NATIONAL FOREWORD
(will be added later)

1 Scope and object

This standard applies to electronic indirect a.c. converter systems with electrical energy storage means in the d.c. link. The primary function of the uninterruptible power system (UPS) covered by this standard is to ensure continuity of an alternating power source. The uninterruptible power system may also serve to improve the quality of the power source by keeping it within specified characteristics.

A variety of uninterruptible power systems have been developed to meet consumers' requirements for continuity and quality of power for different types of loads over a wide range of power, from less than 100 W to several megawatts. Refer to annexes A and B for information on some of the types available.

This standard applies to electronic uninterruptible power systems (UPS):

a) delivering single- or three-phase fixed frequency a.c. output voltage;

b) with energy storage device in the d.c. link if not otherwise specified;

c) with rated voltage not exceeding 1 000 V a.c.;

d) movable, stationary and/or fixed equipment.

This standard also includes the method of specifying all power switches that form integral parts of a UPS and are associated with its output.

Included are interrupters, bypass switches, isolating switches, load transfer switches and tie switches. These switches interact with other functional units of the UPS to maintain continuity of load power.

This standard does not refer to conventional mains distribution boards, rectifier input switches or d.c. switches (for example for batteries, rectifier output or inverter input, etc.), or UPS based on rotating machines.
NOTE 1 – This standard recognizes that the major market usage with the UPS ratings within its scope is in conjunction with information technology equipment.

Under current technology, the majority of UPS load equipment employs power supplies which present a non-linear load to the UPS and can be tolerant of non-sinusoidal voltage waveforms for a limited time duration. UPS output ratings are specified to be compatible with non-linear loading and linear loading, subject to manufacturers' declaration if different.

References within this standard to linear loading are retained for test method reasons, or validation of manufacturers' additional declaration.

NOTE 2 – For use of UPS with a non-sinusoidal output voltage waveform, beyond the stored-energy time recommended in this standard, the agreement of the load equipment manufacturer should be sought.

NOTE 3 – For UPS output frequencies other than 50 Hz or 60 Hz, performance specification is subject to agreement between manufacturer and purchaser.

This standard is intended to define a complete uninterruptible power system in terms of its performance and not individual UPS functional units. The individual UPS functional units are dealt with in the IEC publications referred to in the bibliography given in annex I, which apply in so far as they are not in contradiction with this standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 62040. For dated references, subsequent amendments to, or revision of, any of these publications do not apply. However, parties to agreements based on this part of IEC 62040 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.


Amendment 1 (1997)

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*


IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60364-4 (all parts), *Electrical installations of buildings – Part 4: Protection for safety*

IEC 60417-1:1998, *Graphical symbols for use on equipment – Part 1: Overview and application*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60950:1991, *Safety of information technology equipment*
IEC 60990:1990, *Methods of measurement of touch-current and protective conductor current* 1)


IEC 61140:1997, *Protection against electric shock – Common aspects for installation and equipment*

IEC 60204-2:—, *Semiconductor converters – Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements*

ISO 7000:1989, *Graphical symbols for use on equipment – Index and synopsis*

ISO/DIS 7779:—, *Acoustics – Measurement of airborne noise emitted by computer and business equipment* 2)

3 Terms and definitions

For the purpose of this standard, the following definitions apply. In this standard, IEV definitions are used wherever possible, particularly those in IEC 60050(551).

3.1 Systems and components

3.1.1 Uninterruptible power system (UPS)

Combination of converters, switches and energy storage means, for example batteries, constituting a power system for maintaining continuity of load power (see 3.2.10) in case of input power failure

3.1.2 Converter

Operative unit for electronic power conversion, comprising one or more electronic valve devices, transformers and filters if necessary and auxiliaries if any [IEV 551-12-01]

3.1.3 UPS functional unit

Functional unit, for example, a UPS rectifier, a UPS inverter or a UPS switch

3.1.4 UPS rectifier

An a.c./d.c. converter for rectification [IEV 551-12-07 modified]

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1) A second edition is at present under consideration.

2) To be published. (Revision of ISO 7779:1988).
3.1.5
**UPS inverter**
an a.c./d.c. converter for inversion [IEV 551-12-10 modified]

3.1.6
**DC energy storage system**
system consisting of single or multiple devices (typically batteries) designed to provide the required stored energy time

3.1.7
**DC link**
direct current power interconnection between the rectifier or rectifier/charger and the inverter functional unit

3.1.8
**Secondary cell**
two or more secondary cells connected together and used as a source of electric energy [IEV 486-01-03]

3.1.9
**Valve regulated sealed (secondary) cell**
secondary cell which is closed under normal conditions, but has an arrangement to allow gas to escape if the internal pressure exceeds a predetermined value. The battery cannot normally receive addition to the electrolyte [IEV 486-01-20]

3.1.10
**Vented (secondary) cell**
secondary cell having a cover provided with an opening through which gaseous products may escape [IEV 486-01-18]
NOTE – The opening may be fitted with a venting system.

3.1.11
**Battery charger**
device for changing alternating current power to direct current power for the purpose of charging a battery

3.1.12
**UPS switch**
switch (quenched, line or self commutated, electronic or mechanical, depending on required continuity of load power) used to connect/isolate UPS or bypass to/from load

3.1.13
**Transfer switch**
UPS switch consisting of one or more switches used to transfer power from one source to another
3.1.14  
**electronic (power) switch**  
Operative unit for electronic power switching comprising at least one controllable valve device [IEV 551-13-01]

3.1.15  
**mechanical UPS (power) switch**  
Mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions which may include specified operating overload conditions and also carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit [IEV 441-14-10 modified]

NOTE – A switch may be capable of making but not breaking short-circuit currents.

3.1.16  
**hybrid UPS (power) switch**  
UPS power switch with mechanical separable contacts in combination with at least one controllable electronic valve device

3.1.17  
**self-commutated electronic switch**  
Electronic switch where the commutating voltage is supplied by components within the electronic switch

3.1.18  
**line commutated electronic switch**  
Electronic switch where the commutating voltage is supplied by the line

3.1.19  
**UPS interrupter**  
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

3.1.20  
**UPS isolation switch**  
Mechanical UPS switch which provides in the open position an isolating distance and may be capable of making, carrying and breaking currents such as circuit-breakers and disconnectors, in accordance with UPS operational requirements

3.1.21  
**tie switch**  
UPS switch which can connect two or more a.c. busbars together

3.1.22  
**UPS maintenance bypass switch**  
Switch designed to isolate a section or sections of a UPS for safety during maintenance and to maintain continuity of load power via an alternative path
3.1.23 multiple function UPS switch
UPS switch performing two or more of the functions described in 3.1.19 to 3.1.22

3.1.24 AC input power
power supplied to UPS and bypass, if any, which can be either primary power or standby power

3.1.25 bypass
power path alternative to the indirect a.c. converter

3.1.26 maintenance bypass
power path designed to allow isolation of a section or sections of a UPS for safety during maintenance and/or to maintain continuity of load power. This path may be supplied with primary or standby power

3.1.27 static bypass (electronic bypass)
power path (primary or standby) alternative to the indirect a.c. converter where control is via an electronic power switch, for example transistors, thyristors, triacs or other semiconductor device or devices

3.1.28 UPS unit
complete UPS consisting of at least one each of the following functional units: UPS inverter, UPS rectifier and battery or other energy storage means which may operate with other UPS units to form a parallel or redundant UPS

3.1.29 single UPS
UPS comprising only one UPS unit

3.1.30 parallel UPS
UPS comprising two or more UPS units operating in parallel

3.1.31 partial parallel UPS
UPS with parallel operating inverters with common battery and/or UPS rectifier

3.1.32 redundant system
addition of functional units or groups of functional units in a system to enhance the continuity of load power
3.1.33  
**partial redundant UPS**
UPS with redundancy in inverters or inverters and/or other functional units

3.1.34  
**standby redundant UPS**
UPS in which one or more UPS are held in reserve until the operating UPS unit fails

3.1.35  
**parallel redundant UPS**
UPS with a number of paralleled load-sharing UPS units which, upon failure of one or more UPS units, can take over full load with the remainder

3.2  **Performance of systems and components**

3.2.1  
**primary power**
power normally continuously available which is usually supplied by an electrical utility company but sometimes by the user’s own generation

3.2.2  
**standby power**
power intended to replace primary power in the event of primary power failure

3.2.3  
**bypass power**
power supplied via the bypass

3.2.4  
**backfeed**
condition where a portion of voltage or energy available within the UPS is fed back to any of the input terminals, either directly or by a leakage path

3.2.5  
**normal load**
load that in normal mode of operation, approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer’s operating instructions

3.2.6  
**linear load**
load where the parameter Z (load impedance) is a constant when a variable sinusoidal voltage is applied to it

3.2.7  
**non-linear load**
load where the parameter Z (load impedance) is no longer a constant but is a variable dependent on other parameters, such as voltage or time
3.2.8 **preferred source**
a.c. power source that delivers power to the load under normal conditions

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

3.2.10 **continuity of load power**
availability of the power supplied to the load with voltage and frequency within rated steady-state and transient tolerance bands and with distortion and power interruptions within the limits specified for the load

3.2.11 Reserved for future use

3.2.12 **UPS switch operation**
transfer of a UPS switch from the on-state to the off-state (opening operation) or vice versa (closing operation). Opening with interruption of load current is referred to as “breaking”, closing with initiation of load current flow is referred to as “making”

NOTE 1 – The terms “on-state” and “off-state” originate from semiconductor technology, but are used in a generalized sense also to cover the closed position and the open position respectively, of a mechanical device.

NOTE 2 – The term “opening” and “closing” originate from mechanical switchgear technology, but are used in a generalized sense also to cover removing or applying, respectively, the control signal of a semiconductor switching valve device.

3.2.13 **normal mode of UPS operation**
stable mode of operation that the UPS finally attains when supplied under the following conditions:

a) primary power is present and within its given tolerance;
b) the battery is charged or under recharge within its given restored energy time;
c) the operation is or may be continuous;
d) the phase lock is active, if present;
e) the load is within its given range;
f) the output voltage is within its given tolerance.

Where a UPS switch is used:
g) the bypass is available and within specified tolerances
3.2.14  
**stored energy mode of UPS operation**  
operation of the UPS when supplied under the following conditions:  
a) primary power is disconnected or is out of the given tolerance;  
b) d.c. energy storage system is being depleted;  
c) load is within the given range;  
d) output voltage is within given tolerance.  
NOTE – Commonly referred to as “battery operation”.

3.2.15  
**bypass mode of UPS operation**  
state the UPS attains when operating the load supplied via the bypass only

3.2.16  
**UPS double conversion**  
any UPS operation, where continuity of load power is maintained by a UPS inverter,  
with energy from the d.c. link in normal mode of operation or from the energy storage  
system in stored energy mode of operation (see annex B.1). The output voltage and  
frequency are independent of input voltage and frequency conditions

3.2.17  
**UPS double conversion with bypass**  
UPS operation as for UPS double conversion with the following addition. Under  
temporary or continuous output overload conditions, or in the case of UPS  
rectifier/inverter failure, the load is temporarily supplied with power via the  
alternative bypass path (see annex B.2). Under bypass operation, the load may be  
affected by input supply voltage and frequency variations

3.2.18  
**UPS line interactive operation**  
Any UPS operation where, in normal mode of operation, the continuity of load power  
is maintained by the use of a UPS inverter or a power interface while conditioning  
primary power at the input supply frequency  
When the a.c. input voltage and/or frequency is out of UPS preset variation limits, the  
UPS inverter and battery maintain continuity of load power in stored energy mode of  
operation within the stated output voltage/frequency tolerances (see annex B.3).

3.2.19  
**UPS line interactive operation with bypass**  
UPS operation as for UPS line interactive with the following addition. In the event of  
a UPS functional unit failure, the load may be transferred to an alternative bypass path  
fed from primary or standby power (see annex B.4). In bypass mode of operation, the  
load may be affected by input supply voltage and frequency variations

3.2.20  
**UPS passive standby operation**  
any UPS operation where, in normal mode of operation, the load is primarily supplied  
by primary power and is subject to input voltage (see note) and frequency variations
within stated limits. When the a.c. input supply is outside UPS design load tolerances, the UPS inverter is activated from the battery, and maintains continuity of load power in stored energy mode of operation (see annex B.5)

NOTE – In normal mode, the primary power may be regulated by the additional devices, i.e. ferro-resonant regulators or static devices, etc.

3.2.21
manual control
control of an operation by human intervention [IEV 441-16-04]

3.2.22
automatic control
control of an operation without human intervention, in response to the occurrence of predetermined conditions [IEV 441-16-05]

3.2.23
semi-automatic control
control of a switch where one of the operations (opening or closing) is automatically controlled (see 3.2.22) while the other is manually controlled (see 3.2.21)

3.2.24
synchronous transfer
transfer of load power between two sources which are synchronized in frequency, voltage phase and limits of voltage magnitude

3.2.25
synchronization
adjustment of an a.c. power source to match another a.c. source in frequency and phase

3.2.26
asynchronous transfer
transfer of load power between two sources which are not synchronized

3.2.27
electromagnetic interference (EMI)
degradation of the performance of an equipment, transmission channel or system caused by an electro-magnetic disturbance [IEV 161-01-06]

3.2.28 Equipment mobility (see 1.2.3 of IEC 60950)

3.2.28.1 movable equipment
equipment which is either 18 kg or less in mass and not fixed, or equipment with wheels, castors or other means to facilitate movement by the operator as required to perform its intended use
3.2.28.2  
**stationary equipment**  
equipment that is not movable equipment

3.2.28.3  
**fixed equipment**  
stationary equipment which is fastened or otherwise secured at a specific location

3.2.28.4  
**equipment for building-in**  
equipment intended to be installed in a prepared recess such as in a wall, or similar situation

3.2.29  **Connections to the supply** (see 1.2.5 of IEC 60950)

3.2.29.1  
**pluggable UPS-type A**  
UPS which is intended for connection to the building power supply via non-industrial plugs and socket outlets or via appliance couplers or both

3.2.29.2  
**pluggable UPS-type B**  
UPS which is intended for connection to the building power supply via industrial plugs and socket outlets complying with IEC 60309 or with national standards for similar applications

3.2.29.3  
**permanently connected equipment**  
UPS which is intended for connection to the building power supply wiring by screw terminals

3.2.29.4  
**detachable power supply cord**  
flexible cord, for supply purposes, intended to be connected to the UPS by means of a suitable appliance coupler

3.2.29.5  
**non-detachable power supply cord**  
flexible cord, for supply purposes, fixed to or assembled with the equipment

3.2.30  **Accessibility** (see 1.2.7 of IEC 60950)

3.2.30.1  
**operator access area**  
area to which, under normal operating conditions, one of the following applies:

a) access can be gained without the use of a tool;

b) access can be gained without the use of a tool, the means of access being deliberately provided to the operator;
c) the operator is instructed to enter regardless of whether or not tools are needed to gain access

NOTE – The terms "access" and "accessible", unless qualified, relate to operator access area as defined above.

3.2.30.2 service access area
area, other than an operator access area, to which it is necessary for service personnel to have access even with the equipment switched on

3.2.30.3 restricted access location
room or space where equipment is located, and where either:
a) access can only be gained by service personnel with the use of a special tool or lock and key;
b) access is controlled

3.2.30.4 tool (see 1.2.7.3 of IEC 60950)
screwdriver or any other object which can be used to operate a screw, latch or similar fixing means

3.2.31 Circuit characteristics (see 1.2.8 of IEC 60950)

3.2.31.1 primary circuit
internal circuit which is directly connected to the external supply mains or other equivalent source (such as a motor-generator set) which supplies the electric power. It includes the primary windings of transformers, motors, other loading devices and the means of connection to the supply mains

3.2.31.2 secondary circuit
circuit which has no direct connection to primary power

3.2.31.3 hazardous voltage
voltage exceeding 42,4 V peak, or 60 V d.c., existing in a circuit which does not meet the requirements of either:
– a limited current circuit, or
– a TNV circuit that is in compliance with the requirements of 3.2.31.8

3.2.31.4 extra-low voltage (ELV) circuit
secondary circuit with voltages between conductors, and between any conductor and earth, not exceeding 42,4 V peak, or 60 V d.c. under normal operating conditions, which is separated from hazardous voltage by at least basic insulation, and which
meets neither all of the requirements for an SELV circuit nor all of the requirements 
for a limited current circuit.

3.2.31.5  
**safety extra-low voltage (SELV) circuit**  
secondary circuit which is so designed and protected that under normal and single 
fault conditions, the voltage between any two accessible parts, and for Class I 
equipment (equipment requiring an earth protective conductor), between any 
accessible part and the equipment protective earthing terminal, does not exceed a safe 
value.

**NOTE 1** – Under normal conditions this limit is either 42.4 V peak, or 60 V d.c.

**NOTE 2** – This definition of an SELV circuit differs from the term SELV as used in 
IEC 60364-4.

3.2.31.6  
**limited current circuit**  
circuit which is so designed and protected that, under both normal conditions and a 
likely fault condition, the current which can be drawn is not hazardous (below or 
equal to 0.7 mA a.c. peak or 2 mA d.c.)

3.2.31.7  
**hazardous energy level**  
stored energy level of 20 J or more, or an available continuous power level of 240 VA 
or more, at a potential of 2 V or more.

3.2.31.8  
**telecommunication network voltage (TNV) circuit**  
circuit that, under normal operating conditions, carries telecommunication signals. A 
TNV circuit is considered to be a secondary circuit according to 3.2.31.2 of this 
standard.

3.2.32  
**service personnel** (see 1.2.14.3 of IEC 60950)  
persons having appropriate technical training and experience necessary to:

– perform tasks in service access areas of the equipment, and

– be aware of hazards to which they are exposed in performing a task, and of 
measures to minimize the danger to themselves or other persons.

