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PAKISTAN STANDARD

**UNINTERRUPTIBLE POWER SYSTEMS (UPS) –
PART 5-3: DC OUTPUT UPS –
PERFORMANCE AND TEST REQUIREMENTS**



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KARACHI.**

DRAFT
PAKISTAN STANDARD SPECIFICATION
FOR
UNINTERRUPTIBLE POWER SYSTEMS (UPS) – PART 5-3: DC
OUTPUT UPS –
PERFORMANCE AND TEST REQUIREMENTS

0. FOREWORD

- 0.1 This Pakistan Standard was adopted by the authority of the Board of Directors of Pakistan Standards and Quality Control Authority (PSQCA), after the draft prepared by the Technical Committee for “Power electronics. Industrial-process measurement and control (ESTC-3)” had been approved and endorsed by the National Standards Committee for Electronics on 20-12-2017.
- 0.2 This Standard is an adoption of “IEC Publication 62040-5-3-2016: Uninterruptible power systems (UPS) – Part 5-3: DC output UPS – Performance and test requirements.”
- 0.3 This Standard has been prepared and finalized after taking into consideration the views and suggestions put forwarded by the representative section of technologists, manufacturers and utilizing agencies.
- 0.4 This Standard is subject to periodical review in order to keep pace with the changing requirements and latest development in the industry. Any suggestion for improvement will be recorded and placed before the revising committee in due course.
- 0.5 This Standard covers the technical provisions and it does not purport to include all the necessary provisions of a contract.

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UNINTERRUPTIBLE POWER SYSTEMS (UPS) –

Part 5-3: DC output UPS – Performance and test requirements

1 Scope

This part of IEC 62040 establishes the performance and test requirements applied to movable, stationary and fixed electronic **DC uninterruptible power systems (DC UPS)** that

- are supplied from an AC voltage source not exceeding 1 000 V,
- deliver a **DC output voltage** not exceeding 1 500 V,
- incorporate an **energy storage device**, and
- have a primary function to ensure continuity of DC power to loads.

This document specifies performance and test requirements of a complete **DC UPS** and not of individual **DC UPS functional units**. The individual **DC UPS functional units** are dealt with in IEC publications referred to in the bibliography that apply so far that they are not in contradiction with this document.

DC UPSs have been developed over a wide range of power, from less than a hundred watts to megawatts, to meet requirements for availability and quality of power to a variety of loads. Refer to Annexes A and B for information on typical **DC UPS** configurations and topologies.

This document also includes **DC UPS** performance and test requirements related to **interrupters**, isolating switches, and tie switches, if any, which are integral to the **DC UPS**. These components interact with other **functional units** of the **DC UPS** to maintain **continuity of load power**.

This document does not cover

- conventional AC input distribution boards and their associated switches,
- conventional DC distribution boards and their associated switches,
- conventional AC UPSs covered by IEC 62040-3,
- low-voltage DC power supply devices covered by a specific product standard, for example IEC 61204, and those covered by a specific product standard, for example ITU communication standards, and
- systems wherein the **output voltage** is derived from a rotating machine.

NOTE 1 This document recognises that power availability to information technology (IT) equipment represents a major UPS application. The **DC UPS** output characteristics specified in this document are therefore also aimed at ensuring compatibility with the requirements of IT equipment. This, subject to any limitation stated in the manufacturer's declaration, includes requirements for steady state and **transient** voltage variation as well as for the supply of both resistive and **constant power load** characteristics of IT equipment.

NOTE 2 Test loads specified in this document simulate both resistive and **constant power load** characteristics. Their use is prescribed with the objective of verifying design and performance, as declared by the manufacturer, and also of minimising any complexity and energy consumption during the tests.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

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

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

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

IEC 60146-1-1:2009, *Semiconductor converters – General requirements and line commutated converters – Part 1-1: Specification of basic requirements*

IEC 60146-2:1999, *Semiconductor converters – Part 2: Self-commutated semiconductor converters including direct d.c converters*

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC TR 60721-4-3, *Classification of environmental conditions - Part 4-3: Guidance for the correlation and transformation of environmental condition classes of IEC 60721-3 to the environmental tests of IEC 60068 - Stationary use at weatherprotected locations*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 62040-1, *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*

IEC 62040-2, *Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements*

ISO 7779, *Acoustics – Measurement of airborne noise emitted by information technology and telecommunications equipment*

3 Terms and definitions

3.1 General

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE In this document, IEC 60050 definitions are referenced wherever possible, particularly those of IEC 60050-551.

When an existing IEC 60050 definition needs amplification or additional information, this is indicated by adding the word "modified" after the IEC 60050 reference.

3.2 System and component definitions

3.2.1

DC uninterruptible power system

DC UPS

combination of **converters**, switches and **energy storage devices** (such as batteries), constituting a power system for maintaining **continuity of DC load power** in case of **AC input power failure**

Note 1 to entry: **AC input power failure** occurs when voltages are outside rated steady-state and **transient tolerance bands** or when distortion or interruptions are outside the limits specified for the **DC UPS**.

3.2.2

electronic power converter

power converter

converter

operative unit for electronic power conversion, composing one or more electronic valve devices, transformers and filters if necessary and auxiliaries if any

Note 1 to entry: In English, the two spellings "converter" and "con~~vert~~er" are in use, and both are correct. In this document, the spelling "con~~vert~~er" is used in order to avoid duplications.

Note 2 to entry: Figure 1 shows examples of basic **electronic power converters**.

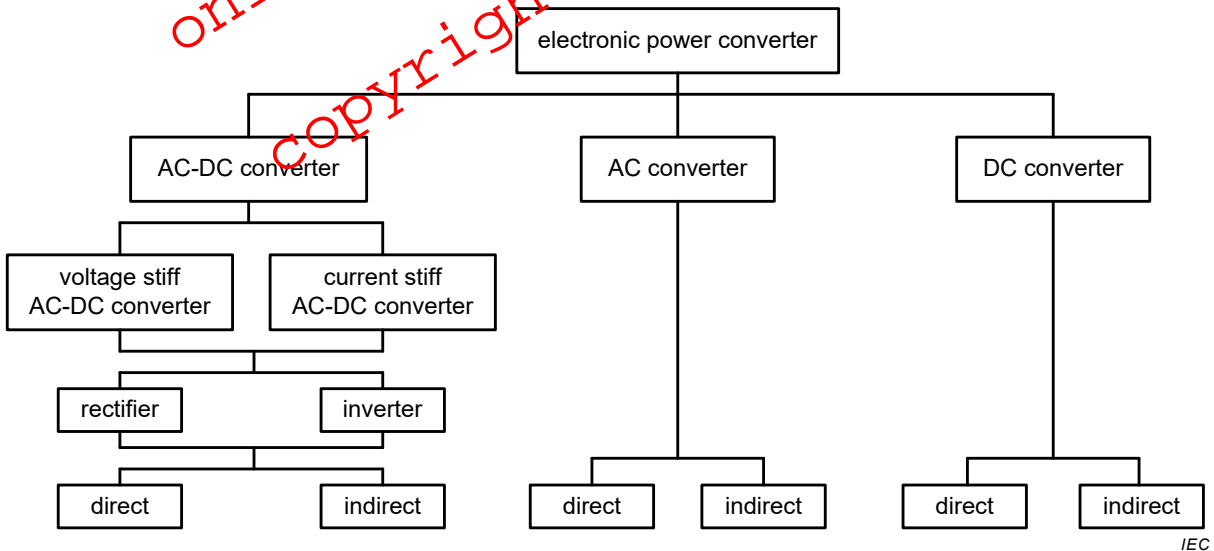


Figure 1 – Examples of basic electronic power converters

[SOURCE: IEC 60050-551:1998, 551-12-01, modified — Note 2 to entry and the figure have been added.]

3.2.3

functional unit

<DC UPS> complete subassembly that performs a given function in a **DC UPS**

EXAMPLE **Converter**, rectifier.

3.2.4

energy storage device

system consisting of single or multiple devices and designed to provide power to the **DC UPS** for the required **stored energy time**

Note 1 to entry: Notwithstanding challenges with respect to recharge, examples of an **energy storage device** include but are not limited to **battery**, double-layer capacitor ("super" or "ultra" capacitor), flywheel and fuel-cell systems.

3.2.5

internal DC bus

integral DC power interface of the components of the **DC UPS** (**battery**, DC circuits, rectifiers, **converters**, etc) including points of connection for the DC output but excluding the physical DC output

3.2.6

battery

one or more electrochemical cells fitted with devices necessary for use, for example case, terminals, marking and protective devices

Note 1 to entry: A typical **battery** consists of

- one string of a quantity of series connected cells, or
- two or more paralleled strings, each string containing the same quantity of series connected cells

[SOURCE: IEC 60050:2004, 482-01-04], modified — The word "electrochemical" has been added to the definition, as well as the note to entry.

3.2.7

secondary battery

<electrochemical cells> **battery** intended to be discharged and recharged

Note 1 to entry: A valve regulated **secondary battery** consists of cells which are closed but have a valve which allows the escape of gas if the internal pressure exceeds a predetermined value. Valve regulated lead-acid cells are abbreviated "VRLA cells" (see IEC 60050-482:2004, 482-05-15).

Note 2 to entry: A vented **secondary battery** consists of cells having a cover provided with an opening through which products of electrolysis and evaporation are allowed to escape freely, or through a venting system, from the cell to the atmosphere (see IEC 60050-482:2004, 482-05-14).

3.2.8

flywheel storage system

mechanical **energy storage device** wherein stored kinetic energy can be converted to DC power during stored energy mode of operation

3.2.9

battery charger

device for **battery** charging and maintaining the charged state of the **battery**

3.2.10

DC UPS switch

controllable switch used in accordance with applicable requirements for load power continuity to interconnect or isolate power ports of **DC UPS units**, or load

3.2.11

DC UPS rectifier

electronic **converter** for rectification

3.2.12**interrupter**

DC UPS switch which is capable of making, carrying and breaking currents under normal circuit conditions, making and carrying currents for a specified time and breaking currents under specified unusual circuit conditions

3.2.13**DC distribution network**

DC system that connects sources and storage systems to distributed loads

3.2.14**AC input power****grid input power**

product of instantaneous components of the alternating grid input current and voltage averaged over a complete cycle

3.2.15**DC UPS unit**

complete **DC UPS** consisting of at least one of each of the following **functional units**: **DC UPS**, **DC output power** module, and **battery** or other **energy storage device(s)**

3.2.16**single DC UPS**

DC UPS comprising only one **DC UPS unit**

3.2.17**parallel DC UPS**

DC UPS comprising two or more **DC UPS units** operating in parallel

3.2.18**redundant system**

system in which one or more **functional units** can fail without affecting **continuity of load power**

3.2.19**parallel redundant DC UPS**

DC UPS with a number of paralleled **load sharing DC UPS units**, which, upon failure of one or more **DC UPS units**, can take over full load with the remaining units

3.3 Performance of systems and components**3.3.1****primary power**

external electrical power source, usually the public mains supply or other equivalent source that may be generated locally

3.3.2**stand-by power**

external electrical power source intended to replace **primary power** in the event of **primary power failure**

3.3.3**power failure**

any variation in power supply which can cause unacceptable performance of the load equipment

3.3.4**continuity of load power**

maintenance of power delivery within the limits specified for the **DC UPS** output under abnormal utility supply conditions

3.3.5**battery ripple current**

superimposed effective (RMS) alternating component of the **battery** current

3.3.6**normal mode**

stable mode of operation that the **DC UPS** attains under the following conditions:

- a) AC input supply is within required tolerances and supplies the **DC UPS**;
- b) the **energy storage device** remains charged or is under recharge;
- c) the load is within the specified **rating** of the **DC UPS**

3.3.7**stored energy mode of DC UPS operation**

stable mode of operation that the **DC UPS** attains under the following conditions:

- a) **AC input power** is disconnected or is out of required tolerance;
- b) all power is derived from the **energy storage device**;
- c) the load is within the specified **rating** of the **DC UPS**

3.3.8**movable DC UPS**

equipment which is either 18 kg or less in mass and not fixed, or equipment with wheels, castors or other means to facilitate movement as required to perform its intended use

Note 1 to entry: Derived from IEC 60950-1.

3.3.9**stationary DC UPS**

equipment that is not **movable** equipment

Note 1 to entry: Derived from IEC 60950-1.

3.3.10**fixed DC UPS**

stationary equipment which is fastened or otherwise secured at a specific location

Note 1 to entry: Derived from IEC 60950-1.

3.3.11**skilled person**

person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which the equipment can create

[SOURCE: IEC 60050-826: 2004, 826-18-01, modified — The reference to "electricity" has been replaced by a reference to "the equipment".]

3.3.12**type test**

conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.3.13

routine test

conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.4 Specified values – General

3.4.1

rating

set of **rated values** and operating conditions of a machine, device or equipment

[SOURCE: IEC 60050-151:2001, 151-16-11, modified — The words "of a machine, device or equipment" have been added.]

3.4.2

rated value

value of a quantity used for specification purposes, generally established by a manufacturer for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08, modified — The words "generally" and "by a manufacturer" have been added.]

3.4.3

reference test load

rated DC load

load or condition in which the output of the **DC UPS** delivers the power (W) for which the **DC UPS** is rated

Note 1 to entry: Rated load is a value of load used for specification purposes, generally established by a manufacturer for a specified set of operating conditions of a component, device, equipment, or system.

3.4.4

resistive load

load that when supplied from a source with a variable voltage presents a resistive impedance that for practical purposes is constant

3.4.5

constant power load

load that when supplied from a source with a variable voltage V presents a resistive impedance R that for practical purposes varies so that the **active power** P consumed by the circuit is constant, i.e. $P = V^2/R = \text{constant}$

3.4.6

step load

instantaneous addition or removal of electrical loads

3.4.7

light load

condition at which the **DC UPS** supplies approximately 10 % of **rated output power**

3.4.8

nominal value

value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The **nominal value** is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.4.9**tolerance band**

range of values of a quantity within specified limits

3.4.10**deviation**

difference between the actual value and the desired value of a variable quantity at a given instant

[SOURCE: IEC 60050-351:2013, 351-41-04, modified – The note to entry has been deleted.]

3.4.11**current limit**

current limit control

function that limits a current to its prescribed maximum value

3.4.12**rated voltage**

V_{rated}

rated value of the voltage assigned by the manufacturer to a component, device or equipment and to which operation and performance characteristics are referred

Note 1 to entry: A **DC UPS** may have more than one **rated voltage** for its input and for its output.

Note 2 to entry: For **DC UPS** with three-phase input, the line-to-line voltage applies.

3.4.13**rated voltage range**

input or **output voltage range** as declared by the manufacturer expressed by its lower and upper **rated voltages**

Note 1 to entry: A **DC UPS** may have more than one **rated voltage range** for its input and for its output.

Note 2 to entry: For **DC UPS** with three-phase input, the line-to-line voltage applies.

3.4.14**RMS voltage variation**

difference between the RMS voltage and the corresponding previously undisturbed RMS voltage

Note 1 to entry: For the purposes of this document, the term "variation" has the following meaning: the difference of the values of a quantity before and after a change of an influenced quantity.

3.4.15**rated current**

input or **output current** of the equipment assigned by the manufacturer for a specified operating condition

[SOURCE: IEC 60050-442:1998, 442-01-02 modified — The word "current" has been replaced by "input or output current" and the words "of an accessory" have been deleted.]

3.4.16**active power**

under periodic conditions, mean value, taken over one period T , of the instantaneous power p :

$$P = \frac{1}{T} \cdot \int_0^T p \cdot dt$$

Note 1 to entry: Under sinusoidal conditions, the **active power** is the real part of the complex power.

Note 2 to entry: The SI unit for **active power** is the watt.

Note 3 to entry: DC, fundamental and harmonic voltages contribute directly to the magnitude of the **active power**. Appropriate instruments used to measure **active power** provide sufficient bandwidth to measure relevant non-symmetrical and harmonic power components.

[SOURCE: IEC 60050-131:2002, 131-11-42, modified — The note 3 to entry has been added.]

3.4.17 **apparent power**

product of the RMS values of voltage and current at a port:

$$S = UI$$

[SOURCE: IEC 60050-131:2002, 131-11-41, modified — Only RMS values are considered.]

3.4.18 **power factor**

ratio of the absolute value of the **active power** P to the **apparent power** S :

$$\lambda = \frac{|P|}{S}$$

[SOURCE: IEC 60050-131:2002, 131-11-46, modified — The words "under periodic conditions" have been deleted".]

3.4.19 **DC UPS efficiency**

ratio of output **active power** to input **active power** under specified testing conditions

Note 1 to entry: Test conditions for **DC UPS efficiency** are found in Annex F.

3.4.20 **rated frequency**

input frequency of the equipment assigned by the manufacturer for a specified operating condition

3.4.21 **frequency variation**

variation of the input frequency

3.4.22 **total harmonic distortion** **THD**

ratio of the RMS value of the **harmonic content** of an alternating quantity to the RMS value of the fundamental component quantity

Note 1 to entry: The English abbreviation **THD** is also used in French.

[SOURCE: IEC 60050-551:1998, 551-17-06, modified — The note to entry has been added.]

3.4.23 **harmonic components**

components of the **harmonic content** as expressed in terms of the order and RMS values of the Fourier series terms describing the periodic function

3.4.24

harmonic content

sum of the **harmonic components** of a periodic quantity

Note 1 to entry: The **harmonic content** is a time function.

Note 2 to entry: For practical analysis, an approximation of the periodicity may be necessary.

Note 3 to entry: The **harmonic content** depends on the choice of the fundamental component. If it is not clear from the context which one is used an indication should be given.

[SOURCE: IEC 60050-551:1998, 551-17-04]

3.4.25

transient

behaviour of a variable during transition between two steady states

3.4.26

stored energy time

minimum time during which the **DC UPS**, under specified service conditions, will ensure **continuity of load power**, when the **primary power** fails

3.4.27

cut-off voltage

specified voltage of the **energy storage device** at which it is considered depleted

3.4.28

restored energy time

maximum time required to, under **normal mode** of operation and with the charging capacity installed, recharge the **energy storage device** of the **DC UPS** so that **stored energy time** can again be achieved

3.4.29

ambient temperature

temperature of the air or other medium where the equipment is to be used

Note 1 to entry: During the measurement of the **ambient temperature** the measuring instrument/probe should be shielded from draughts and radiant heating.

[SOURCE: IEC 60050-826:2004, 826-10-03, modified — The adjective "average" has been deleted, and the definition has been rephrased.]

3.5 Input values

3.5.1

input voltage tolerance

maximum variation of steady-state input voltage specified by the manufacturer for **normal mode** operation

3.5.2

input frequency tolerance

maximum variation of steady-state input frequency specified by the manufacturer for **normal mode** operation

3.5.3

input power factor

ratio of the input **active power** to the input **apparent power** with the **DC UPS** operating in **normal mode**, at rated input voltage, rated load and with a fully charged **energy storage device**

3.5.4**DC UPS rated input current**

input current with **DC UPS** operating in **normal mode**, at rated input voltage, rated load and with a fully charged **energy storage device**

3.5.5**DC UPS maximum input current**

input current with **DC UPS** operating in **normal mode**, at worst-case input voltage, rated load and with a fully depleted **energy storage device**

3.5.6**DC UPS inrush current**

maximum instantaneous value of the input current when the **DC UPS** is switched on for **normal mode**

3.5.7**input current distortion**

maximum input current harmonic distortion, in **normal mode**

3.5.8**supply impedance**

impedance at the input terminals to the **DC UPS** with the **DC UPS** disconnected

3.5.9**high impedance failure**

failure where the **supply impedance** is regarded as infinite

3.5.10**low impedance failure**

failure where the **supply impedance** is negligible

3.5.11**prospective short-circuit current**

I_{cp}
RMS value of the current which would flow if the supply conductors to the circuit are short circuited by a conductor of negligible impedance

3.6 Output values**3.6.1****output voltage**

DC value (unless otherwise specified for a particular load) of the voltage across the **DC UPS** output terminals

3.6.2**output voltage tolerance**

maximum variation of steady-state **output voltage** with the **DC UPS** operating in **normal mode** or in stored energy mode

3.6.3**output current**

DC value of the current (unless otherwise specified for a particular load) from the output terminals

3.6.4**overload capability**

ratio of **output current** to **rated current** over a given time

3.6.5

output power

power available at the **DC UPS** output terminals

3.6.6

load sharing

simultaneous supply of power to a load from two or more power sources

EXAMPLE One load bus being supplied from two or more paralleled **DC UPS** units.

Note 1 to entry: The share allocated to each power source is not necessarily the same.

3.6.7

rated output power

continuous **output power** as declared by the manufacturer

3.6.8

ripple voltage

alternating voltage component of the voltage on the DC side of a **functional unit**

[SOURCE: IEC 60050-551:1998, 551-17-27, modified — The word "convertor" has been replaced by "functional unit".]

4 Environmental conditions

4.1 Test environment

The test environment applicable to this document shall, unless otherwise agreed between manufacturer/supplier and purchaser, comply with pollution degree 2 of IEC 60664-1 and the conditions defined in Clause 4.

NOTE Pollution degree is a characteristic of an environment and is detailed in IEC 60664-1 from where the following is derived.

- Pollution degree 1 applies where there is no pollution or only dry, non-conductive pollution.
- Pollution degree 2 applies where there is only non-conductive pollution that might temporarily become conductive due to occasional condensation.
- Pollution degree 3 applies where a local environment within the equipment is subject to conductive pollution, or to dry non-conductive pollution that could become conductive due to expected condensation.

4.2 Normal conditions

4.2.1 Operation

4.2.1.1 Ambient temperature and relative humidity

A **DC UPS** shall perform as rated when operating within the following minimum ambient ranges:

- temperature +15 °C to +30 °C;
- relative humidity 10 % to 75 % non-condensing.

*Compliance is verified when the **DC UPS** passes the test specified in 6.5.3.*

NOTE A requirement for the **DC UPS** to perform when operating beyond the minimum ambient ranges is considered an unusual condition. See 4.3.

Compliance with the temperature and relative humidity ranges above is verified in accordance with IEC TR 60721-4-3 when performed as described in 6.5.3. Refer to Annex G for further clarification.

4.2.1.2 Altitude

A **DC UPS** conforming to this document shall be designed to operate as rated at an altitude up to and including 1 000 m above sea level.

If agreed between the manufacturer/supplier and the purchaser that the **DC UPS** shall operate at a specific altitude in excess of 1 000 m, the manufacturer shall state, for that altitude:

- new **rated output power**, if different from the **rated output power** specified for normal conditions.

NOTE The following Table 1 is provided for guidance. It is an example of the power derating required by altitude.

Table 1 – Example of power derating factors for use at altitudes above 1 000 m

Altitude		Derating factor	
m	feet	Convection cooling	Forced air cooling
1 000	3 300	1,000	1,000
1 200	4 000	0,994	0,990
1 500	5 000	0,985	0,975
2 000	6 600	0,970	0,950
2 500	8 300	0,955	0,925
3 000	10 000	0,940	0,900
3 500	11 600	0,925	0,875
3 600	12 000	0,922	0,870
4 000	13 200	0,910	0,850
4 200	14 000	0,904	0,840
4 500	15 000	0,895	0,825
5 000	16 500	0,880	0,800

This table is derived from ANSI C57.96-1999 for loading of dry-type distribution and power transformers.
Values are generally calculated by interpolation for altitudes not listed.

4.2.2 Storage and transportation

DC UPS equipment conforming to this document shall accept stationary storage within a building and be transportable in its normal shipping container by a commercial and pressurized aircraft, cargo ship or by truck, within the following minimum ambient ranges:

- temperature -25 °C to $+55\text{ °C}$;
- relative humidity 10 % to 95 % (non-condensing).

*Compliance is verified when the **DC UPS** passes the test specified in 6.5.2.*

Containers not designed for wet (condensing) ambient conditions shall be marked by adequate warning labels.

Unless otherwise declared by the **DC UPS** manufacturer, **DC UPS** equipment conforming to this document shall be able to be stored at an altitude with equivalent air pressure of not less than 70 kPa.

NOTE The air pressure at an altitude of 3 000 m above sea level is approximately 70 kPa.

The stored energy device may require other storage and transportation conditions, for example for a **battery** the duration of high or low **ambient temperature** can affect the **battery**

life. The **battery** manufacturer typically provides instructions for **battery** transportation, storage and recharging.

4.3 Unusual conditions

4.3.1 General

4.3 lists conditions that, subject to an agreement between the manufacturer and the purchaser, require special design and/or special protection features. The purchaser shall identify any requirements that deviate from the normal conditions in 4.2.

4.3.2 Operation

Unusual operating conditions to be identified include the following:

- pollution degree in excess of 2 (see Note in 4.1);
- temperature and relative humidity conditions exceeding the ranges listed in 4.2;
- altitude conditions exceeding those listed in 4.2;
- exposure to abnormal vibration, shocks, tilting;
NOTE 1 This is a concern for **DC UPS** installed in a vehicle or marine vessel.
- exposure to earthquake acceleration forces;
NOTE 2 More details are given in IEC 60068-3-3.
- electromagnetic immunity exceeding the applicable requirements in IEC 62040-2;
- radioactive immunity to radiation levels exceeding those of the natural background;
- any of the following: moisture, steam, fungus, insects, vermin dust, abrasive dust, corrosive gases, salt laden air or contaminated cooling refrigerant, damaging fumes, explosive mixtures of dust or gases, restriction of ventilation (for **DC UPS** and/or **battery**), radiated or conducted heat from other sources.

4.3.3 Storage and transportation

Unusual storage and transportation conditions to be identified include the following:

- temperature and relative humidity conditions exceeding the ranges listed in 4.2;
- altitude conditions exceeding those listed in 4.2;
- exposure to abnormal vibration, shocks, tilting and to earthquake acceleration forces;
- special transportation and equipment handling requirements.

5 Electrical conditions, performance and declared values

5.1 General

5.1.1 DC UPS configuration

The **DC UPS** manufacturer/supplier shall declare and describe the **DC UPS** configuration, including

- quantity of **DC UPS units** and their topology,
- redundancy configuration as applicable, and
- any **DC UPS switch** necessary for connection, interruption, transfer, or isolation.

The declaration and its description may reference the applicable subclauses and figures in Annexes A and B and can be contained in a technical data sheet. Annex C presents a technical data sheet for guidance. This data sheet may be included in the **DC UPS** user manual.

5.1.2 Markings and instructions

DC UPS complying with this document shall be marked and supplied with adequate instructions for the installation and operation of the **DC UPS** for its controls and indications.

5.2 DC UPS input specification

5.2.1 Conditions for normal mode operation

A **DC UPS** conforming to this document shall be compatible with public low-voltage supplies and be capable of remaining in **normal mode** of operation when connected to an AC input supply presenting characteristics as follows:

- a) **rated voltage**;
- b) **RMS voltage variation** $\pm 10\%$ of **rated voltage**;
- c) **rated frequency**;
- d) **frequency variation** $\pm 2\%$ of **rated frequency**;
- e) for three-phase input, voltage unbalance with an unbalance ratio of 5 %;
- f) **total harmonic distortion (THD)** of voltage $\leq 8\%$ with a maximum level of individual harmonic voltages according to the compatibility levels for individual harmonic voltages in low-voltage networks given in Table 2. See Note 3 below;
- g) **transient** voltages, superimposed high-frequency voltages and other electrical noise such as that caused by lightning or capacitive or inductive switching; within the applicable electromagnetic immunity levels prescribed in IEC 62040-2.

NOTE 1 A decrease in frequency is assumed not to coincide with an increase in AC line voltage and vice versa.

NOTE 2 The above limits apply to public low voltage AC supplies. **DC UPS** designed for industrial applications or separately generated supplies are generally required to meet more severe conditions. The purchaser then specifies such conditions as applicable. In the absence of such information, the manufacturer/supplier applies their experience as to the compatibility of the design for the intended installation.

NOTE 3 Compatibility levels for individual harmonic voltages in public low-voltage networks are specified in IEC 61000-2-2. The Table 2 below is an extract from IEC 61000-2-2:2002 presenting such compatibility levels (RMS values as percent of RMS value of the fundamental component).

Table 2 – Compatibility levels for individual harmonic voltages in low voltage networks

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3 ^a		Even harmonics	
Harmonic order	Harmonic voltage	Harmonic order	Harmonic voltage	Harmonic order	Harmonic voltage
<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
5	6	3	5	2	2
7	5	9	1,5	4	1
11	3,5	15	0,4	6	0,5
13	3	21	0,3	8	0,5
$17 \leq n \leq 49$	$2,27 \times (17/n) - 0,27$	$21 \leq n \leq 45$	0,2	$10 \leq n \leq 50$	$0,25 \times (10/n) + 0,25$

^a The levels given for odd harmonics that are multiples of three apply to zero sequence harmonics. Also, on a three-phase network without a neutral conductor or without load connected between line and ground, the values of the 3rd and 9th harmonics may be much lower than the compatibility levels, depending on the unbalance of the system.

5.2.2 Input characteristics to be declared by the manufacturer

The manufacturer shall declare the actual and applicable input characteristics. In addition to those covered in 5.2.1, the following characteristics shall be declared:

- a) number of phases;
- b) neutral requirements;
- c) **rated current**;
- d) **power factor at rated current**;
- e) inrush current characteristics;
- f) maximum steady state current at the worst-case condition, including the effect of **battery** charging, mains tolerance (for example $\pm 10\%$ voltage tolerance) and any continuously permitted overload; and, where applicable, curve of current against time;
- g) **total harmonic distortion (THD)** of current and minimum **prospective short-circuit current (I_{cp})** required from the AC input supply for compliance with the **THD** of current declared;

NOTE 1 For THD current compliance purposes the minimum **prospective short-circuit current** requirement is generally given as a multiple of the rated input current of the **DC UPS**. The value is typically 33 times for rated input current ≤ 300 A and 20 times for rated input current > 300 A. For example for a **DC UPS** with 16 A of rated input current, the minimum **prospective short-circuit current** from the AC input supply is 33×16 A = 528 A.

- h) earth leakage current characteristics (where in excess of 3,5 mA);
- i) AC power distribution system compatibility (TN, TT or IT as defined in IEC 60364-1).

NOTE 2 The declaration when in the form of a technical data sheet is typically included in the user manual. Annex C presents a technical data sheet for guidance.

5.2.3 Characteristics and conditions to be identified by the purchaser

The purchaser shall identify any conditions and characteristics that are more severe than those declared by the manufacturer.

Further, the purchaser shall identify any particular conditions that may be required by national wiring regulation and any adverse or special service conditions including

- a) pre-existing harmonic voltage distortion when in excess of 75 % of the IEC 61000-2-2 compatibility levels at the intended point of coupling of the **DC UPS**. Refer to Note 3 in 5.2.1,
- b) requirements for compatibility with characteristics of protective devices of the **DC UPS** input supply,
- c) requirements for all-pole isolation of the **DC UPS** from the AC input supply, and
- d) stand-by power generator characteristics, if any.

NOTE IEC 60034-22 presents characteristics for internal combustion engine-driven generating sets.

Such service conditions and **deviations** may require special design and/or protection features.

5.3 DC UPS output specification

5.3.1 Conditions for the DC UPS to supply a load

Subject to either

- the input conditions of 5.2.1 being satisfied, or
- the **energy storage device** being available,

a **DC UPS** conforming to this document shall be capable of supplying loads intended for connection to a **DC distribution network** and that are compatible with the output characteristics of the **DC UPS** as declared by the manufacturer.

5.3.2 Characteristics to be declared by the manufacturer

The manufacturer shall declare the actual and applicable output characteristics, including the following:

- a) performance classification *XX* in accordance with 5.3.4;
- b) **rated voltage**, for example 380 V DC;
- c) identification of polarities available for load connection, as defined in 312.2.4 of IEC 60364-1:2005, for example L+, L-. The midpoint M shall be identified only if it is intended to carry load current, for example L+, M, L-;
- d) grounding compatibility (TN, TT or IT as defined in 312.2.4 of IEC 60364-1:2005); including information about what polarities, if any, may be earthed by the installer;
- e) polarity grounding techniques;
- f) AC component (**ripple voltage**);
- g) **rated output power** (W) and **rated current**;
- h) **overload capability**;
- i) **current limit** identification given by the ratio of current limitation to rated **output current** which can be supplied by the **DC UPS** for a specified time;
- j) fault clearing capability: the rated fault clearing capability shall be given as the maximum load protective device **rating** with which the **DC UPS** can co-ordinate under fault conditions;
- k) no-load losses and **DC UPS efficiency** at 100 %, 75 %, 50 % and 25 % **reference test load** (refer to Annex F for guidance);

NOTE 1 Efficiency values at intermediate load values are generally calculated.

NOTE 2 The declaration when in the form of a technical data sheet is typically included in the user manual. Annex C presents a technical data sheet for guidance including particular performance characteristics under abnormal conditions, for example high AC input voltage.

5.3.3 Characteristics and conditions to be identified by the purchaser

The purchaser shall identify any condition and characteristic that are more severe but not limited to than those declared by the manufacturer.

Further, the purchaser shall identify any particular condition that may be required by national wiring regulation and any adverse or special load condition, including

- a) inrush and start-up characteristics,
- b) time varying characteristics including period and duty cycle,
- c) independent earthing of any output polarity required,
- d) load distribution facilities,
- e) requirements for all polarities of the **DC UPS** to be isolated from the load via a disconnect device,
- f) coordination requirements with downstream protective devices,
- g) future extension/expansion requirements,
- h) functional safety (see IEC 61508 (all parts)),
- i) degree of redundancy (see Annex A), and
- j) automatic load shedding.

5.3.4 Performance classification

The manufacturer shall classify the **DC UPS** complying with this document in accordance with the coding

XX

where X is an alpha character.

The first X character denotes the **output voltage** variation from steady-state when operating in **normal mode** and a **step load** is applied as defined in 6.4.2.9.3.

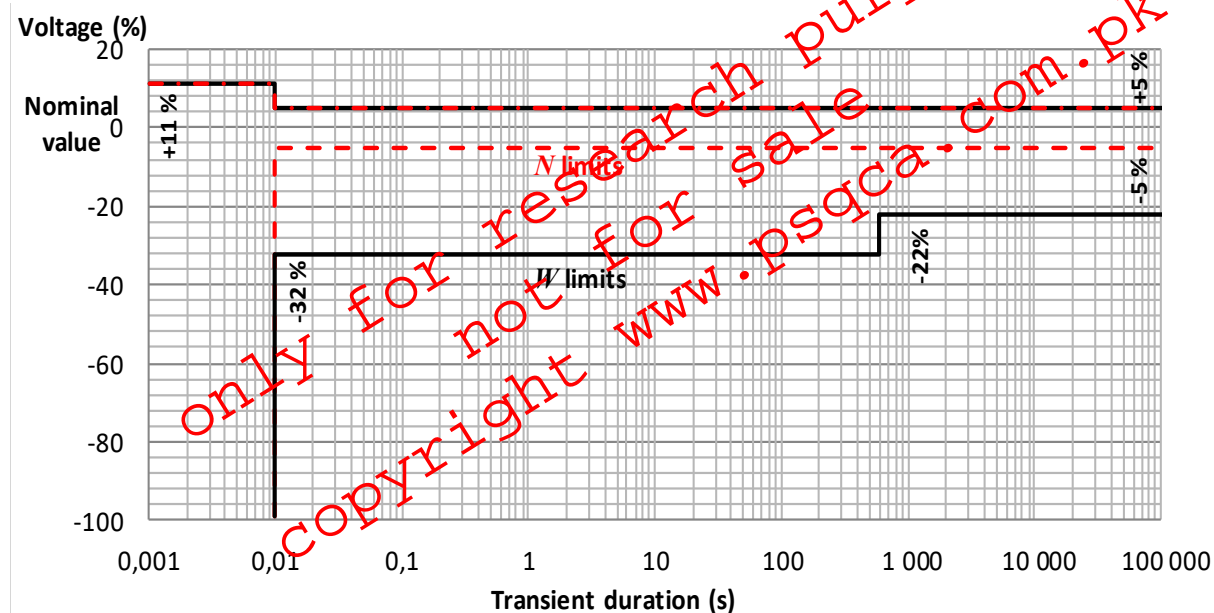
The second X character denotes the **output voltage** variation from steady-state when operating in **stored energy mode** and a **step load** is applied as defined in 6.4.2.9.4.

X shall take on one of the following meanings:

N = narrowband **output voltage** variation

W = wideband **output voltage** variation

The **DC UPS** dynamic **output voltage** performance requirements are defined by the limits in Figure 2.



IEC

Figure 2 – Dynamic output performance

Compliance with the dynamic output performance declared is verified by performing the electrical **type tests** described in 6.4.2.9 and 6.4.3 and by observation that test results obtained are within the limits of the applicable limit in Figure 2.

NOTE 1 The limits mentioned in Figure 2 are representative of requirements for switch-mode power supplies compatible with ITU-T L.1200 requirements.

NOTE 2 The objective of classifying **DC UPS** by performance is to provide a common base on which all **DC UPS** manufacturers/supplier's data are evaluated. This enables purchasers, for similar **DC UPS** power ratings, to compare products from different manufacturers under the same measurement conditions.

NOTE 3 Purchasers are reminded that due to the diversity of load types, **DC UPS** manufacturers' data are based on industry standard test loads that simulate typical load applications expected.

NOTE 4 The actual performance in a given application is subject to variation under **transient** conditions since actual load ratings, individual sequencing, and start currents are likely to differ from the standardized test situations.

NOTE 5 A **DC UPS** with performance classification NW represents an example of a **DC UPS** with a narrow-band **output voltage** in **normal mode** and with a wide-band **output voltage** in stored energy mode (for example a direct energy storage connect single conversion topology **DC UPS**). The **DC UPS** has a dynamic voltage response

conforming to curve *N* of Figure 2 upon a **step load** in **normal mode**. The **DC UPS** has a dynamic voltage response conforming to curve *W* of Figure 2 upon change into stored energy mode and upon a **step load** in stored energy mode.

NOTE 6 Refer to Annex E for guidance on measurement techniques.

NOTE 7 The performance is generally determined by the **DC UPS** topology – refer to Annex B.

5.4 Stored energy specification

5.4.1 General

5.4 specifies details that apply to a **secondary battery**, presently the most common technology selected to provide energy storage for use when the AC input supply is unavailable.

It is recognized that other technologies, for example flywheel systems, may replace the need for a **battery** system. Such technologies may be fully compatible with **DC UPS** characteristics primarily intended for batteries. With this in mind, subject to an agreement between the manufacturer/supplier and the purchaser and where applicable, the specification may be used for other stored energy technologies.

5.4.2 Battery

5.4.2.1 Requirements for all batteries

A **battery** intended to serve as an **energy storage device** for a **DC UPS** complying with this document shall comply with the applicable clauses of IEC 62040-1 regarding safety requirements for location, ventilation, marking and protection of a **battery**.

5.4.2.2 Characteristics to be declared by the manufacturer

The manufacturer shall either declare the following **battery** characteristics in the user manual or in the **DC UPS** technical data sheet (see Table C.1):

- a) expected life (either design life or float service life – but not both);
- b) quantity of blocks or cells and of paralleled strings;
- c) nominal voltage of total **battery**;
- d) **battery** technology (vented or valve-regulated, lead-acid, NiCd, etc.);
- e) nominal capacity of total **battery**;
- f) **stored energy time** (see 6.4.4.1);
- g) **restored energy time**;
- h) ambient reference temperature;
- i) polarities, if any, that are earthed by the installer (remote **battery** only);
- j) RMS ripple current during **normal mode** of **DC UPS** operation

When a remote **battery** is part of the supply, and if the power cabling and/or **battery** protection is not part of the supply, the following additional characteristics shall be declared:

- k) maximum **battery** current at the end of the discharge during stored energy mode as specified by the manufacturer;
- l) DC fault current **rating**;
- m) cable voltage drop recommendation between the remote **battery** and the **DC UPS** if of topology other than direct connection;
- n) overcurrent protection requirements;

The manufacturer/supplier shall supply the following additional information if requested by the purchaser:

- o) charging regime, for example constant voltage, constant current, boost or equalization capability, two-state charging;
- p) charging voltage and **tolerance band**;
- q) end of discharge voltage;
- r) charging **current limit** or range.

5.4.2.3 Characteristics and conditions to be identified by the purchaser

The purchaser shall identify any requirements, characteristics and conditions that deviate or are more severe than those listed in 5.4.2.1 and 5.4.2.2. This includes any particular conditions required by national regulation and any adverse or special service conditions including when a **battery** is supplied by third parties.

NOTE National regulations may specify a minimum back-up autonomy time and define the type of **energy storage device** to be used.

5.5 DC UPS switch specification

DC UPS switches supplied as an integral part of a **DC UPS** are covered by the prescribed electrical service conditions and performance requirements in this Clause 5 and need not to be specified separately.

Switches that are supplied separately, intended to operate in conjunction with the **DC UPS** shall be compatible with the applicable electrical service conditions and performance requirements of the **DC UPS**, and shall be specified in compliance with their own product standard.

Examples of product standards that apply to particular switches are

- automatic transfer systems (ATS): IEC 60947-6-1, and
- manual isolation, tie and transfer switches: IEC 60947-3.

5.6 Communication circuits

The manufacturer shall provide adequate instructions for use and installation of any communication and signaling circuits supplied as an integral part of the **DC UPS** and intended to be connected to information technology equipment, for example programmable logic computers, local area networks (LAN) or to telecommunication networks.

6 DC UPS tests

6.1 Summary

6.1.1 Venue, instrumentation and load

6.1.1.1 Test venue

A **DC UPS** shall generally be tested at the manufacturer's premises and in accordance with Table 3.

Tests may be performed on the **DC UPS** in its complete form or, alternatively, on a **functional unit**.

Testing of **DC UPS** may require facilities that are not available at the manufacturer's premises and/or facilities that are not economically justified within the scope of a particular supply. The manufacturer may then elect to

- a) use a third party competent body to carry out compliance testing on the manufacturer's behalf. Evidence of third party certification shall be deemed sufficient to prove compliance with the relevant clauses;
- b) demonstrate by calculation or by experience and/or testing of similar designs or sub-assemblies in similar conditions and through compilation of a technical construction file that the design is compliant. Evidence through a technical construction file shall be deemed sufficient to prove compliance with the relevant clauses;
- c) defer, subject to an agreement with the purchaser, applicable tests to be performed on site (see 6.3).

Separate tests on diverse **functional units** may be necessary for large and/or complex **DC UPS** configurations that cannot be completely tested prior to delivery on site. When such necessity arises, the **functional unit** test of 6.6 applies and the manufacturer/supplier and the purchaser should agree on conditions for final site testing. The manufacturer's recommendation should be followed in this respect.

6.1.1.2 Test instrumentation

Instruments used for the measurement of electrical parameters shall have sufficient bandwidth to accurately measure true RMS value on waveforms which may be other than a fundamental sinewave, i.e. may present considerable **harmonic content**. Whichever type of instrumentation is used, its accuracy shall be in relation to the characteristic being measured and regularly calibrated in accordance with applicable standards. Refer to IEC 61000-4-30 for guidance on selection of instrumentation.

6.1.1.3 Test load

Load tests are performed by connecting loads to the **DC UPS** output to simulate representative actual load conditions or by connecting the actual load when available.

Routine and **type tests** shall be performed as prescribed in the relevant test clause, for example no-load, **light load**, **resistive load**, **constant power load** or **reference test load**.

Where not otherwise prescribed in the relevant test clause, load tests shall be performed with **reference test load**.

Large **DC UPS** that operate in parallel connection may be load-tested by testing individual **DC UPS units** separately.

NOTE In particular cases, a special load, including the actual site load, may be used if agreed upon between manufacturer/supplier and purchaser.

6.1.2 Routine test

Routine tests shall be performed on each **DC UPS** to verify that the requirements of this document are met. **Routine tests** are generally performed before delivery, at the manufacturer's premises. **Routine tests** are listed in Table 3 and detailed in 6.2.

Test of characteristics other than those covered by **routine tests** is subject to an agreement between the manufacturer and the purchaser.

6.1.3 Site test

Uninterruptible power systems covered by this document vary from complete small **movable DC UPS** with integral batteries, to large multi-module **DC UPS** that may be delivered as separate **functional units** intended for final assembly and wiring on site. Such large **DC UPS** may require their final performance test to be completed on site. Refer to 6.3 for more details.

6.1.4 Witness test

In addition to the **routine tests** performed by the manufacturer, the purchaser may wish their representative to witness testing of selected items of Table 3 and/or of other specific items.

Witness tests are subject to an agreement between the manufacturer and the purchaser.

NOTE The purchaser may evaluate the need for witness testing taking into account the manufacturer's quality assurance status.

6.1.5 Type test

Type tests shall be performed on a **DC UPS** that represents a series of substantially identical products. **Type tests** are intended to assure that such identical products become compliant with their full specification when produced under relevant quality standards and after having passed the **routine tests** detailed in 6.2. The **DC UPS** used for type-testing is not necessarily supplied to any purchaser. **Type tests** are listed in Table 3 and detailed in 6.4 and 6.5.

6.1.6 Schedule of tests

Tests shall be performed in accordance with Table 3.

Table 3 – DC UPS test schedule

Test description	Routine test	Type test	Subclause
Cable and interconnection check	x	x	6.2.2.2
Control device(s)	x	x	6.2.2.3 a)
Protective device(s)	x	x	6.2.2.3 b)
Auxiliary device(s)	x	x	6.2.2.3 c)
Supervisory, monitoring, signalling device(s)	x	x	6.2.2.3 d)
Auto transfer to stored energy mode and back to normal	x	x	6.2.2.3 e)
Manual disconnection/reconnection	x	x	6.2.2.3 f)
No load	x	x	6.2.2.4
Full load	x	X	6.2.2.5
AC input failure	x	x	6.2.2.6
AC input return	x	x	6.2.2.7
Input supply compatibility			
Steady-state input voltage tolerance		X	6.4.1.2
Input frequency tolerance		X	6.4.1.3
Input inrush current		X	6.4.1.4
Harmonic distortion of input current		X	6.4.1.5
Power factor		X	6.4.1.6
Efficiency		X	6.4.1.7
Stand-by power generator compatibility		X	6.4.1.8
Phase rotation test		X	6.4.1.9
Output – Resistive load			
Normal mode – No load		X	6.4.2.1
Normal mode – Full load		X	6.4.2.2
Stored energy mode – No load		X	6.4.2.3
Stored energy mode – Full load		X	6.4.2.4
Load sharing test		X	6.4.2.5

Test description	Routine test	Type test	Subclause
Output overvoltage test		X	6.4.2.6
Periodic output voltage variation test (modulation)		X	6.4.2.7
Overload – Normal mode		X	6.4.2.8.1
Overload – Stored energy mode		X	6.4.2.8.2
Fault clearing capability – Normal mode		X	6.4.2.8.3
Fault clearing capability – Stored energy mode		X	6.4.2.8.4
Dynamic performance – Normal to stored energy mode		X	6.4.2.9.1
Dynamic performance – Stored energy to normal mode		X	6.4.2.9.2
Dynamic performance – Step load – Normal mode		X	6.4.2.9.3
Dynamic performance – Step load – Stored energy mode		X	6.4.2.9.4
Simulation of parallel redundant DC UPS fault		X	6.4.2.10
Output – Constant power load			
Output characteristics – Constant power load		X	6.4.3
Stored and restored energy times			
Stored energy time		X	6.4.4.1
Restored energy time		X	6.4.4.2
Battery ripple current			6.4.4.3
Restart test		X	6.4.4.4
Environmental			
Repetitive shock during transportation		X	6.5.1.2
Free-fall during transportation		X	6.5.1.3
Storage in dry heat, damp heat and cold environments		X	6.5.2
Operation in dry heat, damp heat and cold environments		X	6.5.3
Acoustic noise		X	6.5.4

6.2 Routine test procedure

6.2.1 Environmental

No **routine tests** are required.

NOTE Refer to 6.5 for environmental **type tests**.

6.2.2 Electrical

6.2.2.1 Insulation and dielectric

Insulation and dielectric is a safety requirement not within the scope of this document.

NOTE Insulation and dielectric compliance is verified during the applicable **DC UPS** safety test.

6.2.2.2 Cable and interconnection check

The **DC UPS** shall be inspected in accordance with the manufacturer's installation and wiring diagrams to determine that

- all AC supply terminals are connected to the AC input supply, all DC supply terminals are connected to the DC input supply from the stored energy source (as applicable) and to the load, and
- any communication circuit is connected as required.

Further, all temporary test connections introduced or removed during any insulation and dielectric tests shall be confirmed as having been restored to their normal condition.

Compliance is checked by inspection.

6.2.2.3 Light load and functionality

The **light load** test is a functional test carried out to verify that the **DC UPS** is correctly connected and that all functions operate properly. The load applied is limited, for practical and cost reasons, to a percentage of the **rated value**, for example 10%. Correct operation of the following shall be verified:

- a) all control switches and other means to activate **DC UPS** operation;
- b) protective devices (refer to 7.5.3 of IEC 60146-1-1:2009);
- c) auxiliary devices, such as contactors, fans, outlets, annunciators and communication devices;
- d) supervisory, monitoring and remote signalling devices (if any);
- e) auto transfer to stored energy mode and back to **normal mode** by failing and subsequently restoring the AC input voltage;

NOTE This test is typically performed in conjunction with AC fail/return tests of 6.2.2.6 and 6.2.2.7.

- f) Manual disconnection of a **DC UPS unit** part of a **parallel DC UPS** configuration followed by manual reconnection. This test applies to **parallel redundant DC UPS's** only.

Compliance is verified by observation that the devices and functions intended to control, protect, supervise, measure and signal DC UPS activities perform as expected and that the load voltage remains within specified values during the manual and automatic transfers.

6.2.2.4 No load

The **DC UPS output voltage** shall remain within the specified values when the **DC UPS** operates at nominal input voltage and frequency and with no load connected at the output.

Compliance is checked by test.

6.2.2.5 Full load

The **DC UPS** shall remain in **normal mode** of operation and its **output voltage** within the specified values when operating at nominal input voltage and frequency while supplying a **reference test load**.

Large **DC UPS** in parallel connection may be load tested by testing the individual **DC UPS units** separately or as a whole.

Compliance is checked by test.

6.2.2.6 AC input failure

The test shall be performed with a **battery** or other appropriate DC source. The input failure is simulated by interrupting the AC input as far upstream as practical and carried out in accordance with Annex D.

The **DC UPS** shall not be damaged during operation with the loss of one input phase (**type test** only).

Compliance is verified by test when, following the input AC failure, the DC UPS operates in stored energy mode within steady state output voltage limits specified in 5.3.4.

6.2.2.7 AC input return

This test shall be performed either by restoring the **AC input power**, or simulated by energizing all **DC UPS** input feeders at the same time. This test shall be performed with an **energy storage device** connected.

Proper operation of all **DC UPS rectifiers**, including walk-in, if applicable, shall be observed. **DC output voltage** variations shall also be measured.

*Compliance is verified by test when, following the input AC return, the **DC UPS** operates in **normal mode** within steady state **output voltage** limits specified in 5.3.4.*

NOTE 1 Walk-in is a function that controls the input AC current so that it increases gradually within a specified time when the **DC UPS** starts or restarts. Walk-in is also called soft-start.

NOTE 2 This test is generally performed in conjunction with the **light load** test of 6.2.2.3 e).

6.3 Site test procedure

DC UPS that are delivered as separate **functional units** intended for final on-site assembly and wiring require their final performance tests to be completed on site. The site test procedure generally consists of the manufacturer's commissioning procedure and of completion of any **routine tests** of Table 3 that were not completed prior to delivery.

Site tests shall preferably occur under conditions representing those of actual service and shall use the load available on site. The load shall not exceed the rated continuous load of the complete **DC UPS** as configured on site.

Where not otherwise prescribed in the relevant test clause, tests shall be performed with **reference test load**

NOTE 1 When subject to an agreement with the **DC UPS** manufacturer, the purchaser formulates a specific site acceptance test (SAT) schedule as part of a purchase contract.

NOTE 2 For economic reasons and to avoid unnecessary stress to the **DC UPS**, the purchaser generally confine to the site-test schedule to verify essential characteristics not otherwise verified.

6.4 Type test procedure (electrical)

6.4.1 Input – AC supply compatibility

6.4.1.1 General

The AC input supply shall present the applicable characteristics declared for the **DC UPS** (see 5.2.2 i)) and be capable of

- maintaining the voltage waveform within the limits of 5.2.1 when the **DC UPS** operates in **normal mode** at rated **DC output power** (see Note 3 in 5.2.1), and
- providing a variable frequency and voltage within the characteristics declared for the **DC UPS** input (see 5.2.1).

Alternative test methods in the absence of a variable frequency/voltage generator are permitted.

6.4.1.2 Steady-state input voltage tolerance

With the **DC UPS** in **normal mode** of operation and input set at nominal, the input voltage shall be adjusted to the minimum and maximum values of the tolerance range declared by the manufacturer. The **DC UPS** shall remain in **normal mode** of operation over the specified tolerance range with the ability to recharge the **battery**.

The **DC UPS output voltage** shall be measured and its tolerance recorded at nominal, minimum and maximum input voltage.

Where the design of the **DC UPS** prevents **normal mode** of operation above 10 % of nominal supply voltage by a change of mode to stored energy mode, the value recorded shall be the voltage prior to change of mode. The input voltage shall be the maximum rated input voltage to ensure operation without circuit damage.

6.4.1.3 Input frequency tolerance

The steady-state **input voltage tolerance** test (see 6.4.1.2) shall be repeated with the input frequency adjusted to the limits specified by the manufacturer in conjunction with the input voltage variations. The **DC UPS** shall remain operating in **normal mode**.

NOTE A decrease in frequency is assumed not to coincide with an increase in line voltage, and vice versa.

6.4.1.4 Inrush current

Two inrush current tests shall be performed sequentially. The first test shall be performed after an absence of input voltage for more than 5 min.

The subsequent test shall be performed after an absence of input voltage for 1 s. If the **DC UPS** topology requires a time delay greater than 1 s, the test shall be performed with the manufacturer specified delay, which shall be stated in the installation instructions.

For the purpose of this test, initial current surges attributable to energization of RFI capacitors in input filters with a time duration of less than 1 ms shall be disregarded.

The **prospective short-circuit current (I_{cp})** of the **AC input power** supply shall be at least 33 times the rated input current of a **DC UPS** with rated input current less than 300 A or at least 20 times for **DC UPS** with rated input current over 300 A. Testing at an (I_{cp}) lower than specified is permitted when the test result is corrected by an appropriate calculation.

The input supply shall be switched on to the **DC UPS** input coincident with various angular points on the input voltage waveform in order to determine the worst-case inrush current condition.

NOTE The worst-case inrush current will normally be found for transformer coupled units, when switched on at the zero voltage point and for direct rectifier/capacitor loads at or near the peak of the input supply voltage waveform.

*Compliance is verified when the inrush current to the **DC UPS** input is within the limit declared by the manufacturer.*

6.4.1.5 Harmonic distortion of input current

The harmonic distortion of the input current is tested at nominal power up to the 50th harmonic using the **reference test load**.

*Compliance is verified when the **total harmonic distortion (THD)** of input current to the **DC UPS** is within the limits declared by the manufacturer.*

6.4.1.6 Power factor

The **input power factor** is tested at **reference test load** in **normal mode** of operation and at rated AC input supply conditions as defined in 5.2.1.

*Compliance is verified when the **input power factor** of the **DC UPS** input current is equal or greater than that declared by the manufacturer*

6.4.1.7 Efficiency

The no-load losses and the **DC UPS efficiency** at 100 %, 75 %, 50 % and 25 % **reference test load** shall be measured as prescribed in Annex F.

Compliance is verified when no-load losses measured is equal or lower than that declared by the manufacturer and when the computed efficiency values are equal to or greater than those declared by the manufacturer.

6.4.1.8 Stand-by power generator compatibility test

The applicable **routine tests** listed in Table 3 shall be repeated using the output of a stand-by power generator as the source of input supply. The characteristics of the stand-by power generator shall be specified by the manufacturer.

Compliance is verified by test.

NOTE 1 This test is generally performed in conjunction with the **input voltage tolerance** tests (see 6.4.1.2 and 6.4.1.3).

NOTE 2 Subject to an agreement between the manufacturer/supplier and the purchaser, this test is performed on site.

NOTE 3 IEC 60034-22 presents characteristics for internal combustion engine-driven generating sets.

6.4.1.9 Phase rotation test

With the **DC UPS** operating in **normal mode** with fully charged batteries and at **light load** the input source is to be removed. The input source phase rotation is then to be reversed and reapplied to the **DC UPS** rectifier input.

*Compliance is verified when the **output voltage** of the **DC UPS** remains within the applicable tolerance of Figure 2.*

6.4.2 Output characteristics – Resistive load

6.4.2.1 Normal mode – No load

With the **DC UPS** operating under steady-state conditions at no load, in **normal mode** and at nominal input voltage, measure the DC **output voltage** (V_0) and the AC component (**ripple voltage**).

The frequencies of concern for **ripple voltage** measurements are 1 Hz to 150 kHz.

*Compliance is verified when $[(V_0 - V_{Rated}) / V_{Rated}] * 100$ (%) is within the limits of the performance classification declared in 5.3.2 a) and when the AC component (**ripple voltage**) is within the limit declared in 5.3.2 f).*

6.4.2.2 Normal mode – Full load

With the **DC UPS** operating under steady-state conditions at 100 % **reference test load**, in **normal mode** and at nominal input voltage, measure the DC **output voltage** (V_{100}) and the AC component (**ripple voltage**).

The frequencies of concern for ripple voltage measurements are 1 Hz to 150 kHz.

*Compliance is verified when $[(V_{100} - V_{Rated}) / V_{Rated}] * 100$ (%) is within the limits of the performance classification declared in 5.3.2 a) and when the AC component (**ripple voltage**) is within the limit declared in 5.3.2 f).*

6.4.2.3 Stored energy mode – No load

With the **DC UPS** operating under steady-state conditions at no load and in stored energy mode, measure the DC **output voltage** (V_0) and the AC component (**ripple voltage**).

This test is required for *XN* output type only (see 5.3.4).

The frequencies of concern for **ripple voltage** measurements are 1 Hz to 150 kHz

*Compliance is verified when $[(V_0 - V_{Rated}) / V_{Rated}] * 100$ (%) is within the limits of the performance classification declared in 5.3.2 a) and when the AC component (**ripple voltage**) is within the limit declared in 5.3.2 f).*

6.4.2.4 Stored energy mode – Full load

With the **DC UPS** operating under steady-state conditions at 100 % **reference test load** and in stored energy mode, measure the DC **output voltage** (V_{100}) and the AC component (**ripple voltage**). This test requires instrumentation with scanning time sufficient to observe changes resulting from the energy storage device voltage fall with time. For **DC UPS** with an energy storage device rated for less than 10 min, it is permissible to connect an additional **battery** or a substitute DC power supply to enable testing and to stabilize measurements.

This test is required for *XN* output type only (see 5.3.4).

The frequencies of concern for **ripple voltage** measurements are 1 Hz to 150 kHz

*Compliance is verified when $(V_{100} - V_{Rated}) / V_{Rated} * 100$ (%) is within the limits of the performance classification declared in 5.3.2 a) and when the AC component (**ripple voltage**) is within the limit declared in 5.3.2 f).*

6.4.2.5 Load sharing test

Load sharing shall be measured for reference (at the output of two or more **DC UPS units** in parallel configuration) in accordance with the manufacturer's specification or with any specific agreement between the manufacturer and purchaser.

Compliance is verified by test.

6.4.2.6 Output overvoltage test

Output overvoltage protection shall be checked by raising the **output voltage** above the sum of the declared **rated voltage**, the upper steady state variation and an additional 5 % or as otherwise agreed between the manufacturer and purchaser.

Compliance is verified by observing output shutdown.

6.4.2.7 Periodic output voltage variation test (modulation)

Only when, subject to a specific agreement between the purchaser and the manufacturer, this test is specified, it shall be checked by voltage recording at different loads and operating conditions.

*Compliance is verified when, during the test, the **DC UPS output voltage** remains within the applicable limits of Figure 2.*

6.4.2.8 Overload and fault clearing capability

6.4.2.8.1 Overload – Normal mode

With the **DC UPS** operating at **light load** in **normal mode**, apply a **resistive load** which shall result in **DC UPS** overload as declared in 5.3.2 h).

*Compliance is verified when the **DC UPS** continues to operate within the manufacturer's stated condition for the time duration specified.*

6.4.2.8.2 Overload – Stored energy mode

The test of 6.4.2.8.1 shall be repeated in stored energy mode, with the storage energy device fully charged.

This test is required for *XN* output type only (see 5.3.4).

NOTE The time duration of the test is limited by the stored energy source.

*Compliance is verified by the **DC UPS** not being damaged or showing signs of over-heating.*

6.4.2.8.3 Fault clearing capability – Normal mode

With the **DC UPS** operating under **normal mode** test conditions of 6.4.2.1, a **light load** may be applied if desired (see 6.2.2.3). A short circuit shall then be applied through a suitable fuse or circuit-breaker of a current **rating** in accordance with the manufacturer or supplier's stated protective device clearance capability (see 5.3.2 j)).

The manufacture is permitted to define compliance conditions including

- a limit for the impedance of cables connecting the **DC UPS** output to the protective device and to the short-circuit,
- a minimum Ah capacity of the **battery** connected, and
- a time constant (L/R) in the range of 10 ms to 12 ms for a **prospective short-circuit current** greater than 20 kA and 3 ms for a **prospective short-circuit current** less than 20 kA.

Compliance is verified when the dynamic output performance remains within the limits of the performance classification declared in 5.3.2 a) during this event unless otherwise stated by the manufacturer or supplier.

If the **DC UPS** is rated for operation over a range of input and **output voltages**, the short circuit test shall be performed at the highest nominal rated input and **output voltages**.

NOTE Fault clearing capability test verifies the **DC UPS** output performance when applying a conditional short-circuit.

6.4.2.8.4 Fault clearing capability – Stored energy mode

The test of 6.4.2.8.3 shall be repeated in stored energy mode unless the manufacturer or supplier states that the **DC UPS** cannot co-ordinate with external protective devices in this mode of operation.

6.4.2.9 Dynamic performance

6.4.2.9.1 Normal to stored energy mode

With the **DC UPS** initially operating at 100 % **reference test load** in **normal mode**, the input supply shall be interrupted for a minimum of 1 s, starting at each of the following conditions independently:

- a) where the input voltage waveform passes through zero;
- b) at the peak of the input voltage waveform.

At each of these conditions, the tests shall be performed a minimum of three times to ascertain repeatability.

The **DC UPS** input and output waveforms shall be observed on suitable storage instrumentation to permit the calculation of any **transient** performance **deviation** of the **output voltage** waveform during the transition from normal to stored energy mode of operation.

The test is generally performed in conjunction with 6.2.2.6 AC input failure (see Figure D.1).

The dynamic performance measurement starts at the time

- after opening the switch S1, when the input voltage is out of the specified **tolerance band** (for high impedance mains failure), or
- after closing the switch S2, when the current raises through S2 (for low impedance mains failure);

Compliance is verified when the dynamic output performance remains within the limits of the performance classification declared in 5.3.2 a) during this event.

6.4.2.9.2 Stored energy to normal mode

With the **DC UPS** initially operating a 100% **reference test load** in stored energy mode, the input supply shall be reconnected and the output observed for any **deviation** during the transition from stored energy mode to **normal mode** of operation. This test is generally performed in conjunction with the storage energy time test (see 6.4.4.1).

Compliance is verified when the dynamic output performance remains within the limits of the performance classification declared in 5.3.2 a) during this event.

6.4.2.9.3 Step load – Normal mode

With the **DC UPS** operating in **normal mode** under no load, apply a 100 % **reference test load** in steps comprising two loads: one equal to 20 % followed not less than 1 s by one equal to 80 %.

Reduce the load to 20 % of **rated output power** by switching off the 80 % load.

Measure the **DC UPS output voltage** throughout the step loading.

Compliance is verified when the dynamic output performance remains within the limits of the performance classification declared in 5.3.2 a) during this event.

6.4.2.9.4 Step load – Stored energy mode

Repeat the test in 6.4.2.9.3 except that the **DC UPS** shall operate in stored energy mode.

This test is required for *XN* output type (see 5.3.4).

Compliance is verified when the dynamic output performance remains within the limits of the performance classification declared in 5.3.2 a) during this event.

6.4.2.10 Simulation of parallel redundant DC UPS fault

This test is required for **DC UPS** incorporating parallel redundancy. The test shall be conducted with rated load applied to the **DC UPS**. By failure simulation, the redundant **functional units** and **DC UPS unit** as applicable shall be made to fail (for example semiconductor failure). The **output voltage transient** shall be measured and shall comply with the manufacturer's declared limits. Both **high** and **low impedance failures** in redundant **DC UPS** shall be considered. **Low impedance failure** mode should be simulated by shorting an appropriate power semiconductor in the redundant **DC UPS**. **High impedance failure** mode should be simulated by opening the connection to an appropriate power semiconductor in the redundant **DC UPS**.

Compliance is verified when the dynamic output performance remains within the limits of the performance classification declared in 5.3.2 a) during this event.

6.4.3 Output characteristics – Constant power load

The requirements for **constant power load** are deferred for future consideration.

6.4.4 Stored and restored energy

6.4.4.1 Stored energy time

The **stored energy time** shall be determined by switching off the AC input to the **DC UPS** operating at rated power and measuring the duration that the specified **output power** is maintained.

Assuming that the **energy storage device** is a **battery**, subject to any particular agreement between the purchaser and the **DC UPS** manufacturer, the reference temperature of the **battery** shall be 25 °C. The temperature of the **battery** bank shall be measured immediately prior to the test for the purpose of calculation of any adjustment to the expected **stored energy time**.

NOTE 1 Similar consideration applies for other stored energy technologies.

The **battery** voltage shall not fall below the **cut-off voltage** specified before the **stored energy time** has elapsed.

Before carrying out this test, operate the **DC UPS** in **normal mode** of operation with nominal input supply and no output load applied for a period in excess of the manufacturer's stated **restored energy time**.

Apply a 100 % resistive reference load and interrupt the input supply to force stored energy mode of operation. Record the **DC UPS output voltage**. Wait for the declared duration of the **stored energy time**. Record the **DC UPS output voltage**.

*Compliance is verified when both **output voltage** measurements are within the declared range in 5.3.2 a).*

NOTE 2 Since new batteries often do not provide full capacity during a start-up period, the discharge test is generally repeated after a reasonable **restored energy time**, if the time achieved initially is less than specified limit. A number of charge/discharge cycles may be necessary before full **battery** capacity is achieved.

6.4.4.2 Restored energy time (to 90 % capacity)

At the cessation of stored energy test of 6.4.4.1, reapply the input supply to the **DC UPS** and operate in **normal mode** of operation, at nominal input supply voltage and at 100 % **reference test load**.

After the manufacturer's stated **restored energy time** has elapsed, the test of 6.4.4.1 shall then be repeated.

*Compliance is verified when the new value of **stored energy time** is not less than 90 % of the declared duration of the **stored energy time**.*

NOTE Stored energy and **restored energy times** are influenced by **ambient temperature** and the values stated by the manufacturer for **restored energy time** is the time to restore 90 % of rated capacity unless otherwise stated.

6.4.4.3 Battery ripple current measurement

The AC component (RMS value) of the **battery** current shall be measured when a limit for **battery ripple current** is specified. The **DC UPS** shall operate in **normal mode** and the **battery** shall be fully charged. Worst-case ripple current shall be reported if this measurement is affected by the loading of the **DC UPS**.

*Compliance is verified when the ripple current measured is equal or lower than that the value specified by the **battery** manufacturer – see 5.4.2.2 j).*

NOTE As an example the limit for AC component (RMS value) of the **battery** current is typically 5 % of the numerical value of the rated Ah **battery** capacity (lead-acid) and 10 % (NiCd).

6.4.4.4 Restart test

Automatic or other restart means shall be tested after a complete shutdown of the **DC UPS**. The **DC UPS** restart test shall assess that proper mains voltages are present or that the **energy storage device** has been depleted and automatically restarted into **normal mode**.

*Compliance is verified when the **DC UPS normal mode** of operations is returned per manufactures design criteria.*

6.5 Type test procedure (environmental)

6.5.1 Environmental and transportation test methods

6.5.1.1 General

The following tests are intended to simulate the environmental and transportation requirements the **DC UPS** is designed to meet. The transportation-related tests assess the construction of the **DC UPS** in the shipping container against resistance to damage by normal handling operations during transportation.

6.5.1.2 Shock test

The following steps shall be carried out on a completed **DC UPS** with a mass less than 50 kg, excluding the transportation packaging and in the chronological order below:

- a) as initial measurements, perform the electrical **routine tests** described in 6.2.2 on the **DC UPS**;
- b) ensure the **DC UPS** is non-operational and pack it in its normal shipping state for transportation;
- c) subject the packaged **DC UPS** to two 15 g_n half-sine shock pulses of 11 ms nominal duration in all three planes, in accordance with IEC 60068-2-27;

NOTE No electrical measurements are taken during the test.

- d) as final inspection after the above tests, unpack the **DC UPS** and check for signs of physical damage or distortion to component parts;
- e) as final measurements, perform **light load** and functional tests (see 6.2.2.3) as **routine tests**.

Compliance is verified when the requirements of items d) and e) are satisfied.

Final measurements and requirements may be combined with those of the free fall test (see 6.5.1.3).

Consideration should be given to any test result consequences that may require dielectric tests to be applied in accordance with the relevant safety standard.

6.5.1.3 Free fall test

The following free fall test steps shall be performed in the chronological order below:

- a) as initial measurements, perform the electrical **routine tests** described in 6.2.2 on the **DC UPS**;
- b) ensure the **DC UPS** is non-operational and packed in its normal shipping state for transportation;
- c) test the **DC UPS** by allowing it to fall freely from a point of suspension onto a solid surface. The surface of the package which impacts the solid surface through the fall is the surface on which the package normally rests. The method of test is in accordance with IEC 60068-2-31. Ensure the following test conditions are met:
 - 1) the test is carried out twice;
 - 2) the test is made with the **DC UPS** in its integral transport case or shipping state for transportation;
 - 3) the height of fall is in accordance with Table 4;
 - 4) the height of fall is measured from the part of the **DC UPS** nearest to the test surface.

Table 4 – Free fall testing

Mass of unpacked specimen kg	Height of fall mm
$M \leq 10$	250
$10 < M \leq 50$	100
$50 < M \leq 100$	50
$100 < M$	25

NOTE No measurement is taken during the test.

- d) as final inspection after the above tests, unpack the **DC UPS** and check for signs of physical damage or distortion to component parts;
- e) as final measurements, perform **light load** and functional tests (see 6.2.2.3) as **routine tests**.

Compliance is verified when the requirements of d) and e) are satisfied.

Consideration should be given to any test result consequences that may require dielectric tests to be applied in accordance with the relevant safety standard.

6.5.2 Storage

The following storage test steps shall be performed in the chronological order below:

- a) as initial measurements, perform the electrical **routine tests** described in 6.2.2 on the **DC UPS**. Before carrying out these tests, charge internal **battery** for the period defined in the manufacturer's instructions;

- b) ensure the **DC UPS** is not operational, but packed in its normal shipping state for transportation and storage with controls in shipping state;
- c) conduct tests as follows:
 - 1) dry heat as per the normal environmental conditions: $+55\text{ °C} \pm 2\text{ °C}$ for a duration of 16 h using the test method Bb of IEC 60068-2-2;
 - 2) damp heat as per the normal environmental conditions: $+40\text{ °C} \pm 2\text{ °C}$ at a humidity of 90 % to 95 % for a duration of 96 h using IEC 60068-2-78;
 - 3) cold as per the normal environmental conditions: $-25\text{ °C} \pm 3\text{ °C}$ for a duration of 16 h where practicable using test method Ab of IEC 60068-2-1.

NOTE No electrical measurement are required during the tests.

- d) as final measurements after the tests, unpack the **DC UPS**, inspect for signs of physical damage or distortion to components and for corrosion of metallic parts.;
- e) as final measurements, allow the **DC UPS** to return to normal **ambient temperature** and pressure and perform the **light load** and functional tests (see 6.2.2.3) as **routine tests**.

Compliance is verified when the requirements of d) and e) are satisfied.

6.5.3 Operation

The following operation test steps shall be performed in the chronological order below:

- a) perform the electrical **routine tests** described in 6.2.2 on the **DC UPS**;
- b) ensure the **DC UPS** works in **normal mode** of operation at rated input voltage and **rated output power**;
- c) conduct tests in the following sequence:
 - 1) dry heat as per the normal environmental conditions or as per the manufacturer's stated maximum value for a duration of 16 h using test method Bb/Bd of IEC 60068-2-2;
 - 2) damp heat as per the normal environmental conditions: $+30\text{ °C} \pm 2\text{ °C}$ at a humidity of 72 % to 78 % for a duration of 96 h using test method Cb of IEC 60068-2-78;
 - 3) cold as per the normal environmental conditions or as per the manufacturer's stated minimum temperature for a duration of 2 h using test method Ab/Ad of IEC 60068-2-1;
 - 4) damp heat repeated.

In the case where the **DC UPS** incorporates **energy storage device (s)** in the form of batteries, conduct the test with temperature between $+15\text{ °C}$ minimum and $+30\text{ °C}$ maximum.

- d) take measurements during testing as applicable to check that the **DC UPS** continues to function according to this document in normal and stored energy modes of operation;
- e) repeat step a) after the **DC UPS** has returned to ambient conditions to confirm normal operation;
- f) as final requirements after the tests, perform the **light load** and functional tests (see 6.2.2.3) as **routine tests** and check the **DC UPS** for signs of physical damage or distortion and that it continues to perform in accordance with the initial characteristics.

Compliance is verified when the requirements of e) and f) are satisfied.

6.5.4 Acoustic noise

The manufacturer shall state in the technical documentation the acoustic noise level that is to be measured in accordance with the method of measurement specified in ISO 7779 and governed by the normal positioning expected in use (for example, table-top, wall-mounted or free-standing).

Values shall be measured when the **DC UPS** operates at rated steady-state **resistive load** under the following conditions;

- **normal mode** of **DC UPS** operation, at rated input voltage;
- **stored energy mode of DC UPS operation.**

The acoustic noise level shall be measured at the 1 m distance and stated in dBA (dB referenced to acoustic weighing scale A obtained from a sound level meter complying with IEC 61672-1).

The acoustic noise from audible alarms shall not be included in the values stated.

The acoustic noise from fans required to operate under any rated condition shall be included in the values stated.

*Compliance is verified when the values measured are within the values declared by the **DC UPS** manufacturer.*

6.6 DC UPS functional unit tests (where not tested as a complete DC UPS)

6.6.1 DC UPS rectifier tests

Line-commutated rectifiers shall be tested in accordance with the applicable tests in Clause 7 of IEC 60146-1-1:2009.

Self-commutated rectifiers shall be tested in accordance with 6.6.2.

Routine tests will cover insulation test and **light load** test and a checking of auxiliary protection devices and control systems.

Type tests will include additional load tests, determination of losses, temperature rise, etc.

6.6.2 DC UPS converter tests

Where applicable, **converter** tests shall be performed in accordance with the applicable tests in Clause 7 of IEC 60146-2:1999 that presents a schedule of **routine tests**, **type tests** and optional tests.

6.6.3 DC UPS switch tests

DC UPS switches that are regarded as integrated parts of a complete **DC UPS** and are matched to the requirements of the **DC UPS** are not tested separately.

DC UPS switches that are not regarded as integrated parts of a complete **DC UPS** shall be tested in accordance with their own product standard.

The **DC UPS type test** program shall include tests to prove the **rated values** given in Clause 5 of this document as far as those values are not proved by adequate calculation. If previous **type tests** have been performed, the original manufacturer's specifications shall be acceptable and no further tests will be required.

6.6.4 Stored energy/battery tests

Unless otherwise specified in the purchase contract, factory tests on an **energy storage device** within a **DC UPS** or in separate **DC UPS** cabinets shall be limited to initial **type tests** and to such routine production tests deemed necessary, by the **DC UPS** manufacturer, to verify the performance of the **energy storage device**.

Stored and **restored energy times** and any additional on-site testing, shall be a matter of agreement between the **DC UPS** manufacturer or supplier, and the purchaser.

Special charging regimes, such as boost/equalization requirements required by the **energy storage device** manufacturer, shall be demonstrated.

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Annex A (informative)

DC UPS configurations

A.1 General

DC UPS are used to supply power to equipment which requires continuous operation, also referred to as critical or essential loads. Examples of critical loads include but are not limited to telecommunication facilities, data centers, process control, emergency lighting, etc. **DC UPS** function is to supply continuous power to critical loads, and specifically for a specified time when utility outage occurs. A **DC UPS** also provides a highly regulated **output power** quality due to its independent output from the AC input. A general **DC UPS** systems consist of an AC to DC rectifier(s) section, **energy storage device** (typically an internal **battery** system or an external bank of batteries) section, in some cases additional DC-DC **converters**, controller and associated distribution equipment. Unlike the AC UPS the **DC UPS** does not include a static transfer switch or bypass circuitry. Various **DC UPS** configurations are used to achieve different degrees of availability of load power and/or to increase output capacity **rating** and redundancy

Annex A presents the characteristics of typical configurations in use.

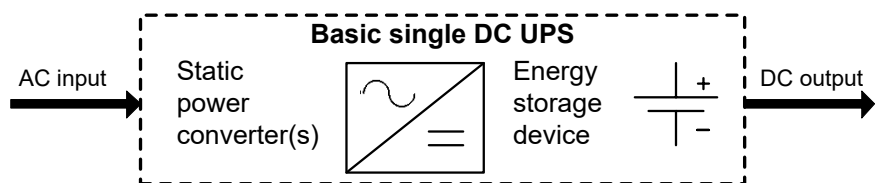
A.2 Single DC UPS

A.2.1 Introduction

A **single DC UPS** comprises a stored energy device and one or more **functional units** in the form of static power **converter(s)**, for example a rectifier/**battery charger** and a DC-DC **converter**. A **single DC UPS** generally presents availability consistent with equipment requiring reliability integrity level 1 (RIL1 – IEC 62040-3:2011, Annex K).

A.2.2 Basic single DC UPS

A basic **single DC UPS** contains no alternative circuit path for the purpose of ensuring **continuity of load power**. See Figure A.1.



IEC

Figure A.1 – Basic single DC UPS

In the case of an **AC input power failure**, the stored energy device (for example a **battery**) will supply the power at a decreasing DC voltage until it is too low for satisfactory DC output. The type and capacity of the **battery** will determine the length of time the system can operate without an AC input supply.

NOTE The following **DC UPS** topologies represent examples of a basic **single DC UPS**: direct energy storage connect, series **converter** connect and shunt **converter** connect. Refer to Annex B.

A.2.3 Scalable single DC UPS

A **single DC UPS** may be designed for scalability of the system capacity and/or redundancy by connecting several like **single DC UPS** and/or **DC UPS functional units** in parallel. Scalable **single DC UPS** are classified as follows:

– **Modular single DC UPS**

A **skilled person** performs servicing and field replacement. In some cases, hot-swappable replacement is permitted. Scalability is achieved by connecting either **functional units** in parallel within the **single DC UPS** cabinet or by connecting like **single DC UPS** cabinets in parallel.

– **Monolithic single DC UPS**

Servicing and field replacement requires isolation and/or system shut-down. Scalability is achieved by connecting like **single DC UPS** cabinets in parallel.

A.3 Parallel DC UPS

A.3.1 General

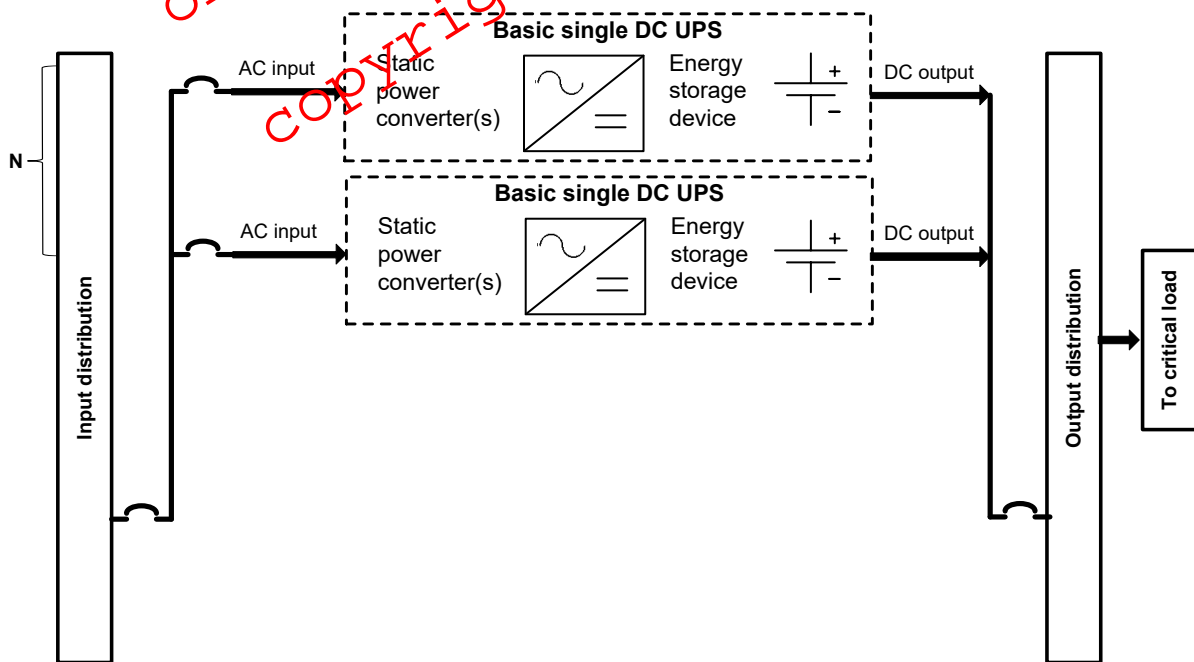
A **parallel DC UPS** increases the quantity and/or availability of power that can be supplied to the load.

A **parallel DC UPS** consists of a " $N + r$ " paralleled **DC UPS units** wherein a quantity of " N " **DC UPS units** is sufficient to support the load and where " r " stands for the quantity of redundant **DC UPS units**.

A.3.2 Parallel non-redundant DC UPS

A parallel non-redundant **DC UPS** consists of " $N + 0$ " paralleled **DC UPS units**, i.e. a configuration without any redundant **DC UPS units**. The availability of a parallel non-redundant **DC UPS** is lower than that of each paralleled **DC UPS unit** because the failure of any **DC UPS unit** affects the continuity of power to the load.

Figure A.2 shows a typical " $N + 0$ " parallel non-redundant **DC UPS**.



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Figure A.2 – System sized for load (N DC UPS units) – No redundancy

A.3.3 Parallel redundant DC UPS

A **parallel redundant DC UPS** contains at least one redundant **DC UPS unit** and provides higher availability than that of a parallel non-redundant **DC UPS** because any **DC UPS unit** can fail without affecting the continuity of power to the load.

Figure A.3 shows a typical " $N + 1$ " **parallel redundant DC UPS**.

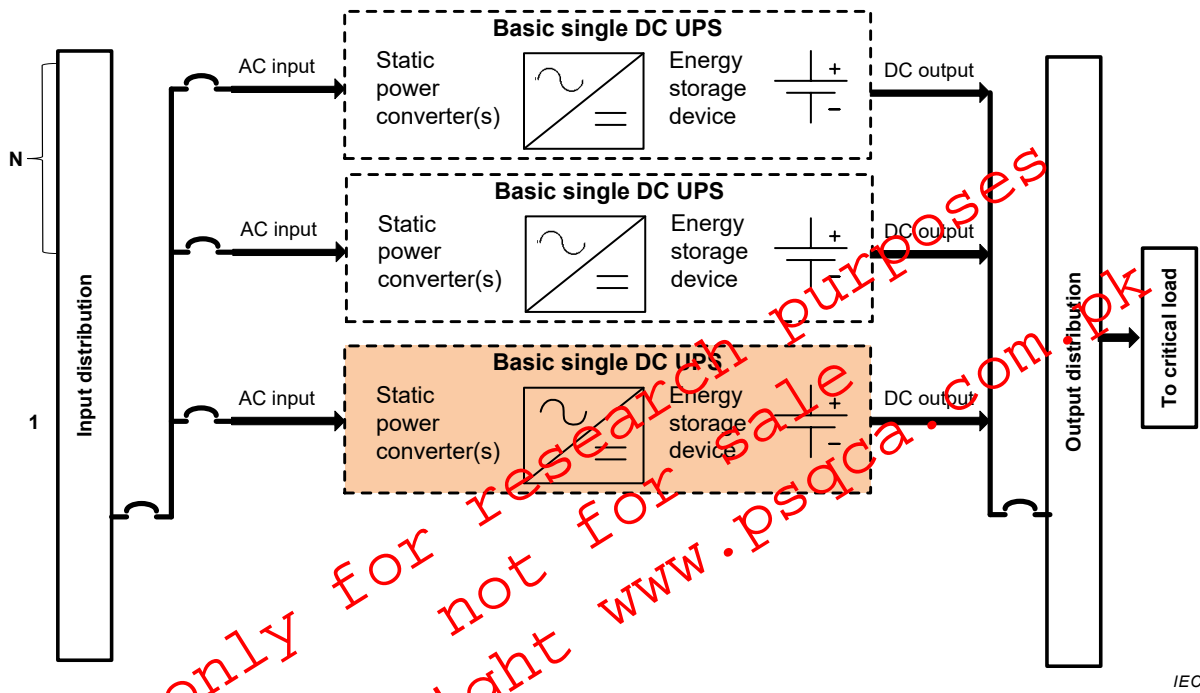


Figure A.3 – System sized for load (N DC UPS units) – $N + 1$ redundancy

A.3.4 Enhanced parallel redundant DC UPS

Further availability enhancement can be achieved by increasing the number of redundant **DC UPS units** from 1 to r .

Figure A.4 shows a typical " $N + r$ " **parallel redundant DC UPS**.

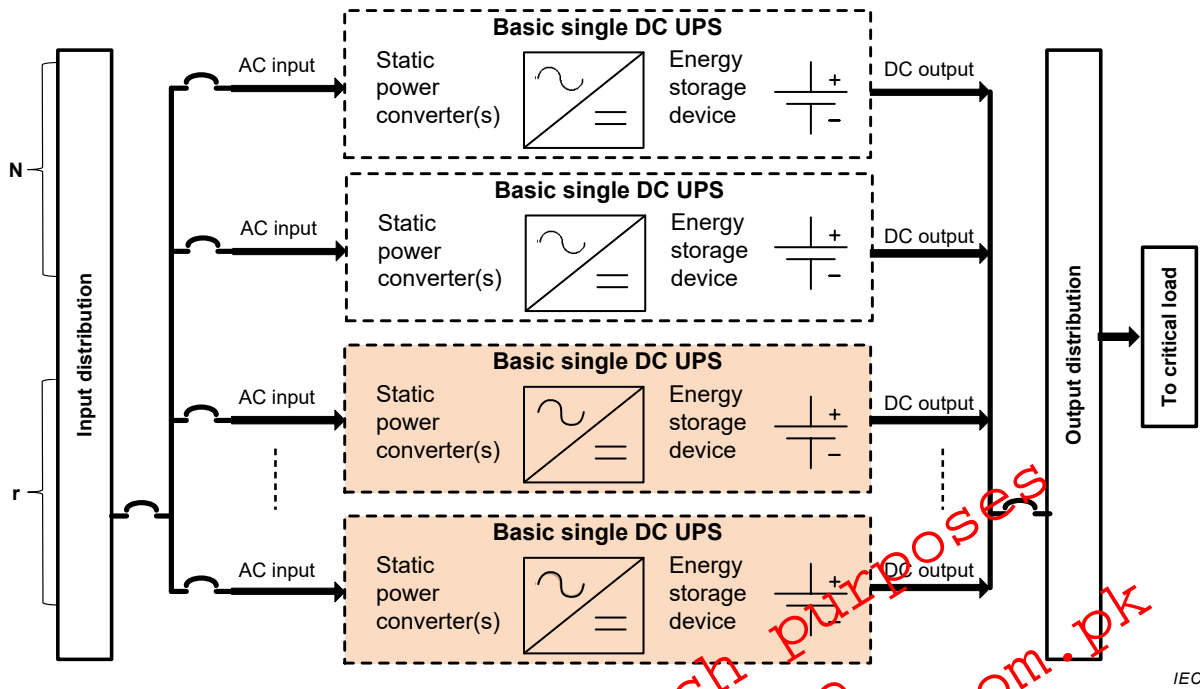


Figure A.4 – System sized for load (N DC UPS units) – $N + r$ redundancy

A.4 Dual bus

A.4.1 General

Dual bus configuration is primarily intended to supply loads equipped with redundant power supplies and with dual input cords.

A dual bus **DC UPS** consists of either dual bus system $2(N + r)$ **DC UPS units**; or as a dual bus distribution ($N + r$) variant **DC UPS units**, wherein a quantity of " N " **DC UPS units** is sufficient to support the load and where " r " stands for the quantity of redundant **DC UPS units**.

A.4.2 Dual bus system $2(N + r)$

The dual bus system $2(N + r)$ **DC UPS** comprises any two **DC UPS** configurations of Annex A whose DC outputs are connected to separate buses. See Figure A.5.

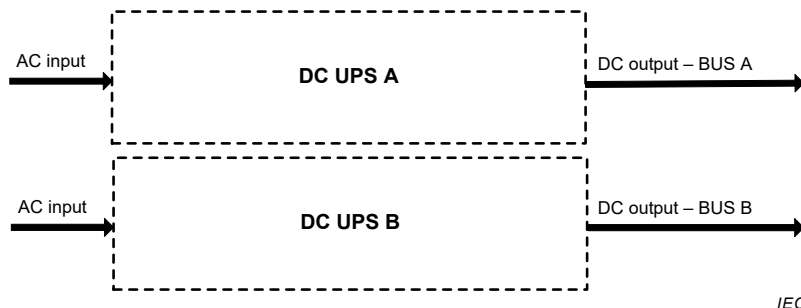


Figure A.5 – Dual bus DC UPS

The $2(N + r)$ configuration provides highest availability because, in addition to satisfying the requirements to supply loads equipped with redundant power supplies, the DC output buses of this configuration are fault tolerant, i.e. a fault on one bus does not affect the other bus.

The $2(N + r)$ requires however duplication of the equipment and the infrastructure.

A.4.3 Dual bus distribution ($N + r$)

The dual bus distribution ($N + r$) variant consists of any one **DC UPS** configuration of Annex A whose single DC output is connected to two separate buses. See Figure A.6.

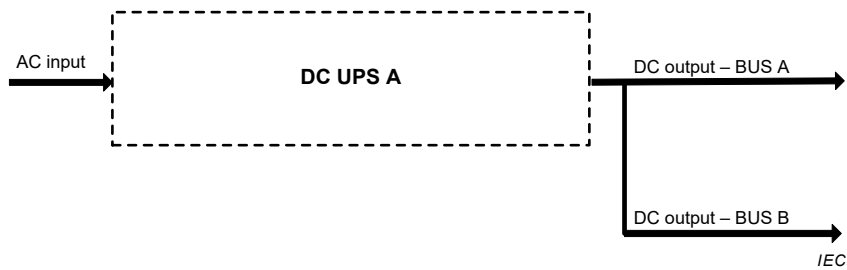


Figure A.6 – Dual bus DC UPS variant

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Annex B (informative)

Topologies – DC UPS

B.1 General

Annex B describes the most commonly used **DC UPS** topologies in the form of simple block diagrams including the most common form of stored energy source, a **battery**. This is notwithstanding that other forms of stored energy sources are equally possible. See 5.4.1.

For each topology, depending on the load and the power distribution system requirements, additional circuits and components such as filters (**transient/EMC**) and input isolation transformers may be required. These details are omitted for simplicity. The technical merits are not discussed and the purchaser should verify with the vendor the suitability of any system for the intended load requirements. Refer to Annex C.

B.2 Basic topologies

B.2.1 General

Three basic topologies are shown in Figures B.1, B.2 and B.3. They differ in terms of **output voltage** behaviour during stored energy mode of operation. The description of each topology is in B.2.2, B.2.3 and B.2.4

Direct energy storage connect topology contains an AC-DC **converter** that when operating in **normal mode** provides a tightly regulated **output voltage** to the load and maintain the **energy storage device** charged. In stored energy mode, for example during an **AC input power failure** the AC-DC **converter** is not active and the power to the load is provided directly from the **energy storage device**. The **output voltage** will decrease as the **energy storage device** discharges or until it reaches a predetermined level at which the load can no longer operate properly.

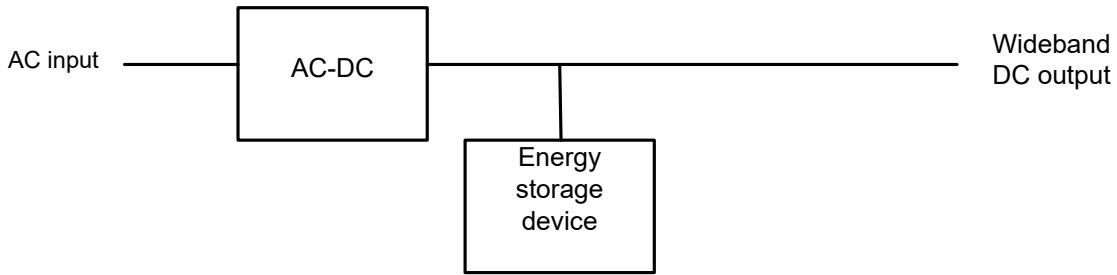
Series **converter** connect and shunt **converter** connect contain an additional DC-DC **converter** that regulate **output voltage** under normal and stored energy modes of operation until the end of **energy storage device** discharge level.

B.2.2 Direct energy storage connect

The direct energy storage connect topology **DC UPS** consists of one or more rectifiers (modular or monolithic), an **energy storage device** that is directly connected to the output, and of associated distribution that can be internal or external to the **DC UPS**. This architecture provides a single power path to the load being served. See A.2.3 for details about scalability of modular and monolithic **DC UPS units**.

In case of **AC input power failure**, the **energy storage device** (for example a **battery** or bank of batteries) will supply power at decreasing DC voltage to the load, until the voltage reaches a level, which is too low for satisfactory operation of the powered equipment. The type and capacity of the **battery** will determine the length of time the system can operate without an AC input supply.

NOTE Direct energy storage connect topology **DC UPS** generally performs with *NW* characteristics (see 5.3.4)



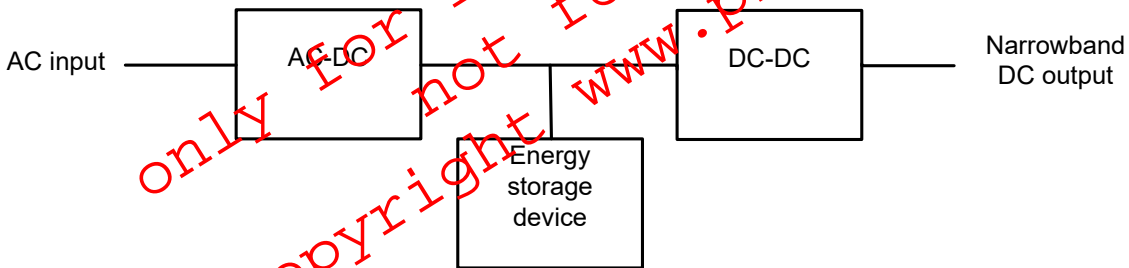
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Figure B.1 – Direct energy storage connect

B.2.3 Series converter connect

The series **converter** connect topology **DC UPS** consists of a direct energy storage connect topology **DC UPS** to which a series connected **DC-DC converter** is inserted in series with the output to the DC load. The purpose of the **DC-DC converter** is to assure that the output to the DC load remains constant during **energy storage device** discharge.

NOTE Series **converter** connect topology **DC UPS** generally performs with *NN* characteristics (see 5.3.4)



IEC

Figure B.2 – Series converter connect

B.2.4 Shunt converter connect

The shunt **converter** connect topology **DC UPS** consists of a direct energy storage connect topology **DC UPS** to which a series connected **DC-DC converter** is inserted between the **AC-DC converter** and the **energy storage device**. The purpose of the **DC-DC converter** is to assure that the output to the DC load remains constant irrespective of the discharge and recharge characteristics of the **energy storage device**.

NOTE Shunt **converter** connect topology **DC UPS** generally performs with *NN* characteristics (see 5.3.4)

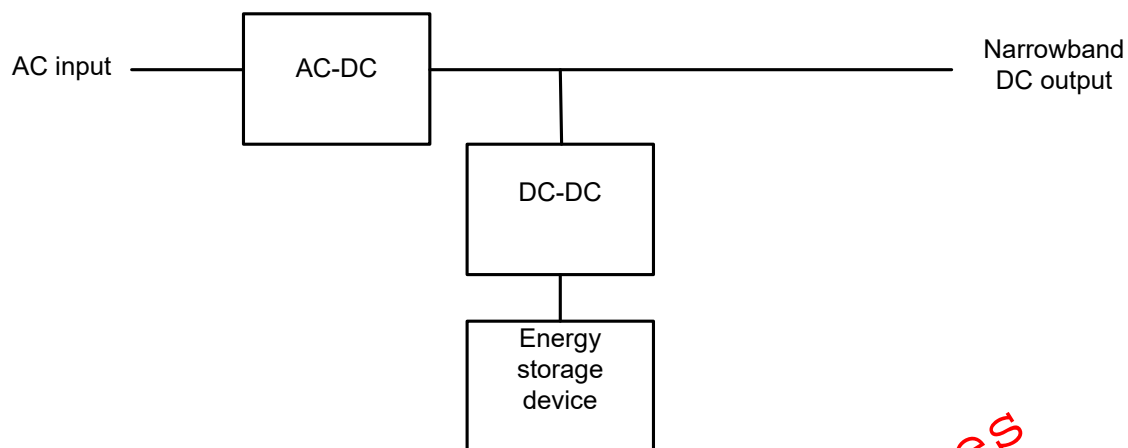


Figure B.3 – Shunt converter connect

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Annex C (informative)

Purchaser specification guidelines

C.1 General

A variety of **DC UPSs** have been developed to meet the requirements for continuity and quality of power. There are different types of loads over a wide range of power from less than one hundred watts to several megawatts.

Annex C has been compiled to assist purchasers to formalize criteria important to their application and/or to confirm agreement with conditions declared by the manufacturer/supplier.

For an explanation of typical **DC UPS** configurations, modes of **DC UPS** operation and topologies, the reader's attention is drawn to Annexes A and B.

The **DC UPS** technical data sheet contained in Annex C presents a summary of the normal and unusual environmental and electrical conditions to be considered. This data sheet also references the specific subclause of concern. The reader's attention is drawn to Clauses 4 (Environmental conditions) and 5 (Electrical conditions, performance and declared values).

Table C.1 – DC UPS technical data – Manufacturer's declaration (1 of 4)

IEC 62040-5-3:2016 subclause (except if otherwise noted)	Declared Characteristics General	Manufacturer's declared values	Purchaser's identified values
	Model (manufacturer's reference)		
5.3.2 g)	Output power , rated	W	
5.1.1	DC UPS configuration		
5.3.4	Performance classification		
	Mechanical		
	Dimensions (height × width × depth)	mm	
	Mass	kg	
	Mass with batteries (if integrated)	kg	
6.5.4	Acoustic noise at 1 m:		
	– normal mode	dBA	
	– stored energy mode	dBA	
	Environmental		
4.2.1.1	Ambient temperature range	°C	
	Relative humidity range	%	
4.2.1.2	Altitude	m	
4.3	Additional or unusual conditions		
5.6	Communication circuits		
	(List communication/signalling circuits)		
			(continued)

Table C.1 (2 of 4)

IEC 62040-5-3:2016 subclause (except if otherwise noted)	Declared characteristics Output (electrical)	Manufacturer's declared values	Purchaser's identified values
5.3.2 d)	DC power distribution system – compatibility (TN, TT, IT)		
5.3.2 b)	Voltage (steady state) – rated	V	
<u>6.4.2.1 and 6.4.2.2</u>	– <u>normal mode variation at no load and full load</u>	%	
<u>6.4.2.3 and 6.4.2.4</u>	– <u>stored energy mode variation at no load and full load</u>	%	
6.4.2.9.1 and 6.4.2.9.2	– transfer normal mode/stored energy mode	%, s	
6.4.2.9.3	– <u>normal mode variation at step load</u>	%	
6.4.2.9.4	– <u>stored energy mode variation at step load</u>	%	
<u>5.3.2 g)</u>	Current – rated	A	
5.3.2 h)	– overload capability (% of rated current/time duration)	% / s	
5.3.2 i)	– limitation (% of rated current/time duration)	% / s	
5.3.2 j) 6.4.2.8.3 and 6.4.2.8.4	– fault clearing capability (normal/stored energy mode)	Fuse type and rating	
5.3.2 k) and 6.4.1.7	AC/DC efficiency in normal mode – 100 % load	%	
5.3.2 k) and 6.4.1.7	– 75 % load	%	
5.3.2 k) and 6.4.1.7	– 50 % load	%	
5.3.2 k) and 6.4.1.7	– 25 % load	%	
5.3.2 k) and 6.4.1.7	– no-load losses	W	
5.5	Stand-alone switch (list any and its product standard)		
5.3.3	Additional or unusual conditions		
			(continued)

Table C.1 (3 of 4)

IEC 62040-5-3:2016 subclause (except if otherwise noted)	Declared characteristics Input (electrical)	Manufacturer's declared values	Purchaser's identified values
5.2.1 a)	Voltage (steady-state, RMS) – rated	V	
5.2.1 b)	– tolerance	%	
5.2.1 c)	Frequency – rated	Hz	
5.2.1 d)	– tolerance	%	
5.2.2 a)	phases required (1, 2 or 3)		
5.2.2 b)	neutral required (yes/no)		
5.2.2 c)	Current RMS – rated (with the energy storage device charged)	A	
5.2.2 d)	– power factor		
5.2.2 e)	– inrush characteristics	%	
5.2.2 f)	– maximum (with low input voltage and energy storage device charging) – current against time	A %, s	
5.2.2 g)	– total harmonic distortion (THD) and minimum prospective short-circuit current	% (THD) kA (I_{cp})	
5.2.2 h)	Earth leakage current	mA	
5.2.2 i)	AC power distribution system – compatibility (<i>TN, TT, IT</i>)		
5.2.3	Additional or unusual conditions		
			(continued)

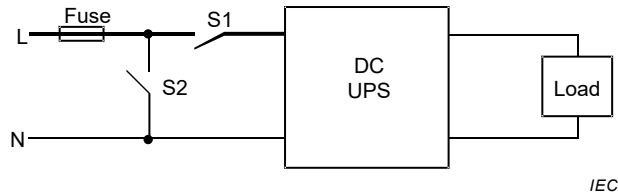
Table C.1 (4 of 4)

IEC 62040-5-3:2016 subclause (except if otherwise noted)	Declared characteristics Battery/stored energy device		Manufacturer's declared values	Purchaser's identified values
5.4.2.2 d)	Technology			
5.4.2.2 a)	Expected life	Design life or	years	
		float service life		
5.4.2.2 b)	Quantity of blocks or cells of paralleled strings			
5.4.2.2 c)	Nominal voltage (total)		V DC	
5.4.2.2 e)	Nominal capacity		Ah	
5.4.2.2 f)	Stored energy time (back-up time at 100 % rated load)			
5.4.2.2 g)	Restored energy time (recharge time to 90 % capacity)			
5.4.2.2 h)	Ambient reference temperature		°C	
5.4.2.2 i)	Earth condition/Isolation			
5.4.2.2 j)	RMS ripple current		%of rated battery Ah capacity	
5.4.2.2 k)	Maximum discharge current		A	
5.4.2.2 l)	Fault current rating		A DC	
5.4.2.2 m)	Maximum cable voltage drop recommendation at nominal discharge current		% of nominal battery voltage	
5.4.2.2 n)	Protection requirements by others			
5.4.2.2 o)	Charging regime			
5.4.2.2 p)	Charge voltage (float, boost) and tolerance band		V DC	
5.4.2.2 q)	End of discharge voltage		V DC	
5.4.2.2 r)	Charge current limit (or range)		A DC	
5.4.2.3	Additional or unusual conditions			
				(end)

Annex D (normative)

Input mains failure – Test method

The characteristics of the **DC UPS** when the mains fail shall be tested using the circuit of Figure D.1.



Key

L mains phase(s)

N mains neutral (or phase where no neutral is used)

S1 switch or contactor capable of carrying and of opening the **DC UPS rated input current**

S2 switch or contactor capable of carrying the mains fault current while the fuse opens

Fuse rated to support the **DC UPS** at **light load**.

Figure D.1 – Connection of test circuit

Test D.1 – High impedance mains failure

Normal mode of operation, **light load**:

- S1 = closed;
- S2 = open;
- Open S1 to simulate the mains failure.

Test D.2 – Low impedance mains failure

Normal mode of operation, **light load**:

- S1 = closed;
- S2 = open;
- Close S2 to simulate the mains failure (fuse blown).

The fuse **rating** shall comply with the **DC UPS** input current. The S2 **rating** shall be according to the fuse **rating**.

Annex E (informative)

Dynamic output performance – Measurement techniques

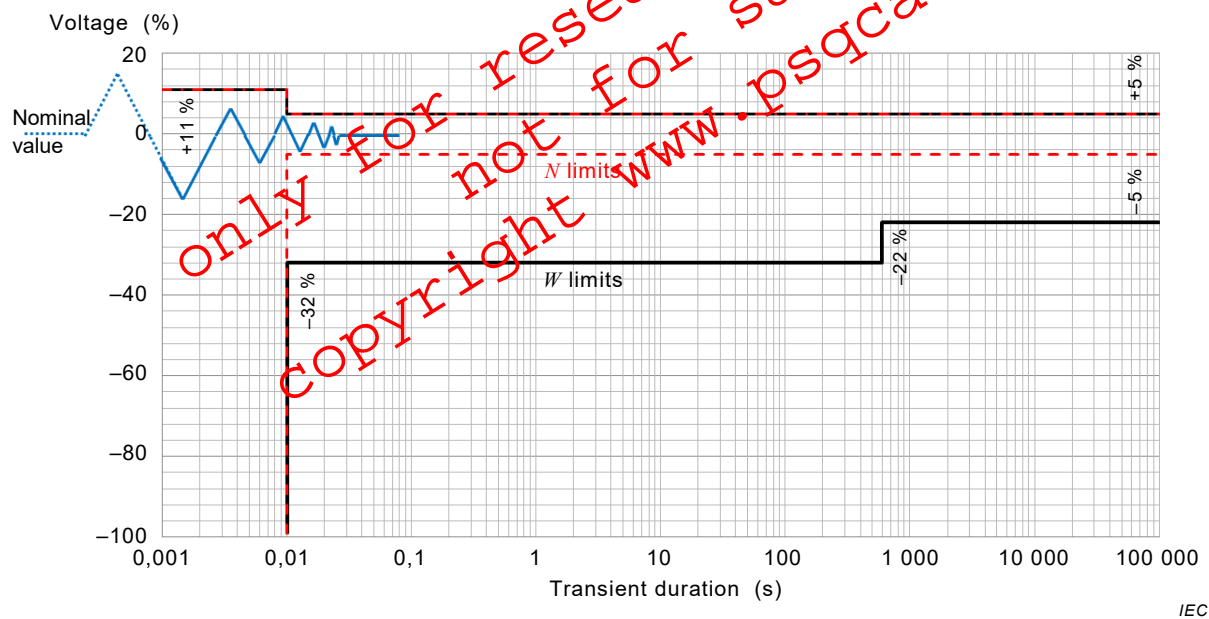
E.1 General

Annex E provides guidance for validation of the dynamic output performance of a **DC UPS** as specified in 5.3.4.

E.2 Graphical validating method

The graphical evaluation consists of recording the waveform of the **DC UPS output voltage variation**, for example with an oscilloscope, and then by transporting this waveform into Figure E.1 (see 5.3.4).

Validation is achieved when the **voltage variation** fits within the applicable limits in Figure E.1. The voltage variation between 0 and 0,001 s is ignored. Refer to 6.4.2.9.1 for further timing details. Figures E.1 and E.2 below provide examples of the graphical validating method



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Figure E.1 – Example: Narrowband validation of dynamic voltage response

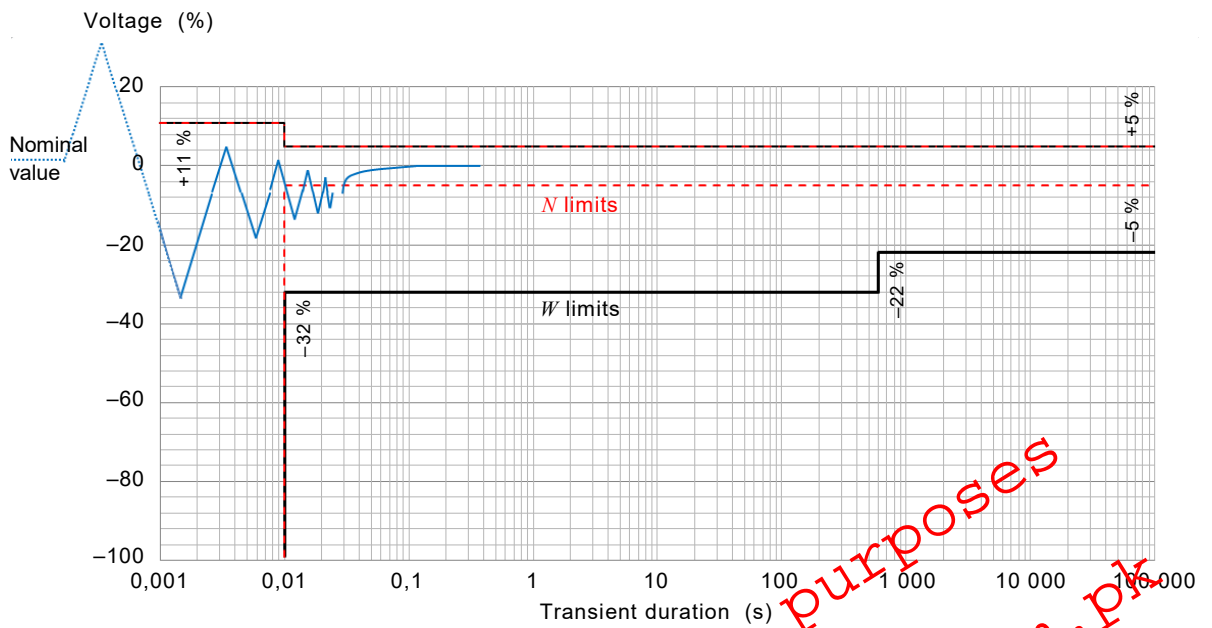


Figure E.2 – Example: Wideband validation of dynamic voltage response

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Annex F (normative)

DC UPS efficiency – Methods of measurement

F.1 General

Annex F prescribes conditions and methods to be followed when determining **DC UPS efficiency** during **type tests** specified in 6.4.1.7.

F.2 Measurement conditions

F.2.1 Environmental conditions

The **ambient temperature** shall be between 20 °C to 30 °C, and remaining environmental conditions shall be within the limits specified in 4.2.

F.2.2 Operational and electrical conditions

For the purpose of Annex F, the efficiency measurements shall be performed with a **resistive load** capable of being adjusted so that the **DC UPS** delivers 25 %, 50 %, 75 % and 100 % of the power (W) for which it is rated. The input loss shall be measured at no-load. The following requirements apply for each measurement.

- a) The **DC UPS** shall operate in **normal mode**.
- b) Transfer of energy to and from the **energy storage device** shall be prevented during the test. The **energy storage device** may be disconnected during the test to prevent such transfer of energy.
- c) The **DC UPS** and the load shall have been operated for a sufficient length of time to reach steady state conditions. The length of time determined during temperature rise **type tests** plus 25 % is considered sufficient. Alternatively, trend variation of less than 2 °C temperature variation over not less than three consecutive readings with no less than 10 min interval may be considered steady-state for the purpose of Annex F.
- d) All **DC UPS** sub-systems intended to be operational in **normal mode** shall be activated, and load condition shall be within the range of 95 % to 105 % of the intended load.
- e) The AC input to the **DC UPS** shall be at 97 % to 103 % of the **rated voltage** and 99 % to 101 % of the **rated frequency** and otherwise within the tolerances specified in IEC 61000-2-2.

NOTE 1 The test with **resistive load** is considered to be the most reliable in terms of repeatability and constitutes a solid base for the evaluation of efficiency improvements at all load levels.

NOTE 2 For tolerances, refer to 7.8 of IEC 60146-1-1:2009.

F.2.3 Instrumentation

The combination of instruments and transducers used for the measurement of **DC UPS efficiency** shall

- provide true RMS measurements of the active input power and of the **output power**, with an uncertainty at full rated load of less than or equal to 0,5 % at the 95 % confidence level notwithstanding that voltage and current waveforms can include **harmonic components**, and
- measure input and output values simultaneously.

NOTE 1 The confidence level of an instrument's uncertainty is understood as the probability of measurements presented by such instrument being accurate within the uncertainty limits. A normal distribution of data with coverage factor 1,960 represents a 95 % confidence level which is a generally accepted level. For further information, refer to ISO/IEC Guide 98-3.

NOTE 2 Simultaneous input and output measurements are generally provided through separate input and output instruments. Nevertheless, one single multi-channel instrument providing fast serial sampling ("multiplexed sampling") is also deemed to provide simultaneous measurements.

F.3 Measurement method

Under the conditions specified in F.2.1 and F.2.2, using the instrumentation described in F.2.3, the measurement of the **DC UPS efficiency** shall be carried out as follows.

- a) 100 % **reference test load** shall be applied to the output of the **DC UPS** and a suitable stabilization time be allowed to reach the steady-state conditions as specified above.
- b) The active input and **output power** (W) shall be measured simultaneously in three successive readings taken no more than 15 min apart. The **DC UPS efficiency** shall be calculated for each reading.

Where a **DC UPS** is connected to more than one input source, the active input power to be considered is the sum of all inputs.

Where a **DC UPS** supplies more than one output, the active **output power** to be considered is the sum of all outputs.

- c) The arithmetic mean of the 3 **DC UPS** efficiencies calculated in b) shall then be obtained. The result is considered to be the value of the efficiency measure.
- d) Steps a), b) and c) shall be repeated for 75 %, 50 %, and 25 % reference load conditions.
- e) Steps b) and c) shall be repeated for no-load conditions, except that only the **active power** losses shall be recorded.

F.4 Test report

A recommended format for the test report is provided in Annex C. Should the **DC UPS** technical sheet in Table C.1 be used, the sheet shall be completed for each performance classification declared by the manufacturer. The following information shall be recorded in the test report:

- a) **equipment details:**
 - brand, model, type and serial number;
 - product description, as appropriate;
 - **rated voltage** and frequency;
 - **rated output power**;
 - details of manufacturer marked on the product (if any);
 - in the case of products with multiple functions or with options to include additional modules or attachments, the configuration of the appliance as tested shall be noted in the report.
- b) **test parameters:**
 - **ambient temperature** (°C);
 - input and output test voltage (V)
 - information and documentation on the instrumentation, set-up and circuits used for electrical testing.
- c) **measured data:**
 - efficiency in % rounded to the first decimal place at the given **rated** load fraction;
 - input power in W at no-load;
 - measurement method used (see F.3);
 - any notes regarding the operation of the equipment.
- d) **test and laboratory details:**

- test report number/reference;
- date of test;
- name and signature of authorized test person(s).

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Annex G (informative)

Climatic test

G.1 General

The objective of Annex G is to clarify the relationship between the climatic environmental requirements in 4.2.1.1 and 4.2.2 and the **type test** procedures in 6.5.2 and 6.5.3.

G.2 Testing of compliance to climatic requirements

The columns in the table below reveal the relationship between

- IEC 60721-3-3 climatic condition class 3K2 (climatogram), and
- IEC 60068-2 climatic tests

The reader's attention is drawn to column "Recommended test" that lists the three tests x), y) and z) necessary and sufficient for the purpose of verifying compliance of a DC UPS with the climatic conditions of class 3K2.

Table G.1 – Recommended tests for IEC 60721-3-3 – Class 3K2 (continuously temperature-controlled enclosed locations; humidity not controlled)

IEC 60721-3-3 – Climatic conditions			IEC 60068-2 – Climatic conditions				
Environmental parameter	Class 3K2	Nearest IEC 60068-2	Recommended test		Note No.		
			Test method	Severity		Test methods	Severity
					x) Dry heat 60068-2-2: Bb/Bd +30° C, 16 h y) Cold 60068-2-1: Ab/Ad None z) Damp heat 60068-2-56: Cb None	1), 2) 3) 3)	
	a) Low air temperature	+15 °C	As recommended test		See above		
	b) High air temperature	+30 °C	As recommended test		See above		
	c) Low relative humidity	10 %	As recommended test		See above		
	d) High relative humidity	75 %	As recommended test		See above		
	e) Low absolute humidity	2 g/m ³	As recommended test		See above		
	f) High absolute humidity	22 g/m ³	As recommended test		See above		
	g) Rate of change of temperature	0,5 °C/min	60068-2-14: Nb	+5 °C to ambient two cycles 1 °C/min $t_1 = 3$ h	Test normally not required – See note 4)		4)
	h) Low air pressure	70 kPa	60068-2-13: M	70 kPa, 30 min	Test normally not required – See note 5)		5)
i) High air pressure	106 kPa	No IEC 60068-2 test		Test normally not required – See note 6)		6)	

IEC 60721-3-3 – Climatic conditions		IEC 60068-2 – Climatic conditions				
Environmental parameter	Class 3K2	Nearest IEC 60068-2		Recommended test		Note No.
		Test method	Severity	Test methods	Severity	
j) Solar radiation	700 W/m ²	60068-2-5: Sa Procedure C	1 120 W/m ² , 72h, 40°C	Add 10 °C to the dry-heat test: evaluate materials for photochemical reactions		7)
k) Heat radiation User selection from 3Z1, 3Z2 or 3Z3		No IEC 60068-2 test		Test normally not required – See note 8)		8)
l) Movement of surrounding air 1 m/s of user selection from 3Z4, 3Z5 or 3Z6		No IEC 60068-2 test		Test normally not required – See note 9)		9)
m) Condensation	No					
n) Wind-driven precipitation (rain, snow, hail, etc.)	No					
o) Water from sources other than rain	No					
p) Formation of ice	No					
NOTE "No" in the class column means that no IEC 60721-3-3 condition is specified.						
<p>1) To test products against the conditions of the climatogram, only three tests are normally used:</p> <ul style="list-style-type: none"> – dry heat test, where the relative humidity shall not exceed 50% but is not specifically controlled; – cold test, where humidity is not controlled; – damp heat test steady state, where both temperature and humidity are controlled. <p>These are shown as tests x, y and z in the climatogram. The cold and humidity conditions in this class are within the standard atmosphere conditions as defined in IEC 60068-1 and are therefore considered benign for most products and consequently no test is recommended. The other boundary conditions of the climatogram are not normally tested since there are no suitable IEC 60068-2 tests available.</p>						
<p>2) The test temperature is equivalent to the environmental parameter of IEC 60721-3-3 for this class. The choice of the duration of 16 h is considered to be sufficient for most products to demonstrate that its design is adequately tolerated to function at this temperature.</p>						
<p>3) These low temperatures and humidity conditions are within the standard atmospheric conditions described in IEC 60068-1, and so no test is recommended.</p>						
<p>4) The temperature range in this class is considered to be within the standard atmospheric conditions described in IEC 60068-1, and so no change in temperature test need be recommended.</p>						
<p>5) For sealed products or for products containing/processing liquids, test M of IEC 60068-2-13 is recommended. For normal applications where the effect of air pressure is evaluated at the component level, no test is recommended.</p>						
<p>6) There is no IEC 60068-2 test method for this condition, which is within the standard range of atmospheric conditions as defined in IEC 60068-1 and is therefore considered benign for most products. No test is recommended.</p>						
<p>7) The IEC 60068-2-5 procedure C test for simulating the effects of solar radiation at ground level is chosen since it produces continuous irradiation thus allowing assessment of photo-degradation effects. Although the severity of this class is 700 W/m², the only Sa test condition contained in IEC 60068-2-5 is for a solar radiation value of 1 120 W/m².</p> <p>Solar tests are not considered satisfactory, since it is difficult to replicate the actual radiation experienced in practice. It is recommended that this condition should be evaluated by increasing the temperature of the dry heat test by 10 °C and evaluating materials and components for photochemical reactions. For more information, refer to IEC TR 60721-4-0.</p> <p>Products may be protected against the effect of solar radiation, for example, by the fitting of efficient heat shields, in which case the elevated temperature for the dry heat test can be omitted or reduced in severity depending on the effectiveness of the precautions. It should be normal practice to model such precautions in order to give confidence in the ability of the product to resist the effect of solar radiation.</p>						
<p>8) No test is recommended. No value is available in IEC 60721-3-3 for heat radiation, and the effect is normally included in the dry heat test. For products mounted near sources of high heat radiation, special precautions such as heat shields or insulation may be necessary or an additional elevated temperature test may be required, the degree of elevation being dependant on the severity of the heat source.</p>						
<p>9) No test is recommended. No suitable IEC 60068-2 test exists, and the condition is considered as benign for most products. Precautions should be taken, especially for large products if a special condition (3Z4, 3Z5 or 3Z6) is chosen, and the users may have to develop their own methodology if the condition is to be evaluated.</p>						

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