COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

NORME DE LA CEI

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC STANDARD

Publication 146-4

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1986

Convertisseurs à semiconducteurs

Quatrième partie: Méthode de spécification des performances et procédures d'essais des alimentations sans interruption

Semiconductor convertors

Part 4: Method of specifying the performance and test requirements of uninterruptible power systems

Bureau Central de la Commission Electrotechnique Internationale

3, rue de Varembé

Genève, Suisse

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SEMICONDUCTOR CONVERTORS

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 22B: Semiconductor Convertors, IEC Technical Committee No. 22: Power Electronics.

The text of this standard is based upon the following documents:

Six Months' Rule	Report on Voting
22B(CO)44	22B(CO)47

Further information can be found in the Report on Voting indicated in the table above.

3.6 *Invertor*

Electronic convertor for inversion.

3.7 *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.

3.8 *Transfer switch*

UPS switch consisting of one or more switches used to transfer power from one source to another.

3.9 *Electronic power switch*

Operative unit for electronic power switching comprising at least one electronic controllable valve device.

3.10 *Quenching*

The termination of current conduction in an arm without commutation.

3.11 *Commutation*

The transfer of current from one arm to another with both arms carrying current simultaneously.

3.12 *Line commutation*

External commutation whereby the commutating voltage is supplied from the line.

3.13 *Self-commutation*

Commutation whereby the commutating voltage is supplied by components within the convertor or the electronic switch.

3.14 *Prime power*

Power normally continuously available which is usually supplied by an electrical utility company but sometimes by the user's own generation.

3.15 *Stand-by power*

Power intended to replace prime power in the event of prime power failure.

3.16 *A.C. input*

Power supplied to UPS and bypass, if any, which can be either prime power or standby power.

3.17 *Bypass*

Power path alternative to the indirect a.c. convertor.

3.18 *Bypass power*

Power (prime or stand-by power) supplied via the bypass.

3.19 *Power failure*

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

3.20 *UPS unit*

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

3.21 *Single UPS*

UPS comprising only one UPS unit.

3.22 *Parallel UPS*

UPS comprising two or more UPS units operating in parallel.

3.23 *Partial parallel UPS*

UPS with parallel operating invertors with common battery and/or rectifier.

3.24 *Partial redundant UPS*

UPS with redundancy in invertors or invertors and/or other functional units.

3.25 *Redundant UPS*

UPS with redundancy in UPS units.

3.26 *Redundancy*

Addition of functional units or groups of functional units in a system to enhance the continuity of load power.

3.27 *Stand-by redundant UPS*

Redundant UPS in which one or more UPS units are held in reserve until the operating UPS unit fails.

3.28 *Parallel redundant UPS*

Redundant UPS with a number of paralleled load-sharing UPS units the remainder of which, upon failure of one or more UPS units, takes over the full load.

3.29 *Rating*

Set of rated values and operating conditions.

3.30 *Rated value*

Quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment.

3.31 *Nominal value*

Suitable approximate quantity value used to designate or identify a component, device or equipment.

3.32 *Limiting value*

Greatest or smallest admissible value of a specified input or output quantity.

3.33 *Tolerance band*

Range of values of a quantity within specified limits.

3.34 *Output voltage*

R.M.S. value (unless otherwise specified for a particular load) of the voltage between the output terminals.

3.35 *Output current*

R.M.S. value of the current (unless otherwise specified for a particular load) from the output terminals.

3.36 *Output power*

Active power (sum of the power of the fundamental frequency components of voltage and current and power of the harmonic components) from the output terminals.

3.37 *Load power factor*

Characteristic of an a.c. load in terms expressed by the ratio of active power to apparent power assuming an ideal sinusoidal voltage.

3.38 *Short circuit output current*

Current which flows from the UPS into a short circuit across its output terminals.

3.39 *Output impedance*

Impedance presented by the convertor to the load for specified frequencies.

3.40 *Relative harmonic content*

Ratio of the r.m.s. values of the harmonic content to the r.m.s. value of the total non-sinusoidal periodic function.

3.41 *Periodic output voltage modulation*

Periodic variation of output voltage amplitude at frequencies less than the fundamental output frequency.

Note. — For the purpose 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.

The term "deviation" has the following meaning: The difference between the actual values of a quantity and the ideal waveform or nominal value respectively.

3.42 *R.M.S. voltage variation*

Difference between the r.m.s. voltage and the corresponding previously undisturbed r.m.s. voltage.

3.43 *Voltage time integral variation*

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

3.44 *Peak voltage variation*

Difference between the actual peak voltage and the corresponding value of the previously undisturbed waveform.

3.45 *Frequency modulation*

Variation of the output frequency.

3.46 *UPS efficiency*

Ratio of output power to input power under specified service conditions with no energy transfer to or from the energy storage means.

3.47 *Stored energy time*

Minimum time during which the UPS will ensure continuity of load power under specified service conditions starting with a fully charged energy storage means when a.c. input power fails.

3.48 *Restored energy time*

Maximum time required by the energy storage means of the UPS to be fully charged with the UPS operating under specified service conditions.

3.49 *Transient*

That part of the variation in a quantity during transition from one steady-state operating condition to another which ultimately disappears.

3.50 *Subtransient (less than half a cycle) voltage waveform variation*

Difference between the voltage waveform and the corresponding portion of the previous half cycle of the voltage.

3.51 *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.

3.52 *Transfer time*

Time interval between the initiation of transfer and the instant when the output quantities have been transferred.

3.53 *Interruption time*

Time interval during which the output voltage is below the lower limit of the tolerance band.

3.54 *Supply impedance*

Impedance at the input lines to the UPS with the UPS disconnected.

4. Types of uninterruptible power systems (UPS)

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

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

4.1 *Single UPS*

The simplest arrangement is a single UPS.

4.1.1 *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. The load will not normally be disturbed by an a.c. input power failure (see Figure 1).

4.1.1.1 *Single UPS with a common rectifier for invertor and battery*

The invertor 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 1). The rectifier has to be controlled so as to recharge and maintain the battery in a charged condition.