3.2.33  
**operator** (see 1.2.14.4 of IEC 60950)  
any person, other than service personnel

**NOTE** – The term "operator" in this standard is the same as the term "user" and the 
two can be used interchangeably.

3.2.34  
**touch current** (IEC 60990)  
current which flows into a network representing the impedance of the human body.
3.2.35 protective conductor current (IEC 60990)
current in the protective conductor as measured by an ammeter of negligible impedance (see annex F, figure F.3)

3.2.36 burn-in
operation of units or systems prior to their ultimate application intended to stabilize their characteristics and to identify early failures

3.2.37 dielectric tests
tests which consist of the application of a voltage higher than the rated voltage for a specified time to verify the dielectric withstand strength of insulation materials and spacing

3.2.38 dielectric withstand strength
specified voltage or potential gradient below which a dielectric material will continue to resist electrical current flow

3.2.39 type test
testing of a representative sample of the equipment with the objective of determining if the equipment, as designed and manufactured, can meet the requirements of this standard

NOTE – Purchasers should note that for physically large units and/or high power ratings adequate test facilities to perform some of the type tests may not exist, or not be economically viable.

This situation also applies to some electrical tests for which no commercially available test simulation equipment is available or which require specialized test facilities beyond the scope of a manufacturer's premises.

Where these situations exist, the manufacturer may elect to either:
a) use a certified test house to carry out testing for compliance on his behalf. Evidence of third party certification shall be deemed sufficient to prove compliance with the relevant clauses;
b) demonstrate that the design is compliant by calculation or by experience and/or testing of similar designs or subassemblies in similar conditions.

Testing of parameters other than those listed as routine shall be a matter of agreement between the manufacturer and the purchaser as a contract condition.

3.2.40 routine test
test made for quality control by the manufacturer on every device or representative samples, or on parts or materials or complete equipments as required to verify during production that the product meets the design specification [IEV 151-04-16 modified]
3.3 Specified values – General

3.3.1 rating
set of rated values and operating conditions of a machine or a device or equipment [IEV 151-04-04 modified]

3.3.2 rated value
quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment [IEV 151-04-03]

3.3.3 nominal value
suitable approximate quantity value used to designate or identify a component, device or equipment [IEV 151-04-01]

3.3.4 limiting value
in a specification, the greatest or smallest admissible value of one of the quantities [IEV 151-04-02]

3.3.5 current limit (control)
function that maintains a current within its prescribed value

3.3.6 tolerance band
range of values of a quantity within specified limits

3.3.7 deviation
difference between the desired value and the actual value of a variable at a given instant [IEV 351-04-26]

3.3.8 rated voltage
input or output voltage (for three-phase supply, the phase-to-phase voltage) as declared by the manufacturer

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

3.3.10 r.m.s. voltage variation
difference between the r.m.s voltage and the corresponding previously undisturbed r.m.s. voltage
NOTE – For the purposes of this standard, the term "variation" has the following meaning: the difference of the values of a quantity before and after a change of an influence quantity.

3.3.11 voltage time integral variation

difference between the voltage time integral over one half-cycle and the corresponding value of the previously undisturbed waveform

3.3.12 peak voltage variation

difference between the peak voltage and the corresponding value of the previously undisturbed waveform

3.3.13 phase angle

angle (usually expressed in electrical degrees or radians) between reference points on one or more a.c. waveforms

3.3.14 rated current

input or output current of the equipment as declared by the manufacturer

3.3.15 active power, $P$

sum of the electrical power at the fundamental frequency and the powers of each harmonic component [IEV 131-03-18 modified]

3.3.16 power factor, $\lambda$

ratio of the active power to the apparent power [IEV 131-03-20]

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

3.3.17 apparent power, $S$

product of the r.m.s. values of voltage and current at a port [IEV 131-03-16]

$$S = UI$$

3.3.18 displacement factor

displacement component of the power factor; ratio of the active power of the fundamental wave to the apparent power of the fundamental wave

3.3.19 UPS efficiency

ratio of output active power to input active power under specified conditions with no significant energy transfer to and from the energy storage means
3.3.20
rated frequency
input or output frequency as declared by the manufacturer

3.3.21
rated frequency range
input or output frequency range as declared by the manufacturer, expressed by its lower and upper rated frequencies

3.3.22
frequency variation
variation of the input or output frequency

3.3.23
total harmonic distortion (THD)
ratio in percent of the r.m.s. value of the harmonic content to the r.m.s. value of the fundamental component of the alternating quantity

3.3.24
total distortion factor (TDF)
ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the alternating quantity

3.3.25
individual harmonic distortion
ratio of the r.m.s. value of a special harmonic component to the r.m.s. value of the fundamental component

3.3.26
harmonic components
components of the harmonic content as expressed in terms of the order and r.m.s. values of the Fourier series terms describing the periodic function

3.3.27
harmonic content
quantity obtained by subtracting from an alternating quantity its fundamental component [IEV 551-17-04]
NOTE – The harmonic content may be given as a time-function or as an r.m.s. value.

3.3.28
form factor
ratio of r.m.s. value to the average value of a periodic quantity rectified [IEV 101-14-56 modified]

3.3.29
peak factor
ratio of its peak value to the r.m.s. value of a periodic quantity
NOTE – The term "crest factor" has the same meaning.
3.3.30 transient
behaviour of a variable during transition between two steady states [IEV 351-04-07]

3.3.31 recovery time
time interval between a step change in one of the control quantities or influence quantities and the instant when the stabilized output quantity returns to and stays within the steady-state tolerance band

3.3.32 stored energy time
minimum time during which the UPS will ensure continuity of load power, under specified service conditions when the primary power fails, starting with the energy storage means sufficiently charged according to 3.3.34
NOTE – Fully charged is intended as restored energy after a restored energy time recharge.

3.3.33 cut-off voltage
specified voltage at which a discharge of a battery is considered finished [IEV 486-03-04]

3.3.34 restored energy time
maximum time required to recharge sufficiently the energy storage means of the UPS with the charging capacity installed (after a discharge as specified in 3.3.33 with the UPS operating under specified service conditions) to ensure another such discharge
NOTE – This period is the time taken after a stored energy time discharge to restore sufficient energy to repeat the stored energy time discharge.

3.3.35 ambient temperature
temperature of the air or other medium where the equipment is to be used [IEV 826-01-04]

3.4 Input values

3.4.1 input voltage tolerance
maximum variation of steady-state input voltage with the UPS operating in normal mode

3.4.2 input voltage distortion
input voltage harmonic distortion in normal mode
3.4.3 input frequency tolerance
maximum variation of steady-state input frequency with the UPS operating in normal mode

3.4.4 input power factor
ratio of the input active power to the input apparent power with the UPS operating in normal mode at rated input voltages at rated output apparent power, and fully charged battery

3.4.5 UPS rated input current
input current with UPS operating in normal mode, at rated input voltage, rated output apparent power, rated output active power and fully restored d.c. energy storage system

3.4.6 UPS maximum input current
input current with the UPS operating under worst-case conditions of permitted overload, input voltage tolerance and with a depleted d.c. energy storage system

3.4.7 UPS inrush current
maximum instantaneous value of the input current when the UPS is switched on for normal mode

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

3.4.9 supply impedance
impedance at the input terminals to the UPS with the UPS disconnected

3.4.10 high impedance failure
failure where the supply impedance is regarded as infinite (see annex G)

3.4.11 low impedance failure
failure where the supply impedance is negligible (see annex G)

3.5 Output values

3.5.1 output voltage
r.m.s. value (unless otherwise specified for a particular load) of the voltage between the output terminals
3.5.2 **output voltage tolerance**
maximum variation of steady-state output voltage with the UPS operating in normal mode or in stored energy mode

3.5.3 **periodic output voltage variation**
periodic variation of the output voltage amplitude at frequencies less than the fundamental output frequency

3.5.4 **output frequency tolerance**
maximum variation of steady-state output frequency with the UPS operating in normal mode or in stored energy mode

3.5.5 **output current**
r.m.s. value of the current (unless otherwise specified for a particular load) from the output terminals

3.5.6 **short-circuit output current**
maximum output current from the UPS into a short circuit across its output terminals in each mode of operation

3.5.7 **output overcurrent**
maximum output current of the UPS over a predetermined time, with the output voltage remaining within its rated range

3.5.8 **overload capability**
output current capability of the UPS in excess of its stated continuous current over a given time, with the output voltage remaining within its rated range, in normal or in stored energy mode

3.5.9 **output impedance**
impedance presented by the UPS at its output terminals to the load at specified frequencies

3.5.10 **output active power**
active power from the output terminals

3.5.11 **load sharing**
simultaneous supplying of power to a load from more than one power source
3.5.12 load power factor
characteristics of an a.c. load in terms expressed by the ratio of active power to apparent power assuming an ideal sinusoidal voltage
NOTE – For practical reasons, the total load power factor including harmonic components may be stated in the manufacturer's technical data sheets.

3.5.13 output apparent power
product of the r.m.s. output voltage and r.m.s. output current

3.5.14 output apparent power – reference non-linear loading
output apparent power measured when the UPS output is loaded by the reference non-linear load defined in annex F
NOTE – Only UPS designed and so designated for a specific application or only linear loads are excluded from requirement.

3.5.15 rated output apparent power
continuous output apparent power as declared by the manufacturer

3.5.16 rated output active power
output active power as declared by the manufacturer

3.5.17 make-time
interval of time between the initiation of the closing operation and the instant when the current begins to flow in the main circuit [IEV 441-17-40]
NOTE – In the case of an electronic switch, the initiation is the instant when a control signal is applied to the control terminal of the switch.

3.5.18 break-time
interval of time between the initiation of the opening operation of a UPS switch and the end of current flow in the circuit considered [IEV 441-17-39 modified]
NOTE – In the case of an electronic switch, the initiation is the instant when a control signal is applied to the control terminal of the switch.

3.5.19 interruption time
time interval during which the output voltage is below the lower limit of the tolerance band
3.5.20
**transfer time**
time interval between initiation of transfer and the instant when the output quantities have been transferred

3.5.21
**total UPS transfer time**
time interval between the occurrence of an abnormality or out-of-tolerance condition and the instant when the output quantities have been transferred

3.5.22
**unbalanced load**
three-phase load with different current or power factor in any of the phases

3.5.23
**step load**
instantaneous addition or removal of electrical loads to a power source

3.5.24
**sinusoidal output voltage**
output voltage waveform complying with the minimum requirements given in clause 2 of IEC 61000-2-2

3.5.25
**non-sinusoidal output voltage**
output voltage waveform outside the tolerances given in 3.5.24

4  General ambient service conditions

4.1  Normal environmental and climatic service conditions

An item of equipment which complies with this standard shall be capable of withstanding the conditions defined in this subclause, unless other values are agreed between manufacturer/supplier and purchaser.

NOTE – Using the UPS at the limits of 4.1.1 to 4.1.4 guarantees operation, but may affect the effective life of certain components, in particular the life endurance of the energy storage device and its stored energy time.

4.1.1  Altitude

A UPS conforming to this standard shall be designed to operate under rated conditions at a height up to and including 1,000 m above sea level.

NOTE – The manufacturer can state on request a necessary derating of equipment to be applied at a height exceeding 1,000 m. The following table is provided for guidance.
### Table 1 – Derating factors for use at altitudes above 1 000 m

<table>
<thead>
<tr>
<th>Altitude m</th>
<th>Derating factor ¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 000</td>
<td>1,0</td>
</tr>
<tr>
<td>1 500</td>
<td>0,95</td>
</tr>
<tr>
<td>2 000</td>
<td>0,91</td>
</tr>
<tr>
<td>2 500</td>
<td>0,86</td>
</tr>
<tr>
<td>3 000</td>
<td>0,82</td>
</tr>
<tr>
<td>3 500</td>
<td>0,78</td>
</tr>
<tr>
<td>4 000</td>
<td>0,74</td>
</tr>
<tr>
<td>4 500</td>
<td>0,7</td>
</tr>
<tr>
<td>5 000</td>
<td>0,67</td>
</tr>
</tbody>
</table>

¹) Since fans lose efficiency with altitude, forced air-cooled equipment will have a smaller derating factor.

### 4.1.2 Ambient service temperature

A UPS conforming to this standard shall be able to operate under rated conditions in a minimum temperature range from 0 °C to +40 °C, except for indoor office ambient temperature range from +10 °C to +35 °C.

NOTE – Using the UPS at the limit of the above-mentioned ranges guarantees operation, but may affect the effective life of certain components, in particular, the life endurance of the energy storage device and its stored energy time. Refer to the manufacturer for details on life limitations, or where the energy storage device is purchased separately, the battery manufacturer.

### 4.1.3 Relative humidity

A UPS conforming to this standard shall be designed for a minimum ambient relative humidity range from 20 % to 80 % (non-condensing).

### 4.1.4 Ambient storage and transportation conditions

UPS equipment conforming to this standard shall be able to be stored non-operating in the conditions defined in this subclause, if no other conditions are given by the manufacturer's instructions.

NOTE – Storage duration may be limited because of recharging requirements of an incorporated battery. The manufacturer states these requirements on request.

### 4.1.4.1 Altitude

UPS equipment conforming to this standard shall be able to be transported by pressurized aircraft up to 15 000 m above sea-level in normal shipping containers or
packages for a flight duration of maximum 16 h. Normal storage height shall not exceed 1 000 m above sea-level.

4.1.4.2 Transportation and storage temperature

UPS equipment conforming to this standard shall be transportable in its normal shipping container, for example by aircraft or by truck, in a minimum ambient temperature range from −25 °C to +55 °C.

For stationary storage within a building, the minimum temperature range shall be from −25 °C to +55 °C.

NOTE – When a battery is included, the duration of high or low ambient temperature may be limited due to a reduction of the battery life endurance. The battery manufacturer's transportation and storage instructions should be observed.

4.1.4.3 Relative humidity

During transportation and storage of a UPS in its normal shipping container, the unit shall withstand relative humidity from 20 % up to 95 %. The shipping container shall be designed adequately, unless dry ambient conditions are guaranteed. Containers not designed for wet ambient conditions shall be marked by adequate warning labels.

4.2 Unusual service conditions to be identified by the purchaser

The purchaser shall identify any deviations from the normal service conditions as given in 4.1 to 4.1.4.3 in case he should not be able to ensure the conditions given there. Conditions of the kind given below in 4.2.1 and 4.2.2 may require special design or special protection features.

4.2.1 Environmental conditions to be identified

a) Damaging fumes
b) Moisture
c) Dust
d) Abrasive dust
e) Steam
f) Explosive mixtures of dust or gases
g) Salt air
h) Weather or dripping water
i) Extreme changes in temperature
j) Cooling water containing acid or impurities which may cause scale, sludge, electrolysis or corrosion of the converter parts exposed to the water
k) Strong electromagnetic fields
l) Radio-active levels above those of the natural background
m) Fungus, insects, vermin, etc.
n) Restriction of ventilation
o) Radiated or conducted heat from other sources
p) Battery service conditions

4.2.2 Mechanical conditions to be identified
a) Exposure to abnormal vibration, shocks, tilting or earthquakes
b) Special transportation or storage conditions (purchaser should identify method of handling equipment)
c) Space and weight limitations

5 Electrical service conditions and performance

5.1 General - All UPS

5.1.1 UPS configurations
Reference should be made to annexes A, B and C for details of the configurations of UPS, both as single units and interconnected units forming redundant and parallel units.

5.1.2 Equipment markings and instructions
UPS complying with this standard shall be marked and supplied with adequate instructions for the installation and operation of the UPS and its controls and indications.

5.1.2.1 Rating information
UPS shall be provided with adequate markings in order to specify:
- input supply requirements;
- output ratings.

For UPS intended to be installed by anyone other than service personnel, the markings shall be readily visible, either in an operator access area, or shall be located on an outside surface of the equipment. If located on an outside surface of fixed UPS, the marking shall be discernible after the UPS has been installed as in normal use.

Markings that are not visible from the outside of the UPS are considered to be in compliance if they are directly visible when opening a door or cover. If the area behind a door or cover is not an operator access area, a readily visible marker shall be attached to the UPS to indicate clearly the location of the marking when the UPS is of the operator-installable type (see 5.1.2.2). It is permitted to use a temporary marker.

The markings of input and output shall include the following:

a) rated voltage(s) or rated voltage range(s), in volts (V) for line/line and/or line/neutral values.
The voltage range shall have a hyphen (-) between the minimum and maximum rated voltages. When multiple rated voltages or voltage ranges are given, they shall be separated by a solidus (/).

For UPS with multiple rated voltages, the corresponding rated currents shall be marked so that the different current ratings are separated by a solidus (/), and the relation between rated voltage and associated rated current appears distinctly;

NOTE – Some examples of rated voltage markings are: Rated voltage range: 220 V-240 V. This means the UPS is designed to be connected to any supply having a nominal voltage between 220 V and 240 V.

Multiple rating voltage: 120/220/240 V. This means that the UPS is designed to be connected to a supply having a nominal voltage of 120 V, 220 V or 240 V, usually after internal adjustment.

b) symbol for the nature of supply, particularly for d.c.;

c) rated frequency or rated frequency range, in hertz (Hz), unless the equipment is designed for d.c. only;

d) rated current, in amperes (A).

UPS with a rated voltage range shall be marked with either the maximum rated current, or with the current range:

a) number of phases (1 – 3), with or without neutral;

b) rated output active power, in watts (W) or kW;

c) rated output apparent power, in voltamperes (VA) or kVA;

d) maximum ambient operating temperature range (optional);

e) stored energy time, in minutes or hours at an ambient temperature of 25 °C and rated output active power (only for built-in batteries) (optional marking);

f) manufacturer’s name, trade mark or identification mark;

g) manufacturer’s model or type reference.

NOTE – Additional markings are allowed, provided they do not give rise to misunderstanding.

Where symbols are used, they shall conform to ISO 7000 and IEC 60417, where appropriate symbols exist.

For UPS designed with additional separate automatic bypass/maintenance bypass, additional input a.c. supply or external batteries, it shall be allowed that the relevant supply ratings to be specified in the accompanying installation instructions.

Where this is done, the following instruction shall appear on or near the point of connection:

SEE INSTALLATION INSTRUCTIONS BEFORE CONNECTING TO THE SUPPLY
5.1.2.2 Safety instructions and documentation

If it is necessary to take special precautions to avoid the introduction of hazards when operating, installing, maintaining, transporting or storing UPS, the manufacturer shall make available the necessary instructions.

The operating instructions (and for pluggable UPS intended for user installation, also the installation instructions) shall be made available to the user.

NOTE 1 – Special precautions may be necessary, such as d.c. connection of the UPS to the battery and the interconnection of separate units, if any.

NOTE 2 – Where appropriate, installation instructions should include reference that national wiring rules may override these instructions.

NOTE 3 – Maintenance information is normally made available only to service personnel.

The manufacturer shall provide the user with guidance on the level of competence necessary for installation, for example:

a) operator installable: any pluggable type A or B-UPS with battery already installed by the supplier, or which can be safely installed by the operator (see 3.2.29);

b) service personnel installable: any fixed UPS or UPS with batteries not installed when delivered to the user which require technical skill to complete the installation.

The manufacturer shall provide the user with guidance on the level of competence necessary to operate the UPS, such as:

a) can be operated by an individual with no previous experience;

b) can be operated by individuals with previous training.

When the disconnect device is not incorporated in the UPS, or when the plug on the power supply cord is intended to serve as the disconnect device, the installation instructions shall state that:

a) for permanently connected UPS, a readily accessible disconnect device shall be incorporated in the fixed wiring;

b) for pluggable UPS, the socket-outlet shall be installed within 2 m of the UPS and shall be easily accessible.

For UPS systems intended for use as pluggable UPS-type A, where the earth leakage currents of the UPS and the connected load flow together in the primary UPS protective earth conductor, under any mode of operation, the installation instructions shall indicate the permitted level of earth leakage current of a load to be connected to the UPS so as not to exceed the total limit of earth leakage current for a pluggable type A: 3.5 mA. Where the user is unsure of the total, instructions shall state the connection method for a permanently connected system.

For pluggable UPS-type B and permanently connected UPS without automatic backfeed isolation, the instructions shall require the fitting by the user of a warning label on all primary power isolators installed remote from the UPS area, to warn
electrical maintenance personnel that the circuit feeds a UPS. The warning label shall carry the following wording or equivalent:
5.1.3 Equipment safety

5.1.3.1 UPS designed for use in operator accessible areas

UPS designed for use in operator accessible areas and/or operator installable (see 5.1.2.2) shall meet the applicable safety requirements and criteria of IEC 60950.

5.1.3.2 Additional protection for pluggable UPS-type A

In addition to the requirements of 5.1.3.1, pluggable UPS-type A shall be provided with automatic backfeed protection to prevent potential risk of electric shock from being present on the exposed pins of the cord plug and/or appliance coupler during interruption of the input mains or withdrawal of the plug. This protection shall also act for any single component failure in the UPS or insulation failure on the load equipment.

As an exception, this requirement need not be met where circuit design prevents this occurrence under normal and component failure situations.

5.1.3.3 Backfeed protection switching device(s)

The protection mentioned in 5.1.3.2 shall employ a switching device(s) having air gap contacts on each supply pole, according to the minimum clearance in secondary circuits given in table 5 of IEC 60950, under the column headed as "Circuits not subjected to transient overvoltage", for reinforced insulation at the rated input supply voltage. The minimum creepage shall be as given in table 6 of IEC 60950, Pollution degree 2, Material group IIIb, except for situations permitted in the notes to table 6 of IEC 60950. This protection shall act within a maximum time of 1 s.

5.1.3.4 Pluggable UPS-type B and permanently connected UPS

Where no automatic backfeed protection is provided, the manufacturer shall warn users as in 5.1.2.2.

5.1.3.5 UPS designed for use in electrical switch rooms

UPS designed for use in electrical switch rooms and designed for installation/operation of control and switchgear by electrically qualified personnel shall meet the appropriate national safety standard applicable at the installation site. Where no national standard is applicable, the UPS shall meet the safety criteria of IEC 61140 or similar applicable IEC standards in the absence of an IEC-UPS safety standard. Compliance with such standards shall be a matter of agreement between the manufacturer and the purchaser.

5.2 UPS input specifications

5.2.1 Normal service conditions

Compatibility with public low-voltage supplies:
Equipment conforming to this standard shall be capable of operating in normal mode of operation when connected to an input supply having the following conditions, if not otherwise specified.

a) Input voltage variation: ±10 % of nominal rated voltage
b) Input frequency variation: ±2 % of nominal rated frequency
c) For three-phase inputs, the ratio of negative to positive sequence components shall not exceed 5 % (see 2.5 of IEC 60146-1-1).
d) Input voltage total distortion factor D 0,08 with the following maximum level of individual harmonic voltages according to the table 2 below (extract from table 1 of IEC 61000-2-2 for public low-voltage supplies) up to the 40th harmonic.

NOTE – The limit to order 40 is conventional.

### Table 2: Compatibility levels for individual harmonic voltages in low-voltage networks –
(extract from IEC 61000-2-2)

<table>
<thead>
<tr>
<th>Harmonic order</th>
<th>Harmonic voltage</th>
<th>Odd harmonics non-multiple of 3</th>
<th>Even harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
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<td>3.5</td>
<td>15</td>
<td>6</td>
</tr>
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<td>13</td>
<td>3</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>&gt;21</td>
<td>10</td>
</tr>
<tr>
<td>19</td>
<td>1.5</td>
<td>&gt;12</td>
<td>&gt;12</td>
</tr>
<tr>
<td>23</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>1.5</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

NOTE – All the above harmonic levels are assumed not to occur simultaneously.

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

NOTE 2 – If a bypass is used, its input should be within tolerances acceptable for the load.

NOTE 3 – The above limits apply to public low voltage supplies. UPS designed for industrial applications or separately generated supplies may be required to meet more severe conditions. For these situations, the purchaser must specify the parameters or, in the absence of such information, the manufacturer/supplier may apply his experience as to the compatibility of the design for the intended installation.
5.2.2 Rated values and characteristics

The following rated values and characteristics shall be specified by the manufacturer (if applicable).

a) Rated a.c. input voltage
b) AC input voltage tolerance
c) Rated input frequency
d) Input frequency tolerance
e) Number of phases (if more than a single phase)
f) Rated input current
g) Maximum continuous input current (worst-case condition, i.e. including battery charging, mains tolerance and permitted overload)
h) Input current total harmonic distortion
i) Input current individual harmonic current levels (n ≤ 40) measured or calculated at rated input current when supplied with a voltage source of negligible distortion
j) Maximum input current (where applicable, curve of current against time)
k) Input power factor
l) Input neutral requirements
m) Inrush current requirements
n) Earth leakage current requirements (where in excess of 3.5 mA)
o) In case of three-phase inputs, the maximum allowable mains voltage unbalance
p) Power system configurations designed as defined in IEC 60364-4, e.g. TN, TN-C, TN-S, TN-C-S, TT, IT)

5.2.3 UPS input conditions to be identified by the purchaser

The purchaser shall identify any deviations from the normal service conditions and characteristics stated in 5.2.2. These deviations may require special design and/or protection features.

a) Supply impedance and system configuration (e.g. TN, TN-C, TN-S, TN-C-S, TT, IT)

NOTE – If the place of installation is unknown, the manufacturer/supplier may use his experience and state the values in the technical data sheet.
b) Voltages in excess of variations given in 5.2.1
c) Frequency in excess of variations given in 5.2.1
d) Superimposed high-frequency voltages
e) Existing voltage harmonics on point of coupling of the UPS
f) Transient voltages or other electrical noise, such as that caused by lightning or capacitive or inductive switching

NOTE – The above information is also required in the case of standby power.
g) Protective device characteristics in the UPS input supply
h) Requirements for all-pole isolation (where required by national wiring regulations)
i) Standby generator characteristics.

5.3 UPS output specifications

5.3.1 Steady-state and dynamic output voltage characteristics

UPS conforming to this standard shall have output voltage dynamic performance characteristics not exceeding the limits of figures 1, 2 or 3 under the following conditions (see also annexes D.10 and H).

a) Change of operating mode (e.g. normal/stored energy/bypass, etc.)
b) Application of increasing/decreasing load steps under linear and reference non-linear load under the test conditions of 6.3.

Single-cord connected UPS designed to be safely installed by the operator for use in an office environment, either desk or floor-mounted, and intended to be marketed by a third party without reference to the manufacturer, shall be capable of accepting all loads, both linear and non-linear, within its rating, unless any limitations are stated by the manufacturer within the user instructions.

Step non-linear loading is defined as application of the test circuit in annex E set for dissipating the required steady-state output active power for the percentage load step relative to the rated steady-state active output power of the UPS. The load circuit is then first de-energized before application, so that its capacitor voltage starts from zero voltage when applied to the UPS output. Where it is known that the actual installed load has input current limiting for initial start-up, it shall be permitted to modify the test circuit to simulate actual conditions in determining output dynamic performance characteristics of the UPS.

![Figure 1 – Output dynamic performance classification 1](image-url)
Figure 2 – Output dynamic performance classification 2

UPS complying with figure 1 or figure 2 will be suitable for most types of loads.

NOTE – Deviation from the voltage limits of figures 1 and 2 for load steps is permitted where load tolerances permit and in agreement with the purchaser.

Where output dynamic performance limits are exceeded, and the load characteristics suit, the maximum recommended deviation is shown in figure 3.

Figure 3 – Output dynamic performance classification 3
NOTE – Figure 3 is suitable only for loads capable of withstanding a wide voltage tolerance and a period of zero voltage for up to 10 ms duration (e.g. switched-mode power supplies).

5.3.1.1 Output characteristic – Sinusoidal output voltage

The output voltage waveform is sinusoidal in both normal and stored energy mode of operation with total distortion factor D and individual harmonics within the limits of table 2 (5.2.1).

Voltage limits under dynamic conditions (see 6.3.6 to 6.3.8) shall not exceed the undervoltage and overvoltage transient limits of figures 1, 2 or 3.

Exceptionally, under reference non-linear loading, any limitations in output rating shall be stated by the manufacturer so as to remain within the limits of table 2 (5.2.1).

5.3.1.2 Output characteristic – Non-sinusoidal output voltage

Where the output voltage waveform exceeds the limits of table 2 (5.2.1) in any mode of operation and where the load equipment will tolerate such waveforms, the following limits apply:

a) Rise time $dU/dt$, measured between 0.1 $U_p$ and 0.9 $U_p$ (see figure 4)

b) Peak voltage $U_p$

![Figure 4 – Example of non-sinusoidal output voltage waveform](image)

On the condition of rated output active power, the minimum requirements shall be:

i) $dU/dt \leq 10V/\mu s$;

ii) $U_p$ maximum = rated output voltage $\times \sqrt{2}$.

NOTE – The advice of the load equipment manufacturer should be sought for operation on this type of waveform beyond a limit of 15 min.
5.3.2 Rated output values and characteristics

The following rated values and characteristics shall be specified in all modes of operation by the manufacturer/supplier (if applicable).

a) Rated output voltage
b) Output voltage tolerance
c) Number of phases
d) Rated output current for specified load power factor or power factor range – linear load
e) Rated output current at specified load power factor or power factor range – non-linear load
f) Nominal frequency and frequency tolerance band
g) Maximum relative harmonic content of the output voltage at rated linear and non-linear load
h) Maximum synchronized frequency range and maximum phase error for synchronization of the UPS inverter with the bypass or bypasses
i) UPS nominal inverter frequency or frequency range non-synchronized with the bypass
j) Rate of change of frequency when synchronizing
k) Permissible load unbalance (multi-phase only)
l) Relation between load unbalance and voltage unbalance
m) Phase angle displacement tolerance between line-to-line or line-to-neutral voltages (multi-phase only)
n) Permissible range of load power factor
o) Output voltage transient deviation (r.m.s., time integral) and recovery time for a step change in load current for both linear and non-linear loads (see annex E)
p) UPS efficiency at rated load
q) UPS output fault clearing capability: the rated fault clearing capability shall be given as the maximum load protective device rating with which the UPS can coordinate under fault conditions whilst still maintaining continuity of load power
r) Overload capability: the overload is given by the ratio of overload current to rated output current which can be applied to the UPS for specified time values without exceeding the established limitations under prescribed conditions of operation. The duration of overload capability is valid after steady-state operation when rated load has resulted in thermal equilibrium. The overload power factor shall be specified

NOTE – The figures given are valid under floating voltage of the battery, if not otherwise agreed to.
s) Current limit identification: if current limiting circuits are provided in the UPS, the voltage versus current characteristic shall be provided (if requested)

5.3.3 Single UPS and parallel UPS with bypass

Ratings shall be in accordance with 5.3.2 and in addition, the following shall be added for the transfer switch:

...
a) Transfer switch voltage rating  
b) Continuous current rating  
c) Load power factor  
d) Interruption time rating  
e) Total system transfer time and interruption time (if any)  
f) Rated UPS output fault clearing capability on bypass (see 5.3.2, item q)  
g) Output voltage transient deviation and recovery time on transfer of rated load for both linear and non-linear loads

5.3.4 **Performance requirements to be identified by the purchaser**

The purchaser shall identify any special UPS performance requirements if these deviate from 5.3.2 and 5.3.3.

a) Maximum load step and load profile versus time  
b) A load which is not balanced between phases as specified in 5.3.2, item k  
c) Loads generating (especially even) harmonic currents  
d) Loads generating circulation of a d.c. current, for example half-wave  
e) Earth conditions of the output neutral required  
f) Protective device(s) characteristic with which the UPS output is required to coordinate  
g) Type of load or loads to be connected (linear/non-linear) and individual load ratings  
h) Output relative harmonic content

5.3.4.1 **Special performance requirements**

Special performance requirements regarding the following items should be specified by the purchaser.

a) Output voltage stabilization and phase angle tolerance (three-phase UPS)  
b) Frequency stability  
c) Synchronization and rate of change of frequency during synchronization  
d) Efficiency  
e) Load distribution  
f) Future extension  
g) Degree of redundancy  
h) Output overvoltage protection

5.4 **UPS intermediate d.c. circuit and/or battery circuit specification**

The following rated values and characteristics shall be specified by the manufacture/supplier (if applicable).

a) Nominal d.c. voltage  
b) Nominal d.c. current
c) Isolation of d.c. link from input and/or output
d) Earth conditions of d.c. link
e) Type of batteries (if built-in)
f) Number of batteries and Ah rating (if built-in)
g) Stored energy time (built-in batteries only)
h) Restored energy time (built-in batteries only)
i) Nominal d.c. battery charging voltage and tolerance band
j) Charging current limit value or range
k) Battery ripple current or voltage
l) Battery undervoltage and/or overvoltage charging protection levels
m) Battery charging regime, i.e. constant voltage, constant current, boost or equalization capability, two-state charging
n) Battery protective device ratings and type and number
o) Battery protection requirements (remote battery)
p) Battery cable voltage drop recommendations (remote battery)

5.5 UPS switches, rated values and performance

5.5.1 General

For UPS switches which are not regarded as integrated parts of a UPS, such as transfer switches and tie switches, the following values and characteristics shall be specified by the manufacturer/supplier.

a) Normal service conditions
b) Continuous duty

Rated values of those UPS switches which are regarded as integrated parts of a UPS unit are matched to the requirements of the UPS and are not stated separately.

5.5.2 UPS switches

The following consistently rated values shall be specified (if appropriate).

a) Voltage and its tolerance band
b) Number of poles/number of phases
c) Continuous current capability
d) Short-circuit making capability
e) Short-circuit breaking capability
f) Overload current capability (see 5.3.2, item r)
g) Make time
h) Break time
i) Circuit repetitive peak off-state voltage
j) Circuit non-repetitive peak off-state voltage
k) Leakage current
l) Maximum permissible rate of rise of the off-state voltage
m) Losses at rated load (if not included in the UPS values)
n) Isolation capability
o) Load power factor limits
p) Frequency and its tolerance band
q) Rate of rise of current at closing

NOTE – With transfer switches the rated values and characteristics should be specified for each set of input terminals. In addition, the maximum transfer times for both transfer directions should be specified.

5.6 Redundant and parallel UPS systems (refer to annex A)

5.6.1 Standby redundant UPS

5.6.1.1 Without bypass

The following shall be stated.

a) Total number of UPS units, as well as number of UPS units working normally in parallel (if any)
b) UPS ratings and performance in accordance with 5.2, 5.3 and 5.4
c) UPS switch losses are to be included in overall efficiency
d) UPS switch ratings as defined in 5.3.3 (bypass)

5.6.1.2 With bypass

The same items as those in 5.6.1.1 shall be stated and, in addition, bypass ratings as defined in 5.3.3.

5.6.2 Parallel redundant UPS

5.6.2.1 Without bypass

The following shall be stated.

a) Total number of equal UPS units working normally in parallel
b) Number of UPS units in parallel needed to supply specified maximum continuous load
c) UPS switch and transfer performance specifications in accordance with 5.3.3 for connecting or disconnecting a UPS unit
d) Continuous rating with all UPS units in operation in accordance with 5.2, 5.3 and 5.4
e) Continuous rating with minimum required number of UPS units in operation in accordance with 5.2, 5.3 and 5.4
5.6.2.2 With bypass

The same items as those in 5.6.2.1 shall be stated and, in addition, bypass ratings and performance in accordance with B.2.

5.7 Electromagnetic compatibility

See IEC 62040-2.

5.8 Signalling circuits

The manufacturer shall provide, when fitted, adequate instructions for use and installation of all signalling circuits intended to be connected to information technology equipment, e.g. computers, LAN networks, etc. or telecommunication circuits, etc. These signals shall meet the SELV requirements of IEC 60950 and (where applicable) any local regulations regarding telecommunication networks when designed to be connected to such networks.

6 Electrical tests for UPS

6.1 General

Uninterruptible power systems covered by this standard range from complete small portable UPS with integral batteries, to multi-module large UPS which are supplied as complete UPS or as UPS functional units intended for final assembly and wiring on-site. This standard is therefore arranged to take account of the wide variation of UPS installations in the testing procedures.

Smaller equipments, normally shipped as a complete UPS, shall be completely tested before being shipped, in accordance with these provisions.

Testing of larger equipment can be limited to tests in the manufacturer's works on the individual UPS functional units that are to be shipped separately.

Other tests, such as tests on large complete UPS or tests on-site are included, if separately specified.

6.1.1 Type tests

The tests shall be performed to verify that the design of the product is appropriate to meet performance requirements specified in this standard and/or those specified separately by the manufacturer or purchaser for special applications.

NOTE – For UPS in series production, some of the type tests may be repeated at specified intervals on a specified number of samples to verify that the quality of the product is maintained.

6.1.2 Routine tests

Routine tests shall be performed on each UPS or UPS functional units, if they are shipped separately, before delivery, to verify that the requirements of this standard are met.
Due to the diversity of the UPS types and construction, it shall be at the manufacturer's discretion as to how and which tests are performed to prove the functionality of a complete UPS design. The tests shown in table 3 are generally applicable, but certain tests will be done with a subassembly, whilst others are done with the UPS in its complete form.

6.1.3 Test conditions

The tests shall be performed in electrical conditions equivalent to those in real service. If not practicable, the UPS and UPS functional units, respectively, shall be tested under such conditions as to allow the specified performance to be determined.

In UPS tests, the UPS functional units and other equipment may be tested separately if this is more convenient.

NOTE 1 – The purchaser's attention is drawn to the content of the notes in 6.1.3 and the type test definition, 3.2.39, before formulating any test schedule as part of a purchase contract. It is advisable for economic reasons to confine the performance of tests to those which are considered necessary.

NOTE 2 – When the purchaser or his representative desires to witness factory tests, he should so specify on the order. If so agreed before the order, the contract may specify that the supplier provides a report of tests performed on the product.

NOTE 3 – Reference may be made to type tests previously performed on an identical or similar product with test conditions at least equal to the requirements of the contract or the purchaser's specification.

NOTE 4 – It should be a matter of agreement between the manufacturer/supplier and the purchaser to discriminate between tests to be performed in the manufacturer's/supplier's works, if applicable, and those to be conducted on site in the final installation.

NOTE 5 – The necessity for on-site testing generally applies to installations of large multi-module systems and/or where the battery is not part of the UPS purchase contract or of a type that cannot be commissioned except in the final installation, and/or where verification of compliance with national EMC standards as a complete installation is desired.

6.2 UPS functional unit tests (where applicable)

6.2.1 UPS rectifier tests

Rectifier tests shall be performed in accordance with 4.1.3 to 4.2, where applicable, of IEC 60146-1-1. 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.

6.2.2 UPS inverter tests

Inverter tests shall be performed in accordance with clause 5 of IEC 60146-2 if applicable. The schedule of routine tests, type tests and optional tests is given in 5.2.2
of IEC 60146-2 and corresponds to the UPS inverter test performance, except that it includes additional tests of harmonic content and optional tests concerning special features of inverter equipment, where applicable.

The test items in the schedule are specified in 5.3 to 5.17 of IEC 60146-2.

### 6.2.3 UPS switch tests

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

Operational tests shall be performed in accordance with IEC 60146-1-1 where applicable; for example, the following test procedures are usually applicable.

a) Insulation, according to IEC 60146-1-1  
b) Checking of auxiliary devices, according to IEC 60146-1-1  
c) Checking of protective devices, according to IEC 60146-1-1  
d) Checking of supervisory and remote signalling circuits  
e) Checking of measuring devices  
f) Light load transfer test  

In addition to the tests mentioned above, a type test programme will include tests to prove the rated values given in clause 5 of this standard 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.

g) A complete functional test, e.g. switching of loads  
h) Transfer time test  
i) Load test, temperature rise, according to IEC 60146-1-2  
j) Short-time overload, according to IEC 60146-1-2  
k) Short-circuit capability, according to IEC 60146-1-2

### 6.2.4 Monitoring and control equipment tests

The following tests shall be performed.

a) Insulation tests (4.2.1 of IEC 60146-1-1)  
b) Checking of electrical circuits  
c) Checking of operational controls

### 6.2.5 Battery tests

Unless otherwise specified in the purchase contract, factory tests on valve regulated type batteries within a UPS or in separate UPS battery cabinets shall be limited to initial type tests and such routine production tests deemed necessary, by the UPS manufacturer, to verify the performance of the battery.
Any additional on-site testing in accordance with 6.6.15, 6.6.16 and 6.6.17 shall be a matter of agreement between the UPS manufacturer or his supplier, and the purchaser.

Testing of vented type batteries will consist of tests in accordance with 6.6.15, 6.6.16 and 6.6.17 after complete installation and commissioning on site, when so specified in the purchase contract.

Special charging regimes, such as boost/equalization requirements required by the battery manufacturer, shall be demonstrated.

6.3 Type tests of manufacturer's declared characteristics as a complete UPS

If complete UPS testing is not performed at the factory, a functional unit test in accordance with 6.2 shall be completed prior to testing on site.

Instruments used for the measurement of electrical parameters shall have sufficient bandwidth to accurately measure true r.m.s value on waveforms which may be other than a fundamental sinewave, i.e. having considerable harmonic content.

NOTE 1 – The measurements can be accomplished by the use of conventional memory oscilloscopes and high performance multimeters and wattmeters using analogue or digital technologies.

Whichever type of instrumentation is used, its accuracy shall be in relation to the characteristic being measured and regularly calibrated in accordance with national standards.

Load tests are performed by connecting a reference non-linear load (referenced in annex E) and/or linear loads to the UPS output to simulate actual loads, or with the actual load when available.

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

Load tests are performed to measure voltage distortion in steady-state, and peak output voltage transient deviations are specified under step load conditions in addition to other specified parameters.

NOTE 2 – In particular cases, a special load can be used as agreed upon between manufacturer/supplier and purchaser. The UPS should be so designated for special use.
Table 3 – Type tests for UPS performance characteristics
(for non-electrical tests see clause 7)

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6.3.1 **Control and monitoring signals**

The operation of indications and signals are checked on a routine basis while the following tests are being carried out.

6.3.2 **Input voltage and frequency tolerance test**

The UPS shall be in normal mode of operation with the UPS output loaded at rated output apparent power.

The input supply shall be from a variable frequency/voltage generator whose output impedance shall be capable of maintaining the voltage waveshape within the limits of IEC 61000-2-2. Alternative test methods in the absence of a variable frequency/voltage generator are permitted.

6.3.2.1 **Steady-state input voltage tolerance test**

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

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

Where the design of the 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.

6.3.2.2 **Input frequency tolerance test**

The test of 6.3.2.1 shall be repeated with the input frequency adjusted to the limits specified by the manufacturer in conjunction with the input voltage variations of 6.3.2.1 (see note).

Where the UPS output frequency is synchronized with the input frequency, the range of synchronization shall be checked.

Where the total input frequency range exceeds the stated range of synchronization, the UPS output normally reverts to free running operation. The free running frequency shall be recorded for non-synchronous conditions.

**NOTE –** A decrease in frequency is assumed not to coincide with an increase in line voltage, and vice versa.
6.3.3 Inrush current test

The inrush current test shall be performed after an absence of input voltage for more than 5 min and after an absence of 1 s. The measured value shall not exceed the manufacturer's declared value.

NOTE – The test should be repeated sufficiently to obtain worst-case peak current, which will normally be found for transformer coupled units when switched at the zero voltage point, and for direct rectifier/capacitor loads at or near the peak of the input supply voltage waveform.

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.
Whenever possible, the mains supply shall be from a power source with a minimum prospective short-circuit capability consistent with a mains supply rating necessary to supply the required input supply continuous rated current, including the switching device and wiring to the input terminals of the UPS.

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

**6.3.4 UPS output characteristics tests – Static conditions – Normal and stored energy mode of operation**

Where the manufacturer/supplier specifies the power factor range of the load that can be connected to the UPS output, the following tests shall include measurement of parameters at each end of the power factor range in addition to any nominal power factor measurement taken.

**6.3.4.1 Output – Normal mode – No load**

With the UPS operating in normal mode of operation at no load and nominal input voltage and frequency, measure the output voltage and its fundamental and harmonic components.

**6.3.4.2 Output – Normal mode – Full load**

Apply a linear load equal to 100% of the UPS rated output apparent power to the output.

In steady-state conditions, measure the output voltage and its on-load fundamental and harmonic components. Compute no-load to full-load output voltage regulation.

Exceptionally, for UPS where output in normal mode of operation is directly connected solely by a switching device to the input supply, the harmonic content test is unnecessary in tests 6.3.4.1 and 6.3.4.2.

**6.3.4.3 Output – Stored energy mode – No load**

With the UPS operating in stored energy mode and the output at no-load, measure the output voltage, frequency and its fundamental and harmonic components.

**6.3.4.4 Output – Stored energy mode – Full load**

Apply a linear load equal to 100% of the UPS rated output active power.

In steady-state conditions at the beginning of battery discharge time, measure the output voltage, frequency and its on-load fundamental and harmonic components. Compute the no-load to full-load output voltage regulation.

NOTE – For UPS where the storage device is rated for less than 10 min, it is permissible to connect an additional battery to enable testing and stable measurement.
This test requires instrumentation in which scanning time is sufficient to observe any changes that may result as the storage device voltage falls with time.

Observe the above parameters until UPS shuts down on battery cut-off. Compute total output voltage regulation and worst-case fundamental and harmonic levels, which shall not exceed the manufacturer’s stated values.

6.3.4.5 Output voltage unbalance test

Output voltage unbalance on three-phase output UPS shall be checked under symmetrical load conditions and unbalanced load conditions. For the unbalanced load condition, two phases shall be loaded phase to phase or phase to neutral if a neutral exists at nominal rated current linear load, the other phase at no load unless otherwise specified by the manufacturer/supplier.

Phase-to-phase and phase-to-neutral (if neutral provided) output voltage are to be observed. Voltage unbalance shall be given in either terms of voltage unbalance ratio or voltage unbalance factor (5.12 of IEC 60146-2). Phase angle deviations shall be determined by calculation from the values of phase-to-phase and phase-to-neutral voltages.

6.3.4.6 DC components in the output (under consideration)

The 10 s average output voltage shall be less than 0.1 % of r.m.s value.

6.3.5 UPS output characteristics – Overload and short-circuit

6.3.5.1 Output – Normal mode – Overload

With the UPS operating under the test conditions of 6.3.4.1, apply a resistive load which shall result in the UPS output being in excess of the manufacturer’s full load rating. Check that the UPS continues to operate within the manufacturer’s stated conditions for the time duration specified, in accordance with 3.5.8.

NOTE – In some cases, the UPS will change mode of operation to bypass mode where so declared by the manufacturer.

The UPS shall not be damaged, or show signs of over-heating.

6.3.5.2 Output – Stored energy mode – Overload

The test of 6.3.5.1 shall be repeated in stored energy mode, with the storage energy device fully charged. The UPS shall not be damaged and shall function correctly when restarted.

6.3.5.3 Output – Normal mode – Short-circuit

The test of 6.3.5.1 shall be repeated in normal mode of operation at no load, except that a short circuit shall be applied to the output terminals. For three-phase outputs, phase-to-phase or phase-to-neutral if a neutral is provided. The output short-circuit current and its duration shall be observed and recorded.
On completion of this test, the UPS shall be reset, protective devices reset and/or replaced. The UPS shall not be damaged and shall function correctly when restarted.

6.3.5.4 Output – Stored energy mode – Short-circuit

The test of 6.3.5.3 shall be repeated in stored energy mode of operation with the energy storage devices fully charged. The UPS shall not be damaged and shall function correctly when restarted.

6.3.5.5 UPS rated output fault clearing capability – Normal mode

The test of 6.3.5.3 shall be repeated, except that the short circuit shall be made by a suitable fuse/circuit-breaker of a current rating in accordance with the manufacturer's/supplier's stated protective device clearance capability (item q of 5.3.2). The output dynamic performance shall remain within the limits of figures 1, 2 or 3 of 5.3.1 during this event unless otherwise stated by the manufacturer/supplier.

6.3.5.6 UPS rated output fault clearing capability – Stored energy mode

The test of 6.3.5.5 shall be repeated in stored energy mode unless the manufacturer/supplier states that the UPS cannot co-ordinate with external protective devices in this mode of operation.

6.3.6 UPS output dynamic characteristic tests

6.3.6.1 Change of operating mode – Normal to stored energy mode – Linear load (resistive)

With the UPS initially operating under the test conditions of 6.3.4.2, 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 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.

6.3.6.2 Change of operating mode – Stored energy to normal mode – Linear load (resistive)

The test of 6.3.6.1 shall be repeated except that in this case, the input supply shall be switched on at any angular position on the input supply waveform and the output observed for any deviation during the transition from stored energy mode to normal mode of operation.
6.3.6.3 Change of operating mode – Stored energy to normal mode (where applicable)

Where synchronization is a feature of the UPS, during the test of 6.3.6.2, during a time interval covering the transition back to normal mode, the input and output voltage waveforms shall be checked to ensure that, at the point of transition, the phase angle between the input supply voltage waveform and output voltage waveform does not exceed the limits stated.

NOTE – This test will require instrumentation that can capture a delayed time event, since the synchronization period prior to change of mode is a variable. In some cases, it may be possible to use communication signals from the UPS or trigger signals within the UPS to a

6.3.6.4 Change of operating mode – Normal to bypass mode (where applicable)

Where the UPS has a bypass mode of operation which is automatic in operation under conditions of output overload or UPS inverter fault, the test of 6.3.5.1 and/or 6.3.5.2 shall be repeated to force bypass operation due to overload. The input and output voltage waveforms shall be observed during transitions normal to bypass mode, and vice versa, which shall remain within stated values.

Where in addition the manufacturer declares that automatic change to bypass mode is inhibited if the bypass voltage or frequency is out of tolerance (except under certain fault conditions), the input supply voltage and frequency shall be adjusted beyond the specified range to demonstrate compliance with the UPS specification beyond which the UPS operation in bypass mode is inhibited.

6.3.7 UPS output dynamic load characteristic tests

6.3.7.1 Output load steps – Linear load

With the UPS operating under the conditions of 6.3.4.1, apply a resistive load equal to 100% output active power, comprising two loads: one equal to 20% and one equal to 80%.

At the point of application of the load when the output waveform is at its peak value, observe the output waveform on suitable storage instrumentation to permit calculation of any dynamic performance deviation.

Reduce the load to 20% of rated output active power by switching off the 80% load. Repeat the previous measurements at the instant of disconnection and compute the value which shall remain within the stated limits.

6.3.8 UPS output characteristics – Reference non-linear loads

6.3.8.1 Reference non-linear load output distortion – Normal mode

With the UPS operating in normal mode of operation, apply a reference non-linear load (see annex E) set to obtain rated output apparent power for the UPS under test.

In steady-state conditions, measure the output voltage waveform and its fundamental and harmonic content. The values shall not exceed the manufacturer's stated values. In
addition, the reference non-linear load capacitor d.c. voltage shall be measured to ensure its value shall be within the limits calculated by the formula in annexe E for parameter $U_c$.

### 6.3.8.2 Reference non-linear load output distortion – Stored energy mode

With the UPS operating in the steady-state conditions of 6.3.8.1 at 100 % reference non-linear load, interrupt the input supply to force transition to stored energy mode of operation. Repeat the measurements of 6.3.8.1, the values shall not exceed the manufacturer's stated values.

### 6.3.8.3 Reference non-linear load – Change of operating mode – Normal to stored energy mode

With 100 % reference non-linear load, repeat the tests of 6.3.6.1 and record the transient performance during change of operating mode.

### 6.3.8.4 Reference non-linear load steps – Normal mode $\leq 4,0$ kVA rating

With the UPS operating under the conditions of 6.3.4.1, apply a reference non-linear load according to 6.3.8.1 set to obtain 25 % of rated output apparent power as a base load.

In steady-state conditions apply, at the peak value of the output voltage waveform, an additional reference non-linear load set to 75 % of rated output apparent power.

At the instant of application of the additional load, measure the output voltage waveform transient deviation.

In steady-state conditions, switch off the reference non-linear load set to 75 % rated output apparent power at the peak value of the output voltage waveform. At the time of disconnection, repeat the measurements of output voltage waveform transient deviation.

### 6.3.8.5 Reference non-linear load steps – Normal mode $> 4,0$ kVA rating

With the UPS operating in normal mode of operation, apply a reference non-linear load according to 6.3.8.1 set to obtain 33 % of rated output apparent power as a base load.

In steady-state conditions apply, at the peak value of the output voltage waveform, an additional reference non-linear load set to 33 % of rated output apparent power.

At the instant of application of the additional load, measure the output voltage transient deviation. With 66 % base load, apply at the peak of the output voltage waveform a further 33 % reference non-linear step load and repeat measurement of transient voltage deviations.

In steady-state conditions, switch off 33 % of the step reference non-linear load at the peak of the output voltage waveform. At the time of disconnection repeat measurements of the output voltage waveform.
Repeat again, switching off the next 33 % step reference non-linear load to return to the original 33 % base load, and record the transient deviation of the output waveform.

The 33 % steps of reference non-linear load shall apply unless the manufacturer/supplier defines a different specification in his data sheets.

6.3.8.6 Reference non-linear load steps – Stored energy mode

The tests of 6.3.8.4 and 6.3.8.5 shall be repeated in the stored energy mode, except where bypass mode is specified to withstand load inrush current, or where change of load is not permitted according to the manufacturer's instructions.

6.3.9 Stored and restored energy time tests

6.3.9.1 Stored energy time

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

Apply a linear load equal to the rated output active power and interrupt the input supply to force stored energy mode of operation.

