BS EN 62509:2011

BSI Standards Publication

Battery charge controllers for photovoltaic systems — Performance and functioning

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National foreword

This British Standard is the UK implementation of EN 62509:2011. It is identical to IEC 62509:2010.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 62234 2

ICS 27.160

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2011.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62509

September 2011

ICS 27.160

English version

Battery charge controllers for photovoltaic systems - Performance and functioning
(IEC 62509:2010)

Contrôleurs de charge de batteries pour systèmes photovoltaïques - Performance et fonctionnement
(CEI 62509:2010)

Leistung und Funktion von Photovoltaik-Batterieladereglern
(IEC 62509:2010)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 82/614/FDIS, future edition 1 of IEC 62509, prepared by IEC TC 82, Solar photovoltaic energy systems, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62509 on 2011-01-20.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

This standard is to be used in conjunction with EN 62093.

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)	2012-03-02
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-01-20

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62509:2010 was approved by CENELEC as a European Standard without any modification.

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

Publication	Year	Title	EN/HD	Year
IEC 61836	-	Solar photovoltaic energy systems - Terms, definitions and symbols	-	-
IEC 62093	-	Balance-of-system components for photovoltaic systems - Design qualification natural environments	EN 62093	-

CONTENTS

BATTERY CHARGE CONTROLLERS FOR PHOTOVOLTAIC SYSTEMS – PERFORMANCE AND FUNCTIONING

1 Scope

This International Standard establishes minimum requirements for the functioning and performance of battery charge controllers (BCC) used with lead acid batteries in terrestrial photovoltaic (PV) systems. The main aims are to ensure BCC reliability and to maximise the life of the battery. This standard shall be used in conjunction with IEC 62093, which describes test and requirements for intended installation application. In addition to the battery charge control functions, this Standard addresses the following battery charge control features:

- photovoltaic generator charging of a battery,
- load control,
- protection functions,
- interface functions.

This standard does not cover MPPT performance, but it is applicable to BCC units that have this feature.

This standard defines functional and performance requirements for battery charge controllers and provides tests to determine the functioning and performance characteristics of charge controllers. It is considered that IEC 62093 is used to determine the construction requirements for the intended installation which includes but is not limited to aspects such as the enclosure, physical connection sturdiness and safety.

This standard was written for lead acid battery applications. It is not limited in terms of the BCC capacity to which it may be applied, however, the requirements for test equipment when applied to BCC with high voltage or current, for example, greater than 120 V or 100 A, may be difficult to achieve. These approaches may be applicable to other power sources and other battery technologies like Ni-Cd batteries by using the corresponding values of cell voltages.

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 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 62093, *Balance-of-system components for photovoltaic systems – Design qualification natural environments*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61836 apply as well as the following.

3.1
battery charge controller (BCC)
an electronic device/s that controls the charging and discharging of the battery in a photovoltaic energy system. The charge control function may be included as a subsystem within another product.

3.2
bulk charge
initial charging stage aimed at restoring the battery charge as fast as possible, in which all the available charging current from the PV generator, or the maximum current rating of the BCC, is delivered to the battery.

NOTE Sometimes referred to as boost charge.

3.3
bulk voltage
threshold voltage used by the BCC as a control parameter to change charging mode from bulk charge to the next charging stage

NOTE Sometimes referred to as boost voltage.

3.4
bulk charge delay time
the amount of time for which the bulk voltage is to be maintained before the change from the bulk charge stage to the next charging stage is made

3.5
equalise current
a constant current applied to the battery during equalise charge; normally determined by battery manufacturer recommendations

3.6
equalise charge
a relatively high voltage charging stage that is maintained for a defined time. Charge control can be achieved by constant voltage or constant current regulation or a combination of both. Equalise charge is intended to bring all cells to the same state of charge and remove electrolyte stratification in flooded cells by causing them to produce gas and stir the electrolyte.

3.7
equalise voltage
the voltage that the battery is allowed to reach during equalisation. This voltage is set above the gassing point for flooded batteries and below the maximum allowable voltage that the battery can withstand without damage.

3.8
equalise time
time that the equalise voltage is maintained from the moment that the battery has reached the equalise voltage, to the moment when the equalise charge is terminated to enter the next charging stage

3.9
float charge
a constant voltage charging stage in which the battery is maintained at a voltage below the gassing point to complete the charging cycle and compensate for battery self discharge

3.10
float voltage
the minimum constant voltage necessary to offset the internal losses of the battery

3.11
load disconnect point
condition (usually battery voltage) at which the load terminals of the charge controller are switched off to prevent the battery from over discharging, or at which a control signal or alarm

is triggered to signal a low battery state of charge. When the condition is a battery voltage, the abbreviation LVD (Low Voltage Disconnect) is usually used.

3.12
load reconnect point
condition (usually battery voltage) at which the load terminals of the charge controller are switched back on to allow the battery to supply the load, or at which a control signal or alarm is switched off to signal a battery state of charge that warrants the supply of the load. When the condition is a battery voltage, the abbreviation LVR (Low Voltage Reconnect) is usually used.

3.13
self-adaptive
an algorithm that modifies the charge controller set-points based on state of charge calculations, battery state of charge history, etc., or a combination of these parameters

3.14
temperature compensation for end of charge voltage set-points
a temperature dependent coefficient applied to the end of charge voltage set-points when the temperature of the battery differs from the reference temperature (usually 25 °C). In addition to the temperature coefficient, temperature compensation normally has minimum and maximum limits that should be adhered to (i.e. voltage set-points should be constrained within a range).

4 Functionality and performance requirements of a PV BCC

4.1 General

This Clause describes the performance and functionality requirements for PV battery charge controllers (BCC). These requirements are divided in 5 main categories:

- Battery lifetime protection.
- Efficiency.
- User interface.
- Fail safe functions.
- Marking and documentation.

The provisions in this standard are not intended to preclude or rule out innovative control techniques aimed at providing effective battery charging. These however shall be verifiable by testing.

4.2 Applicability of requirements

Required provisions ensure reliable operation and essential protection functions, and are generally easily achievable on even inexpensive BCCs intended for small installations (e.g. single module installations at extra low voltage).