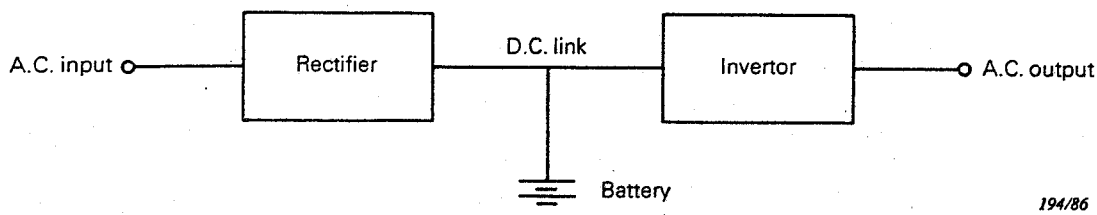


FIG. 1. — Single UPS with a common rectifier for invertor and battery.

In case of 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 invertor. The type and capacity of the battery will determine the length of time the system can operate without an a.c. input supply.

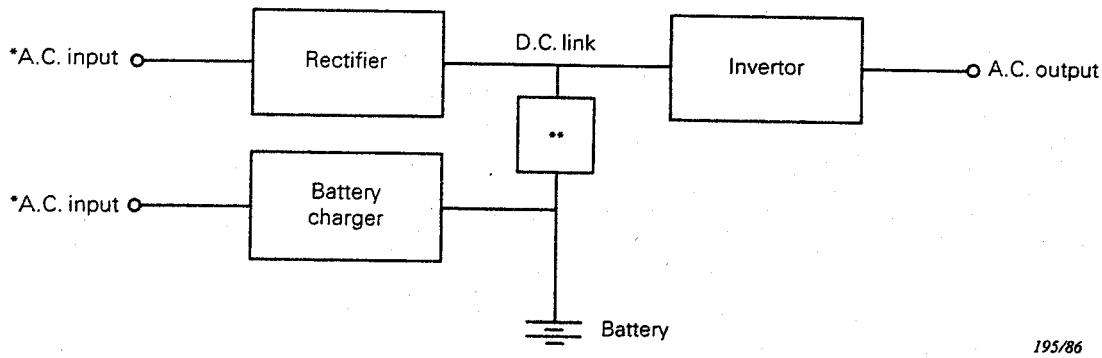
The frequency, number of phases and voltage levels of the input and output may be different.

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.

4.1.1.2 *Single UPS with separate battery charger*

The requirements of the rectifier to supply the invertor input power and charge the battery may conflict with each other so that the UPS may be designed with a separate battery charger.

From a user's point of view, the above comments on single UPS apply to this system also.



* The a.c. input terminals may be combined.
** Blocking diode, or thyristor, or switch.

FIG. 2. — Single UPS with separate battery charger.

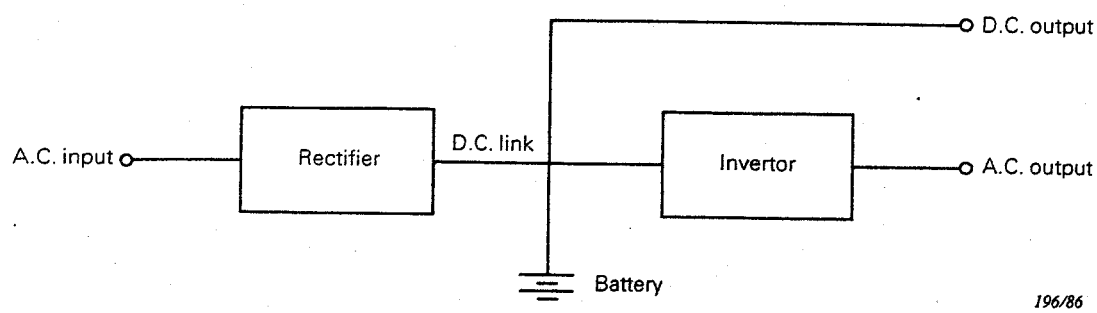


FIG. 3. — Single UPS with d.c. and a.c. output.

4.1.1.3 *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 3.

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

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

4.1.2 *Single UPS with bypass*

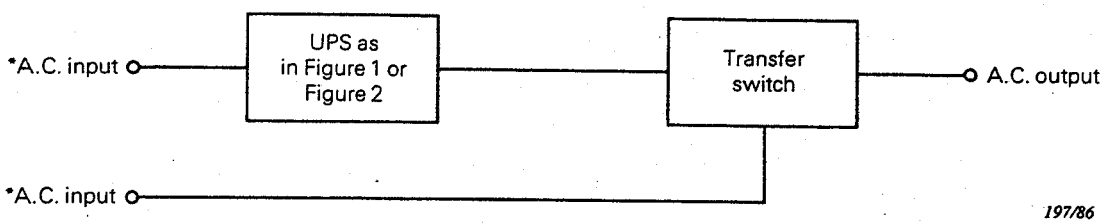
4.1.2.1 *Continuous operation*

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 clearing currents);

c) Peak load.



* The input terminals may be combined.

FIG. 4. — Single UPS with bypass.

Some restrictions for addition of a bypass are the following:

The input and output frequency must 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.

4.1.2.2 *Active stand-by operation*

In active stand-by operation, the load is supplied by the a.c. input through the bypass (the invertor is operating at no load), and upon input power failure, the invertor and battery maintain continuity of load power. All restrictions outlined under Sub-clause 4.1.2.1 apply.

4.1.2.3 *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 invertor is activated and with the battery maintains continuity of load power. All restrictions outlined under Sub-clause 4.1.2.1 apply.

4.2 *Parallel UPS*

4.2.1 *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 5a and 5b.