Measure the output voltage at the beginning and end of stored energy operation. Measure the time of operation in stored energy mode up to the UPS shutdown which shall not be less than the manufacturer's stated figure at normal ambient test temperature of 25 °C.

NOTE – Since new batteries often do not provide full capacity after an initial charge, the stored energy test may need to be repeated after a reasonable restored energy time has elapsed, if the original test failed to meet specified times. A number of cycles are often necessary before final performance is achieved.

6.3.9.2 Restored energy time (to 90 % capacity)

At the cessation of stored energy test of 6.3.9.1, reapply the input supply to the UPS and operate in normal mode of operation, at nominal input supply voltage and rated output active and apparent power. Measure maximum UPS input current at the start of restored energy time.

After the manufacturer's stated restored energy time has elapsed, measure the input and output voltage, current and wattage. Determine that the input current has reached a lower equilibrium indicating the end of restored energy time.

6.3.10 Efficiency and input power factor

When stable input conditions are reached, both input and output currents, voltages and power shall be measured at both 100 % linear load, 100 % apparent and active power and 100 % reference non-linear load.
The computed efficiency and input power factor of the UPS shall be within the manufacturer's stated limits.

Following measurement of efficiency, the test of 6.3.9.1 shall be repeated. Verify that the new value of stored energy time is not less than 90% of the time previously measured.

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.

6.3.11 Backfeed test

For pluggable UPS-type A, a test on the automatic backfeed protection shall be performed in accordance with annex F or as required by applicable national standards.

6.3.12 Electromagnetic compatibility test

See IEC 62040-2.

6.4 Reserved for future use

6.5 Reserved for future use

6.6 Factory witness tests/on-site tests

It shall be a matter of agreement between the manufacturer/supplier and the purchaser as to which of the following tests are to form part of the purchase contract, as this will be dependent upon the degree to which the UPS or UPS functional units can be tested by the manufacturer prior to delivery.

UPS may be type or routine tested in the factory as a complete UPS and less extensive operational tests with batteries and load are performed on site. Alternatively, routine tests in the factory may be restricted to UPS functional units or combinations of them. The final test on site then replaces the UPS routine factory test. The tests shown in table 4 may be performed in any order.
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<td>6.6.6</td>
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<tr>
<td>AC input return test</td>
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<td></td>
<td>6.6.7</td>
</tr>
<tr>
<td>Simulation of parallel redundant UPS fault</td>
<td>X</td>
<td></td>
<td>6.6.8</td>
</tr>
<tr>
<td>Transfer test</td>
<td>X</td>
<td></td>
<td>6.6.9</td>
</tr>
<tr>
<td>Full load test</td>
<td>X</td>
<td></td>
<td>6.6.10</td>
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<tr>
<td>UPS efficiency test</td>
<td></td>
<td>X</td>
<td>6.6.11</td>
</tr>
<tr>
<td>Unbalanced load test</td>
<td>X</td>
<td></td>
<td>6.6.12</td>
</tr>
<tr>
<td>Balanced load test</td>
<td>X</td>
<td></td>
<td>6.6.13</td>
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<tr>
<td>Current division in parallel or parallel redundant UPS test</td>
<td></td>
<td>X</td>
<td>6.6.14</td>
</tr>
<tr>
<td>Rated stored energy time test</td>
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<td></td>
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<tr>
<td>Rated restored energy time test</td>
<td>X</td>
<td></td>
<td>6.6.16</td>
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<tr>
<td>Battery ripple current test</td>
<td>X</td>
<td></td>
<td>6.6.17</td>
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<tr>
<td>Overload capability test</td>
<td>X</td>
<td></td>
<td>6.6.18</td>
</tr>
<tr>
<td>Short-circuit test</td>
<td>X</td>
<td></td>
<td>6.6.19</td>
</tr>
<tr>
<td>Short-circuit protection device test</td>
<td>X</td>
<td></td>
<td>6.6.20</td>
</tr>
<tr>
<td>Restart test</td>
<td>X</td>
<td></td>
<td>6.6.21</td>
</tr>
<tr>
<td>Output overvoltage test</td>
<td>X</td>
<td></td>
<td>6.6.22</td>
</tr>
<tr>
<td>Periodic output voltage variation test</td>
<td>X</td>
<td></td>
<td>6.6.23</td>
</tr>
<tr>
<td>Frequency variation test</td>
<td>X</td>
<td></td>
<td>6.6.24</td>
</tr>
<tr>
<td>Radiofrequency interference and conducted noise tests</td>
<td>X</td>
<td></td>
<td>6.6.25</td>
</tr>
<tr>
<td>Harmonic components test</td>
<td>X</td>
<td></td>
<td>6.6.26</td>
</tr>
<tr>
<td>Earth fault test</td>
<td>X</td>
<td></td>
<td>6.6.27</td>
</tr>
<tr>
<td>On-site ventilation test</td>
<td>X</td>
<td></td>
<td>6.6.28</td>
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<td>Environmental tests</td>
<td>X</td>
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<td>7.1</td>
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<tr>
<td>Vibration and shock tests</td>
<td>X</td>
<td></td>
<td>7.2</td>
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<tr>
<td>Audible noise test</td>
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<td></td>
<td>7.3</td>
</tr>
<tr>
<td>Standby generator compatibility test</td>
<td>X</td>
<td></td>
<td>6.6.29</td>
</tr>
</tbody>
</table>
6.6.1 UPS tests

UPS testing shall be performed after wiring of the functional units to form a complete UPS either at the factory or at the installation site (see table 4). The interconnecting cables shall be checked for correct wiring, insulation and quality of wiring terminations.

6.6.2 Test specifications

The tests 6.6.3 to 6.6.27 when conducted on site shall use the maximum available load which does not exceed the rated continuous load of the complete UPS site configuration:

a) with and without bypass, where appropriate;
b) with and without redundancy, where appropriate.

All other tests shall be conducted with full rated linear load.

6.6.3 Light load test

This test shall be performed to verify that the UPS is correctly connected and all functions operate properly. The following tests shall be performed (with and without a.c. input):

a) output voltage and frequency;
b) operation of all control switches, meters and other means required to determine proper UPS operation.

6.6.4 UPS auxiliary device(s) test

The functioning of UPS auxiliary devices, such as lighting, cooling, pumps, fans, annunciators and optional devices, shall be verified in conjunction with the light load test, or during another test if it is more convenient.

6.6.5 Synchronization test

This test shall be performed when synchronization to an external source is required. Frequency variation limits shall be tested by use of a variable frequency generator or by simulation of circuit conditions. While synchronized, the phase angle between the external source and the UPS inverter shall be measured and checked against the manufacturer's acceptable limits.

This test may be performed during another test if it is more convenient.

6.6.5.1 Output frequency slew rate test

Where applicable, this test shall be performed to determine the output frequency rate of change during synchronization to an external source.
6.6.6 AC input failure test

The test shall be performed with a battery (if available) or other appropriate d.c. source, by interrupting the a.c. input power, or shall be simulated by switching off all rectifiers and bypass feeders at the same time.

Output voltage variations shall be checked for specified limits. Frequency variation shall also be measured.

The UPS shall not be damaged during operation with the loss of one phase or improper phase rotation in a three-phase system.

The input failure should be conducted by interrupting the a.c. input as far upstream as practical.

6.6.7 AC input return test

This test shall be performed either by restoring the a.c. input power, or simulated by switching on all UPS rectifiers and bypass feeders at the same time.

Proper operation of all UPS rectifiers, including walk-in, if applicable, shall be observed.

AC output voltage and frequency variations shall also be measured.

This test shall normally be performed with a battery or appropriate d.c. source. If the test in 6.6.15 is specified, this test shall be performed at the end of that test.

6.6.8 Simulation of parallel redundant UPS fault test

This test shall be required for UPS incorporating parallel redundancy. The test shall be conducted with rated load applied to the UPS. By failure simulation the redundant functional units or UPS units shall be made to fail (e.g. inverter semiconductor failure). The output voltage transients and frequency shall be measured and shall comply with the manufacturer's declared limits.

6.6.9 Transfer test

This test shall be performed for UPS with bypass capability, particularly in the case of an electronic bypass switch.

The test shall be conducted with rated available load applied to the output of the UPS. By failure simulation or output overload, the load shall be transferred to the bypass automatically and then back to the UPS either automatically or operator controlled when failure simulation or output overload is removed.

The output voltage transient shall be measured and comply with the manufacturer's declared limits. The phase angle between the bypass and the UPS inverter shall also be observed during this operation.
6.6.10 Full load test
Load tests shall be performed by connecting loads to the UPS output, equivalent to rated load, using a dummy load or the actual load, if available.

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

If the actual load is available, additional tests, where desired, shall be performed to measure output voltage deviations under step load condition and also steady-state output voltage and current harmonics with the actual load.

6.6.11 UPS efficiency test
UPS efficiency shall be determined by the measurement of the input and output active power in normal mode of operation and available load.

6.6.12 Unbalanced load test
Unbalanced loads shall be applied to the UPS or UPS units, where appropriate. The output voltage unbalance shall be measured.

Phase angle deviations shall be measured or calculated from the measured values of phase-to-phase and phase-to-neutral voltages.

6.6.13 Balanced load test
Balanced loads shall be applied to the UPS or UPS units. The output voltage unbalance shall be measured.

Phase angle deviations shall be measured or calculated from the measured values of phase-to-phase or phase-to-neutral voltages.

6.6.14 Test of current division in parallel or parallel redundant UPS
Current division in the parallel or parallel redundant UPS units or functional units shall be measured with either simulated or actual load.

6.6.15 Rated stored energy time test
The stored energy time shall be determined by switching off the a.c. input to the UPS operating at rated available load and measuring the duration that the specified output power is maintained.

The battery cut-off voltage shall not fall below the specified value before this time has elapsed.

NOTE – Since new batteries often do not provide full capacity during a start-up period, the discharge test should be 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.
6.6.16 Rated restored energy time

Restored energy depends on the charging capacity of the rectifiers and the battery characteristics. If a certain recharging rate is specified, it shall be proved by repeating the discharge test after the specified charging period.

6.6.17 Battery ripple current measurement

If limits of battery ripple current are specified, then the ripple current, which depends upon UPS operation, shall be measured under normal operating conditions, and if applicable under unbalanced load conditions.

6.6.18 Overload capability test

The specified kilovoltamperes (kVA) or kilowatts (kW) overload(s) shall be applied to the UPS output for the time interval (s) specified. The output voltage and current shall be measured with the a.c. input power applied.

If this test is carried out, then it shall be conducted in accordance with item r) of 5.3.2.

6.6.19 Short-circuit test

A short-circuit shall be applied to the UPS output and the following items shall be measured for a UPS without bypass and with the a.c. power applied:

a) the operation of protective devices or circuits;

b) the peak output short-circuit current;

c) the output steady-state short-circuit current and length of time, if specified.

Use of appropriate circuit protective devices (fuses, circuit-breakers) shall be permitted when making these tests.

These tests shall be conducted in accordance with item q) of 5.3.2 as applicable.

6.6.20 Short-circuit protection device test

Fuse or circuit-breakers capability of a UPS may be tested, if specified, by short-circuiting the UPS output via the protective device of a specified type and rating.

The test is carried out at an appropriate UPS load, under normal operation, if not otherwise specified by the purchaser.

6.6.21 Restart test

Automatic or other restart means shall be tested after a complete shutdown of the UPS.

6.6.22 Output overvoltage test

Output overvoltage protection shall be checked.
6.6.23 Periodic output voltage variation test

When this test is specified, it shall be checked by voltage recording at different loads and operating conditions.

6.6.24 Frequency variation test

The test shall be made in accordance with 5.13 of IEC 60146-2, if applicable.

6.6.25 Radiofrequency interference and conducted noise test

For radiofrequency interference and conducted noise, see IEC 62040-2.

Other test and measuring methods will be a matter of agreement between the manufacturer/supplier and the purchaser.

NOTE – The emission level of a UPS is measured under conditions of resistive load by the manufacturer. Installation site conditions may cause deviations due to pre-existing emissions on site and emissions caused by the actual load equipment connected to the UPS output.

6.6.26 Harmonic components measurement

Harmonic components of the output voltage shall be tested under rated linear load conditions or with the actual load.

Input current and voltage total harmonic distortion (THD) shall be measured under rated available load conditions with the a.c. input source specified by the manufacturer, or in actual service conditions where the manufacturer/supplier and the purchaser agree. Allowable harmonic currents caused by the UPS in the a.c. input may be specified by electricity utility companies. Method of specification and checking shall be a matter of agreement between the manufacturer/supplier and the purchaser.

6.6.27 Earth fault test

If the UPS output is isolated from earth and the load system is isolated from earth relying on earth leakage detection, then an earth fault can be applied to any output terminals. UPS output transient (if any) shall be measured and remain within the limits of figures 1, 2 or 3 of 5.3.1.

If the d.c. link is isolated from earth, then an earth fault can be applied to a battery terminal and the UPS output transients (if any) shall be measured.

6.6.28 On-site ventilation test

Where appropriate, this test is performed with the actual load or equivalent dummy load. The dummy load if used shall be placed outside the UPS area to avoid influences of its dissipation upon UPS ventilation.

The temperature conditions of all UPS cubicles are to be observed.
Peak temperatures to be expected may also be calculated from actual and expected values, or specified values of air inlet and cooling methods applied.

### 6.6.29 Standby generator compatibility test

The tests in 6.6.3, 6.6.5, 6.6.7, 6.6.9, 6.6.10, 6.6.21, 6.6.26 and 6.6.27 shall be repeated using the output of the standby generator as the source of input supply, where applicable.

### 6.7 UPS switches testing procedure

UPS switches not tested according to 6.2 to 6.6 shall be tested in accordance with this schedule.

#### 6.7.1 Testing schedule

<table>
<thead>
<tr>
<th>Test</th>
<th>Type test</th>
<th>Routine test</th>
<th>Optional test</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnection cable check</td>
<td>X</td>
<td>X</td>
<td></td>
<td>6.7.3</td>
</tr>
<tr>
<td>Light load test</td>
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<td>X</td>
<td></td>
<td>6.7.4</td>
</tr>
<tr>
<td>Full load test</td>
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<td>X</td>
<td></td>
<td>6.7.5</td>
</tr>
<tr>
<td>Transfer test (if applicable)</td>
<td>X</td>
<td></td>
<td></td>
<td>6.7.6</td>
</tr>
<tr>
<td>Overload capability test</td>
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<td></td>
<td></td>
<td>6.7.7</td>
</tr>
<tr>
<td>Short-circuit current capability test (if applicable):</td>
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<td>X</td>
<td>6.7.8</td>
</tr>
<tr>
<td>a) making</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) breaking</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overvoltage test:</td>
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<td>6.7.9</td>
</tr>
<tr>
<td>a) circuit repetitive peak off-state voltage</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) circuit non-repetitive peak off-state voltage</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiofrequency interference and conducted noise</td>
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<td>X</td>
<td></td>
<td>6.7.10</td>
</tr>
<tr>
<td>Audible noise</td>
<td></td>
<td>X</td>
<td></td>
<td>6.7.11</td>
</tr>
<tr>
<td>On-site ventilation test</td>
<td></td>
<td>X</td>
<td></td>
<td>6.7.12</td>
</tr>
<tr>
<td>Earth fault</td>
<td></td>
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<td>6.7.13</td>
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<tr>
<td>Environmental tests</td>
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<td></td>
<td>6.7.14</td>
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<tr>
<td>Vibration and shock tests</td>
<td>X</td>
<td></td>
<td></td>
<td>6.7.14</td>
</tr>
</tbody>
</table>

1) According to special agreement.

#### 6.7.2 Test specifications

The following tests, when conducted on site, shall use the maximum available load that does not exceed the rated continuous load.
6.7.3 **Interconnection cable check**

The interconnecting cables shall be checked for correct wiring, insulation and the quality of the terminations.

6.7.4 **Light load test**

This test is carried out to verify that the UPS switch is correctly connected and all functions operate properly. The load applied is limited for economic reasons to a percentage of the rated value.

The following shall be checked:

a) operation of all control switches and other means to put units into operation;

b) operation of protective and warning devices;

c) operation of remote signalling and remote control devices.

6.7.5 **Full load test**

Load tests are performed by connecting a resistive load or the actual load to the UPS switch output.

In particular cases a special load can be used as agreed upon between supplier and purchaser.

6.7.6 **Transfer test**

Transients and transfer time shall be measured during rated load transfer to an alternate supply source, and rated load retransfer back to the original source. Load transfer is induced by a simulated fault, where practicable.

Additional electrical testing shall be carried out to check the functionality and faults of such switches as tie, bypass switches by simulations.

6.7.7 **Overload capability test**

The overload capability test is a load test. Specified values of short-time overload or starting-up sequences of actual load are to be applied for the time interval specified. Specified values of voltage and current shall be recorded.

6.7.8 **Short-circuit current capability test**

If short-circuit current capability is specified, it shall be tested by application of a short-circuit to the UPS switch output, if necessary via a suitable fuse/circuit-breaker. Peak short-circuit current shall be recorded.

6.7.9 **Overvoltage test (electronic power switches)**

a) Circuit repetitive peak off-state voltage shall be tested by increasing the voltage across the switch up to a maximum voltage that may apply in synchronized and unsynchronized conditions using a variable test voltage supply.
b) Circuit non-repetitive peak off-state voltage shall be tested using suitable pulse-generating equipment capable of providing a peak voltage of no more than 2.3 times the normal peak voltage and a duration of no more than 1.3 ms.

6.7.10 Radiofrequency interference and conducted noise

For radiofrequency interference and conducted noise, international and national regulations are applicable (e.g. CISPR standards).

6.7.11 Audible noise

Test procedure and limits shall be subject to agreement between the purchaser and the supplier.

6.7.12 On-site ventilation test

The test is performed with the actual load or a substitute load. The substitute load shall be placed outside the UPS switch area to avoid influences of its dissipated heat upon the UPS switch ventilation.

Expected peak temperatures can also be calculated from actual values and expected or specified values of air inlet and cooling methods applied.

6.7.13 Earth fault test

If the UPS switch is isolated from earth, then an earth fault can be applied to any terminal. UPS switch transients shall be measured and shall not exceed the limits of figures 1, 2 or 3 of 5.3.1.

6.7.14 Additional tests

Specifications and procedures for additional tests, for example vibration, shock, environmental and drift, shall be a matter of agreement between the purchaser and the supplier.

7 Non-electrical tests

7.1 Environmental and transportation test methods

Where practicable, and where the manufacturer chooses to carry out type testing, the test sequences in accordance with 7.1 and 7.2 are provided to simulate environmental and transportation conditions which the product is designed to meet.
<table>
<thead>
<tr>
<th>Mode of operation</th>
<th>Parameter</th>
<th>Test conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal mode</td>
<td>Output voltage</td>
<td>Rated input voltage</td>
</tr>
<tr>
<td></td>
<td>Output frequency</td>
<td>Rated input frequency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No load and rated output apparent power</td>
</tr>
<tr>
<td>Stored energy mode</td>
<td>Output voltage</td>
<td>No load and rated output apparent power</td>
</tr>
<tr>
<td></td>
<td>Output frequency</td>
<td></td>
</tr>
<tr>
<td>Bypass mode</td>
<td>Output voltage</td>
<td>Rated input voltage</td>
</tr>
<tr>
<td></td>
<td>Output frequency</td>
<td>Rated input frequency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No load and rated output apparent power</td>
</tr>
</tbody>
</table>

### 7.1.1 Transportation

The following tests are to assess the construction of the UPS in the shipping container for its resistance to damage by normal handling operations during transportation.

#### 7.1.1.1 Shock test

This shall be carried out only on units weighing less than 50 kg complete, but excluding the shipping container.

a) Initial measurements: check the electrical characteristics (see table 5) of the UPS before packing it into its shipping state for transportation.

b) Mode of operation: The UPS is non-operational and packed in its normal shipping state for transportation.

c) Test: The packaged specimen shall be subjected to two half-sine shock pulses of 15 g of nominal duration of 11 ms, in all three planes. The method of test shall be as in IEC 60068-2-27.

d) Measurements during testing: No measurements are taken during the test.

e) Final requirements: After the tests, the UPS shall be unpacked and checked for signs of physical damage or distortion to component parts and shall continue to function according to this standard.

f) Final measurements: Same as initial measurements.

NOTE – Final measurements and requirements can be combined with e) and f) of 7.1.1.2 if necessary.

#### 7.1.1.2 Free fall test

a) Initial measurements: Check the electrical characteristics (see table 5) of the UPS.

b) Mode of operation: The UPS is non-operational during the test and packed in its normal shipping state for transportation.

c) Test: The specimen shall be allowed to fall freely from a point of suspension into a solid surface; the surface of the package which touches the solid surface through the fall is the surface on which the package normally rests. The method of test shall be as in IEC 60068-2-32. The following are the minimum requirements:
1) The test shall be carried out twice.
2) The test shall be made with the specimen in its integral transport case or shipping state for transportation.
3) The height of fall shall be according to table 6.
4) The height of fall shall be measured from the part of the specimen nearest to the test surface.

<table>
<thead>
<tr>
<th>Mass M of unpacked specimen</th>
<th>Height of fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td>mm</td>
</tr>
<tr>
<td>M 10</td>
<td>250</td>
</tr>
<tr>
<td>10 &lt; M 50</td>
<td>100</td>
</tr>
<tr>
<td>50 &lt; M 100</td>
<td>50</td>
</tr>
<tr>
<td>100 &lt; M</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 6 – Free fall testing

d) Measurements during testing: No measurement is taken during the test.

e) Final requirements: After the test, the UPS shall be unpacked and inspected for physical damage to component parts, and the UPS shall continue to perform in accordance with the initial characteristics (table 5) and meet the constructional safety requirements.

f) Final measurements: Same as initial measurements.

7.2 Environmental storage and operating test methods

7.2.1 Storage condition tests

a) Initial measurements: Check the electrical characteristics (see table 5) of the UPS. Before carrying out these tests, the battery shall be at a state of full charge. Charge for the period defined in the manufacturer's instructions.

b) Mode of operation: The UPS is not operational, but packed in its normal shipping state for transportation and storage with controls set in shipping state.

c) Tests:

1) Dry heat as per the normal environmental conditions: +55 °C ± 2 °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 °C ± 2 °C at a humidity of 90 % to 95 % for a duration of 96 h using the test method Cb of IEC 60068-2-56.

3) Cold as per the normal environmental conditions: –25 °C ± 3 °C for a duration of 16 h where practicable using test method Ab of IEC 60068-2-1.

4) Damp heat repeated.

d) Measurements during test: No measurement is taken during the tests.

e) Final requirements: After the tests, the UPS shall be unpacked and inspected for signs of damage to components or corrosion of metallic parts. The UPS shall continue to perform in accordance with the initial characteristics (table 5) and meet the constructional safety requirements.
f) Final measurements: Allow unit to return to normal ambient temperature and pressure. After tests, the UPS shall perform in accordance with the initial characteristics.

7.2.2 Operating condition tests

a) Initial measurements: Check the electrical characteristics of the UPS (see table 5).

b) Mode of operation: The UPS works in normal mode of operation at rated input voltage and rated output apparent power.

c) Test: Tests shall be made 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 Bd of IEC 60068-2-2.

2) Damp heat as per the normal environmental conditions: +30 °C ± 2 °C at a humidity of 82 % to 88 % for a duration of 96 h using test method Cb of IEC 60068-2-56.

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 Ad of IEC 60068-2-1.

4) Damp heat repeated.

Exceptionally, where the UPS incorporates stored energy device(s) in the form of batteries, the test temperature shall be at +5 °C minimum and +35 °C maximum.

d) Measurements during testing: Measurements are taken during the tests in order to check that the UPS continues to function according to this standard in the modes of operation listed in table 5 under stabilized temperature conditions.

e) Final measurements: Same as initial measurements.

f) Final requirements: After the tests, the UPS shall work in accordance with the initial characteristics (see table 5) and meet the constructional safety requirements.

7.3 Acoustic noise

The manufacturer shall state in the technical documentation the acoustic noise level of the UPS. The measurements shall be made in normal mode and in battery mode of operation, and the values shall be stated in acoustic-decibels (dBA) at 1 m. The sound measurement shall be made at the normal input voltage and rated linear load in steady-state. Where automatically switched fans are used, these must be switched on. Audible alarms are excluded from the measurement. The method of measurement shall be as specified in ISO 7779, and shall be governed by the normal positioning expected in use (for example, table-top, wall-mounted or free-standing).
Annex A
(informative)

Types of Uninterruptible Power Systems (UPS) configurations

Introduction

An Uninterruptible Power System (UPS), as described in this standard is an electronic power system. Its primary function is to provide specified continuity and quality of power to a user's equipment in the event of a partial or total failure of the normal source of power, which is usually the local electric utility. This is accomplished by converting some form of stored energy to supply power to the user's equipment for a specified period of time when the utility power is no longer available or acceptable.

The user's equipment, typically referred to as the critical or protected load, may consist of one piece of equipment, or may be a room or building full of equipment. This is the equipment that the user has determined needs to be provided with power that has a better continuity and quality than that power which is normally available. The critical load is predominantly some form of data processing equipment, although it may be other equipment such as lighting, instrumentation, pumps or communication equipment. The stored energy to support this load, usually in the form of batteries, may be needed to supply power to the equipment for a specified time, which may be momentary or for many hours. The time interval is commonly referred to as stored energy time or back-up time.

A variety of UPS have been developed to meet the user's requirements for continuity and quality of power for different types of loads over a wide range of power from less than one hundred watts to several megawatts.

The following text outlines the variation of UPS configurations ranging from the single unit to the more complex systems for added security of load power.

Various types of UPS configurations are used to achieve different degrees of continuity of load power and/or to increase output power rating.

This annex explains some typical arrangements in use, and the important characteristics of each of these.

A.1 Single UPS

The simplest arrangement is a single UPS.

A.1.1 Single UPS without bypass

A single UPS is capable of ensuring continuity of load power as long as it continues to operate within its specification.
A.1.2 Single UPS with a common rectifier for inverter and battery

The inverter always supplies the power to the load and it takes its power from either the a.c. input via the rectifier or from the battery (see figure A.1). The rectifier has to be controlled so as to recharge and maintain the battery in a charged condition.

![Figure A.1 – Single UPS with common rectifier for inverter and battery](image)

In the case of an a.c. input power failure, the battery will supply the power at a decreasing d.c. voltage until it is too low for satisfactory output of the inverter. The type and capacity of the battery will determine the length of time the system can operate without an a.c. input supply.

The frequency, number of phases and voltage levels of the input and output may be different. The output can be designed to meet much more stringent specifications than those normally obtainable from the input power source, i.e. closer voltage and frequency tolerances and reduced transient variations, as well as protection against input power failure.

A.1.3 Single UPS with separate battery charger

The requirements on the rectifier to supply the inverter input power and charge the battery may conflict each other, so that the UPS may be designed to have a separate battery charger (figure A.2). From a user’s point of view, the above comments on single UPS apply to this system as well.

![Figure A.2 – Single UPS with separate battery charger](image)

NOTE 1 – The a.c. input terminals may be tied.
NOTE 2 – Blocking diode, thyristor or switch.
A.1.4 **Single UPS with d.c. and a.c. outputs**

Some applications require a source of uninterruptible d.c. power as well as a.c., and combined systems are possible. An example is given in figure A.3.

In some cases, the choice of the d.c. link voltage is restricted by the needs of the d.c. output.

This standard applies to indirect a.c. converter systems: therefore, only the a.c. output of this system is covered by this standard.

Figure A.3 – Single UPS with d.c. and a.c. output

A.1.5 **Single UPS with bypass**

A.1.5.1 **Double conversion**

By the addition of a bypass, the continuity of load power can be improved by activation of the bypass by means of a transfer switch in case of:

a) UPS failure;
b) load current transients (inrush currents or fault currents);
c) peak load.

NOTE – The input terminals may be tied.

Figure A.4 – Single UPS with bypass

Some restrictions to the addition of a bypass are the following:

The input and output frequency shall normally be the same, and if the voltage levels are different, a bypass transformer is required. For some loads, synchronization of the UPS to the bypass a.c. input is required to maintain continuity of load power.

NOTE – Use of the bypass introduces the possibility of an a.c. input disturbance affecting the load.
A.1.5.2 Line interactive operation

In line interactive operation, the load is supplied by the a.c. input through the bypass (the inverter is operating at no load), and upon input power failure, the inverter and battery maintain continuity of load power. All restrictions outlined under A.1.5.1 apply.

A.1.5.3 Passive stand-by operation

In passive stand-by operation, the load is supplied by the a.c. input through the bypass, and upon input power failure, the inverter is activated and with the battery maintains continuity of load power. All restrictions outlined under A.1.5.1 apply.

A.2 Parallel UPS

A.2.1 Parallel UPS without bypass

If parallel UPS units or partial parallel units are used, the system shall be treated as one UPS.

Two examples of partial parallel and parallel UPS are shown in figures A.5a) and A.5b).

Figure A.5a – Partial parallel UPS (with inverters in parallel)
A.2.2 Parallel UPS with bypass

As the parallel UPS is operated as a single UPS, then all the comments in A.1.5 fully apply to this, and the configuration is equivalent to figure A.4.

A.3 Redundant UPS

A.3.1 Stand-by redundant UPS

Upon failure of the operating UPS units, the stand-by is switched into service, thereby taking over the load, and the failed UPS is disconnected.

A.3.1.1 Stand-by redundant UPS without bypass

This system retains the characteristics as indicated in A.1 and it provides a method of improving the continuity of load power.
A.3.1.2 Stand-by redundant UPS with bypass

A bypass circuit can be included to improve still further the continuity of load power as indicated in A.1.5, and furthermore, to provide for transferring the load from one UPS to the other. As it has a low impedance, the bypass will allow full load current to flow without significant reduction of output voltage.

NOTE – The input terminals may be tied.

Figure A.7 – Stand-by redundant UPS with bypass

A.3.2 Parallel redundant UPS

A parallel redundant UPS consists of a number of UPS units sharing the load current. The total capacity of the parallel redundant UPS will be in excess of the load requirements by at least the capacity of one UPS unit, so that one or more of these can be disconnected with the remainder maintaining the continuity of load power.

A.3.2.1 Parallel redundant UPS without bypass

NOTE – The input terminals may be tied.

Figure A.8 – Parallel redundant UPS without bypass

If a UPS unit fails, it must be isolated to prevent it from interfering with the others so that the remainder can continue to supply the full load. In addition, synchronizing the load-sharing circuits are required in these systems.
NOTE – There may be some parts of a parallel redundant UPS which are common to all units. Failure of such a common part may result in loss of continuity of load power.

A.3.2.2 Parallel redundant UPS with bypass

One or more bypass can be connected around such a system as in the previous case, providing the capabilities of A.2.2.
Annex B
(informative)

Examples of Uninterruptible Power System (UPS) operation

This annex describes some of the typical circuit arrangements in use and the mode of operation of each of these in block diagram form. Other circuit topologies are available which fall into the general category of each type.

Additional necessary circuit details, such as filters (transient and EMC), transformer isolation, etc., 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 equipment.

The following clauses give various examples of UPSs.

B.1 UPS double conversion

<table>
<thead>
<tr>
<th>AC input (note 1)</th>
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<th>DC link</th>
<th>Inverter</th>
<th>AC output</th>
</tr>
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<tbody>
<tr>
<td>Battery charger (optional)</td>
<td>Note 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1 – The input terminals may be tied.
NOTE 2 – Blocking diode, thyristor or switch.

Figure B.1 – UPS double conversion

In normal mode of operation, the load is continuously supplied by the rectifier/inverter combination.

When the a.c. input supply is out of UPS preset tolerances, the unit enters stored energy mode of operation, where the battery/inverter combination continues to support the load for the duration of the stored energy time, or until the a.c. input returns to UPS design tolerances, whichever is the sooner.

NOTE – This type is often referred to as an “on-line UPS”, meaning the load is always supplied by the inverter irrespective of the condition of the a.c. input supply. The term “on-line” also means “on-the-mains”. To prevent confusion in definition, this term should be avoided and the above term used.
B.2 UPS double conversion with bypass

By the addition of a bypass, the continuity of load power can be improved by activation of the bypass by means of a transfer switch in the case of:

a) UPS failure;
b) load current transients (inrush currents or fault currents);
c) peak load.

Some restrictions to addition of a bypass are the following.

The input and output frequency shall normally be the same, and if the voltage levels are different, a bypass transformer is required. For some loads, synchronization of the UPS to the bypass a.c. input shall maintain continuity of load power.

NOTE 1 – Use of the bypass introduces the possibility of an a.c. input disturbance affecting the load.

NOTE 2 – The bypass supply may be linked to the rectifier a.c. input if a dedicated stand-by supply is not required.

NOTE 1 – The a.c. input terminals may be tied.

NOTE 2 – Blocking diode or thyristor or switch.

Figure B.2 – UPS double conversion with bypass

In normal mode of operation, the load is primarily supplied by the rectifier/inverter combination.

When the a.c. input supply is out of UPS preset tolerances, the unit enters stored energy mode of operation, where the battery/inverter combination continues to support the load for the duration of the stored energy time, or until the a.c. input supply returns within UPS design tolerances, whichever is the sooner.
In the event of a rectifier/inverter failure or the load current becoming excessive, either transiently or continuously, the unit enters bypass mode where the load is temporarily supplied via the bypass line from primary or stand-by power.
B.3 UPS line interactive operation

![Diagram of UPS line interactive operation](image)

**Figure B.3 – UPS line interactive operation (UPS-LI)**

In normal mode of operation, the load is supplied with conditioned power via a parallel connection of the a.c. input and the UPS inverter. The inverter or the power interface is operating to provide output voltage conditioning and/or battery charging. The output frequency is dependent upon the a.c. input frequency.

When the a.c. input supply voltage is out of UPS preset tolerances, the inverter and battery maintain continuity of load power in stored energy mode of operation and the power interface disconnects the a.c. input supply to prevent backfeed from the inverter.

The unit runs in stored energy mode for the duration of the stored energy time or until the a.c. input supply returns within UPS design tolerances, whichever is the sooner.

B.4 UPS line interactive operation with bypass

By the addition of a bypass, the continuity of load power can be improved by activation of the bypass by means of a transfer switch in the case of:

a) UPS failure;

b) load current transients (inrush currents or fault currents);

c) peak load.

Some restrictions to addition of a bypass are the following.

The input and output frequency shall normally be the same and if the voltage levels are different, a bypass transformer is required.

NOTE 1 – Use of the bypass introduces the possibility of an a.c. input disturbance affecting the load.
NOTE 2 – The bypass supply may be linked to the switch a.c. input if a dedicated stand-by supply is not required.
In normal mode of operation, the load is supplied with conditioned power via a parallel connection of the a.c. input and the UPS inverter. The inverter or the power interface is operating to provide output voltage conditioning and/or battery charging. The output frequency is dependent upon the a.c. input frequency.

When the a.c. input supply voltage is out of UPS preset tolerances, the inverter and battery maintain continuity of load power in stored energy mode of operation, and the switch disconnects the a.c. input supply to prevent backfeed from the inverter.

The unit runs in stored energy mode for the duration of the stored energy time, or until the a.c. input supply returns within UPS design tolerances, whichever is the sooner.

In the event of a UPS functional unit failure, the load may be transferred to bypass fed from primary or stand-by power.
B.5 UPS passive stand-by operation

In normal mode of operation, the load is supplied with the a.c. input power primary power via the UPS switch. Additional devices may be incorporated to provide power conditioning, e.g. ferro-resonant transformer or automatic tap changing transformers.

When the a.c. input supply is out of UPS preset tolerances, the unit enters stored energy mode of operation by activating the inverter, and the load is transferred to the inverter directly or via the UPS switch (which may be electronic or electro-mechanical).

The battery/inverter combination maintains continuity of load power for the duration of the stored energy time, or until the a.c. input supply returns to within UPS preset tolerances and the load is transferred back, whichever is the sooner.

NOTE – This type is often referred to as an "off-line UPS" meaning electronically conditioned power is fed to the load only when the a.c. input supply is out of tolerance. The term "off-line" also means "not-on-the-mains" when in fact the load is primarily fed from the mains in normal mode of operation. To prevent confusion in definition, this term should be avoided and the above term used.
Annex C
(informative)

Explanation of UPS switch definitions

Introduction

The term UPS switches applies to all power switches that form functional units of a UPS and are associated with its application. Included are interrupters, bypass switches, isolating switches, load transfer switches and tie switches. These switches interact with other functional units of the UPS to maintain continuity of load power. Other switches or breakers, such as conventional mains distribution boards, rectifier input switches, battery disconnect switches, or other general purpose breakers or switches that are used for convenience are not included in this discussion.

The information in this annex is intended to provide description of types of switches, their general characteristics and common applications.

Application of UPS switches

UPS switches are used in conjunction with UPS in many configurations, and a number of commonly used configurations are shown in the following clauses. For simplicity, the UPS switches are shown in the diagrams as separate units, but in practice, a UPS switch may be an integral part of a UPS unit.

Abbreviations

For convenience, the following abbreviations are used throughout this annex:

<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Definitions see subclause</th>
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</thead>
<tbody>
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<td><strong>EPS</strong> – Electronic power switch</td>
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<tr>
<td><strong>MPS</strong> – Mechanical UPS power switch</td>
<td>3.1.15</td>
</tr>
<tr>
<td><strong>HYB</strong> – Hybrid UPS power switch</td>
<td>3.1.16</td>
</tr>
<tr>
<td><strong>INT</strong> – UPS interrupter</td>
<td>3.1.19</td>
</tr>
<tr>
<td><strong>ISO</strong> – UPS isolation switch</td>
<td>3.1.20</td>
</tr>
<tr>
<td><strong>TRA</strong> – Transfer switch</td>
<td>3.1.13</td>
</tr>
<tr>
<td><strong>TIE</strong> – Tie switch</td>
<td>3.1.21</td>
</tr>
<tr>
<td><strong>MBP</strong> – UPS maintenance bypass switch</td>
<td>3.1.22</td>
</tr>
</tbody>
</table>
C.1 UPS interrupters

UPS interrupters are on-off switches in series with UPS units (figure C.1a). In addition, the term may be used to describe the device which connects or disconnects loads to or from a common output bus.

![Figure C.1a](image)

Figure C.1a

Figure C.1b shows UPS interrupters used in a parallel redundant UPS to connect or disconnect UPS units to or from a common bus. The interrupters enable operating units to remain connected to the load while a failed unit is instantly isolated from the load without disturbance of load power.

![Figure C.1b](image)

NOTE – These inputs may be tied.

Figure C.1b

In some UPS designs, the inverter itself is used as a UPS interrupter. In this type of configuration, the inverter may be designed to act as an impedance to power flow.

Figure C.1c shows UPS interrupters used to connect or disconnect a load branch or branches to or from the common bus.
Figure C.1c

Figure C.1 – UPS interrupters
C.2 Transfer switches

Automatic or manual transfer switches are used in the case of:

a) UPS failure;
b) maintenance;
c) load current transients (inrush current or fault currents);
d) peak load.

These switches may be operated as synchronous or asynchronous transfer.

C.2.1 Types of transfer switches

There are three types of transfer switches:

a) mechanical;
b) electronic;
c) hybrid.

Such characteristics as transfer time, overcurrent rating and isolation of input and output are different between these switches.

C.2.1.1 Mechanical transfer switches

These transfer switches have advantages regarding isolation.

Figure C.2 shows a mechanical transfer switch where, in normal UPS operation, MPS1 is closed and MPS2 is open.

NOTE – These inputs may be tied.

Figure C.2 – Mechanical transfer switches

C.2.1.2 Electronic transfer switches

These transfer switches have advantages regarding transfer time; however, they do not provide isolation capability.

Figure C.3 shows the electronic transfer switch where, in normal UPS operation, EPS1 is conducting and EPS2 is not.
NOTE – These inputs may be tied.

Figure C.3 – Electronic transfer switches

C.2.1.3 Hybrid transfer switches

In the example of the transfer switch in figure C.4a, the UPS is the usual power source with a mechanical switch in its output. Upon failure of the operating UPS, the electronic switch in the bypass will be turned on before the mechanical switch automatically opens.

NOTE – Transfer switch EPS in figures C.4a and C.4b in off-state do not provide isolation of the load from the bypass input.

Operation of the transfer switch in figure C.4b is almost the same as in figure C.4a except that another mechanical switch, MPS2, also closes after the electronic switch closes. Therefore, the electronic switch only carries the load current for a short time. The advantage of the hybrid switches is that they possess the merits of both the electronic and mechanical switches.

NOTE – These inputs may be tied.

Figure C.4 – Hybrid transfer switches
C.2.2 Other examples of use of the transfer switches

C.2.2.1 Load transfer switches

Switches used for switching of load from one source to another are called "load transfer switches". Figure C.5 shows an example of mechanical load transfer switches and figure C.6 shows electronic load transfer switches.

NOTE – These inputs may be tied.

Figure C.5 – Mechanical load transfer switches

NOTE – These inputs may be tied.

Figure C.6 – Electronic load transfer switches
**C.3 UPS isolation switches**

UPS isolation switches are used as auxiliary parts of UPS switches. A typical use of the UPS isolation switches is to isolate electronic UPS switches from power sources for maintenance purposes. Figures C.7a and C.7b show examples of the use of UPS isolation switches with electronic switches.

UPS isolation switches may also be used as UPS interrupters as shown in figure C.8.

NOTE – These inputs may be tied.

**Figure C.7a**

**Figure C.7b**

*Figure C.7 – Isolation switches with electronic switches*
C.4 UPS maintenance bypass switches

UPS maintenance bypass switches are used to bypass the transfer switch and ensure the continuity of load power. Figures C.9a and C.9b show examples of UPS maintenance bypass switches.

Figure C.9 – Maintenance bypass switches

NOTE – These inputs may be tied.

Figure C.9 – Maintenance bypass switches
C.5 Tie switches

UPS tie switches may be used to connect two or more UPS units or loads in such a way as to provide operating flexibility, especially in redundant or partially redundant systems. Figures C.10a and C.10b illustrate examples of tie switches.

NOTE – These inputs may be tied.

C.6 Multiple function UPS switches

UPS switches can be combined in different ways. In such cases, each UPS switch can perform multiple functions and it is therefore not necessary to cascade separate functions. For example, figure C.11 illustrates a parallel redundant UPS with the capability of UPS unit interruption and UPS transfer to bypass. If the UPS interrupters are capable of isolation, then they perform the isolation functions for the UPS units. In the transfer switch operation, the UPS interrupters operate in unison.
NOTE – These inputs may be tied.

Figure C.11 – Multiple function switches
Annex D
(informative)

Purchaser specification guidelines

A variety of UPS are available to meet the user requirements for continuity and quality of power for different types of loads over a wide range of power from less than one hundred watts to several megawatts.

This annex has been compiled to assist purchasers to identify criteria, important to their application or confirmation, that may be requested by the manufacturer/supplier in order to advise on the appropriate type of UPS for a given application.

Additionally, it identifies the performance characteristics to be supplied by the manufacturer/supplier for a UPS in conformity with the requirements of this standard, together with any operational limitations to performance.

For an explanation of typical UPS configurations and methods of UPS operation, the reader's attention is drawn to annexes A, B and C.

The items listed below are intended as a checklist to assist a purchaser to choose the type of UPS which best meets his needs, and to specify it adequately in conjunction with the manufacturer/supplier.

D.1 Type of UPS, additional features and system requirements
a) Single
b) Multi-module (see D.7 for additional information)
c) Bypass to primary or stand-by power system
d) AC generator stand-by power system (if applicable)
e) Required bypass transfer time (if applicable)
f) Galvanic separation required between input and/or d.c. link and/or output
g) Earthing of input and/or d.c. link and/or output
h) Maintenance bypass circuits and other installation requirements, such as UPS system isolators and tie switches
i) Compatibility with intended power system (e.g. as referred to in IEC 60364-4)
j) Remote emergency power off (EPO) or emergency stop requirements

D.2 UPS input
For primary power system and stand-by power system (if any):
a) Nominal input voltage and voltage variation limits desired
b) Number of phases and requirements for neutral lines
c) Nominal input frequency and variation limits desired
d) Special conditions regarding, for example, super-imposed harmonics, transient voltages, supply impedance, etc.

e) Limitations regarding, for example, inrush currents, harmonics currents, etc.

f) Stand-by power system rating

g) Supply protection requirements (short circuit, earth faults)

D.3 Load to be operated from UPS

a) Type – Examples:
   1) computers;
   2) motors;
   3) saturating transformer power supplies;
   4) diode rectifiers;
   5) thyristor rectifiers;
   6) switched type power loads and other types of loads.

b) Continuous apparent power and power factor requirements
c) Single and/or three-phase loads
d) Inrush currents
e) Start-up procedure

f) Special features of loads, such as operating duty, unbalance between phases and non-linearity (generation of harmonic currents)
g) Branch-circuit fuse and breaker ratings

h) Maximum step load and load profile

i) Required method of connection of loads to UPS output

NOTE – The diversity of types of load equipment and their relevant characteristics are always changing with technology. For this reason, the UPS output is characterized by loading with passive reference loads to simulate, as far as practical, the expected load types, but it cannot be taken that these are totally representative of the actual load equipment in a given application.

The UPS Industry has generally specified UPS output characteristics under conditions of linear loading, i.e. resistive or resistive/inductive. Under present technology, many loads have a non-linear characteristic, due to power supplies of the rectifier capacitor type, either single or three-phase (see annex E).

The effect on the output of the UPS by non-linear loads both in steady-state and dynamic is, in many cases, to cause deviation from the output characteristic specified by the manufacturer/supplier where these are quoted under linear load conditions.

Due to the higher peak to r.m.s. steady-state current ratios, the output voltage total harmonic distortion may be increased beyond the stated limit. Compatibility with the load for higher levels of THD is a matter of agreement between the manufacturer/supplier and the purchaser;

Application of non-linear load steps may result in a deviation from the linear dynamic voltage characteristics due to high transient inrush currents relative to steady-state,
especially where the UPS employs electronic current limiting in normal mode of operation.

This effect also applies to switching of transformers and other magnetic devices subject to magnetic remanence.

These effects of high transient inrush currents on the load voltage may be tolerable where these loads are the first to be energized or have no deteriorative effect on the loads already connected.

Some UPS topologies use the a.c. input supply/bypass for this purpose to permit economic sizing of the UPS system. Equally, while single units may not tolerate these load steps within the specification, in multi-module or redundant systems, the total system can tolerate such load steps.

Where the load is sensitive to frequency variation beyond normal mains limits, or is sensitive to voltage variation or distortion of the supply waveform, the choice of the best UPS topology for these applications should be investigated.

The advice of the manufacturer/supplier should be sought in respect of these matters.

D.4 UPS output

a) Rated output power and power factor
b) Number of phases
c) Nominal output voltage, steady-state and transient tolerance bands
d) Nominal output frequency and tolerance band
e) Special requirements regarding, for example, synchronization, relative harmonic content and modulation
f) Voltage adjustability range
g) Phase-angle tolerance (only for multi-phase output)
h) Unbalanced load capability required (only for multi-phase output)
i) Co-ordination between UPS and load protective devices
j) Supply protection requirements (short circuit, overload, earth faults)

D.5 Battery (where applicable)

a) Type of battery/batteries and construction
b) Nominal voltage, number of cells, ampere hour capacity (if supplied by purchaser)
c) Rated stored energy time
d) Rated restored energy time
e) Battery service life required
f) Presence of other loads on battery and their voltage tolerances
g) Availability of separate battery rooms
h) Battery protection and isolation devices
i) Special requirements regarding, for example, ripple current
j) Temperature of battery room installation (recommended 20 °C to 22 °C)
k) Battery cut-off voltage
l) Temperature compensated charging voltage/boost or equalization requirements

D.6 General application requirements and special service conditions

a) Efficiency at specified load conditions
b) Ambient temperature range of operation
c) Cooling system (UPS and battery installation)
d) Instrumentation (local/remote)
e) Remote control and monitoring system
f) Special environmental conditions: equipment exposed to fumes, moisture, dust, salt air, heat, etc.
g) Special mechanical conditions: exposure to vibration, shocks or tilting, special transportation, installation or storage conditions, limitations to space or weight
h) Performance limitations regarding, for example, electrical and audible noise
i) Future extensions of the UPS system

D.7 Multi-module system configurations

(See annexes A, B and C for some typical configurations)

a) Redundant UPS
b) Non-redundant UPS
c) Common system battery
d) Separate module batteries
e) Type of UPS switches
f) Configuration of UPS switches

D.8 Electromagnetic compatibility

a) Required emission standards and level category to which the equipment shall comply
b) Applicable immunity standards and test level to which the equipment shall comply
### D.9 Technical data sheets – Manufacturer's declaration

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<th>Manufacturer's declared values</th>
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<td>Break</td>
</tr>
<tr>
<td></td>
<td>Break time/Make time (if applicable)</td>
<td>ms</td>
</tr>
<tr>
<td>Subclause</td>
<td>Characteristic of equipment</td>
<td>Manufacturer's declared values</td>
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</tr>
<tr>
<td><strong>Electrical output characteristics – Static characteristics – Normal mode</strong></td>
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<tr>
<td>5.3.2</td>
<td>Rated output voltage</td>
<td>V r.m.s</td>
</tr>
<tr>
<td></td>
<td>Output voltage variation</td>
<td>V r.m.s</td>
</tr>
<tr>
<td></td>
<td>Output frequency (nominal)</td>
<td>Hz</td>
</tr>
<tr>
<td>6.3.2.2</td>
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<td>6.3.6.3</td>
<td>Output frequency synchronized phase error at change of mode</td>
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<td></td>
<td>Rated output apparent power</td>
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<td>Rated output active power across linear load</td>
<td>W</td>
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<td></td>
<td>Rated output active power across a reference non-linear load</td>
<td>W</td>
</tr>
<tr>
<td>6.3.4.2</td>
<td>Total voltage distortion across a linear load</td>
<td>%</td>
</tr>
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<td>Total voltage distortion across a reference non-linear load</td>
<td>%</td>
</tr>
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<td>6.3.4.2</td>
<td>Individual harmonics voltage</td>
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<td>Output voltage d.c. component - linear load</td>
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<td>6.3.4.3</td>
<td>Rated peak output voltage</td>
<td>V</td>
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<td>Rated peak output voltage variation</td>
<td>V</td>
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<tr>
<td>5.3.1.2</td>
<td>Non-sinusoidal voltage rise time 0,1 to 0,9 peak (if waveform exceeds 0,5 V/µs)</td>
<td>V/µs</td>
</tr>
<tr>
<td>5.3.2</td>
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<tr>
<td>5.3.2</td>
<td>Output frequency variation</td>
<td>Hz</td>
</tr>
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<td>5.3.2</td>
<td>Rated output apparent power</td>
<td>VA</td>
</tr>
<tr>
<td>5.3.2</td>
<td>Rated output active power</td>
<td>W</td>
</tr>
<tr>
<td>5.3.2</td>
<td>Rated output active power non-linear load</td>
<td>W</td>
</tr>
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<td>6.3.4.4</td>
<td>Total output voltage distortion</td>
<td>% THD</td>
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<tr>
<td>5.3.2 and 6.3.8.2</td>
<td>Individual harmonic voltage-linear load</td>
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</tr>
<tr>
<td>5.3.2 and 6.3.8.2</td>
<td>Individual harmonic voltage-non-linear load</td>
<td>See separate declaration</td>
</tr>
<tr>
<td>5.3.2 and 6.3.5.4</td>
<td>Short-circuit capability</td>
<td>See separate declaration</td>
</tr>
<tr>
<td>5.3.2 and 6.3.5.2</td>
<td>Overload capability</td>
<td>See separate declaration</td>
</tr>
<tr>
<td>5.3.2</td>
<td>Range of load power factor permitted</td>
<td></td>
</tr>
<tr>
<td>5.3.2</td>
<td>Number of output phases (multiphase only)</td>
<td>Phase(s)</td>
</tr>
</tbody>
</table>

**Electrical characteristics – Dynamic characteristics – Stored energy mode**

<table>
<thead>
<tr>
<th>Subclause</th>
<th>Characteristic of equipment</th>
<th>Manufacturer's declared values</th>
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<tbody>
<tr>
<td>6.3.6.1</td>
<td>Output voltage dynamic variation during transfer from stored energy mode to normal mode</td>
<td>See separate declaration</td>
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<tr>
<td>6.3.7.1</td>
<td>Output voltage dynamic variation due to load changes</td>
<td>See separate declaration</td>
</tr>
</tbody>
</table>

**Efficiency**

<table>
<thead>
<tr>
<th>Subclause</th>
<th>Characteristic of equipment</th>
<th>Manufacturer's declared values</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6.11</td>
<td>Efficiency input/output</td>
<td>%</td>
</tr>
</tbody>
</table>

**Synchronization (if applicable)**

<table>
<thead>
<tr>
<th>Subclause</th>
<th>Characteristic of equipment</th>
<th>Manufacturer's declared values</th>
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</thead>
<tbody>
<tr>
<td>6.3.6.4</td>
<td>Acceptable voltage difference</td>
<td>%</td>
</tr>
<tr>
<td>6.3.2.2</td>
<td>Range of frequency synchronization</td>
<td>Hz</td>
</tr>
<tr>
<td>6.3.6.4</td>
<td>Maximum phase error</td>
<td>degrees</td>
</tr>
</tbody>
</table>

**5.4 Stored energy mode of operation**

<table>
<thead>
<tr>
<th>Subclause</th>
<th>Characteristic of equipment</th>
<th>Manufacturer's declared values</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3.9.1</td>
<td>Stored energy time (for integral batteries) at rated load</td>
<td>min</td>
</tr>
<tr>
<td>6.3.9.2</td>
<td>Restored energy time to 90 % charge (for integral batteries)</td>
<td>h</td>
</tr>
<tr>
<td></td>
<td>Battery rating and quantity (for integral battery)</td>
<td>Ah and units</td>
</tr>
<tr>
<td></td>
<td>Battery recharge profile</td>
<td>See separate declaration</td>
</tr>
</tbody>
</table>
D.10 Classification of uninterruptible power systems by performance

The objective of classifying UPS by performance is to provide a common base on which all UPS manufacturer's/supplier's data are measured.

This enables purchasers, for similar UPS power ratings, to compare different manufacturer's products under the same measurement conditions.

Purchasers are reminded that due to the diversity of load types, UPS manufacturers' data are based on industry standard dummy loads which simulate typical load applications expected.

The actual performance in a given application may be subject to variation under transient conditions since actual individual load ratings, sequencing, and starting currents may differ from standardized test situations.

UPS complying with this standard will be classified by the manufacturer in accordance with the following coding:

a) the first three characters specify the quality of load power in normal mode of operation which can be expected to account for over 90% of service duty. Choice is determined by the application as to whether tight tolerance of voltage and frequency is necessary for the load or a wider tolerance is acceptable;

b) the second two characters specify the waveshape in both normal (including any temporary static bypass operation) and stored energy mode of operation.

Application of increasing non-linear load may result in distortion of the waveshape from that resulting from pure resistive inductive loads.
Where the waveshape is normally sinusoidal, any limitations on non-linear loading will be specified by the manufacturer and the classification "X" signified.

UPS which intentionally generate a non-sinusoidal output waveform, i.e. square, quasi-square, etc., the designation "Y" signifies this. This waveshape is suitable for many loads on a temporary or permanent duty;

c) the last three characters specify the UPS transient voltage performance under different conditions and defines the worst case measured. These performance characteristics are measured under industry standard load conditions: actual performance in a given application should be verified by the manufacturer/supplier.

### Table D.1 – Classification of UPS by performance

<table>
<thead>
<tr>
<th>Classification code</th>
<th>Classification options</th>
<th>Classification options</th>
<th>Classification options</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>S</td>
<td>1</td>
<td>VFI: Where the UPS output is independent of supply (mains) voltage and frequency variation. The supply voltage is assumed to be within IEC 61000-2-2 limits. This is because the supply voltage is not controlled, and according to NOTE below this table, IEC 61000-2-2 only defines normal levels of harmonics and distortion, and nothing about frequency variation.</td>
</tr>
<tr>
<td>F</td>
<td>S</td>
<td>2</td>
<td>VFD: Where the UPS output is dependent on supply (mains) voltage and frequency variations</td>
</tr>
<tr>
<td>I</td>
<td>S</td>
<td>3</td>
<td>VI: Where the UPS output is dependent on supply (mains) frequency variations but supply voltage variations are conditioned by electronic/passive voltage regulating devices within the limits of normal operation</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
<td>1</td>
<td>S: Generated waveform is sinusoidal with total harmonic factor D &lt; 0.08 and harmonics within IEC 61000-2-2 under all linear/ reference non-linear load conditions</td>
</tr>
<tr>
<td>S</td>
<td>2</td>
<td>2</td>
<td>X: Generated waveform is sinusoidal with its quality as for “S” under linear load conditions. Under reference non-linear load the total distortion factor D will exceed 0.08 if loaded beyond the manufacturer's stated limits</td>
</tr>
<tr>
<td>S</td>
<td>3</td>
<td>3</td>
<td>Y: Generated waveform is non-sinusoidal and exceeds the limits of IEC 61000-2-2. (Refer to the manufacturer for waveform type)</td>
</tr>
</tbody>
</table>

NOTE – IEC 61000-2-2 defines normal levels of harmonics and distortion that can be expected from public low-voltage supplies at the consumer terminals before connection of a given installation.
Annex E  
(normative)  

Reference non-linear load  

To simulate a single-phase steady-state rectifier/capacitor load, the UPS is loaded with a diode rectifier bridge which has a capacitor and a resistor in parallel on its output. The total single-phase load may be formed by a single load as per figure E.1, or formed by multiple equivalent loads in parallel.

![Diagram of reference non-linear load](image)

NOTE – Resistor $R_s$ can be placed either on the a.c. or d.c. side of the rectifier bridge.

**Figure E.1 – Reference non-linear load**

**Calculation method**

$U$ Rated output voltage of UPS, r.m.s.  

$f$ UPS output frequency in hertz  

$U_C$ Rectified voltage  

$S$ Apparent power across a reference non-linear load – power factor 0,7 i.e. 70 % of the apparent power $S$ will be dissipated as active power in the two resistors $R_1$ and $R_s$.  

$R_1$ Load resistor – set to dissipate an active power equal to 66 % of the total apparent power $S$  

$R_s$ Series line resistor – set to dissipate an active power equal to 4 % of the total apparent power $S$  

A ripple voltage of 5 % peak-to-peak of the capacitor voltage $U_C$ corresponds to a time constant of $R_1 \times C = 7,5/f$.  

From peak voltage, distortion of line voltage, voltage drop in line cables and ripple voltage of rectified voltage the average of the rectified voltage $U_C$ will be empirically:

$$U_C = \sqrt{2} \times 0,92 \times 0,96 \times 0,975 \times U = 1,22 \times U$$

and the values of resistors $R_s$, $R_1$ and capacitor $C$ in farads will be calculated by the following:
\[ R_S = 0.04 \times U^2/S \]
\[ R_1 = U_C^2 / (0.66 \times S) \]
\[ C = 7.5/(f \times R_1) \]

For dual frequency 50 Hz or 60 Hz, 50 Hz shall be used in the calculation. The capacitance value used shall be not less than the calculated value.

NOTE 1 – The voltage drop in the diode bridge is neglected.

NOTE 2 – Tolerances on calculated component values:

\[ R_S : \pm 10 \% \]
\[ R_1 : \text{to be adjusted during test to obtain rated output apparent power.} \]
\[ C : 0 \text{ to } + 25 \% \]

Test method

a) The reference non-linear load test circuit shall initially be connected to an a.c. input supply at the rated output voltage specified for the UPS unit under test.

b) The a.c. input supply impedance shall not cause a distortion of the a.c. input waveform greater than 8 % when supplying this test load (requirement of IEC 61000-2-2).

c) The resistor \( R_1 \) shall be adjusted to obtain the rated output apparent power (\( S \)) specified for the UPS under test.

d) After adjustment of resistor \( R_1 \), the reference non-linear test load shall be applied to the output of the UPS under test without further adjustment.

e) The test load shall be used, without further adjustment, whilst performing all tests to obtain parameters required under reference non-linear loading, as defined in the various clauses.

Connection for reference non-linear loads to UPS

a) For single-phase UPS, the reference non-linear load is used with apparent power \( S \) equal to the UPS rated apparent power up to 33 kVA.

b) For single-phase UPS rated above 33 kVA, the reference non-linear load is used with an apparent power \( S \) of 33 kVA, plus linear load up to the apparent and active power rating of the UPS.

c) For three-phase UPS rated up to 100 kVA designed for single-phase loads, three equal single-phase reference non-linear loads shall be connected either line-neutral or line-to-line, depending on UPS design.

d) For three-phase UPS rated above 100 kVA, the loads in accordance with item c) shall be used up to 100 kVA, plus linear load up to the apparent and active power rating of the UPS.
Annex F
(normative)

Backfeed protection test

For protection of personnel against electric shock, a UPS shall not allow excessive earth leakage currents between any of the input terminals of the UPS during its stored energy mode of operation, due to backfeed from the UPS output or load fault conditions.

For tests F.1 and F.2, possible single fault conditions within the UPS shall be determined by circuit inspection and investigation, but shall include potential external load faults such as phase-to-earth insulation failures. Compliance is checked by the tests F.1 and F.2.

F.1 Test for pluggable Type A or B UPS

With the UPS in stored energy mode of operation, and with the UPS input mains plugs disconnected from the mains, the following conditions shall apply for both no-load and full-load conditions.

a) Under no-fault and any UPS single-fault conditions, the leakage current shall not exceed 3.5 mA when measured by the circuit shown in figure F.3, between any two user-accessible input pins of the mains plug.

b) Where backfeed protection is provided by an internal detection system, such a system shall operate within 1 s for pluggable UPS Type A of the disconnection of the input mains plug, and 5 s for pluggable UPS type B and permanently connected.

F.2 Test for permanently connected UPS
(only for UPS with backfeed protection)

The test shall be run according to figure F.1 for single-phase output UPS and according to figure F.2 for three-phase output UPS. The conditions shall be as for Test F.1 with the mains disconnected from the UPS input terminal, except the earth protective conductor shall not be disconnected during the test. The leakage current shall not exceed 3.5 mA in both no fault and single fault conditions when measured between any input terminal and the protective conductor.

NOTE – Permanently connected UPS only

Figure F.1 – Test set-up for single-phase output
The value of resistive load $R$ shall be equal to that specified as the maximum rated output active power by the manufacturer.

### F.3 Measuring instrument for earth leakage current tests

The instrument comprises a rectifier/moving coil meter with additional series resistance, the two being shunted by a capacitor, as shown in figure F.3. The effect of the capacitor is to reduce the sensitivity to harmonics and other frequencies above power frequency. The instrument should also include a $\times 10$ range obtained by shunting the meter coil by a non-inductive resistor. It is permitted to include overcurrent protection also, provided that the method used does not affect the basic characteristics of the instrument.

- $M$ 0 mA – 1 mA moving coil meter
- $R_1 + RV_1 + R_m$ at 0,5 mA d.c.
  - 500 $\Omega \pm 1$ % with $C = 150 \text{ nF} \pm 1$ %
  - 2 000 $\Omega \pm 1$ % with $C = 112 \text{ nF} \pm 1$ %
- D1-D4 Rectifier
- $R_S$ Non-inductive shunt for $\times 10$ range
- $S$ Sensitivity button (press for maximum sensitivity)

**Figure F.3 – Measuring instrument for earth leakage current tests**

$RV_1$ is adjusted for the desired value of total resistance at 0,5 mA d.c.

The meter is calibrated at the following calibration points on the maximum sensitivity range at 50 Hz to 60 Hz sinusoidal:

- 0,25 mA
- 0,5 mA
- 0,75 mA
The response is checked at the 0.5 mA calibration point as follows:

Sensitivity at 5 kHz sinusoidal: 3.6 mA ± 5 %.
Annex G
(normative)

Input mains failure – Test method

The characteristics of the UPS when the mains fails shall be tested using the following circuit:

![Diagram of test circuit]

**Figure G.1 – Connection of test circuit**

G.1 High impedance mains failure test

Normal mode of operation:

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

G.2 Low impedance mains failure test

Normal mode of operation:

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

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

For use on three-phase supplies, the switch poles of each switch shall open/close simultaneously.
Annex H
(informative)

Determination of output voltage transient deviation characteristics

Introduction

This deviation is characterized by the limits of under/overvoltage defined in figures 1, 2 and 3 of 5.3.1 and relevant subclauses, and is measured as a single event transient commencing at the instant of:

a) change of operating mode (e.g. normal/stored energy);
b) application of a step load, and vice versa,

and lasting until the output voltage waveform returns to steady-state conditions.

Effects of random single transients or multiple fast burst transients originating external to the UPS on the input supply and coupled through to the UPS output are not considered.

Effects of continuous repetitive subcycle transients on the output waveform in steady-state conditions are determined separately by harmonic content measurements required under the relevant clause.

The objective is to determine the loss of volt-time area from steady-state values or its effect during the transient period resulting from a change of mode or step loading, to which the UPS will be subjected on successive half-cycle real time basis, until steady-state conditions are reached.

Since there are no standardized curves of time-related voltage tolerances applicable to all load equipment, the curves of figures 1, 2 and 3 of 5.3.1 have been determined from practical experience of the UPS industry when supporting linear and non-linear loads.

Load susceptibility to these transients depends upon the type of load, and the purpose of the measurement is to characterize the type of load the UPS can adequately support.

To permit different test methods, depending on the UPS design characteristics, but to achieve a common form of declaration to the user, the manufacturer's declaration needs only to indicate compliance with figures 1, 2 or 3 of 5.3.1, as required by the classification method for UPS in annex D.

H.1 General considerations

The dynamic testing has to take into account differences in output waveshape, the effects of linear and reference non-linear loads and UPS circuit topology.
H.1.1 Output waveshape

UPS covered by this standard have waveshapes ranging from pure sinusoidal through to square wave.

UPS designed to support both linear and non-linear loads are generally of the sinewave type.

UPS designed to support only non-linear loads of the rectifiers of the capacitor input type may have any waveshape capable of supporting the rectifier load capacitance energy requirements.

H.1.2 Linear and non-linear loads

Linear loads, often containing magnetic components, are more sensitive to increases/decreases in volt-time area on a half-cycle by half-cycle basis. For these loads, the measurement criteria is the change in r.m.s. value from the desired value.

This type of load is normally tolerant of single transient deviations not exceeding 200% of nominal r.m.s. voltage if the time duration is less than 1 ms and these do not need to be considered.

The reference non-linear load draws current only when the supply voltage exceeds the load capacitor voltage and is therefore more affected by the loss of the peak voltage. This type of load is very tolerant of waveshape type as its volt-time area requirement is only to refresh capacitor lost energy. In general practical use, the loss of up to a half-cycle has no detrimental effect, since the function of the capacitor is to store and supply load energy during this interval. Dynamic performance considerations for this type of load are limited to ensuring the maintenance of the load capacitor voltage within stated limits during transient testing.

H.1.3 UPS circuit topology

Circuit topology has an effect on the dynamic performance during change of operating mode.

UPS designed for use with linear loads are generally of the continuous operation type, or line-interactive type, electronically switching between supplies without any discontinuity in load current, often called no-break.

UPS designed only for non-linear loads, mainly single-phase UPS of the smaller kVA rating, have only to consider load capacitor energy requirements and often incorporate a changeover switching device between supplies. This device may be electromechanical in nature, resulting in a complete loss in output voltage during the transition time of the device of between 1,0 ms to 10,0 ms in duration. The acceptance criteria is the maintenance of load capacitor voltage within stated tolerances during both change of mode and step load conditions. The purpose of characterizing with linear loading for these types of UPS is only to define the break time of the switching device, if applicable.
UPS designed for both types of load have to maintain the r.m.s. values within figures 1 or 2 of 5.3.1 for linear loads.

For use on non-linear loads, the criteria is maintaining the load capacitor voltage within stated tolerances equivalent to the sinewave tolerances of figure 3 of 5.3.1.

**H.2 Test methods and instrumentation**

The choice of method of computation of the transient will be determined by available test equipment and the sophistication of its measurement capability on a subcycle basis for the waveshapes to be computed.

**H.3 Sinusoidal output voltage waveforms**

Where sinusoidal waveshapes are present, observation of the output waveform on an oscilloscope or chart recorder may provide sufficient measurement accuracy in determining the deviation in real time on a successive half-cycle by half-cycle basis, augmented if necessary by additional mathematical calculation.

An alternative method by summation of the UPS output waveform with a reference waveform source, e.g. in shape, amplitude and frequency, to provide the instantaneous sum difference in time can be used. This sum difference from the desired value is used to compute voltage deviation. This method can be subject to error if phase differences occur between UPS output waveform and reference waveform during the transient time.

**H.4 Non-sinusoidal output voltage waveforms**

(trapezoidal/quasi-square/square)

Waveforms of this type are generally only used to supply non-linear loads of the rectifier/capacitor type where load current pulses are only drawn when the UPS output voltage exceeds the load capacitor voltage. Acceptance is verified by using the test circuit of figure H.2.

Under conditions of reference non-linear loading, short-time subcycle transients may have no practical effect on the load function even though observable on the UPS output voltage waveform.

Under conditions of step loading, only the change of the capacitor voltage of existing connected loads needs to be considered whilst applying or removing additional loads. This also holds for change of mode with 100% reference non-linear load.
**H.5 Resistive load test method – Change of operating mode/step load**

![Diagram of resistive load test method](image)

**Figure H.1 – Resistive load test method – Change of operating mode/step load**

With the UPS loaded with 100% resistive load, at the initiation of the transient both load voltage and current are monitored.

The voltage waveform is observed to determine output voltage deviation in conjunction with the current waveform to determine any discontinuity of the load current.

Where the UPS incorporates a switching device to transfer the load between UPS supplies, the device changeover/switching time shall be determined from the voltage/current measurement and characterized as in figures 1, 2 or 3 of 5.3.1.

**H.5.1 Step loading – Resistive**

Using the test circuit of figure H.1, in each mode of operation, apply the load steps as required in 6.3.7.1, observing the change in output voltage, and compute the deviation over time to characterize within the limits of figures 1, 2 or 3 of 5.3.1.
H.6 Reference non-linear load test method – Change of operating mode/step load

![Diagram]

**Figure H.2 – Reference non-linear load test method – Change of operating mode/step load**

Using the test circuit of figure H.2, monitor the capacitor voltage of the reference non-linear load with the UPS loaded to 100% of rated load. While initiating the change of mode, observe the change in capacitor voltage, which should remain within the stated tolerances of figures 1 or 2 of 5.3.1.

**H.6.1 Step loading reference non-linear load**

Using the test circuit of figure H.2, apply or reduce the required step loads in accordance with 6.3.8.5, 6.3.8.6. Monitor the load capacitor voltage of the base load connected to the UPS whilst applying or disconnecting other step loads.

Observe capacitor voltage changes, which should remain within stated tolerances of figures 1 or 2 of 5.3.1.