Recommended provisions ensure more effective battery charging, better efficiencies, longer battery lifetime and additional user interface functions. They are intended to provide and/or facilitate more advanced battery charging and load management.

4.3 Battery lifetime protection requirements

4.3.1 Prevent leakage current from battery to PV generator

The BCC shall limit leakage current flowing from the battery to the PV generator in order to prevent battery discharging at night. The allowable reverse current on the PV side shall be ≤ 0,1 % of the BCC rated input current when the battery voltage is equal to the rated voltage.

Compliance shall be verified by test according to 5.2.1.

4.3.2 Basic battery charging functions

4.3.2.1 General

The BCC shall provide appropriate charging set-points and load disconnect set-points for the specific battery technology or technologies it is intended to be used for.

4.3.2.2 Protect battery from over-charge

The BCC shall cut out or regulate the charging current to avoid over-charging of the battery according to battery manufacturer recommended end of charge set-point.

Compliance shall be determined by test according to 5.2.2.

4.3.2.3 Protect battery from over-discharge

The BCC shall have a provision to prevent the battery from over-discharging either by directly interrupting the current to the load, or by a trip signal to enable an external piece of equipment to stop the current to the load, or an alarm.

If battery over-discharge protection is achieved by means of audible or visible alarms that prompt the system user to disconnect all or non-essential load, this shall be clearly stated in the operation manual.

If over-discharge protection is reliant on the installation of an external device that provides over-discharge protection (such as an inverter), this fact shall be clearly stated in the installation manual.

Battery over-discharge protection can be triggered by a battery voltage measurement, a state of charge calculation, a combination of both or other algorithms. The protection set-points may be current compensated. Battery over-discharge protection set-point shall be verifiable by testing. The BCC documentation and/or interface shall clearly specify the algorithms and criteria used to establish the load disconnect and reconnect set-points.

Compliance shall be determined by test according to 5.2.3.

4.3.2.4 Set-point accuracy

The BCC measurement accuracy for voltage set-points for charge control shall be ±1 % or better. For load disconnect it shall be ±2 % or better.

Compliance shall be determined by test according to 5.2.2 and 5.2.3.

4.3.3 Charging regime

4.3.3.1 General

The BCC shall be matched to the specific battery technology for its intended use to ensure that correct charging set-points are implemented. The PV BCC can use a variety of methods to ensure correct charging of batteries, the requirements in this clause include some of the possible solutions and do not limit other solutions.

4.3.3.2 Required charging stages

As a minimum, PV battery charge controllers shall have bulk and float charging stages.

NOTE Some manufacturers give charging stages different names in their documentation than those defined in this standard. Care must be taken to identify the charging characteristics appropriately for each individual unit or manufacturer and cross-reference with the terminology used in this standard.

4.3.3.3 Recommended charging stages

In addition to the requirements of 4.3.3.2, battery charge controllers should provide equalise charge periodically to the battery. The periodicity of equalise charge should be more than 7 days.

4.3.3.4 Adjustable charging set-points

In order to ensure correct charging regime for the battery type, charging set-points should be adjustable or automatically selected either by means of individual set-point adjustment, or by battery type selection or self-detection of type of battery. This can be achieved by hardware means or software through user interface or by adjusting set-points as directed in manuals.

The specific charging regime used depends on the battery technology specified. A guide for the battery set-points for testing purposes where such information is unavailable from the manufacturer is given in Annex A.

Self-adaptive set-points based on advanced algorithms shall be able to be verified using information provided by the user interface and the BCC documentation. No specific test procedure has been developed for devices employing these advanced techniques.

NOTE Adjustable set-points may not be required for BCCs intended for low power applications (< 250 W) and for a particular type of battery.

4.3.3.5 Temperature compensated charging set-points

Bulk, float, and other high voltage or end of charge set-points should be temperature compensated. Temperature compensation if provided should be in accordance with battery manufacturer recommendations for the particular type of battery. Temperature compensated set-points shall be identifiable from the charge controller documentation.

NOTE Lead acid battery manufacturers typically specify a temperature compensation coefficient of –5 mV/°C/Cell.

4.3.3.6 Voltage drop compensation for set-point measurement

The BCC should provide a means to compensate for voltage drop in battery cables, or provide installation instructions to minimise voltage drop.

If the battery charge controller has the provision for battery sense cables, it shall be able to operate with or without these. This is to protect the unit against unintended disconnection of the battery sense cables. This requirement is tested according to 5.2.2 and 5.2.3 by performing the test with and without the sense wires connected at 25 °C test conditions.

4.3.4 Set-point security

Charging set-points shall be secured against change other than by a deliberate and qualified action.

Compliance shall be determined by inspection of the unit and accompanying operating instructions.

NOTE 1 This clause does not apply to battery charge controllers with fixed set-points.

NOTE 2 The use of a tool or password are acceptable means of protection.

4.3.5 Load disconnect capability

Where over-discharge protection is provided by means of load disconnect functionality the load disconnect and reconnect set-points shall be verified by testing according 5.2.3.

The load could be either a load directly switched or a load controlled by the BCC by other means. In the case of a BCC directly switching the load this should be provided by means of an integrated load breaking switching device.

If a BCC has multiple load disconnect set-points, these shall be verifiable by testing and able to be determined from the BCC user interface and/or clearly written in documentation.

NOTE Battery over discharge protection is a mandatory feature (see 4.3.2.3). BCC load disconnection capability is recommended only, but it must be achieved by other external means if not provided by the BCC, as it is essential for battery lifetime protection.

4.4 Energy performance requirements

4.4.1 Stand by self-consumption

With no PV input or load the self-consumption of a PV BCC shall be as detailed in Table 1, when the battery voltage is equivalent to 2,1 V/Cell ± 2 %, and the ambient temperature is 25 °C ± 2 °C.

Compliance shall be determined by test according to 5.3.1.

Table 1 – Requirements for self-consumption

Nominal charging current	Maximum self-consumption
< 5 A	5 mA
5 A ≤ I ≤ 50 A	0,1 % of nominal charging current
> 50 A	50 mA

NOTE The limits given in Table 1 are intended for the charge controller function in "night time" mode. Where there are other peripheral equipment such as load management devices, displays, data loggers and others that share the power supply of the BCC, these shall be disabled or disconnected from the BCC if possible.

4.4.2 BCC efficiency

Power efficiency of the BCC shall be evaluated from 10 % to 100 % of the rated charging current, at a battery voltage equivalent to 2,2 V/Cell ± 2 % and at ambient temperature of 25 °C ± 2 °C.

The efficiency shall be determined by test according to 5.3.2[N1].

4.5 Protection and fail safe requirements

4.5.1 Thermal performance

The BCC shall be capable of handling rated input current/power from the generator and, simultaneously, rated load current to load terminals (if provided) for at least 1 h at the manufacturer's specified maximum rated ambient operating temperature ± 2 °C. Battery voltage shall be 2,2 V/Cell ± 2 %.

Compliance shall be determined by test according to 5.4.1.

NOTE Depending on the relative ratings of PV input and loads terminals, this test may result in battery charge or discharge conditions.

4.5.2 Overcurrent operation

4.5.2.1 PV side

The BCC shall not be damaged by excessive current from the PV generator up to 125 % of the full rated current. The BCC shall continue to operate normally after such an event and shall not require manual resetting.

NOTE The reset time for any automatic resetting trip mechanism, should be no longer than the time indicated in the manufacturer's instructions, if specified.

Compliance shall be determined by test according to 5.4.2.

4.5.2.2 Load side

If the BCC has a load terminal, this terminal shall be current protected to prevent over loads from causing damage to the operation of the essential PV BCC functions.

Compliance shall be determined by test according to 5.4.3.

The rating of the load terminals should match the requirement of the intended application/s.

4.5.3 PV generator and battery reverse polarity

The BCC shall be protected from reverse polarity connection of the PV generator or the battery by hardware or by documented procedure and markings.

NOTE The preferred method of protection against reverse polarity is by hardware means, but procedural documentation is allowed. This is a concern during installation and battery replacement.

Compliance shall be determined by test according to 5.4.4 and 5.4.5.

4.5.4 Open circuit on battery terminals (no battery connection)

BCC with load terminals shall be protected from damage to itself and protect the load from the open circuit voltage of the PV generator in the case of battery disconnection.

Compliance shall be determined by test according to 5.4.6.

4.6 User interface requirements

4.6.1 General

The user interface of a BCC should include any of the following types; LCD screen, LED indicators, audible alarms, relay contacts, other computer interface or other analogue or digital interface. The interface can provide the user with valuable information about the system operation if implemented properly.

The user interface may be integrated into another system component separate from the BCC such as an additional control/logging/interface unit that can be physically connected to the BCC or operate via wireless communication.

4.6.2 Operational information

4.6.2.1 General

The level of information provided to the user is determined by the intended application and its specific requirements.

The user interface of the charge controller should provide information such as detailed in 4.6.2.2.

4.6.2.2 Recommended operation information

- An indication of charging status (i.e. charging or not charging).
- An indication of load-disconnect state (or over discharge protection status).
- An indication of the state-of-charge of the connected battery.

Other additional operational information displayed by the unit may include but is not limited to:

- Charging set-points.
- Battery voltage.
- Charging current.
- Energy input/output.

4.6.3 User adjustable set-points and parameters

If user-adjustable set-points or parameters are provided, the user interface shall provide a facility to modify and display those adjustments as specified in 4.3.3.4.

NOTE This clause does not apply to battery charge controllers with fixed set-points.

Compliance shall be determined by inspection of the unit and accompanying user/installation manual.

4.6.4 Alarms

The following conditions should be signalled by the user interface:

- Low battery state of charge / Low battery voltage / Low availability.
- Load disconnect.
- BCC trip (e.g. by over temperature).

Visible and/or audible alarms, clearly identifiable by the system user, shall be triggered within the unit in case of any of the above conditions occurring. Audible alarms shall be time limited and revert to a visible alarm or be pulsed.

Compliance shall be determined by test according to 5.2.2 and 5.2.3.

5 Tests

5.1 General conditions for tests

5.1.1 Setup and preconditioning for tests

The BCC shall be mounted and installed according to the instructions supplied with the unit. Where the BCC is intended to be installed in a particular manner or configuration (e.g. wall-mounting), the installation shall mimic such conditions.

The BCC shall be installed in a temperature-controlled chamber for all tests. The test procedure shall not commence until the chamber and BCC temperatures have reached thermal stability.

5.1.2 DC power sources for testing

5.1.2.1 PV input

The power source used as the PV input should be a PV generator simulator, however, a voltage and current controlled power source in combination with a series resistor (R_S in the test diagrams) can be used.

If a PV generator simulator is used, it shall have the following minimum ratings:

- $V_{OC} \geq 2 \times V_{BAT\text{-}NOM}$
- $I_{SC} \geq 1{,}25 \times I_{BCC\text{-}IN}$

If a voltage and current controlled power source with a series resistor is used, it shall have the following minimum ratings:

- $V \geq 2 \times V_{BAT\text{-}NOM}$
- $I \geq 1{,}25 \times I_{BCC\text{-}IN}$

Where:

$V_{BAT\text{-}NOM}$ is the nominal battery voltage;
$I_{BCC\text{-}IN}$ is the rated battery charge controller PV input current.

5.1.2.2 Battery simulator

The power supply used for the battery simulation shall be voltage and current controlled and have the following minimum ratings:

- $V \geq 1{,}4 \times V_{BAT\text{-}NOM}$
- $I \geq 1{,}25 \times I_{BCC\text{-}OUT}$

where:

$I_{BCC\text{-}OUT}$ is the rated battery charge controller battery charging current.

5.1.3 General test setup

The general test setup shall be as specified in Figure 1. Any variations or modifications to the basic setup for a particular test are specified in 5.1.4, 5.1.5 and 5.1.6 and in the corresponding test clauses.

Voltage measurements shall be made at the BCC terminals.

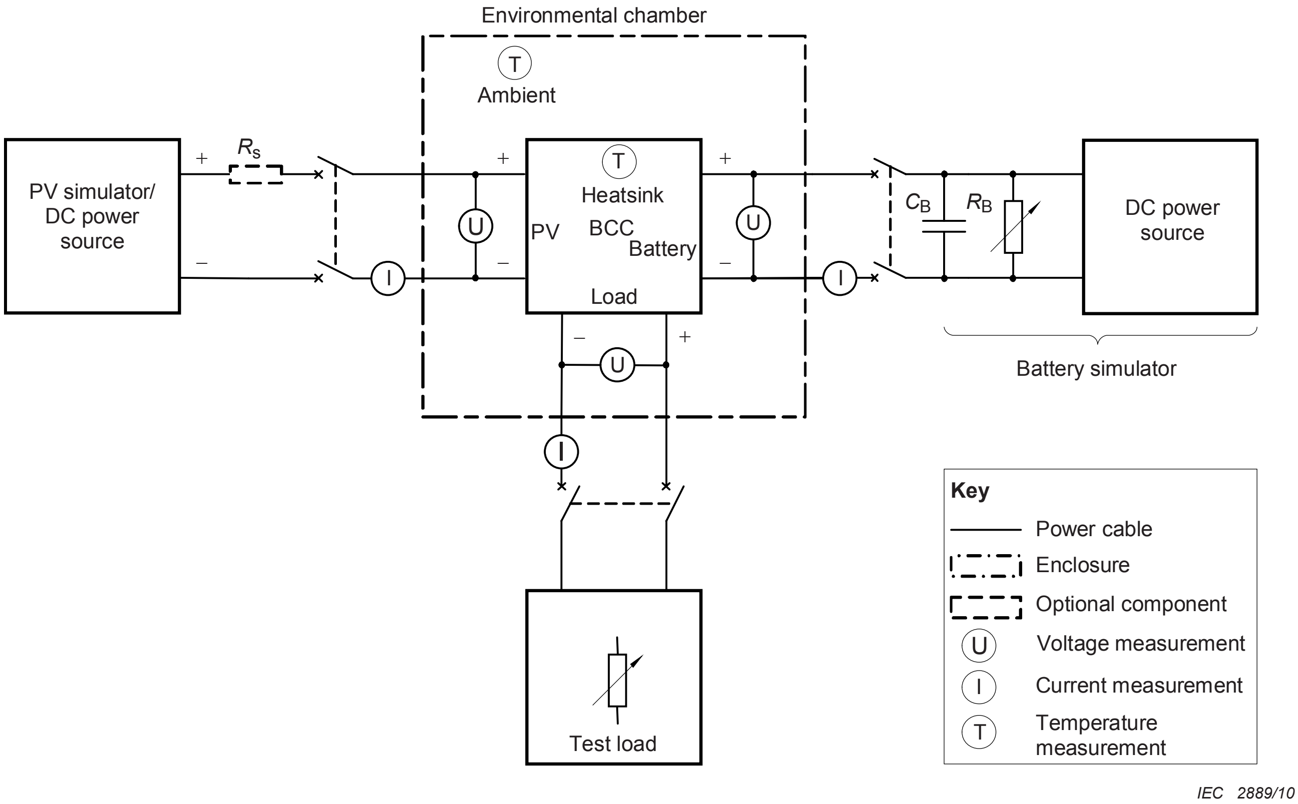

Figure 1 – General test setup

5.1.4 Reverse current test setup

The test setup shall be as specified in Figure 2.

The PV generator input resistance (R_{PV}) shall be calculated using equations 1 and 2.

$$R_{PV} = 1440 \frac{N_S}{I_R} \tag{1}$$

$$P_{R_{PV}} = \frac{(2,1 N_C)^2}{R_{PV}} \tag{2}$$

where:

R_{PV} is the PV generator resistance required to be connected to the system (Ω);

N_S is the number of PV modules in series that would be used in each string for the BCC under test (considering 1 series module per each 12 V of nominal system voltage). It is assumed the standard number of PV cells in a module is 36 cells;

I_R is the rated current (A) of the BCC;

$P_{R_{PV}}$ is the minimum power (W) dissipation rating of R_{PV};

N_C is the number of series cells of the battery, where 1 cell is equivalent to a nominal voltage of 2 V.

NOTE Equation 1 is based on the typical resistance of a-Si:H triple junction PV module technology.

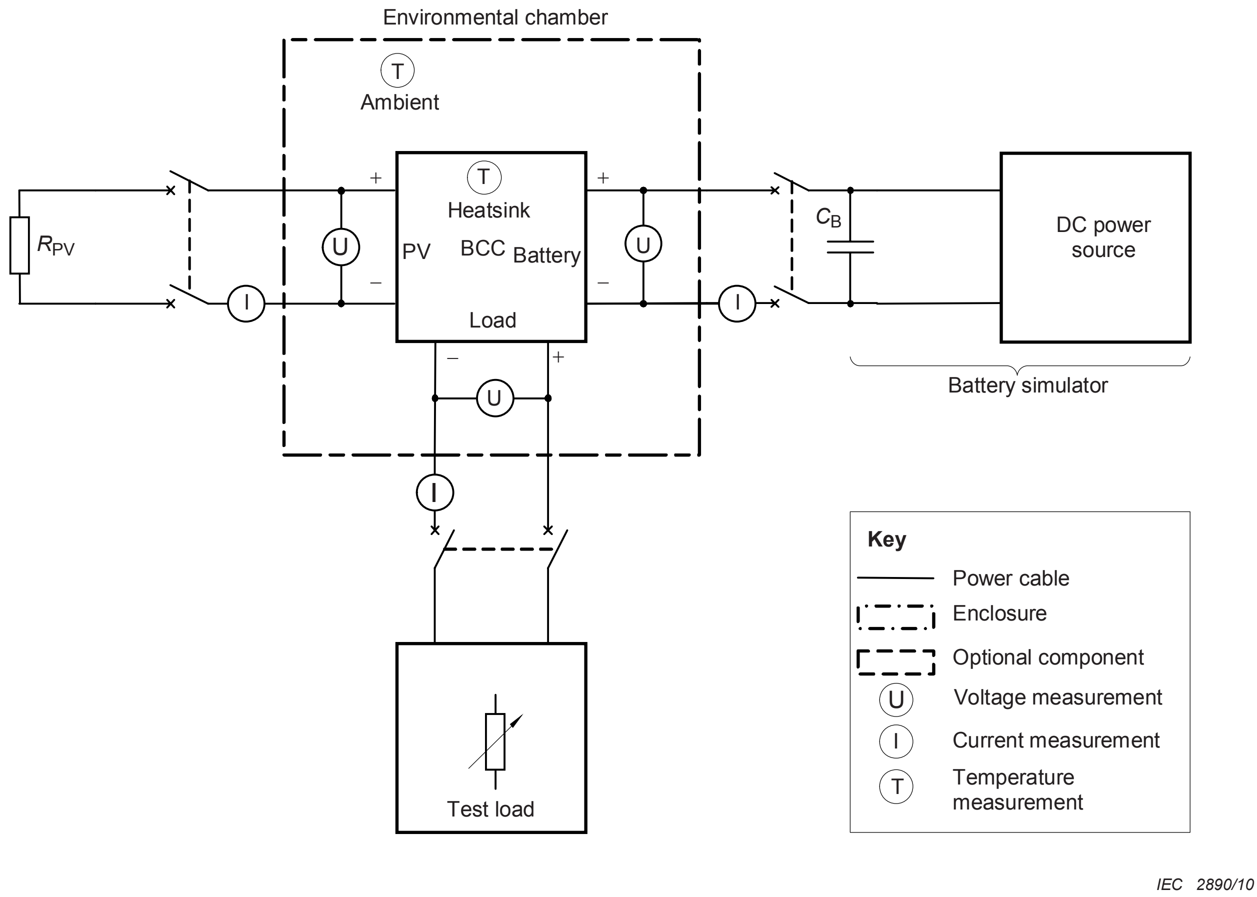

Figure 2 – Reverse current test setup

5.1.5 Charging cycle test setup

5.1.5.1 General

The test setup shall be as specified in Figure 1, with the considerations described below.

5.1.5.2 PV input

A PV generator simulator is the preferred option. If a PV generator simulator of the required voltage and/or current ratings is not available, use a power supply with a series resistor (R_S).

If a power supply with series resistor is used, the PV power supply settings should be as follows:

$$V_{PV-PSU} = 1{,}25 \times V_{BAT-MAX} \tag{3}$$

$$I_{PV-PSU} = \text{ 10 \% of rated PV input current} \tag{4}$$

where:

$V_{BAT-MAX}$ is the maximum expected charging voltage during the set-point tests (e.g. maximum equalisation voltage at 25 °C;

I_{PV-PSU} is the current setting of the PV input power supply;

V_{PV-PSU} is the voltage setting of the PV input power supply.

The voltage drop in R_S should be between 10 % and 15 % of the voltage setting of the PV power supply unit (PSU), therefore:

$$\frac{0{,}1 \times V_{PV-PSU}}{I_{PV-PSU}} \leq R_S \leq \frac{0{,}15 \times V_{PV-PSU}}{I_{PV-PSU}} \quad (5)$$

Thus the minimum required power dissipation of R_S is given by:

$$P_{R_S} = I^2_{PV-PSU} R_S \quad (6)$$

Where:

R_S is the series resistance connected between the PV power supply and the battery charge controller.

5.1.5.3 Battery simulator

The battery side PSU is required as a back up for those BCCs that scan the PV IV curve and therefore disconnect the PV current for a few seconds to perform this operation. It is intended to prevent the battery voltage from dipping too much during such IV curve scans.

The settings of the battery backup PSU shall be:

$$0{,}9 \times V_{BAT} \leq V_{BAT-PSU} \leq 0{,}94 \times V_{BAT}$$

$$I_{BAT-PSU} = 120\ \%\ \mathit{of\ Expected\ charging\ current}$$

where:

V_{BAT} is the battery voltage measured at the BCC terminals;

$V_{BAT-PSU}$ is the backup PSU voltage setting;

$I_{BAT-PSU}$ is the backup PSU current setting.

NOTE $V_{BAT-PSU}$ should be adjusted every time the battery voltage is adjusted for testing as specified in the test steps in 5.2.2.2.

The battery capacitor value (C_B) should be 0,2 F ± 20 %.

R_B is a variable resistor that allows for battery voltage control. Its characteristics should be as follows:

$$R_{B-MIN} = \frac{V_{BAT-MIN}}{I_{CHG}}$$

$$R_{B-MAX} = \frac{V_{BAT-MAX}}{I_{CHG}}$$

$$P_{R_B} = V_{BAT-MAX} I_{CHG}$$

where:

I_{CHG} is the battery charging current required for the test;

R_{B-MIN} is the minimum resistance required for the test;

R_{B-MAX} is the maximum resistance required for the test;

P_{R_B} is the minimum required power dissipation capacity of R_B;

$V_{BAT-MIN}$ is the minimum expected battery voltage during the set-point tests (e.g. simulating battery low state of charge).

5.1.6 Efficiency, thermal performance and PV overcurrent test setup

5.1.6.1 General

The test setup shall be as specified in Figure 1, with the considerations described in 5.1.5.2 and 5.1.6.2.

5.1.6.2 Battery simulator

The voltage on the battery terminals of the BCC shall remain constant for the duration of the tests. A battery simulator can be used if it can maintain a constant voltage. The use of voltage and current controlled power supply unit (PSU) is suitable for this test as long as the following points are considered.

The PSU connected to the BCC battery terminals in this case is required to provide a battery voltage reference ($V_{BAT-PSU}$). This PSU shall operate in voltage regulation mode and supply current to R_B (see Figure 1) at all times during the test.

The settings of this PSU should be:

$$V_{BAT-PSU} = V_{BAT-TEST} \tag{7}$$

$$I_{BAT-PSU} = 1{,}3 I_{CHG-MAX} \tag{8}$$

where:

$V_{BAT-TEST}$ is the test battery voltage measured at the BCC terminals (2,2 V/Cell for efficiency test);

$V_{BAT-PSU}$ is the battery PSU voltage setting;

$I_{CHG-MAX}$ is the maximum expected charging current.

NOTE $V_{BAT-PSU}$ will normally need to be adjusted slightly at each charging current level to compensate for the changing voltage drop in the wiring.

The battery capacitor value (C_B, see Figure 1) shall be 0,1 F ± 20 %.

R_B is a fixed resistor that dissipates the charging current plus the current from the battery PSU. Its characteristics should be as follows:

$$R_B = \frac{V_{BAT-TEST}}{1{,}15 I_{CHG-MAX}} \pm 10\ \% \tag{9}$$

$$P_{R_B} \geq 1{,}3 V_{BAT-TEST} I_{CHG-MAX} \tag{10}$$

where:

R_B is the battery setup resistor required for the test;

P_{R_B} is the minimum required power dissipation capacity of R_B.

5.2 Battery lifetime protection tests

5.2.1 Battery to PV generator leakage current test

5.2.1.1 Objective/scope

This test is intended to measure the reverse current through the BCC from the battery to the PV generator, when the PV generator is connected but not producing any current. The test verifies compliance with the requirements of 4.3.1. Measurements are to be made at 25 °C ± 2 °C.

5.2.1.2 Test setup

As specified in 5.1.4.

5.2.1.3 Test procedure

a) Connect test setup as specified in Figure 2.

b) Ensure the conditions specified in 5.1.1 are met.

c) Adjust the battery voltage to 2,1 V/Cell ± 2 %.

d) Measure the current in the R_{PV} loop.

NOTE Some units may have a delay time, from the time the PV voltage is below the battery voltage to the time that it reduces PV generator leakage current.

e) Compare result to requirement of 4.3.1.

5.2.2 Charging cycle tests

5.2.2.1 Objective/scope

These tests are intended to measure the charging set-points of the BCC at 25 °C and 40 °C. Measurement at both temperatures allows for verification of set-point temperature compensation when the BCC has this capability.

In order to measure the charging set-points it is necessary to monitor a complete charging cycle including all available charging stages of the BCC under test. The number of charging stages varies across different types and manufacturers of BCCs. ON/OFF controllers only have two stages. Regulating units include bulk and float charging as a minimum and equalisation in most cases. Some more sophisticated BCCs include other regulating stages.

5.2.2.2 Test setup

As specified in 5.1.5.

5.2.2.3 Test procedure

a) Connect test setup as specified in Figure 1.

b) Ensure the conditions specified in 5.1.1 are met at 25 °C chamber temperature.

c) Adjust the battery simulator resistor (R_B) to produce nominal battery voltage at 10 % of the rated charging current.

d) Throughout the test, maintain the voltage setting of the battery PSU within the limits specified in 5.1.5.3 particular attention shall be given after each voltage change.

NOTE 1 This is to ensure that the battery voltage is controlled by the BCC and not the battery backup PSU.

e) Set the PV input power supply operating parameters to produce 10 % charging current. For PWM controllers, the MPP voltage of the PV supply shall be 140 % ± 2 % of the nominal battery voltage and the open circuit voltage 175 % ± 2 % of the nominal battery voltage. For MPPT controllers the MPP voltage of the PV supply shall be the mid-point of the operating voltage window of the BCC ± 2 % and the open circuit voltage 125 % ± 2 % of the MPP voltage.

f) Record input and output voltage and current as well as chamber temperature at a sampling rate that provides enough resolution of the parameters observed.

NOTE 2 A 20 second sampling rate generally provides enough resolution if the BCC input provides appropriate filtering of any PWM pulses. However, some units can present ripple voltages and currents with frequencies in the tens to hundreds of hertz; in these cases, the sampling frequency must be adjusted accordingly.

g) Increase the battery voltage stepwise by increasing R_B, until the BCC starts to regulate the charging current in case of regulating controllers (PWM or MPPT) or has cut out the current in case of ON-OFF controllers. Wait 2 min or the specified delay time of the BCC + 1 min, whichever is greater, between voltage steps. Record this voltage as the end of bulk charge voltage.

NOTE 3 Take into account any temperature and/or current compensation when estimating the expected end of charge set-point.

NOTE 4 Battery voltage steps have to be consistent with the required measurement uncertainty, particularly close to the expected regulation set-points. 20 mV per battery cell is appropriate during voltage ramp-up, but 4 mV per battery cell or less is required near regulation points that trigger a step voltage change to ensure appropriate measurement uncertainty.

NOTE 5 Regulation can be identified by monitoring the input voltage and current with an oscilloscope.

h) If the controller is of the regulating type, go to the next step. If the controller is of the ON-OFF type, decrease the voltage stepwise, until the BCC reconnects the PV current. Wait 2 min or the specified delay time of the BCC + 1 minute, whichever is greater, between voltage steps. Record this voltage as the return to charge voltage. Go to step l).

NOTE 6 Take into account any temperature and/or current compensation when estimating the expected end of charge set-point.

Battery voltage steps should be consistent with the required measurement uncertainty, particularly close to the expected regulation set-points.

i) Force an equalization charge if this facility is available.

j) Using an oscilloscope adjust the duty cycle of the BCC to 90 % by increasing R_B.

k) Allow the charge controller to continue the charging cycle automatically (i.e. no further R_B adjustments should be necessary) until it has reached and stayed in float mode for at least half an hour to obtain stable readings and any possible drift behaviour. Record input and output voltages and currents at the different charging stages (equalise, float, etc.).

l) Repeat test at 40 °C ambient (chamber) temperature.

m) End of test.

5.2.3 Load disconnect / load reconnect test

5.2.3.1 Objective/scope

This test is intended to verify the low voltage set-points used for load disconnect (LVD) and load reconnect (LVR). Measurements are required at 25 °C.

Some BCCs do not have load handling capabilities, but have auxiliary contacts that enable the control of the load by external switching devices.

NOTE Advanced BCC may not be dependent on voltage set-points in such cases a suitably modified procedure based on the BCC load control algorithm should be used.

5.2.3.2 Test setup

As specified in 5.1.3.

5.2.3.3 Test procedure

a) Connect test setup as specified in Figure 1.

NOTE 1 For this test, disconnect R_B and the PV input PSU.

b) Ensure the conditions specified in 5.1.1 are met at 25 °C chamber temperature.

c) Set the battery PSU to produce a battery voltage of 2,1 V/cell and connect to the BCC.

d) If the unit has load terminals, set the load resistance to produce a load current of 10 % ± 2 % of the rated load current at rated battery voltage. If the unit has control outputs for the low voltage disconnect function, set the load resistance to the control output to produce a load current that can be managed by this control output.

e) Decrease the battery voltage stepwise, until the BCC disconnects the load (load terminal voltage and current = 0). Wait 2 min or the specified delay time of the BCC + 1 min, whichever is greater, between voltage steps. Record the voltage just before tripping as the LVD measurement.

NOTE 2 Take into account any temperature and/or current compensation when estimating the expected disconnect set-point.

Battery voltage steps should be consistent with the required measurement uncertainty, particularly close to the expected disconnect set-point.

f) Increase the battery voltage stepwise, until the BCC reconnects the load (load terminal voltage = V_{BAT}). Wait 2 min or the specified delay time of the BCC + 1 min, whichever is greater, between voltage steps. Record the voltage just before reconnecting as the LVR measurement.

NOTE 3 Take into account any temperature and/or current compensation when estimating the expected reconnect set-point.

Battery voltage steps should be consistent with the required measurement uncertainty, particularly close to the expected reconnect set-point.

g) Repeat test at 40 °C ambient (chamber) temperature.

h) End of test.

5.3 Energy performance tests

5.3.1 Standby self-consumption test

5.3.1.1 Objective/scope

The aim of this test is to determine the self-consumption of the battery charge controller in standby mode (no PV input or load).

5.3.1.2 Test setup

As specified in 5.1.3.

5.3.1.3 Test procedure

a) Connect test setup as specified in Figure 1.

NOTE For this test, R_B should be removed from the circuit and no PV input or load are required.

b) Ensure the conditions specified in 5.1.1 are met at 25 °C chamber temperature.

c) Adjust the battery voltage to 2,1 V/Cell ± 2 %.

d) Ensure the load terminals or auxiliary control output if present is in active or ON mode.

e) Measure battery voltage and current; record the readings.

f) Repeat measurements at 2,0, 1,9, 1,8 and 1,7 V/Cell in that sequence.

g) End of test.

5.3.2 Efficiency test

5.3.2.1 Objective/scope

The aim of this test is to determine the efficiency curves of the battery charge controller over the range 10 % to 100 % charging current at an ambient temperature of 25 °C.

5.3.2.2 Test setup

As specified in 5.1.6.

5.3.2.3 Test procedure

a) Connect test setup as specified in Figure 1.

NOTE 1 For this test, no load is required.

b) Ensure the conditions specified in 5.1.1 are met at 25 °C chamber temperature.

c) Set the battery voltage to 2,2 V/Cell by adjusting the battery PSU while keeping R_B constant.

NOTE 2 Make sure that the battery PSU operates in constant voltage mode throughout the test.

d) Adjust the PV input current to provide 10 % of rated charging current ± 2 %, and readjust $V_{BAT-PSU}$ to produce a battery voltage of 2,2 V/Cell at the BCC terminals.

e) Ensure that the BCC is operating in bulk mode, and that the load terminals or auxiliary control output (if present) is in active or ON mode.

f) Measure input and output voltage, current and power and record these values at the 10 % charging current reading.

g) Repeat steps d) to f) for 20 % to 100 % of charging current in 10 % increments.

h) Remove supply from the PV input.

i) Apply a resistive load of 100 % nominal current at the load terminals of the BCC.

j) Measure the voltage drop and power efficiency of the BCC.

5.4 Protection and fail safe tests

5.4.1 Thermal performance test

5.4.1.1 Objective/scope

This test is carried out to evaluate the performance of the charge controller at the maximum rated temperature and rated charging current in bulk mode. Where no manufacturer's maximum rated ambient operating condition is specified then this test is to be done at 40 °C. The effect of a load connected via integrated load switching device should be included in this test.

5.4.1.2 Test setup

As specified in 5.1.6.

5.4.1.3 Test procedure

a) Connect test setup as specified in Figure 1.

b) Ensure the conditions specified in 5.1.1 are met at the specified testing temperature ± 2 °C for chamber temperature.

c) Set the battery voltage to 2,2 V/Cell by adjusting the battery PSU while keeping R_B constant.

NOTE Make sure that the battery PSU operates in constant voltage mode throughout the test.

d) Ensuring that the BCC is operating in bulk mode, adjust the PV input current to provide 100 % of rated charging current ± 2 %, and readjust $V_{BAT-PSU}$ to produce a battery voltage of 2,2 V/Cell at the BCC terminals.

e) Apply rated load to load terminals, if provided.

f) Record input and output voltage current and power, as well as heat-sink and chamber temperatures at 1 min intervals or faster for 1 h or until any thermal protection is triggered within the BCC (current regulation, shut down, etc.).

5.4.2 PV overcurrent protection test

5.4.2.1 Test setup

As specified in 5.1.6.

5.4.2.2 Objective/scope

This test is carried out to evaluate the performance of the charge controller under over load conditions at 25° C and 125 % of the rated charging current in bulk mode.

5.4.2.3 Test procedure

a) Connect test setup as specified in Figure 1.

NOTE 1 For this test, no load is required.

b) Ensure the conditions specified in 5.1.1 are met at 25 °C chamber temperature.

c) Set the battery voltage to 2,2 V/Cell by adjusting the battery PSU while keeping R_B constant.

NOTE 2 Make sure that the battery PSU operates in constant voltage mode throughout the test.

d) Ensuring that the BCC is operating in bulk mode, adjust the PV input current to provide 125 % of rated charging current ± 2 %, and readjust $V_{BAT-PSU}$ to produce a battery voltage of 2,2 V/Cell at the BCC terminals.

e) Record input and output voltage current and power, as well as heatsink and chamber temperatures at 1 min intervals or faster for 1 h or until any thermal protection is triggered within the BCC (current regulation, shut down, etc.).

5.4.3 Load over current protection test

5.4.3.1 Objective/scope

This test is carried out to evaluate the performance of the charge controller at 25 °C and 125 % of the rated load current.

5.4.3.2 Test setup

As specified in 5.1.3.

5.4.3.3 Test procedure

a) Connect test setup as specified in Figure 1.

NOTE For this test, R_B should be removed from the circuit and no PV input is required.

b) Ensure the conditions specified in 5.1.1 are met at 25 °C chamber temperature.

c) Adjust the battery voltage to 2,0 V/Cell ± 2 % using the battery power supply.

d) Adjust the load current to 125 % of the rated value by adjusting the load resistance, and readjust $V_{BAT-PSU}$ to produce a battery voltage of 2,0 V/Cell at the BCC terminals.

e) Record battery and load voltage current and power, as well as heatsink and chamber temperatures at 1 min intervals or faster for 1 h or until any thermal protection is triggered within the BCC.

5.4.4 Battery reverse polarity test

5.4.4.1 Objective/scope

This test is intended to verify the BCC tolerance to the connection of the battery in reverse polarity and also to verify the protection of the load from being supplied with negative voltage.

5.4.4.2 Test Setup

As specified in 5.1.3, with the observations specified in the test procedure.

5.4.4.3 Test procedure

a) Review the BCC documentation and the unit itself to verify whether it is capable of withstanding a reverse polarity connection on the battery terminals, or if there is a specific warning not to do so. If a warning is given in the unit or its documentation do not go ahead with the test. Otherwise go to the next step.

b) Connect test setup as specified in Figure 1.

NOTE 1 For this test, R_B and C_B should be removed from the circuit and no PV input is required.

c) With the PV input and battery circuit breakers in the open position, reverse the polarity of the battery PSU. Set the battery voltage to the nominal value ± 2 % and set the current limit of the battery PSU to twice the rated charging current of the BCC.

d) Set the load resistance to draw 10 % of rated current at rated battery voltage.

NOTE 2 Make sure to use an actual resistor or an electronic load which is not polarity sensitive.

e) Record battery, load and PV voltage, current and power at 10 s intervals or faster for the duration of the test.

f) Connect battery and load and maintain the connection for 5 min. Record any alarms displayed by the BCC.

g) Verify that the BCC has not suffered any damage and that reverse voltage has not been fed to the load.

5.4.5 PV generator reverse polarity test

5.4.5.1 Objective/scope

This test is intended to verify the BCC tolerance to the connection of the PV generator in reverse polarity and also to verify the protection of the load from being supplied with negative voltage.

5.4.5.2 Test setup

As specified in 5.1.3 with the observations specified in the test procedure.

5.4.5.3 Test procedure

a) Revise the BCC documentation and the unit itself to verify whether it is capable of withstanding a reverse polarity connection on PV terminals, or if there is a specific warning not to do so. If a warning is given in the unit or its documentation do not go ahead with the test. Otherwise go to the next step.

b) Connect test setup as specified in Figure 1.

NOTE 1 For this test, R_B and C_B should be removed from the circuit and no battery input is required.

c) With the PV input and battery circuit breakers in the open position, reverse the polarity of the PV generator simulator or PSU + series resistor. Set the PV voltage and current and R_S (if applicable) as per 5.1.5.2 for a 100 % charging current.

d) Set the load resistance to draw 10 % of rated current at rated battery voltage.

NOTE 2 Make sure to use an actual resistor or an electronic load which is not polarity sensitive.

e) Record battery, load and PV voltage, current and power at 10 s intervals or faster for the duration of the test.

f) Connect PV input and load and maintain the connection for 5 min. Record any alarms displayed by the BCC.

g) Verify that the BCC has not suffered any damage and that reverse voltage has not been fed to the load.

5.4.6 Battery open circuit test

5.4.6.1 Objective/scope

This test is intended to verify the BCC tolerance to the occurrence of an open circuit on the battery terminals, and the protection of the load from being connected directly to the PV generator voltage.

5.4.6.2 Test setup

As specified in 5.1.6 with the modifications indicated in the test procedure.

5.4.6.3 Test procedure

a) Connect test setup as specified in Figure 1.

b) Set the battery PSU voltage and current according to 5.1.6.2.

NOTE Take into account that for this particular case $I_{CHG\text{-}MAX} = I_{CHG\text{-}PV} - I_{LOAD}$ if the BCC has load terminals.

c) Set the PV input power supply operating parameters to produce rated charging current ± 5 %. For PWM controllers, the MPP voltage of the PV supply shall be 140 % ± 2 % of the nominal battery voltage and the open circuit voltage 175 % ± 2 % of the nominal battery voltage. For MPPT controllers the MPP voltage of the PV supply shall be the mid-point of the operating voltage window of the BCC ± 2 % and the open circuit voltage 125 % ± 2 % of the MPP voltage.

d) If the unit has load terminals, set the load to 5 % of the rated load terminal current at nominal battery voltage.

e) Connect the battery load and PV source in that sequence.

f) Adjust the battery voltage to the nominal value by adjusting the battery PSU and allow the BCC to stay in this condition for 5 min.

g) Disconnect the battery by opening SW2. Allow the unit to stay in this condition for 5 min. Record any alarm of fault signals/messages.

h) Reconnect the battery and verify if the unit is operating normally by reading any signals on the display. Note down any relevant observations.

5.5 User interface tests

User interface requirements are verified mainly by inspection of the BCC and the accompanying instruction and installation manuals. Alarms are verified during other tests such as:

- Load disconnect / load reconnect test (5.2.3)

- Reverse polarity tests (5.4.4 and 5.4.5)
- Thermal performance test (5.4.1)
- Overcurrent protection test (5.4.2 and 5.4.3)

Annex A
(informative)

Battery charging guideline

Table A.1 gives suggested battery voltage set-points for testing purposes where such information is unavailable from battery manufacturer.

Table A.1 – Battery charging setpoint guideline

Values given V per cell for 25 °C	Vented	Sealed/VRLA
Bulk charge	2,4	2,4
Equalization	2,45 to 2,55	2,45
Low voltage disconnect, for discharge current I10	1,80 to 1,85	1,80 to 1,85
Low voltage disconnect, for discharge current 10 % of I10	1,95 to 2,0	1,95 to 2,0
Float	2,35	2,30

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