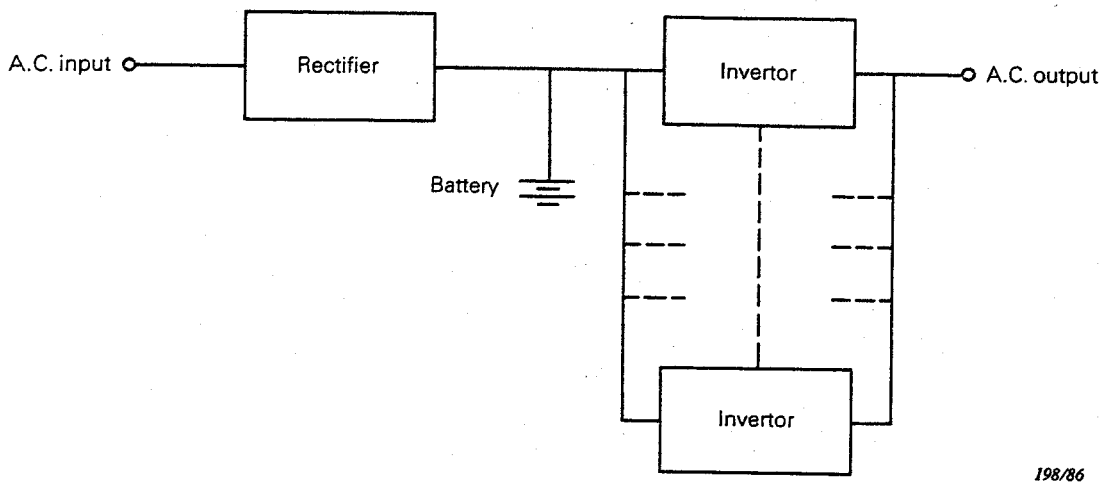
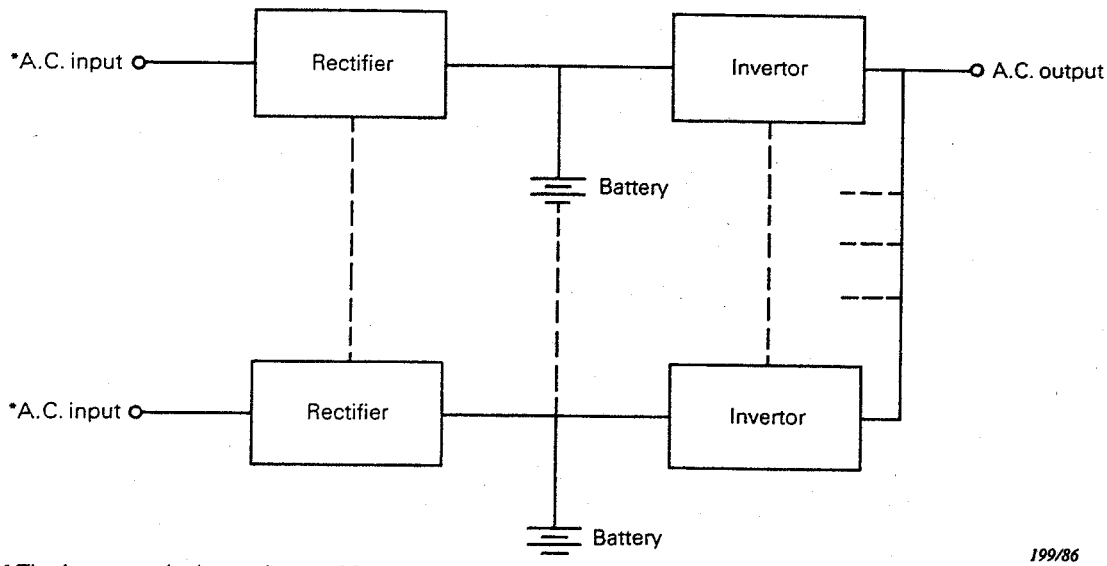


FIG. 5a. — Partial parallel UPS (with invertors in parallel).



* The input terminals may be combined.

FIG. 5b. — Parallel UPS (with UPS units in parallel).

The performance of such parallel UPS will be the same as that associated with a single UPS.

4.2.2 *Parallel UPS with bypass*

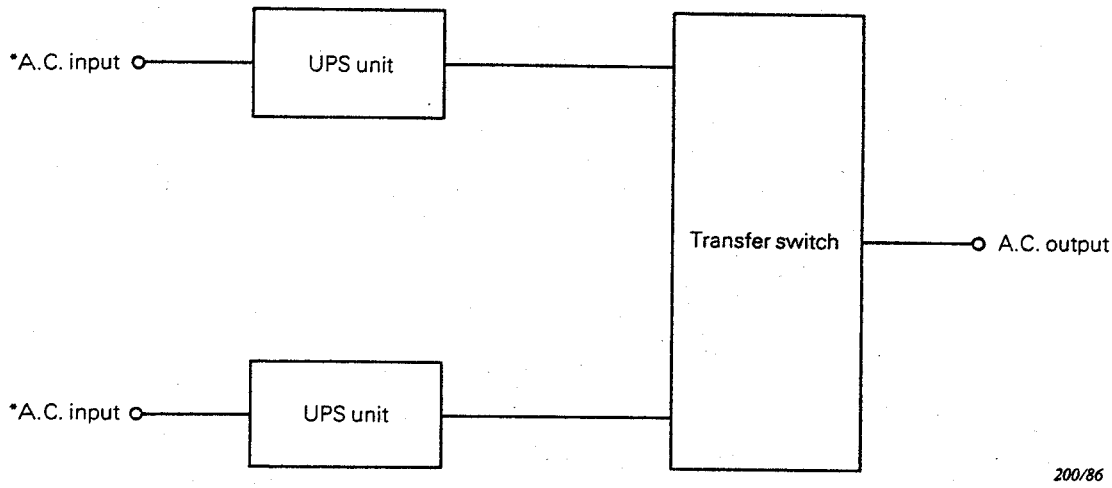
As the parallel UPS is operated as a single UPS, then all the comments in Sub-clause 4.1.2 fully apply to this, and the configuration is equivalent to Figure 4, page 19.

4.3 *Redundant UPS*

4.3.1 *Stand-by redundant UPS*

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

4.3.1.1 *Stand-by redundant UPS without bypass*



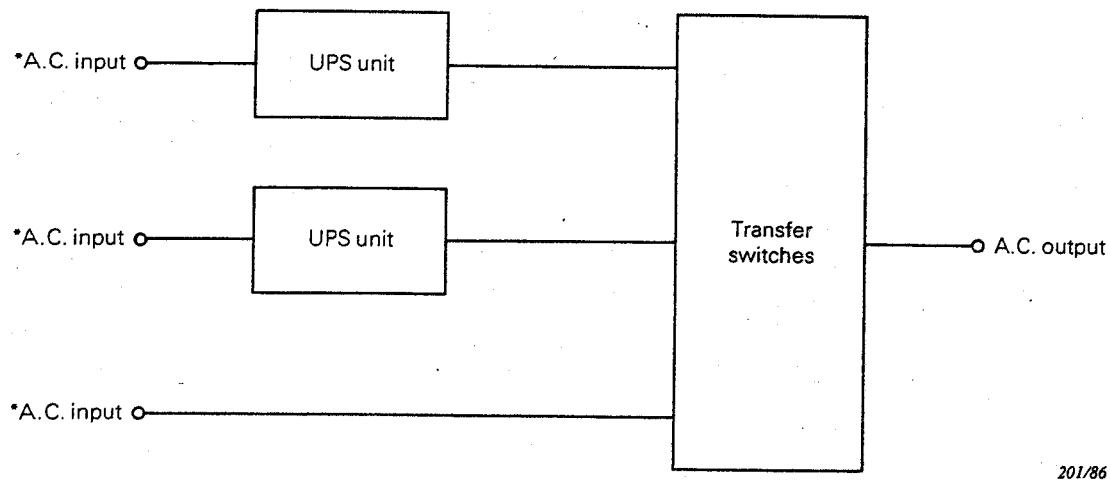
* The input terminals may be combined.

FIG. 6. — Stand-by redundant UPS.

This system retains the characteristics as indicated in Sub-clause 4.1.1 and it provides a method of improving the continuity of load power.

4.3.1.2 *Stand-by redundant UPS with bypass*

A bypass circuit can be included to improve still further the continuity of load power as indicated in Sub-clause 4.1.2.1, 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.



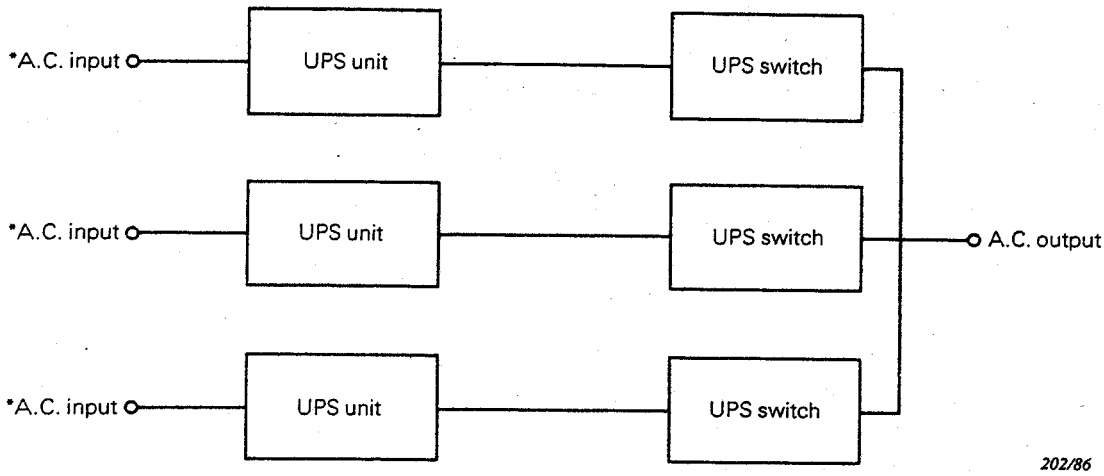
* The input terminals may be combined.

FIG. 7. — Stand-by redundant UPS with bypass.

4.3.2 *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.

4.3.2.1 *Parallel redundant UPS without bypass*



* The input terminals may be combined.

FIG. 8. — Parallel redundant UPS.

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 and load sharing circuits are required in these systems.

Note. — There may be some parts of a parallel redundant UPS which are common to all the units. Failure of such a common part may result in loss of continuity of load power.

4.3.2.2 *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 Sub-clause 4.1.2.1.

5. Service conditions and performance requirements

5.1 *Usual service conditions (excluding batteries)*

Equipment conforming to this standard shall be capable of operating under the following conditions if not otherwise specified:

a) The ambient air temperature is above 0 °C and does not exceed 40 °C.

b) If a liquid is used for cooling purposes, the temperature of the incoming liquid is greater than 5 °C and does not exceed 30 °C.

c) The altitude does not exceed 1 000 m.

d) No conditions listed under Sub-clause 5.2 are present.

e) 1) Input alternating voltage range for an indirect a.c. convertor is equal to the nominal input voltage ±10%.

2) A.C. line input frequency tolerance is ±2% of nominal.

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

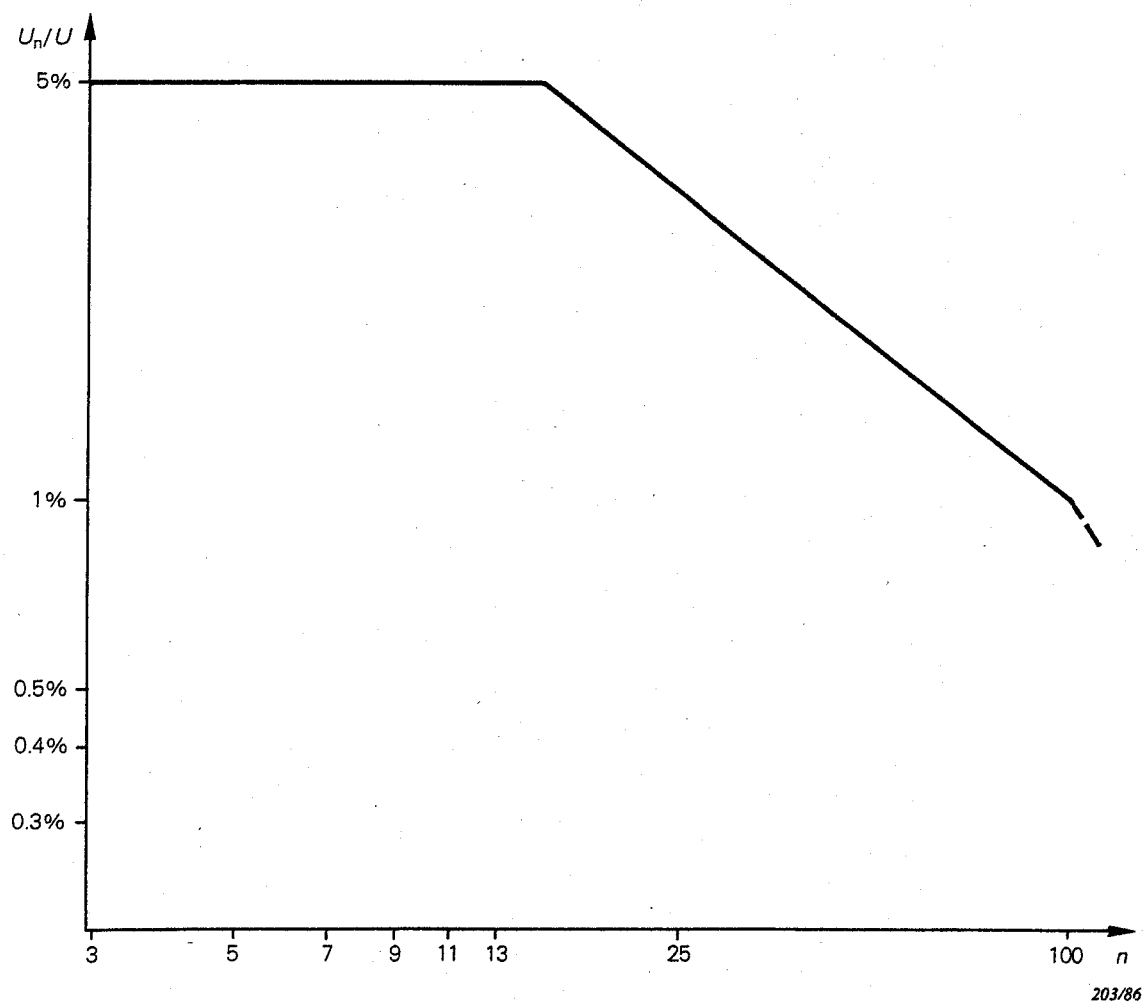
2. — If a bypass is used its input should be within tolerances acceptable to the load.

f) Harmonics on the input alternating voltage supplying an indirect a.c. convertor are restricted by the following limits:

1) Relative harmonic content not exceeding 10%.

2) Harmonic components not exceeding values given in Figure 9.

g) Load current unbalance: The difference between the highest and the lowest fundamental r.m.s. current values in the three-phase output, referred to the rated current of the UPS, does not exceed 0.25 and the maximum line current does not exceed the rated line current of the UPS.



n = order of harmonic component
U_n = r.m.s. value of harmonic order n
U = r.m.s. value of rated input alternating voltage

FIG. 9. — Maximum permitted harmonic component of the input alternating voltage.

5.2 *Service conditions to be identified by the purchaser*

The use of UPS equipment under conditions departing from those noted under usual service conditions shall be considered special. Conditions of the kind given below may require special construction or protective features and, where they exist, shall be specified by the purchaser.

5.2.1 *Environmental conditions to be identified*

a) Damaging fumes.

b) Moisture.

c) Dust.

d) Abrasive dust.

e) Steam.

f) Oil vapour.

g) Explosive mixtures of dust or gases.

h) Salt air.

i) Weather or dripping water.

j) Extreme changes in temperature.

k) Cooling water containing acid or impurities which may cause scale, sludge, electrolysis or corrosion of the convertor parts exposed to the water.

l) Strong electromagnetic fields.

m) Radioactive levels above those of the natural background.

n) Fungus, insects, vermin, etc.

o) Restriction of ventilation.

p) Radiated or conducted heat from other sources.

q) Battery service conditions.

5.2.2 *Mechanical conditions to be identified*

a) Exposure to abnormal vibration, shocks, tilting or earthquakes.

b) Special transportation or storage conditions (purchaser to identify method of handling equipment).

c) Space and weight limitations.

5.2.3 *Electrical conditions to be identified*

5.2.3.1 *A.C. input to UPS*

a) Supply impedance and network configuration.

b) Voltages in excess of tolerances given in Sub-clause 5.1.

c) Frequency in excess of tolerances given in Sub-clause 5.1.

d) High system voltage to ground.

e) Superimposed high frequency voltages.

f) Voltage harmonics in excess of those given in Sub-clause 5.1.

g) Transient voltages or other electrical noise such as that caused by lightning or capacitive or inductive switching.

Note. — The above information is particularly required in case of stand-by power.

5.2.3.2 *Output of UPS*

a) Maximum step load and load profile versus time.

b) A load which is not balanced between phases as specified in Sub-clause 5.1

c) Loads requiring or generating (especially even) harmonic currents.

d) Loads requiring the circulation of a d.c. current.

e) Earth conditions of output.

5.2.3.3 *D.C. link*

a) Isolation of d.c. link from input and/or output.

b) Earth conditions of d.c. link.

5.3 *Equipment performance requirements to be identified by the purchaser*

The following conditions, when they exist, may require unusual construction:

5.3.1 *Performance limitations*

Limitations, if any, on the following items should be specified by the purchaser:

a) audible noise;

b) electrical noise both conducted and radiated;

c) alternating supply current harmonics;

d) output relative harmonic content.

5.3.2 *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.

6. Rated values and performance of UPS

6.1 *General*

The rated values for a UPS define the output values which can be taken from the apparatus under specified service conditions. A UPS shall have its rated load expressed in terms of apparent power available at the output terminals on the basis listed in Sub-clause 6.2.1.

If not otherwise specified, the values shall be based on:

a) usual service conditions;

b) continuous duty.

6.2 *Single and parallel UPS*

c) load power factor;

d) interruption time rating;

e) total system transfer time and interruption time (if any);

f) rated short-circuit current capability on bypass (see Item *m)* of Sub-clause 6.2.1);

g) voltage deviations and recovery time on transfer at rated load;

h) rated short-circuit current capability (if applicable).

6.3 *Stand-by redundant UPS*

6.3.1 *Without bypass*

a) UPS ratings and performance in accordance with Sub-clause 6.2.1.

b) UPS switch losses are to be included in overall power efficiency.

c) UPS switch ratings as defined in Sub-clause 6.2.2 (bypass).

d) Total number of UPS units are to be stated as well as number of UPS units working normally in parallel (if any).

6.3.2 *With bypass*

The same values as those called for in Sub-clause 6.3.1 and, in addition, bypass ratings as defined in Sub-clause 6.2.2.

6.4 *Parallel redundant UPS*

6.4.1 *Without bypass*

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 Sub-clause 6.2.2 for connecting or disconnecting a UPS unit.

d) Continuous rating with all UPS units in operation in accordance with Sub-clause 6.2.1.

e) Continuous rating with minimum required number of UPS units in operation in accordance with Sub-clause 6.2.1.

6.4.2 *With bypass*

The same values as those called for in Sub-clause 6.4.1 and, in addition, bypass ratings and performance in accordance with Sub-clause 4.2.2.

7. Tests for UPS

7.1 *General*

For performance tests see Clause 140 of IEC Publication 146. It should be a matter of agreement between manufacturer and purchaser which of the tests should be performed in the factory and which on site.

Equipment could be type and routine tested in the factory as a complete UPS, and less extensive operational tests with actual batteries and load could be performed on site.

Alternatively, routine tests in the factory could be restricted to UPS functional units or combinations of such. The final test on site then replaces the UPS routine factory test and

ensures correct connection between units, ventilation, cooperation between units, function of battery, etc.

7.2 *Functional unit tests*

7.2.1 *Rectifier tests*

Rectifier tests shall be performed in accordance with Clauses 490 to 492 of IEC Publication 146. 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.

7.2.2 *Invertor tests*

Invertor tests shall be performed in accordance with Clause 5 of IEC Publication 146-2. The schedule of routine tests, type tests and optional tests is given in Sub-clause 5.2.2 and corresponds with the rectifier test performance, except that it includes additional tests of harmonic content and optional tests concerning special features of invertor equipment.

The different test items are specified in Sub-clauses 5.3 to 5.17 of IEC Publication 146-2.

7.2.3 *Testing of UPS switches*

Operational tests shall be performed in accordance with IEC Publications 146 and 146-2, where applicable. For example, the following testing procedures are usually applicable:

a) insulation (IEC Publication 146, Sub-clause 492.1);

b) checking of auxiliary devices (IEC Publication 146-2, Sub-clause 5.4);

c) checking of protective devices (IEC Publication 146, Sub-clause 492.9);

d) checking of supervising and remote signalling circuits;

e) checking of measuring devices;

f) light load transfer test.

Type testing requires in general a functional test of the complete UPS. In addition to the tests mentioned above, a type test program will include:

g) a complete functional test, for example switching of loads;

h) transfer time test;

i) load test, temperature rise (IEC Publication 146-2, Sub-clause 5.5);

j) short-time overload (IEC Publication 146-2, Sub-clause 5.9).

k) short-circuit capability (IEC Publication 146-2, Sub-clause 5.10).

7.2.4 *Testing of monitoring and control equipment*

The following tests shall be performed:

a) insulation tests (IEC Publication 146, Sub-clause 492.1);

b) checking of electrical circuits;

c) checking of operation controls.

7.2.5 *Battery tests*

Testing of storage batteries will consist of tests in accordance with Sub-clauses 7.4.15, 7.4.16 and 7.4.17 after complete installation on site. Factory tests of batteries by the UPS manufacturer are not applicable.

7.3 *UPS testing procedure*

If complete UPS testing is not performed at the factory, a functional unit test in accordance with Sub-clause 7.2 shall be completed prior to testing on site.

Notes 1. — *Measuring accuracy*

Attention should be paid to the influence of harmonics on the result of measuring methods.

2. — *Voltage transients*

Voltage transients are usually measured by oscilloscopes or transient recorders. This method gives the transients of momentary values.

Detailed measuring techniques should be a matter of agreement between manufacturer and purchaser.

7.3.1 *Testing schedule*

Test	Type test	Routine test	Optional test when required for specific application	Sub-clause
Interconnection cable check	×	×		7.4.1
Light load test	×	×		7.4.2
Checking of auxiliary devices	×	×		7.4.3
Synchronization test	×		×	7.4.4
A.C. input failure test	×	×		7.4.5
A.C. input return test	×	×		7.4.6
Simulation of parallel redundant UPS fault	×	×		7.4.7
Transfer test	×	×		7.4.8
Full load test	×		×	7.4.9
UPS efficiency	×			7.4.10
Unbalanced load test	×		×	7.4.11
Output voltage unbalance	×		×	7.4.12
Actual load test			×	7.4.13
Current division in parallel UPS	×	×		7.4.14
Rated stored energy time, battery test			×	7.4.15
Rated restored energy time			×	7.4.16
Battery ripple current			×	7.4.17
On-site ventilation test			×	7.4.18
Overload capability test			×	7.4.19
Short-circuit current capability			×	7.4.20
Short-circuit fuse test			×	7.4.21
Restart			×	7.4.22
Output overvoltage			×	7.4.23
Periodic output voltage modulation			×	7.4.24
Frequency modulation			×	7.4.25
Radio frequency interference and conducted noise			×	7.4.26
Harmonic components			×	7.4.27
Audible noise			×	7.4.28
Earth fault test			×	7.4.29
Additional tests			×	7.4.30
Vibration and shock tests			×	7.4.30
Drift test			×	7.4.30

7.4 *Test specifications*

The following tests when conducted on site shall use the maximum available load which does not exceed the rated continuous load.

a) With and without bypass, where appropriate.

b) With and without redundancy, where appropriate.

7.4.1 *Interconnection cable check*

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

7.4.2 *Light load test*

This test is carried out to verify that the UPS is correctly connected and all functions operate properly. The load applied is limited for economic reasons to some per cent of rated value. The following points should be checked:

a) output voltage and frequency and the correct operation of meters;

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

c) functioning of protective and warning devices;

d) operation of remote signalling and remote control devices.

7.4.3 *Checking of auxiliary devices*

The functioning of auxiliary devices, such as lighting, cooling, pumps, fans, annunciators, etc., should be checked, if convenient, in conjunction with the preliminary light load test.

If there is a stand-by generator set, the test for feeding a UPS requires a light load and a full load test. The load might be achieved by recharging batteries after a light load battery discharge.

7.4.4 *Synchronization test*

If possible, frequency variation limits should be tested by use of a variable frequency generator; otherwise, by simulation of control circuit conditions. If applicable the rate of change of frequency during synchronization shall be measured.

7.4.5 *A.C. input failure test*

The test is performed with a fully charged battery and is carried out by tripping input circuit breakers or may be simulated by switching off all UPS rectifiers and bypass feeders at the same time. Output voltage variations are to be checked for specified limits with an oscilloscope or equivalent. Frequency variation is defined as the steady-state frequency of the UPS with and without a.c. input. The rate of change of frequency is measured by the time it takes to reach steady-state values.

7.4.6 *A.C. input return test*

A.C. input return test is performed by closing a.c. input circuit breakers, or is simulated by energizing rectifiers and bypass feeders.

Proper operation of rectifier starting and voltage and frequency variations are to be observed.

Note. — This test is normally performed with a fully or partially charged battery. If the test in Sub-clause 7.4.15 is specified, this test will be repeated at the end of that test.

7.4.7 *Simulation of parallel redundant UPS fault*

This test is applicable for UPS with parallel redundant connections. Faults of rectifier or invertor units may be carried out by simulation. Output transients are to be observed.

7.4.8 *Transfer test*

This test is applicable for UPS with bypass means, particularly in the case of an electronic bypass switch. Transients shall be measured during load transfer to bypass caused by a simulated fault and load retransfer after clearing of the fault.

7.4.9 *Full load test*

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

Large UPS in parallel connection may be load tested by testing the individual UPS units separately. Load tests are necessary for testing output voltage and frequency, rated stored energy, recharge time, ventilation, temperature rise and determination of efficiency. Load tests are performed to prove transient voltage deviations specified under step load conditions.

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

7.4.10 *UPS efficiency*

UPS efficiency should be determined by the measurement of the active power input and output. In case of a large UPS, the efficiency may be calculated by the addition of separate losses.

7.4.11 *Unbalanced load test*

Unbalanced load test is applicable to three-phase UPS. Unbalanced load at certain specified limits is applied to the UPS or one of its UPS units. The specified voltage unbalance shall be checked.

Ripple current to the battery shall be kept to specified limits under steady-state unbalanced load conditions to be specified.

7.4.12 *Output voltage unbalance*

Output voltage unbalance shall be checked under symmetrical load conditions and unbalanced load conditions.

Phase-to-neutral and phase-to-phase output voltages are to be observed. Voltage unbalance will be given in either terms of voltage unbalance ratio or voltage unbalance factor (IEC Publication 146-2, Sub-clause 5.12) or by the ratio of highest phase voltage minus lowest phase voltage to the average value. Phase angle deviations may be determined by calculation from the values of phase-to-phase and phase-to-neutral voltages.

7.4.13 *Actual load test*

Conditions under actual load may differ from those with a dummy load. Steady-state generation of current and voltage harmonics and transients at load switching conditions should be observed.

7.4.14 *Current division in parallel UPS*

Parallel operating UPS units do not necessarily need equal load sharing. Load sharing between the UPS units shall be measured with a dummy load or actual load under conditions of redundant and non-redundant operation, if applicable.

7.4.15 *Rated stored energy time (battery test)*

This test is a load test to prove the actual possible time of battery operation.

If rated load is not available in the case of large UPS, it is possible to apply a partial load to check the actual battery discharge characteristics and compare these with characteristics specified by the battery manufacturer. Discharge time with rated load shall then be calculated. The test shall be performed with a fully charged battery and also may be done under other battery conditions to be specified, if so agreed. Active power output of the UPS and the battery voltage shall be recorded during the test.

Since new batteries often do not provide full capacity during a starting-up period, the discharge test may be repeated after a reasonable recharge time if the original test has failed.

7.4.16 *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.

7.4.17 *Battery ripple current*

If battery ripple currents are specified, then the ripple current which depends on UPS operation shall be checked under normal operating conditions. Rough measuring methods are sufficient.

7.4.18 *On-site ventilation test*

The test is performed with the actual load, if possible, or a dummy load. The dummy load shall be placed outside of UPS area to avoid influences of its dissipated heat upon UPS ventilation. Temperature conditions of all UPS cubicles are to be observed.

Peak temperatures to be expected may also be calculated from actual and expected or specified values of air inlet and cooling methods applied.

7.4.19 *Overload capability test*

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 are to be recorded. If this is a factory type test, then it shall be conducted in accordance with Item *n)* of Sub-clause 6.2.1.

7.4.20 *Short-circuit current capability*

If short-circuit current capability is specified, it may be tested by application of a short circuit to UPS output if necessary, via a suitable fuse. Short-circuit current is to be recorded. These tests shall be conducted in accordance with Item *m)* of Sub-clause 6.2.1 as applicable.

7.4.21 *Short-circuit fuse test*

Fuse tripping capability of a UPS may be tested, if specified, by short-circuiting the UPS output via a fuse of specified type.

The test shall be repeated to ensure against fuse non-uniformity and switching time during the cycle. The test is carried out at an appropriate UPS load, under normal operation, if not otherwise specified by purchaser.

7.4.22 *Restart*

Automatic or other restart means are to be tested after a complete shut-down of UPS as specified.

7.4.23 *Output overvoltage*

Output overvoltage protection is to be checked.

7.4.24 *Periodic output voltage modulation*

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

7.4.25 *Frequency modulation*

In accordance with Sub-clause 5.13 of IEC Publication 146-2.

7.4.26 *Radio frequency interference and conducted noise*

Radio frequency interferences and conducted noise may be defined by national regulations or the purchaser's specification. Interference of complete UPS may differ from that of functional units.

Radio frequency interference and conducted noise of UPS output may be specified for actual loads. The test and measuring methods will be a matter of agreement between manufacturer and purchaser.

7.4.27 *Harmonic components*

Harmonic components of output voltage are specified under linear load conditions, but may also be checked with the actual load (see Sub-clauses 5.6.3 and 5.6.4 of IEC Publication 146-2).

Allowable harmonic currents caused by the UPS in the a.c. input may be specified by the electric utility companies. Methods of specification and checking shall be a matter of agreement between manufacturer and purchaser.

7.4.28 *Audible noise*

Test procedure and limits shall be a matter of agreement between manufacturer and purchaser.

Audible noise of a complete UPS may differ considerably from the values of individual functional units. Room conditions, resonance and reflection will cause differences from calculated or measured values.

7.4.29 *Earth fault test*

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

If the battery 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.

7.4.30 *Additional tests*

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

8. Purchaser specification guidelines

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.

8.1 *Type of UPS*

a) Single.

b) Parallel.

c) Redundant.

d) Bypass to prime or stand-by power system.

e) A.C. generator stand-by power system (if applicable).

f) Required bypass transfer time (if applicable).

g) Other features.

8.2 *Load to be operated from UPS*

a) Type:
computers;

motors;
saturating transformer power supplies;
diode rectifiers;
thyristor rectifiers;
switched type power loads and other types of loads.

b) Continuous apparent power and power factor.

c) Single and/or three-phase loads.

d) Inrush currents.

e) Start-up procedure.

f) Special features of load 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.

8.3 *UPS output*

a) Rated output power and power factor.

b) Nominal output voltage, steady-state and transient tolerance bands.

c) Nominal output frequency and tolerance band.

d) Special requirements regarding, for example, synchronization, relative harmonic content and modulation.

e) Voltage and adjustability range.

f) Phase angle tolerance allowed (for three-phase).

8.4 *UPS input*

For prime power system and (if any) stand-by power system:

a) nominal input voltage and voltage tolerance band;

b) number of phases;

c) nominal input frequency and tolerance band;

d) special conditions regarding, for example, superimposed harmonics, transient voltages, supply impedance, etc.

e) limitations regarding, for example, inrush currents, harmonic currents, etc.

f) stand-by power system rating.

8.5 *Battery*

a) Type of battery.

b) Nominal voltage, number of cells, available ampere hour capacity (if supplied by purchaser).

c) Rated stored energy time.

d) Rated restored energy time.

e) Presence of other loads on battery and their voltage tolerances.

f) Availability of separate battery room.

g) Special requirements regarding, for example, ripple current.

h) Temperature of battery room.

8.6 *General requirements and special service conditions*

a) Efficiency at specified load conditions.

b) Ambient temperature.

c) Cooling system.

d) Instrumentation.

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 or storage conditions, limitations to space or weight.

h) Performance limitations regarding, for example, electrical and audible noise.

i) Galvanic separation required between input and/or d.c. link and/or output.

j) Earthing of input and/or d.c. link and/or output.

k) Maintenance bypass circuits and other installation requirements.

l) Future extension of the UPS.

APPENDIX A

UPS SWITCHES

A1. General

This appendix refers to all UPS switches. It does not refer to conventional mains distribution boards, rectifier input switches or d.c. switches (for example for batteries, rectifier output or invertor input, etc.).

UPS switches are regarded as integral parts of UPS. Standards for electronic and conventional low-voltage switches cannot be applied generally to this equipment.

A2. Types of UPS switches

A2.1 *Invertor output switches*

a) Circuit breakers.

b) Contactors.

c) Electronic switches

1) line-commutation and quenching;

2) self-commutated.

d) Combinations of electronically and mechanically operated switches to ensure specified performance.

A2.2 *Transfer switches*

Transfer switches may be designed to transfer load current either with or without interruption of voltage as far as conditions of the power sources allow such operation.

A2.2.1 Transfer switches are usually comprised of at least one switch in either of the separate supply sources. The switch can be an electronic or mechanical type or combination thereof.

A3. Service conditions and performance requirements

See Clause 5.

A4. Rated values and performance

A4.1 *Invertor output switches*

Rated values of invertor output switches are matched to the requirements of the UPS and are not stated separately.

A4.2 *Transfer switches*

Transfer switches may have a different rating than that of the UPS, for example load distribution or future extension; therefore, the following rated values shall be specified:

a) nominal voltage and tolerance band;

b) rated output current for specified load power factor;

c) nominal frequency and frequency tolerance;

d) rated short-circuit current capability;

e) transfer time;

f) overload capability.

UPS switching devices are usually operated automatically by UPS monitoring and control and thus performance is governed by operating conditions of the complete UPS.

A5. **Test of UPS switching devices**

See Sub-clause 7.2.3.

Publications de la CEI préparées par le Comité d'Etude n° 22

84 (1957) Recommandations pour les convertisseurs à vapeur de mercure.

84A (1966) Premier complément: Onduleurs à vapeur de mercure.

84B (1967) Deuxième complément: Convertisseurs à vapeur de mercure à puissance réversible.

119 (1960) Recommandations pour les cellules, éléments redresseurs et groupes redresseurs à semiconducteurs polycristallins.

146: — Convertisseurs à semiconducteurs.

146 (1973) Convertisseurs à semiconducteurs.
Modification n° 1 (1975).

146A (1974) Premier complément: Chapitre VII: Marques et indications sur les groupes convertisseurs et sur les blocs.

146-2 (1974) Deuxième partie: Convertisseurs autocommutés à semiconducteurs.

146-3 (1977) Troisième partie: Convertisseurs à courant continu directs à semiconducteurs (hacheurs).

146-4 (1986) Quatrième partie: Méthode de spécification des performances et procédures d'essais des alimentations sans interruption.

237 (1967) Ignitrons utilisés pour la commande des machines à souder.

411: — Convertisseurs de puissance pour la traction.

411 (1973) Convertisseurs statiques monophasés de puissance pour la traction.

411-1 (1975) Première partie: Convertisseurs monophasés de puissance à thyristors.

411-2 (1978) Deuxième partie: Informations techniques supplémentaires.

411-3 (1982) Troisième partie: Convertisseurs autocommutés pour la traction monophasée.

478: — Alimentations stabilisées à sortie en courant continu.

478-1 (1974) Première partie: Termes et définitions.

478-2 (1986) Deuxième partie: Caractéristiques et performances.

478-3 (1976) Troisième partie: Essais concernant les perturbations radioélectriques.

478-4 (1976) Quatrième partie: Essais autres que ceux concernant les perturbations radioélectriques.

633 (1978) Terminologie pour le transport d'énergie en courant continu à haute tension.

686 (1980) Alimentations stabilisées à sortie en courant alternatif.

700 (1981) Essais des valves à semiconducteurs pour le transport d'énergie en courant continu à haute tension.

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84A (1966) First supplement: Mercury-arc inverters.

84B (1967) Second supplement: Mercury-arc convertors for reversible power.

119 (1960) Recommendations for polycrystalline semiconductor rectifier stacks and equipment.

146: — Semiconductor convertors.

146 (1973) Semiconductor convertors.
Amendment No. 1 (1975).

146A (1974) First supplement: Chapter VII: Markings on convertor equipments and assemblies.

146-2 (1974) Part 2: Semiconductor self-commutated convertors.

146-3 (1977) Part 3: Semiconductor direct d.c. convertors (d.c. chopper convertors).

146-4 (1986) Part 4: Method of specifying the performance and test requirements of uninterruptible power systems.

237 (1967) Ignitrons to be used in welding machine control.

411: — Power convertors for electric traction.

411 (1973) Single-phase traction power convertors.

411-1 (1975) Part 1: Single-phase power convertors using thyristors.

411-2 (1978) Part 2: Additional technical information.

411-3 (1982) Part 3: Self-commutated convertors for single-phase traction.

478: — Stabilized power supplies, d.c. output.

478-1 (1974) Part 1: Terms and definitions.

478-2 (1986) Part 2: Rating and performance.

478-3 (1976) Part 3: Radio-frequency interference tests.

478-4 (1976) Part 4: Tests other than radio-frequency interference.

633 (1978) Terminology for high-voltage direct current transmission.

686 (1980) Stabilized power supplies, a.c. output.

700 (1981) Testing of semiconductor valves for high-voltage d.c. power transmission.