test, the power supply S provides power to the circuit made up of resistance R₁, electric reactor X and the test inverter D.

Under all circumstances, the power supply S shall have enough capacity (shall not be less than 2 times of the maximum output power of the tested inverter) to ensure the electric characters specified by the manufacturer can be validated.

b) During the test the resistance and the electric reactor shall be connected between the power supply S and the tested inverter D.

c) After the test, if the inverter is protected by the fuse on the output side, then it can work normally after changing the fuse wire; if the inverter is protected by the breaker on the output side, then it can work normally after the reset of the breaker.

Graph N.1 Test circuit diagram of the short-circuit protection functional verification test
- direct power short circuit fault method
N.2 simulated power short circuit fault method

- Simulated power short circuit fault method: when the inverter is operating on the maximum output power, modulate RLC load to make inverter stay on the resonance oscillation output status when the simulated power is cut off; K2 short circuits the inverter grid side in closure. Graph N.2, check whether the inverter meets the requirements in 7.7.5. After the fault is resolved, remove and check if the inverter works appropriately.

Graph N.2 Test circuit diagram of the short-circuit protection functional verification test
- simulated power short circuit fault method
References

[1] GB/T 191 Packaging Pictorial Signs
[18] UL 1741: 2010 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources