BRITISH STANDARD

BS EN 62093:2005

Balance-of-system components for photovoltaic systems — Design qualification natural environments

The European Standard EN 62093:2005 has the status of a British Standard

ICS 27.160

British Standards

National foreword

This British Standard is the official English language version of EN 62093:2005. It is identical with IEC 62093:2005.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Solar photovoltaic energy systems, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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English version

Balance-of-system components for photovoltaic systems – Design qualification natural environments
(IEC 62093:2005)

Composants BOS des systèmes photovoltaïques –
Qualification et essais d'environnement
(CEI 62093:2005)

BOS-Bauteile für photovoltaische Systeme –
Bauarteignung natürliche Umgebung
(IEC 62093:2005)

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

The text of document 82/374/FDIS, future edition 1 of IEC 62093, prepared by IEC TC 82, Solar photovoltaic energy systems, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62093 on 2005-04-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2006-01-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2008-04-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62093:2005 was approved by CENELEC as a European Standard without any modification.

CONTENTS

BALANCE-OF-SYSTEM COMPONENTS FOR PHOTOVOLTAIC SYSTEMS – DESIGN QUALIFICATION NATURAL ENVIRONMENTS

1 Scope and object

This International Standard establishes requirements for the design qualification of balance-of-system (BOS) components used in terrestrial photovoltaic (PV) systems. This standard is suitable for operation in indoor, conditioned or unconditioned; or outdoor in general open-air climates as defined in IEC 60721-2-1, protected or unprotected. It is written for dedicated solar components such as batteries, inverters, charge controllers, system diode packages, heat sinks, surge protectors, system junction boxes, maximum power point tracking devices and switch gear, but may be applicable to other BOS system components.

This standard is based on that which is specified in IEC 61215 and IEC 61646 for the design qualification of PV modules. However, changes have been made to account for the special features of the balance-of-system components, and to add different levels of severity for the different service environments. Dust, fungus, insects, shipping vibration and shock, and protection class have been added to the appropriate environmental categories. The high and low temperature and humidity limits have also been modified for the appropriate service environments.

This standard does not apply to photovoltaic modules. These are covered by IEC 61215 or IEC 61646. Also, this standard does not apply to concentrator modules or to complete PV systems. Specific electrical safety aspects are not part of this standard.

This standard is applicable to lead-acid and nickel-cadmium cells and batteries. Other electrochemical storage systems will be included when they become available.

The object of this test sequence is to determine the performance characteristics of each BOS components and to show, as far as possible within reasonable constraints of cost and time, that the component is capable of maintaining this performance after exposure to the simulated service natural environmental conditions for which it is intended to be applicable as specified by the manufacturer. The actual life expectancy of components so qualified will depend on their design, their environment and the system conditions under which they are operated.

2 Normative references

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

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc: vibration (sinusoidal)*

IEC 60068-2-21, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27, *Environmental testing – Part 2: Tests. Test Ea and guidance: Shock*

IEC 60068-2-30, *Environmental testing – Part 2: Tests. Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60068-3-6, *Environmental testing – Part 3-6: Supporting documentation and guidance –* Confirmation *of the performance of temperature/ humidity chambers*

IEC 60410, *Sampling plans and procedures for inspection by attributes*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60721-2-1, *Classification of environmental conditions – Part 2-1: Environmental conditions appearing in nature – Temperature and humidity*

IEC 60904-3:1989, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 61215, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61345, *UV test for photovoltaic (PV) modules*

IEC 61427:2005, *Secondary cells and batteries for solar photovoltaic energy systems – General requirements and methods of test*

IEC 61646, *Thin film silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61683, *Photovoltaic systems – Power conditioners – Procedure for measuring efficiency*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Sampling

For qualification testing a quantity of at least three samples of a component (plus spares as desired) shall be taken at random from a production batch or batches, in accordance with the procedure given in IEC 60410. The components shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and shall have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The components shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting and connection instructions, including the maximum permissible system voltage.

In the case of items, for example wires and cables, that do not have previously defined measures, a sufficient amount for the testing purposes shall be taken at random from a production batch or batches, in accordance with the procedure given in IEC 60410.

4 Marking

Each component shall carry the following clear and indelible markings:

– name, monogram or symbol of manufacturer/supplier;
– type or model number;
– serial/batch number, if practical;
– the design service use of this component; outdoor unprotected, outdoor protected, indoor unconditioned and indoor conditioned;
– polarity of terminals or leads (only colour coding is not permissible);
– maximum system voltage for which the component is suitable;
– nominal and minimum values of the power consumption, as specified by the manufacturer for the product type.

The date (and preferably time) and place of manufacture shall be marked on the component or be traceable from the serial or batch number.

NOTE Small components such as wires, connectors, fuses, etc. need not have these elaborate markings. The minimum information is name/monogram/symbol of manufacturer or supplier and the type or model number.

5 Documentation

5.1 General

The documentation shall contain the following information (if relevant):

– compliance with relevant standards (this is especially important with respect to European Directives and the related CE marking);
– installation and disconnection instructions;
– operating instructions;
– service use of the component (see 6.1);
– technical data (circuit diagram and technical specifications);
– troubleshooting instructions;
– safety warnings and instructions;
– information on spare parts;
– warranty;
– instructions for decommissioning and disposal.

In particular, the documentation shall indicate (if relevant):

a) Conditions of surroundings
   1) Range of operating temperature
   2) Range of storage temperature
   3) Maximum relative humidity
b) Physical properties of the component
   1) Dimensions of the enclosure
   2) Weight
   3) Properties of the enclosure (material)
   4) Fasteners
   5) Protection class (IP and IK Code)

6) Connecting terminals
7) Cables (inlet, pull relief, cross-sections)
8) Spare parts

c) Electrical properties of the component

1) For charge controllers

- Listing of incompatible and compatible battery types
- Nominal voltage of input and output (V)
- Maximum module current (A)
- Maximum load current (A)
- Type of controller (series controller, shunt controller, etc.)
- Working principle (PWM, two-point-regulation, state of charge algorithm, etc.)
- All used thresholds (V)
- Temperature compensation for the thresholds (mV/°C/cell)
- Quiescent current
- Curve indicating input and output power/current vs. ambient temperature
- Power consumption to be measured during operation immediately after deep discharge disconnection
- Power consumption during operation at nominal voltage
- Overload protection
- Reverse-polarity protection
- Definition of the allowable voltage area at the input and at the output side
- Warning before load disconnect
- Definition of the output behaviour in the case of no battery connection
- Delayed load disconnection
- Displays (LEDs, display, accuracy)
- Additional functions (MPP tracking, etc.)
- Maximum AC ripple on the battery charging current

NOTE If the negative terminal of the battery, module and load cannot be linked together, this must be clearly stated and the behaviour in such a case must be defined.

2) For batteries

- Type of battery: NiCd, lead-acid, vented (flooded), valve-regulated, gas-tight sealed (NiCd only), tubular plate, flat plate, etc.
- Nominal voltage
- Specific gravity of the electrolyte
- Capacity expressed in C_{120}, C_{20}, C_{10}, C_5
- Charge retention expressed as a percentage: monthly self-discharge/nominal capacity
- Endurance in cycles, measured according to IEC 61427
- Charging efficiency (see IEC 61427)
- Instructions for starting up (the manufacturer must advise if there are special considerations for the initial charging with only the solar generator available as the power source), maintenance, and safety.
- Transportation restrictions

3) For inverters
   - Maximum input current (A)
   - Maximum output current (A)
   - Nominal input voltage and range (V)
   - Nominal output voltage and range (V)
   - Absolute maximum solar voltage (V_{oc})
   - Number of phases
   - Frequency (Hz)
   - Output voltage: sine wave, square wave or modified square wave, etc.
   - Galvanic separation
   - Overload capability curve
   - Curve indicating output power at nominal input voltage vs. ambient temperature
   - Curve indicating maximum output power at nominal input voltage vs. ambient air-pressure (may be expressed in height of installation above sea-level)
   - Maximum ambient temperature
   - Type of load allowed, for example maximum cos(phi), regenerative loads
   - Earthing requirements
   - For standalone inverters: power consumption to be measured during operation immediately after deep discharge disconnection and in standby-mode (there may be several standby modes, e.g. sleep-mode, no-load mode, etc.)
   - Power consumption in standby-mode (there may be several standby modes, e.g. sleep-mode, low-solar-input-mode, etc.)
   - Efficiency curve according to IEC 61683
   - Fuse required on the AC-side of the inverter: size and class
   - If applicable, recommended fuse on the DC-side of the inverter, size and class
   - Definition of the behaviour of the inverter during an overload situation and overload protection
   - Reverse-polarity protection on the DC-side
   - Warning before load disconnect, if relevant
   - Delayed load disconnection, if relevant
   - Displays (LED's, display, accuracy)
   - Additional functions (MPP tracking, etc.)
   - Total harmonic output distortion on a linear load at nominal conditions
   - Total harmonic output voltage distortion on non-linear loads at nominal conditions with a crest factor of 2,5 %
   - List of generic appliances, known to be incompatible with the inverter

All data shall be verified in the course of the following test sequences. Data, which are missing or do not conform to the indications of the manufacturer, shall be conscientiously recorded.

6 Testing

6.1 Service use

The test severities are based on the service use (to be indicated by the manufacturer) of the component. These are defined as follows.

a) Outdoor, unprotected

The component is fully exposed to direct rain, sun, wind, dust, fungus, ice, radiation to the cold night sky, etc.

b) Outdoor, protected

The component is partially covered to protect it from direct rain, sun, wind-blown dust, ice, fungus, and radiation to the cold night sky, etc.

c) Indoor, unconditioned

The component is fully covered by a building or enclosure to protect it from direct rain, sun, wind-blown dust, fungus, and radiation to the cold night sky, etc, but the building or enclosure is not conditioned in terms of temperature, humidity or air filtration.

d) Indoor, conditioned

The component is fully covered by a building or enclosure to fully protect it from rain, sun, wind-blown dust, fungus, and radiation to the cold night sky, etc, and the building or enclosure is generally conditioned in terms of temperature, humidity and air filtration.

The test conditions for these different services are summarized in Table 1.

6.2 Test sequence

The components shall be divided into three groups and subjected to the qualification test sequences in Table 1, carried out in the order laid down. Each box refers to the corresponding subclause in this standard. Test procedures and severities, including initial and final measurements where necessary, are detailed in Clause 11 and summarised in Table 1. Three groups of components shall first be subjected to basic environmental testing, after which a damp heat, cyclic test (see 11.15) shall be done. After each basic environmental test, a visual inspection (VI), a functioning test (FT) and an insulation test (IT) shall be done. All groups/pieces shall be subjected to their individual functioning test before and after each qualification test.

Table 1 contains a summary of test levels. For electronic equipment all tests apply. For batteries certain tests do not apply, a summary can also be found in Table 1.

NOTE 1 Where the final measurements for one test serve as the initial measurements for the next test in the sequence, they need not be repeated. In these cases, the initial measurements are omitted from the test.

NOTE 2 In the case where the component under test has already been subjected to a certain test in another qualification sequence by an accredited test lab, this test may be omitted if it does not have an influence on the whole testing sequence.

In carrying out the tests, the tester shall strictly observe the manufacturer's handling, mounting and connection instructions. The test report shall state the basis for any test omission.

Table 1 – Summary of test levels

Test	Title	Test conditions	Secondary batteries	Other electronic equipment
11.1	Visual inspection	See detailed inspection list in 11.1.2	Yes	Yes
11.2	Functioning test	Ambient temperature: 25 °C; 40 ± 20 % RH Specific component parameter	Yes	Yes
11.4	Insulation test	500/1 000 V DC + twice the open-circuit voltage of the system or 1 min. Insulation resistance of not less than 50 MΩ at 500 V DC.	No	Yes
11.5	Outdoor exposure test - outdoor, unprotected - outdoor, protected - indoor, unconditioned - indoor, conditioned	 60 kWh·m^{-2} total solar irradiation Not required Not required Not required	No	Yes
11.6	Protection against mechanical impact (IK) - outdoor, unprotected - outdoor, protected - indoor, unconditioned - indoor, conditioned	 IK05 IK05 IK05 IK05	Yes	Yes
11.7	Protection against dust, water and foreign bodies (IP-code) - outdoor, unprotected - outdoor, protected - indoor, unconditioned - indoor, conditioned	 IP44 IP44 IP20 IP20	Not relevant	Yes
11.8	Shipping vibration test	10 Hz to 11,8 Hz; 11,9 Hz to 150 Hz Amplitude: 3,5 mm, acceleration: 2 *g* 1 octave/min, Duration on each axis: 2 h; overall: 6 h	Yes	Yes
11.9	Shock test	15 *g*, half-sine, Duration: 11 ms; Sequence: 1 s Number of shocks: 18 (6 × 3)	Yes	Yes

Table 1 *(continued)*

Test	Title	Test conditions	Secondary batteries	Other electronic equipment
11.10	UV test		Not relevant	Yes
	- outdoor, unprotected	As in IEC 61345		
	- outdoor, protected	Not required		
	- indoor, unconditioned	Not required		
	- indoor, conditioned	Not required		
11.11	Thermal cycling test		Yes	Yes
	- outdoor unprotected	50 and 200 cycles from –20 °C to +85 °C		
	- outdoor, protected	50 and 200 cycles from –20 °C to +75 °C		
	- indoor, unconditioned	50 and 200 cycles from 0 °C to +55 °C		
	- indoor, conditioned	Not required		
11.12	Humidity freeze test		No	Yes
	- outdoor, unprotected	10 cycles from +85 °C, 85 % RH to –20 °C		
	- outdoor, protected	10 cycles from +75 °C, 85 % RH to –20 °C		
	- indoor, unconditioned	10 cycles from +55 °C, 85 % RH to 0 °C		
	- indoor, conditioned	Not required		
11.13	Damp heat test		No	Yes
	- outdoor, unprotected	1 000 h at +85 °C, 85 % RH		
	- outdoor, protected	1 000 h at +75 °C, 85 % RH		
	- indoor, unconditioned	1 000 h at +55 °C, 85 % RH		
	- indoor, conditioned	Not required		
11.14	Robustness of terminals test	As in IEC 60068-2-21	Yes	Yes
11.15	Damp heat cyclic test		No	Yes
	- outdoor, unprotected	3 cycles from +75 °C, 95 % RH to 25 °C		
	- outdoor, protected	3 cycles from +55 °C, 95 % RH to 25 °C		
	- indoor, unconditioned	3 cycles from +40 °C, 95 % RH to 25 °C		
	- indoor, conditioned	Not required		

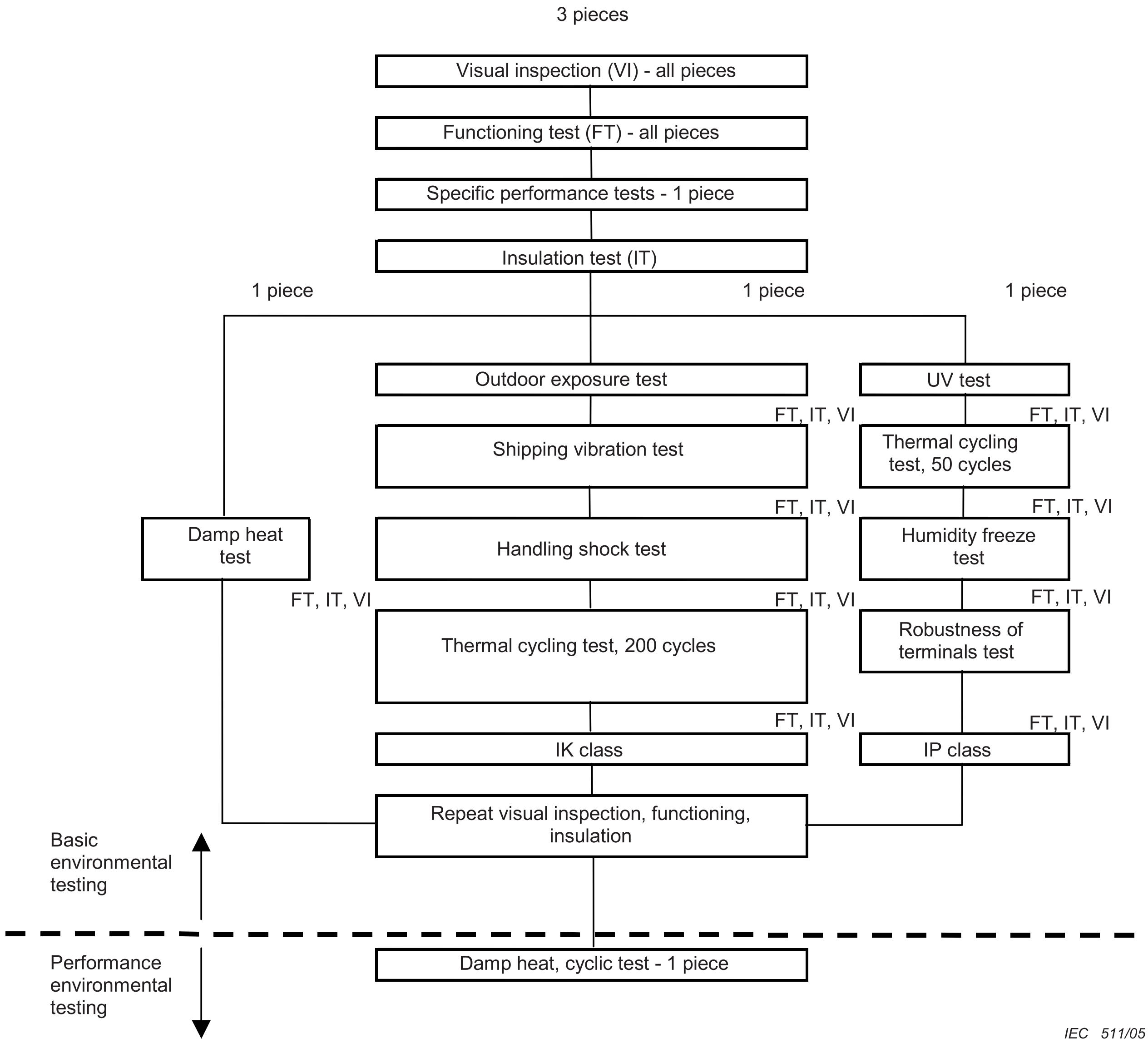

Figure 1 – Qualification test sequence

7 Pass criteria

7.1 General pass criteria

The component design shall be judged to have passed the design qualification tests if each test sample meets all the following criteria:

a) the component passes its specific performance tests;

b) after the final test of each test sequence, the component passes the functioning test;

c) no sample has exhibited any irreversible open-circuit or ground fault during the tests: allowed are such situations which are induced by the component itself for the sake of protecting itself or any other connected device or load (and can hence normally be reset);

d) there is no visual evidence of a major defect, as defined in Clause 8;

e) the component passes the insulation test.

If any component does not meet these test criteria, nor the specific criteria for the component, the design shall be deemed not to have met the qualification requirements, and another two components meeting the requirements of Clause 3 shall be subjected to the whole of the relevant test sequence from the beginning. If one or both of these also fail, the design shall be deemed not to have met the qualification requirements. If, however, both components pass the test sequence, the design shall be judged to have met the qualification requirements.

7.2 Specific requirements for charge controllers

7.2.1 Switching thresholds/operation algorithm

Many charge controllers use the battery voltage as the main parameter for the switching algorithm. However, some charge controllers use other parameters, for example state of charge. Annex A contains some recommended switching voltages for lead-acid batteries.

The manufacturer shall clearly specify to the test lab the operating algorithm of the charge controller. If the battery voltage is used as the main parameter for the switching algorithm, the manufacturer shall specify these thresholds.

7.2.2 Output voltage of a charge controller after battery disconnection

The charge controller shall protect the load from the open-circuit voltage of the PV-array, in case the battery has been disconnected from the system. This is an important feature of good charge controllers, since many loads can be destroyed when they are exposed to the open-circuit voltage of the PV-array.

The manufacturer shall supply a definition of the output behaviour in the case of no battery connection.

7.2.3 User feedback

The charge controller shall provide at least:

– an indication of charging state;
– an indication of load-disconnect state;
– an indication of the state-of-charge of the connected battery.

Certain special purpose charge controllers, for example dedicated controllers for industry applications do not have a user feedback. The manufacturer shall state this.

7.3 Specific requirements for secondary batteries

Lead-acid and nickel-cadmium batteries can only be qualified according to this standard for the conditions ‘indoor conditioned’ and ‘indoor unconditioned’. This implies that many tests are not relevant. Table 1 contains an overview of the tests that apply to the design qualification for secondary batteries.

7.3.1 Charge retention of secondary batteries at high temperatures

7.3.1.1 Purpose

The purpose of this test is to determine the charge retention of batteries during storage at higher temperatures.

7.3.1.2 Procedure

- Condition the battery
- Do an initial capacity test, determine $C_{10,\ before}$
- Keep the battery at 40 °C for 30 days
- Do a new capacity test, determine $C_{10,\ after}$
- Calculate the loss in charge: $C_{loss} = C_{10,\ after} – C_{10,\ before}$

7.3.1.3 Requirements

The loss in charge shall not be more than 15 % for lead-acid batteries and not more than 30 % for nickel-cadmium batteries.

7.3.2 Cycling ability

7.3.2.1 Purpose

The purpose of this test is to determine the capability of the battery to withstand the typical cycling conditions occurring in PV systems.

7.3.2.2 Procedure

According to IEC 61427.

7.3.2.3 Requirements

The test method described in IEC 61427 shall be performed once. The loss compared to the rated capacity (C_{10}) shall be less than 20 %.

7.3.3 Ah-cycling efficiency of secondary batteries

7.3.3.1 Purpose

The purpose of this test is to determine the Ah-cycling efficiency of secondary batteries at low state of charge.

The efficiency of a battery at low state of charge shall be sufficient to enable all energy provided by the PV modules to be converted into usable energy stored in the battery.

7.3.3.2 Procedure

The Ah-cycling efficiency can be expressed as:

$$\text{Ah - cycling efficiency (Ah efficiency)} = \frac{\text{Discharge capacity (Ah)}}{\text{Recharge capacity (Ah)}}$$

The test shall be carried out at 20 °C ± 3 °C.

The test procedure is as follows:

Initial cycle :

- charge at 0,1 C_{10} until 100 % of SOC (state of charge),
- discharge at 0,1 C_{10} (= initial capacity), until 1,8 V per cell (= 100 % of SOC)

Cycling:

- charge at 0,1 C_{10} until 50 % of the initial C_{10} capacity value,
- discharge at 0,1 C_{10} (initial capacity) until 1,8 V per cell.

This cycle is performed four times.

The efficiency test procedure is presented in Figure 2.

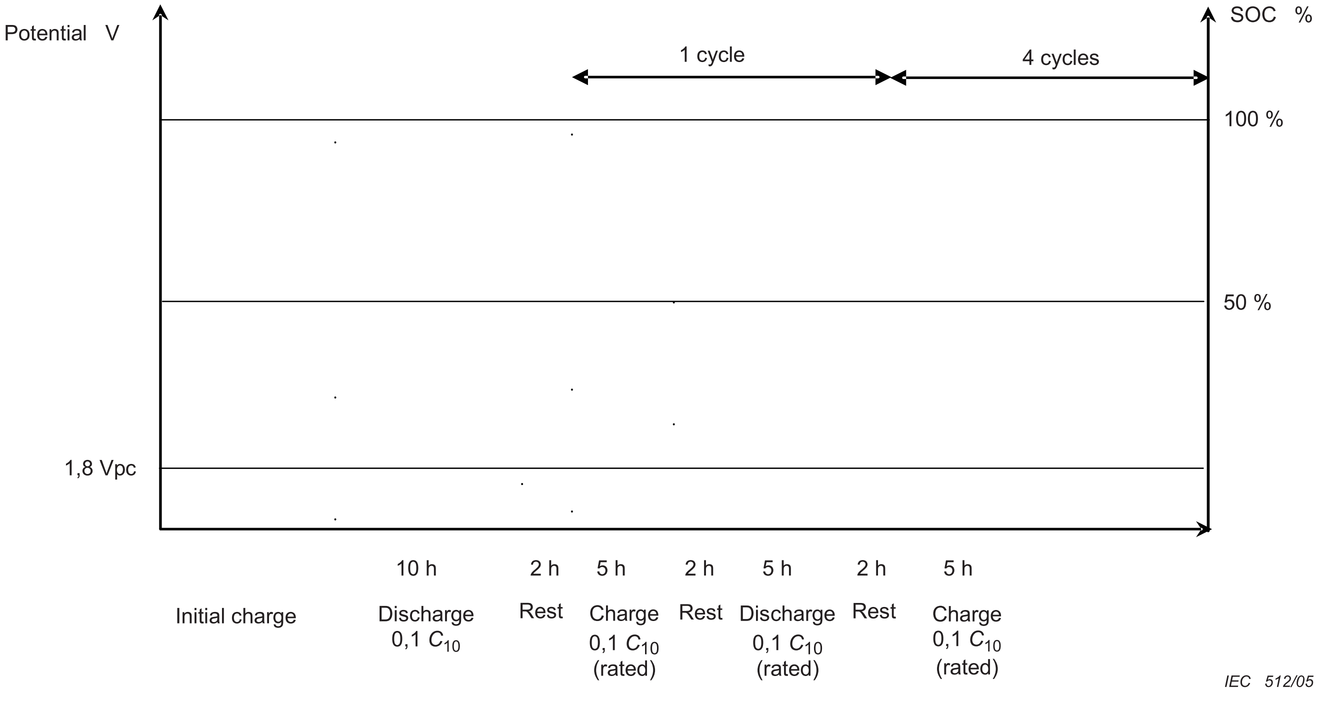

Figure 2 – Cycling conditions of the efficiency test procedure

To calculate the Ah-cycling efficiency value the values of the 4thcycle and the 5th cycle are averaged.

(This range has been selected because the corresponding efficiency values are mostly stable.)

7.3.3.3 Requirements

For flat-plate lead-acid batteries, the Ah-cycling efficiency (at 20 °C) shall be at least 94 %.

For tubular plate lead-acid batteries, the Ah-cycling efficiency (at 20 °C) shall be at least 92 %.

For nickel-cadmium batteries, the Ah-cycling efficiency (at 20 °C) shall be at least 90 %.

8 Major visual defects

For the purposes of design qualification, the following are considered to be major visual defects:

a) broken, cracked, bent, misaligned or torn external surfaces;

b) corrosion of any part of the component, inside or outside;

c) dust, water or fungus intrusion into the electrically active interior of the component;

d) loss of mechanical integrity, to the extent that the installation and/or operation of the component would be impaired.

9 Report

Following design qualification, a report of the qualification tests, with measured performance characteristics and details of any failures, re-tests or omissions shall be prepared by the test laboratory. The report shall meet the requirements laid down in ISO/IEC 17025. A copy of this report shall be kept by the manufacturer for reference purposes.

10 Modifications

Any change in the design, materials, components or processing of the component may require a repetition of some or all of the qualification tests.

11 Test procedures

11.1 Visual inspection

11.1.1 Purpose

The purpose of this test is to detect any visual defects in the component.

11.1.2 Procedure

Carefully inspect each component for the following conditions:

– broken, cracked, bent, misaligned or torn external surfaces;

– faulty interconnections or joints;

– visible corrosion of any part of the active circuit;

– visible corrosion of output connections, interconnections and bus bars;
– visible corrosion of the enclosure surface;
– cracked or damaged wire or cable;
– faulty terminals, exposed energised electrical parts;
– any other conditions which may affect functioning, performance or safety.

Make note of and/or photograph the nature and position of any defects which may worsen and adversely affect the component functioning in subsequent tests.

11.1.3 Requirements

Visual conditions other than the major visual defects listed in Clause 8 are acceptable for the purpose of design qualification.

11.2 Functioning tests

11.2.1 Functioning test procedure – charge controllers for lead-acid batteries

11.2.1.1 Overview

This procedure comprises charge controllers for lead-acid accumulators with liquid electrolyte (vented and valve regulated).

The tests described in this procedure are valid for charge controllers, which use the accumulator terminal voltage as a criterion for operation as well as modern control procedures (e.g. state of charge algorithms). In the case where all or some of these tests are not relevant for a specific type of charge controller, the manufacturer shall state this.

The following symbols are used in this document:

I_{chmax}: maximum charge current permissible
I_{lmax}: maximum load current permissible
$U_{Nominal}$: nominal voltage of the charge controller
U_{bat}: battery voltage
U_{max}: maximum system voltage ≥ highest battery voltage permitted by charge controller (for example, gassing voltage)
U_{min}: minimum system voltage ≥ U_{lcd}
U_{hcd}: voltage at high charge disconnect
U_{hcr}: voltage at high charge reconnect
U_{lcd}: voltage at low charge disconnect
U_{lcr}: voltage at low charge reconnect
U_{oc}: open-circuit voltage of the photovoltaic solar module(s)

11.2.1.2 Determination of thresholds

11.2.1.2.1 Purpose

The purpose of this test is to determine all switching thresholds of the charge controller.

11.2.1.2.2 Apparatus

A resistor (R_x) with a magnitude U_{min}/(I_{chmax} × 1,1) and an allowed power consumption of at least U_{max} × I_{chmax} × 1,1. This resistor is intended to keep the current from being fed into the power supply. In the worst case (maximum module current when load is switched off), the power supply will still supply a current of 0,1 × I_{chmax}. If a four-quadrant power supply is utilised, this resistor is not necessary.

A current/voltage source that can supply at least I_{chmax} at open-circuit voltage (U_{oc}) of the PV-generator connected (power supply 1). Current and voltage shall be capable of being set separately from each other and have limitations.

Another current/voltage source which can supply at least a current with a magnitude (U_{max}/R_x) + I_{lmax} at maximum system voltage (power supply 2). Current and voltage shall be capable of being set separately from each other and have limitations. If a four-quadrant power supply is utilised, a maximum possible current of I_{lmax} is sufficient at maximum system voltage. In this case, the resistor described above (R_x) is no longer necessary.

A variable resistor (R_L) with a power consumption of at least U_{max} × I_{lmax} or a corresponding electronic load.

An oscilloscope for visualising the pulse width modulation when end-of-charge voltages are reached.

Various ammeters and voltmeters.

11.2.1.2.3 Procedure

The system components shall be inspected for visible damage.

Any peculiarities observed shall be conscientiously documented, if necessary by means of photography.

The charge controller is mounted according to the manufacturer's instructions and hooked up as shown in Figure 3. If there are any voltage sensor lines on the charge controller, they shall be connected to power supply 2. Between power supply 1 and the charge controller a minimum of 10 m of the prescribed cable shall be installed to simulate a real system. Between power supply 2 and the charge controller a minimum of 2 m of the prescribed cable shall be installed.

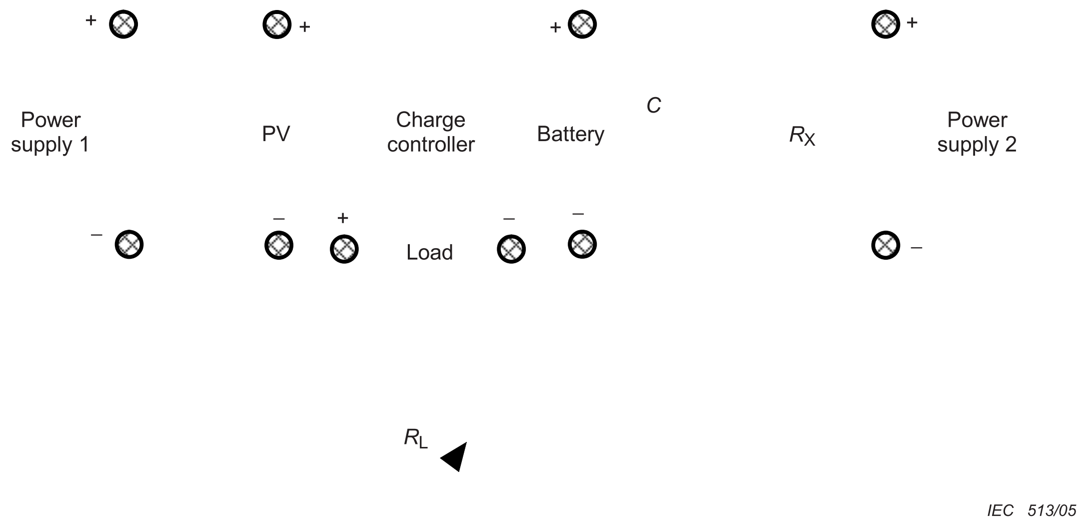

Figure 3 – Diagram of the test set-up without measuring equipment

NOTE 1 Depending on the charge controller under test, a capacitor of at least 50 µF must be connected parallel to the output terminals of the power supply 2.

NOTE 2 It is strongly advised to discuss the actual test set-up with the manufacturer. This test set-up is suitable for many charge controllers on the market. However, depending on certain factors, including power supply type, certain charge controllers will need a modified set-up or specific preparation.

The following examinations are performed at an ambient temperature of approximately 20 °C, as long as nothing else is indicated for the appropriate tests.

11.2.1.2.3.1 Determination of the end-of-charge voltages

1) Set a system voltage of 1,1 × U_{Nominal} at power supply 2.
2) Set R_L so that a load current of 0,5 × I_{lmax} is set.
3) Set a module current of I_{chmax} at power supply 1 (charging conditions). Set the voltage limitation to the open-circuit voltage of the PV generator to be connected.

   NOTE In the case of a shunt controller, be careful not to damage the power supply or the charge controller due to excessive current.
4) Increase the voltage at power supply 2 in steps of 0,2 V. Wait approximately 30 s between the separate steps and observe the system.
5) Repeat step 4 until the following becomes the case, depending on the type of controller:

   Serial controller

   with two-point control: open-circuit at power supply 1, voltage limitation active

   with PWM: start of voltage pulses (change between system voltage and voltage limitation at power supply 1) at PV input of charge controller (oscilloscope).

Parallel controller

with two-point control: short circuit at power supply 1, current limitation active

with PWM: start of voltage pulses (change between system voltage and 0 V) at PV input of charge controller (oscilloscope).

6) Note down voltage setting at power supply 2.

7) If controller has PWM: repeat step 4, but in steps of 50 mV, until the voltage at PV input stays constant at zero (shunt controller) or is limited by the power supply (serial controller). Note down voltage setting at power supply 2.

11.2.1.2.3.2 Determining the charge equalising voltage (if present)

8) Set a module current of 0,2 × I_{chmax} at power supply 1 (discharge conditions).

9) Reduce the voltage at power supply 2 in steps of 0,2 V. Wait approximately 30 s between steps and observe the system.

NOTE This dwell time may be too short for certain types of charge controllers. Please refer to the manufacturers indication.

10) Repeat step 9 until the voltage is below that indicated by the manufacturer as being necessary to activate the gassing function.

11) Repeat steps 3 to 7. If there are several gassing voltages with the appropriate triggering levels, repeat steps 3 to 11 accordingly.

11.2.1.2.3.3 Determination of low charge disconnect and reconnect voltages

12) Repeat step 8. Repeat step 9 until load rejection alarm of controller (if present) is triggered. Note down voltage setting.

13) Repeat step 9 until load rejection. Note down voltage setting.

14) Repeat step 3. Repeat step 4 until load reconnection. Note down voltage setting.

15) Set voltage at power supply 2 to 1,1 × $U_{Nominal}$.

16) Repeat steps 12 to 15 with set load currents of 0 %, 25 %, 75 % and 100 % of I_{lmax}.

NOTE This test can give erroneous results in the case of certain advanced controllers, using current dependent thresholds or thresholds depending on SOC.

11.2.1.3 Requirements

The switching thresholds shall be constant (i.e. within 2 %) before and after each test.

11.2.2 Functioning test procedure – batteries

11.2.2.1 Procedure

– Condition the battery by performing an initial charging procedure as per the manufacturers instruction. This will usually be at I_{10} .
– Determine the C_{10} battery capacity by discharging at I_{10}.
– To conserve the battery, recharge the battery at I_{10} until 1,2 times the rated C_{10} capacity has been charged into the battery.

11.2.2.2 Requirements

The initial measured capacity shall be at least 95 % of the nominal capacity.

The loss of charge before and after each environmental test shall be less than 20 %, referring to the initial measured capacity.

11.2.3 Functioning test procedure – inverters

11.2.3.1 Procedure

Operate the inverter under nominal array configuration and nominal output conditions. After 30 min of operation at rated output power, measure the power efficiency according to IEC 61683, power factor and maximum power point tracking (MPPT) efficiency for the power levels: 10 %, 25 %, 50 %, 75 %, 100 % and 120 % of the rated output power specified by the manufacturer. If the inverter cannot operate at 120 % of the rated output power, the maximum power level possible shall be used.

NOTE Standalone inverters do not incorporate MPPT.

11.2.3.2 Requirements

The overall behaviour of power efficiency, power factor and MPPT efficiency shall not differ from the initial behaviour at start of the design qualification.

11.3 Specific performance tests for components

The purpose of these tests is to determine other relevant component specific features relevant for the performance of the component.

Generally, (unless stated otherwise) these tests only need to be carried out once, whereby the general functioning test described in 11.2 will be repeated after every environmental test.

11.3.1 Specific performance test procedures –charge controllers for lead-acid batteries

11.3.1.1 Temperature compensation for thresholds

11.3.1.1.1 Purpose

The purpose of this test is to

– determine any unwanted shifts of the voltage thresholds due to temperature variations,
– to verify temperature compensation caused by the battery temperature.

11.3.1.1.2 Apparatus

See 11.2.1.2.2.

Additionally, a climatic chamber capable of maintaining temperature levels from –10 °C up to 55 °C.

Every climatic test chamber, which is capable of fulfilling the specifications of IEC 60068-3-6 will be suitable.

11.3.1.1.3 Requirements

The thresholds for the load disconnect shall be stable across the entire range of temperatures.

In contrast to the thresholds of the load disconnection, those of the overcharge protection and gassing functions require a temperature compensation in order to adapt the charging behaviour of the battery to the surrounding temperature.

The thresholds of the deep-discharge protection shall remain stable within ±20 mV/cell and the thresholds of the overload protection shall exhibit a temperature coefficient of –3 mV/K/cell to –5 mV/K/cell.

11.3.1.1.4 Procedure

The voltage thresholds are ascertained under the following temperatures in line with 11.2.1.2.

Test temperatures: 25 °C, –10 °C, 25 °C, 40 °C, 55 °C, 25 °C

The charge controller and temperature-sensor shall be kept at each temperature for at least 15 min.

If the charge controller has an external temperature sensor, only this sensor is exposed to the above temperatures, while the charge controller itself runs under ambient conditions. If the charge controller has no external temperature sensor, the entire charge controller is exposed to the above testing temperatures.

11.3.1.2 Voltage drop test

11.3.1.2.1 Purpose

The purpose of this test is to determine the voltage drop between the input terminals of the charge controller.

11.3.1.2.2 Requirements

The voltage drop at the terminals of the charge controller between battery- and load-terminals (discharging) and between PV-generator- and battery-terminals (charging) may each only amount to a maximum of 0,5 V (12 V systems) or 1 V (24 V systems) at maximum load or maximum charging current.

The voltage drop on the battery-lines can lead to false control-values. Hence, the charge controller shall be equipped with (at least) one of the following precautions:

– battery-sense-lines;
– electronic determination and compensation of the voltage drop;
– mounting recommendations of the manufacturer (wire cross-section, wire length).

11.3.1.2.3 Procedure

Measure the voltage drop at maximum load or maximum charging current at the terminals of the charge controller between battery- and load-terminals (discharging) and between PV-generator- and battery-terminals (charging).

11.3.1.3 Reverse-polarity protection test

11.3.1.3.1 Purpose

To determine whether the charge controller functions safely when current sources with incorrect polarity are connected.

11.3.1.3.2 Procedure

A source of voltage with reverse polarity is connected to the module input terminals and the voltage increased slowly from 0 V to the maximum permissible open-circuit voltage of the solar generator. During this test, a voltage source with correct polarity is connected to the battery terminals of the charge controller.

Then, a battery with a capacity for which the controller is rated is connected to the battery input terminals with reverse polarity. During this test, a voltage source with correct polarity is connected to the module input terminals of the charge controller.

Lastly, a source of voltage with reverse polarity is connected to the module input terminals and the voltage slowly increased from 0 V to the maximum permissible open-circuit voltage of the solar generator. During this test, a battery with a capacity the controller is rated for with reverse polarity is connected to the battery terminals of the charge controller.

11.3.1.4 Overload protection test

11.3.1.4.1 Purpose

To determine whether the overload protection of the charge controller functions properly.

11.3.1.4.2 Requirements

The overload protection shall be able to withstand at least 125 % of the maximum load for which the charge controller is designed. Overload protection can be realised with a normal fuse or with an electronic protection circuit.

11.3.1.4.3 Procedure

At nominal voltage, the load of the current is increased step by step to 125 % or until the protections is activated. If the charge controller has a separate radio outlet, then this shall also be checked for protection from overload.

11.4 Insulation test

11.4.1 Purpose

To determine whether or not the component is sufficiently well-insulated between current-carrying parts and the enclosure.

This test is not required for batteries. Please consider that certain components may contain sensitive protective equipment that will be destroyed when subjected to these tests. Refer to the manufacturer in case of doubt.

11.4.2 Test conditions

The test shall be made on components at ambient temperature of the surrounding atmosphere (see IEC 60068-1) and in a relative humidity not exceeding 75 %.

11.4.3 Procedure

The procedure is as follows.

a) Connect the shorted output terminals of the component to the positive terminal of a DC insulation tester with a current limitation (do not run this test on batteries). Set the current limit to 50 μA.

b) Connect the exposed metal parts of the component to the negative terminal of the tester. If the component has no conductive enclosure, or if the enclosure is a poor electrical conductor, mount the component on a metallic simulated support structure, which is to be connected to the negative terminal of the tester.

c) Increase the voltage applied by the tester at a rate not exceeding 500 $V \cdot s^{-1}$ to a maximum equal to 1 000 V plus twice the maximum system voltage. Maintain the voltage at this level for 1 min. If the maximum system voltage does not exceed 50 V, the applied voltage shall be 500 V.

d) Reduce the applied voltage to zero and short-circuit the terminals of the tester for 5 min, while still connected to the component.

e) Remove the short circuit.

f) Apply a DC voltage of not less than 500 V to the component, with the tester connected as in steps a) and b). Determine the insulation resistance.

11.4.4 Test requirements

The requirements are as follows.

– No dielectric breakdown (less than 50 μA) or surface cracking during step c) shall occur.
– The insulation resistance shall be not less than 50 MΩ.

11.5 Outdoor exposure test

11.5.1 Purpose

To make a preliminary assessment of the ability of the component to withstand exposure to outdoor conditions and to reveal any synergistic degradation effects which may not be detected by laboratory tests.

NOTE Caution should be taken in making absolute judgements about component life on the basis of passing this test because of the shortness of the test and the environmental variability of the test conditions. This test should only be used as a guide or indicator of possible problems.

11.5.2 Apparatus

The apparatus is as follows.

– A solar irradiation monitor, accurate to ±10 %.
– Means to mount the component, as recommended by the manufacturer, co-planar with the irradiation monitor.

11.5.3 Procedure

The procedure is as follows.

a) Open-circuit the component and mount it outdoors, as recommended by the manufacturer, co-planar with the irradiation monitor. Any protective devices recommended by the manufacturer shall be installed before the component is tested.

b) Subject the component to an irradiation totalling 60 $kWh \cdot m^{-2}$, as measured by the monitor, under conditions conforming to general open-air climates defined in IEC 60721-2-1.

11.5.4 Final measurements

Repeat the tests of 11.1 and 11.2.

11.5.5 Requirements

The requirements are as follows.

– No evidence of major visual defects, as defined in Clause 8.
– The functioning requirements of 11.2 shall be met.

11.6 Protection against mechanical impacts (IK-code)

11.6.1 Purpose

The degree of protection (IK-code) defines the extent to which an enclosure provides protection against external mechanical impact.

11.6.2 Requirements

The tests are conducted in conformance with IEC 62262 using the pendulum hammer described in standard IEC 60068-2-75 (test Eha). The equipment is preconditioned for 1 h at –10 °C in a chamber; the test is performed within 1 min of its removal in normal laboratory atmospheric conditions. The methods of this test are described in Annex D of IEC 62262. The equipment is set up according to preparation method 1.

The required IK class for all service environments is IK05.

The enclosure shall show no cracks or distortions, which could be detrimental to its operation.

11.7 Protection against dust, water and foreign bodies (IP-code)

11.7.1 Purpose

The degree of protection (IP-code) defines the extent to which a case provides protection against access to dangerous parts, the penetration of solid foreign bodies and/or the entry of water and dust, as proved by standard testing methods.

11.7.2 Requirements

The required IP-code depends on the conditions under which the component is utilised. If it is operated in solidly built indoor spaces, IP20 in conformance with IEC 60529 is adequate, otherwise IP44 is required.

The tests are conducted in conformance with IEC 60529.

In the case where enclosures are used, which have already a certified IP-rating meeting the requirements of this clause, this test does not need to be done again.

Environment	Minimum IP-class
Outdoor, unprotected	IP44
Outdoor, protected	IP44
Indoor, unconditioned	IP20
Indoor, conditioned	IP20

11.8 Shipping vibration test

11.8.1 Purpose

The purpose of this test is to identify mechanical weak points and/or to ascertain any deterioration of the specified parameters. According to IEC 60068-2-6, it shall be conducted on structural elements or devices, which are exposed to harmonic vibrations during shipment, such as occur on ships, in aircraft and land vehicles.

11.8.2 Requirements

Degree of stringency:

Frequency range:	10 Hz to 11,8 Hz; 11,9 Hz to 150 Hz
Constant amplitude:	3,5 mm
Constant acceleration:	2 *g*
Cycling:	1 octave/min
Duration on each axis:	2 h
Total test duration:	6 h

11.8.3 Apparatus

See IEC 60068-2-6.

11.8.4 Procedure

See IEC 60068-2-6.

The specimens are neither packaged nor energised during the test.

11.9 Shock test

11.9.1 Purpose

In conjunction with the previous test, the purpose of this test is to discover mechanical weak points and/or to determine whether the specified parameters are maintained or deteriorate. The tests are conducted in conformance with IEC 60068-2-27.

11.9.2 Requirements

Degree of stringency:

Amplitude of acceleration:	15 *g*
Type of shock:	half-sine
Duration of shock:	11 ms
Sequence of shocks:	1 s
Number of shocks:	18 (6 × 3)

11.9.3 Apparatus

See IEC 60068-2-27.

11.9.4 Procedure

See IEC 60068-2-27.

The specimens are not packaged or live during the test.

11.10 UV test

11.10.1 Purpose

The purpose of this test is to determine the ability of the component to withstand exposure to ultra-violet (UV) radiation.

11.10.2 Apparatus

The apparatus consists of the items listed below.

a) A temperature controlled test chamber or other arrangement with a window or fixtures for a UV light source and the component under test. The chamber shall be capable of maintaining the component temperature at 60 °C ± 5 °C and a dry condition.

b) A UV light source capable of producing UV radiation with an irradiance uniformity of ±15 % over the test plane of the component and capable of providing the necessary total irradiance in the different spectral regions of interest as defined in item c) of 11.10.3. The final test report shall indicate which UV light source is used.

c) Means for measuring and recording the temperature of the component to an accuracy of ±2 °C. The temperature sensors shall be attached to the front or back surface of the component near the middle. If more than one component is tested simultaneously, it will suffice to monitor the temperature of one representative sample.

d) A calibrated radiometer capable of measuring the irradiance of the UV light produced by the UV light source at the test plane of the component(s).

See IEC 61345 for suggested UV light sources.

11.10.3 Procedure

The test shall be carried out according to the procedure outlined below.

a) Use the calibrated radiometer to measure the irradiance at the proposed component test plane and ensure that, at wavelengths between 280 nm and 400 nm, the test spectral irradiance is never more than 5 times the corresponding standard spectral irradiance specified in the standard AM 1,5 solar irradiance distribution given by Table 1 of IEC 60904-3, that there is no appreciable irradiance at wavelengths below 280 nm and that it has a uniformity of ±15 % over the test plane.

b) Mount the component in the test plane at the location selected in a) with the most critical side (for example, the side with the most wire or cable penetrations) normal to the UV irradiance beam.

c) While maintaining the component temperature within the prescribed range, subject the component to a minimum irradiance of

   – 7,5 kWh·m^{-2} in the wavelength range between 280 nm and 320 nm, and

   – 15 kWh·m^{-2} in the wavelength range between 320 nm and 400 nm.

d) Reorient the component so that the backside is normal to the UV irradiance beam.

e) Repeat step c) for 10 % of the time at the irradiation levels that were performed on the front side.

11.10.4 Final measurements

Repeat the tests of 11.1 and 11.2.

11.10.5 Requirements

The requirements are as follows.

– There shall be no evidence of major visual defects, as defined in Clause 8.

– The functioning requirements of 11.2 shall be met.

11.11 Thermal cycling test

11.11.1 Purpose

The purpose of this test is to determine the ability of the component to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature. The temperature limits for this cycling test are based on the service use of this component: outdoor unprotected, outdoor protected, indoor unconditioned and indoor conditioned.

11.11.2 Apparatus

The apparatus is as follows.

a) A climatic chamber with automatic temperature control, means for circulating the air inside and means to avoid condensation on the component during the test, capable of subjecting one or more components to the thermal cycle in Figure 4. Every climatic chamber which is capable of fulfilling the specifications of IEC 60068-3-6 will be suitable.

b) Means for mounting or supporting the component in the chamber, so as to allow free circulation of the surrounding air.

c) Means for measuring and recording the temperature of the component to an accuracy of ±2 °C. The temperature sensors shall be attached to the front or back surface of the component near the middle. If more than one component is tested simultaneously, it will suffice to monitor the temperature of one representative sample.

d) Means for monitoring, throughout the test, the continuity of the internal circuit of each component.

e) Instrumentation for monitoring in each component, the integrity of the insulation between one of the terminals and the component frame or supporting structure.

11.11.3 Temperatures versus service conditions

The required high and low limits for temperature cycling are provided in Table 2.

Table 2 – Temperature limits for thermal cycling test

Service condition	High temperature	Low temperature	Cycles
Outdoor, unprotected	85 °C	–20 °C	50+200
Outdoor, protected	75 °C	–20 °C	50+200
Indoor, unconditioned	55 °C	0 °C	50+200
Indoor, conditioned			Not required
NOTE The number of cycles is in accordance with Figure 1.			

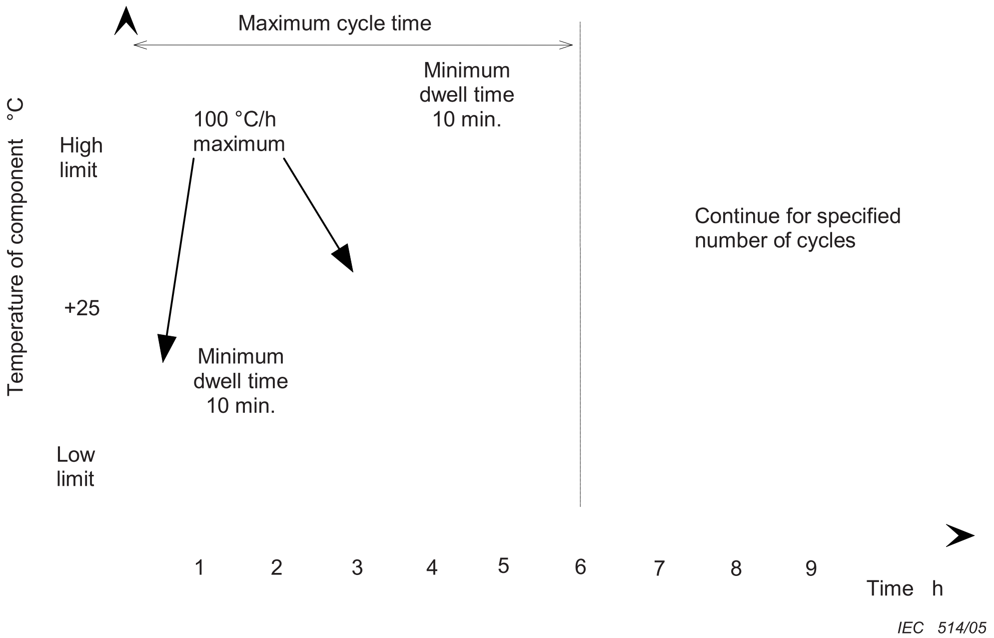

Figure 4 – Thermal cycling test

11.11.4 Procedure

The procedure is as follows.

a) Install the component at room temperature in the chamber. If the component enclosure is a poor electrical conductor, mount the component on a metal frame.

b) Connect the temperature monitoring equipment to the temperature sensor(s). Connect the continuity instrumentation across the component terminals. Connect the insulation monitor between one terminal and the frame or supporting structure.

c) Close the chamber and, with the air around the component(s) circulating at a velocity of not less than $2\ m\cdot s^{-1}$, subject the component to cycling between the component temperature limits specified in Table 2 in accordance with the profile in Figure 4. The rate of change of temperature between the low and high extremes shall not exceed 100 °C/h and the component temperature shall remain stable at each extreme for a period of at least 10 min. The cycle time shall not exceed 6 h. The number of cycles shall be as shown in the relevant blocks in Figure 1.

d) Throughout the test, record the component temperature and monitor the component(s) to detect any open-circuit or ground faults that may occur during the exposure.

11.11.5 Final measurements

After a minimum recovery time of 1 h, repeat tests 11.1 and 11.2.

11.11.6 Requirements

The requirements are as follows.

– There shall be no intermittent open-circuit or ground faults detected during the test.
– There shall be no evidence of major visual defects, as defined in Clause 8.
– The functioning requirements of 11.2 shall be met.

11.12 Humidity-freeze test

11.12.1 Purpose

The purpose of this test is to determine the ability of the component to withstand the effects of high temperature and humidity followed by a cold temperature. This is not a thermal shock test.

11.12.2 Temperatures versus service conditions

The required high and low temperature limits for this test are provided in Table 3.

Table 3 – Temperature limits for humidity-freeze test

Service condition	High temperature	Low temperature
Outdoor, unprotected	85 °C	–20 °C
Outdoor, protected	75 °C	–20 °C
Indoor, unconditioned	55 °C	0 °C
Indoor, conditioned	Not required	Not required

Before conducting the test, the component shall be subjected to the thermal cycling test as shown in Figure 4.

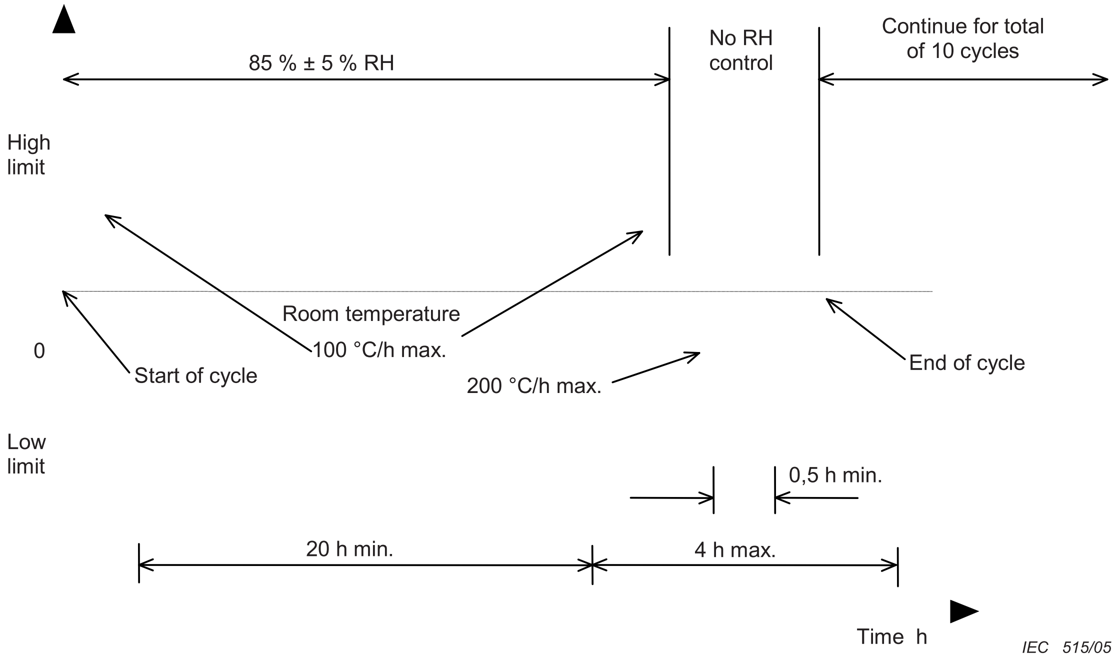

Figure 5 – Humidity-freeze test

11.12.3 Apparatus

The apparatus is as follows.

a) A climatic chamber with automatic temperature and humidity control, capable of subjecting one or more components to the humidity-freeze cycle specified in Figure 5. Every climatic test chamber, which is capable of fulfilling the specifications of IEC 60068-3-6 will be suitable. At sub-zero temperatures, the dew-point of the chamber air shall be the chamber temperature.

b) Means for measuring and recording the component temperature to an accuracy of ±2 °C. It is sufficient to monitor the temperature of one representative sample if more than one component is tested simultaneously.

c) Means for monitoring, throughout the test, the continuity of the internal circuit of each component.

d) Instrumentation for monitoring in each component the integrity of the insulation between one of the terminals and the enclosure or supporting frame structure.

11.12.4 Procedure

The procedure is as follows.

a) Attach a suitable temperature sensor to the front or back surface of the component near the middle.

b) Install the component at room temperature in the climatic chamber at an angle of not less than 5° to the horizontal. If the component enclosure is a poor electrical conductor, mount the component on a metal frame.

c) Connect the temperature monitoring equipment to the temperature sensor(s). Connect the continuity instrumentation across the component terminals. Connect the insulation monitor between one terminal and the frame or component enclosure.

d) After closing the chamber, subject the component to ten complete cycles in accordance with Figure 5. The maximum and minimum temperatures shall be within ±5 °C of the specified levels and the relative humidity shall be maintained within ±5 % of the specified value at all temperatures above room temperature.

e) Throughout the test, record the component temperature and monitor the component to detect any open-circuit or ground faults that may occur during the exposure.

11.12.5 Final measurements

After a recovery time of between 2 h and 4 h, repeat tests 11.1 and 11.2.

11.12.6 Requirements

The requirements are as follows.

– There shall be no intermittent open-circuit or ground faults detected during the test.
– There shall be no evidence of major visual defects, as defined in Clause 8;
– The functioning requirements of 11.2 shall be met.

11.13 Damp heat test

11.13.1 Purpose

The purpose of this test is to determine the ability of the component to withstand the effects of long-term penetration of humidity.

11.13.2 Procedure

The test shall be carried out in accordance with IEC 60068-2-78 with the following provisions.

a) Preconditioning

The component, being at room temperature, shall be introduced into the test chamber.

b) Severities

The humidity level shall be 85 % ± 5 %, the test duration 1 000 h, and the component temperature within ±2 °C of the specified level in accordance with Table 4.

Table 4 – Temperature limits for damp heat test

Service condition	Temperature
Outdoor, unprotected	85 °C
Outdoor, protected	75 °C
Indoor, unconditioned	55 °C
Indoor, conditioned	Not required

c) Recovery

The component shall be submitted to a recovery time of between 2 h and 4 h.

11.13.3 Final measurements

At the end of the recovery time, repeat tests 11.1 and 11.2.

11.13.4 Requirements

The requirements are as follows.

– There shall be no evidence of major visual defects, as defined in Clause 8.
– The functioning requirements of 11.2 shall be met.

11.14 Robustness of terminals test

11.14.1 Purpose

The purpose of this test is to determine that the terminals and the attachment of the terminals to the component will withstand such stresses as are likely to be applied during normal assembly or handling operations.

11.14.2 Types of terminals

Three types of component terminals are considered:

– type A: wire or flying lead;
– type B: tags, threaded studs, screws, etc.;
– type C: connector.

11.14.3 Procedure

Preconditioning: 1 h at standard atmospheric conditions for measurement and test.

11.14.3.1 Type A terminals

Tensile test: as described in IEC 60068-2-21, test Ua, with the following provisions:

– all terminals shall be tested;
– tensile force shall never exceed the component weight.

Bending test: as described in IEC 60068-2-21, test Ub, with the following provisions:

– all terminals shall be tested;
– perform 10 cycles (one cycle is one bend in each opposite direction).

11.14.3.2 Type B terminals

Tensile and bending tests:

a) for components with exposed terminals, each terminal shall be tested as for type A terminals;
b) if the terminals are enclosed in a protective box, the following procedure shall be applied:

a cable of the size and type recommended by the component manufacturer, cut to a suitable length, shall be connected to the terminals inside the box using the manufacturer's recommended procedures. The cable shall be taken through the hole of the cable gland, taking care to utilize any cable clamp arrangement provided. The lid of the box shall be securely replaced. The component shall then be tested as for type A terminals.

Torque test: as described in IEC 60068-2-21, test Ud, with the following provisions:

– all terminals shall be tested;
– severity 1.

The nuts or screws shall be capable of being loosened afterwards unless they are specifically designed for permanent attachment.

11.14.3.3 Type C terminals

A cable of the size and type recommended by the component manufacturer, cut to a suitable length, shall be connected to the output end of the connector, and the tests for type A terminals shall be carried out.

11.14.4 Final measurements

Repeat tests 11.1 and 11.2.

11.14.5 Requirements

The requirements are as follows.

– There shall be no evidence of mechanical damage.
– The functioning requirements of 11.2 shall be met.

11.15 Damp heat, cyclic test

11.15.1 Purpose

The purpose of this test is to determine the suitability of components, equipment or other articles for use and storage under conditions of high humidity when combined with cyclic temperature changes and, in general, producing condensation on the surface of the specimen.

11.15.2 Procedure

The test shall be carried out in accordance with IEC 60068-2-30 with the following provisions:

Test Db, variant 2, b-cycle

The humidity level shall be 95 % ± 5 %

A minimum number of 3 cycles

Lower temperature: 25°C

Upper temperature: see Table 5

Table 5 – Temperature limits for damp heat, cyclic test

Service condition	Temperature
Outdoor, unprotected	75 °C
Outdoor, protected	55 °C
Indoor, unconditioned	40 °C
Indoor, conditioned	Not required

The component shall operate under worst-case conditions concerning the internal heat losses. These shall at least include conditions of maximum load and maximum power input.

In the last cycle, the functioning test for the component (see 11.2) shall be done at the upper temperature level of the cycle.

11.15.3 Final measurements

At the end of the recovery time, repeat tests 11.1 and 11.2.

11.15.4 Requirements

The requirements are as follows.

– There shall be no evidence of major visual defects, as defined in Clause 8.

– The functioning requirements of 11.2 shall be met.

Annex A
(informative)

Switching thresholds for charge controllers using the battery voltage as the main parameter for the switching algorithm

The following thresholds are recommended at a surrounding temperature of 20 °C and an acid concentration of 1,24 kg/l.

– High charge disconnect:	>2,30 V/cell
– High charge reconnect by two-point regulation:	2,15 V/cell to 2,35 V/cell
– Low charge disconnect:	1,80 V/cell to 1,90 V/cell
– Low charge reconnect:	2,05 V/cell to 2,15 V/cell

At other acid concentrations, the required thresholds must be adjusted according to the manufacturer's specifications.

NOTE 1 The lower limit of the low charge disconnect voltage is an absolute minimum.

NOTE 2 These values are primarily intended for charge controllers that use the battery voltage as the main parameter for the switching algorithm. Some manufacturers use other parameters, e.g. state of charge.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE Where an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068-1	- [1]	Environmental testing Part 1: General and guidance	EN 60068-1	1994 [2]
IEC 60068-2-6	- [1]	Part 2: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	1995 [2]
IEC 60068-2-21	- [1]	Part 2-21: Tests - Test U: Robustness of terminations and integral mounting devices	EN 60068-2-21	1999 [2]
IEC 60068-2-27	- [1]	Part 2: Tests - Test Ea and guidance: Shock	EN 60068-2-27	1993 [2]
IEC 60068-2-30	- [1]	Part 2: Tests - Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)	EN 60068-2-30	1999 [2]
IEC 60068-2-75	- [1]	Part 2-75: Tests - Test Eh: Hammer tests	EN 60068-2-75	1997 [2]
IEC 60068-2-78	- [1]	Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	2001 [2]
IEC 60068-3-6	- [1]	Part 3-6: Supporting documentation and guidance - Confirmation of the performance of temperature/humidity chambers	EN 60068-3-6	2002 [2]
IEC 60410	- [1]	Sampling plans and procedures for inspection by attributes	-	-
IEC 60529	- [1]	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 [2] 1993
IEC 60721-2-1	- [1]	Classification of environmental conditions Part 2: Environmental conditions appearing in nature - Temperature and humidity	HD 478.2.1 S1	1989 [2]

[1] Undated reference.

[2] Valid edition at date of issue.

Publication	Year	Title	EN/HD	Year
IEC 60904-3	1989	Photovoltaic devices Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	EN 60904-3	1993
IEC 61215	- [1]	Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval	EN 61215	2005 [2]
IEC 61345	- [1]	UV test for photovoltaic (PV) modules	EN 61345	1998 [2]
IEC 61427	2005	Secondary cells and batteries for photovoltaic energy systemes (PVES) - General requirements and methods of test	EN 61427	- [3]
IEC 61646	- [1]	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval	EN 61646	1997 [2]
IEC 61683	- [1]	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency	EN 61683	2000 [2]
IEC 62262	- [1]	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)	EN 62262	2002 [2]
ISO/IEC 17025	- [1]	General requirements for the competence of testing and calibration laboratories	EN ISO/IEC 17025	2000 [2]

[3] To be published.

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