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2004-03

Reciprocating internal combustion engine driven alternating current generating sets –

Part 11: Rotary uninterruptible power systems – Performance requirements and test methods

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

RECIPROCATING INTERNAL COMBUSTION ENGINE DRIVEN ALTERNATING CURRENT GENERATING SETS –

Part 11: Rotary uninterruptible power systems – Performance requirements and test methods

FOREWORD

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International Standard IEC 88528-11 has been prepared jointly by IEC technical committee 2: Rotating machinery, and ISO technical committee 70: Internal combustion engines.

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

FDIS	Report on voting
2/1275/FDIS	2/1280/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

IEC 88528-11 is integrated into the ISO 8528 series listed below, under the general title *Reciprocating internal combustion engine driven alternating current generating sets:*

Part 1: Application, ratings and performance

Part 2: Engines

Part 3: Alternating current generators for generating sets

Part 4: Controlgear and switchgear

Part 5: Generating sets

Part 6: Test methods

Part 7: Technical declarations for specification and design

Part 8: Requirements and tests for low-power generating sets (available in English only)

Part 9: Measurement and evaluation of mechanical vibrations (available in English only)

Part 10: Measurement of airborne noise by the enveloping surface method

Part 12: Emergency power supply to safety services

RECIPROCATING INTERNAL COMBUSTION ENGINE DRIVEN ALTERNATING CURRENT GENERATING SETS –

Part 11: Rotary uninterruptible power systems – Performance requirements and test methods

1 Scope

This International Standard, which forms part of the ISO 8528 series, specifies criteria, including performance and test methods, for rotary uninterruptible power systems (UPS) arising out of a combination of mechanical and electrical rotating machines. This standard applies to power supplies primarily designed for supplying uninterrupted a.c. power to the consumer. When operated without input mains feed, the power is provided by stored energy and/or reciprocating internal combustion (RIC) engine and the output power is provided by one or more rotating electrical machines.

This part 11 applies to a.c. power supplies primarily designed for supplying uninterruptible electrical power for stationary land and marine use, excluding supplies for aircraft, land vehicles or locomotives. It also excludes power supplies where the output power is generated by static converters. (See IEC 62040-3.)

The use of a rotary UPS installation to improve the quality of a.c. power supply, to provide voltage and/or frequency conversion, and to provide peak shaving is also described.

For some specific applications (for example, essential hospital supplies, offshore, non-stationary applications, high rise buildings, nuclear, etc.) supplementary requirements may be necessary. The provisions of this part of ISO 8528 should be used as a basis.

2 Normative references

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

IEC 60034-1:2003, *Rotating Electrical Machines – Part 1: Rating and performance*

IEC 60034-22:1996, *Rotating Electrical Machines – Part 22: AC generators for reciprocating internal combustion (RIC) engine driven generating sets*

IEC 60417 (all parts), *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets*

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

IEC 61000, *Electromagnetic compatibility (EMC)*

ISO 3046-1:2003, *Reciprocating internal combustion engines*

ISO 7000, *Graphical symbols for use on equipment*

ISO 8178-1, *Reciprocating internal combustion engines – Exhaust emission measurement – Part 1: Test-bed measurement of gaseous and particulate exhaust emissions*

ISO 8528-1, *Reciprocating internal combustion engine driven alternating current generating sets – Part 1: Application, ratings and performance*

ISO 8528-6, *Reciprocating internal combustion engine driven alternating current generating sets – Part 6: Test methods*

ISO 8528-9, *Reciprocating internal combustion engine driven alternating current generating sets – Part 9: Measurement and evaluation of mechanical vibrations*

ISO 8528-10, *Reciprocating internal combustion engine driven alternating current generating sets – Part 10: Measurement of airborne noise by the enveloping surface method*

3 Terms and definitions

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

3.1 General

3.1.1
generating set
one or more RIC engines to produce mechanical energy and one or more generators to convert the mechanical energy into electrical energy together with components for transmitting the mechanical energy (for example, couplings, gearbox) and where applicable bearing and mounting components

3.1.2
uninterruptible power system (UPS)
power system for maintaining continuity of load power in the event of failure of the mains power

3.1.3
rotary UPS
UPS where one or more electrical rotating machines provide the output voltage

3.1.4
converter
set of equipment, static or rotating, to convert one type of electric current to another type, different in nature, voltage and/or frequency

3.1.5
power system reactor
regulated or non-regulated inductance in series with the input of some types of UPS

3.1.6
machine set
any combination of one or more electrical rotating machines

3.1.7
energy storage device
device to provide stored energy on failure of the normal power supply system. This energy shall be available either during the total failure time or until the take over of a power supply by the RIC engine

3.1.8
continuity of load power
availability of the power supplied to the load with voltage and frequency within steady-state and transient tolerance bands and with distortion and power interruptions within the limits specified for the load

3.2 Performance of systems and components

3.2.1
mains power
power normally continuously available which is supplied from the electrical power system or by independent electrical power generation

3.2.2
backfeed
condition where a portion of the voltage or energy available within the UPS is fed back to any of the input terminals, either directly or by a leakage path

3.2.3
linear load
load where the parameter Z (load impedance) is a constant when a variable sinusoidal voltage is applied to it and that a sinusoidal voltage causes a sinusoidal current

3.2.4
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

3.2.5
power failure
any variation in the input voltage or frequency of the mains power not within acceptable limits

3.2.6
redundant operation
any operation with the addition of parallel functional units or groups of functional units in a system to enhance the availability of load power

3.2.7
power conditioning mode
stable mode of operation that the UPS finally attains when operating under the following conditions:

– normal power is present and within its given tolerance;
– full (100 %) stored energy available within its given restored energy time;
– the operation is or may be continuous;
– the load is within its given range;
– the output voltage is within its given tolerance.

Where a bypass is used:

– the input voltage is available and within specified tolerances;
– the phase lock is active, if present.

3.2.8
independent mode
operation of the UPS when operating under the following conditions:

– normal power is disconnected or is out of given tolerance;
– energy is from storage device or RIC engine;
– load is within the given range;
– output voltage and frequency are within given tolerances.

3.2.9
bypass mode
state the UPS attains when operating and the load is supplied via the bypass

3.2.10
off mode
state that the rotary UPS attains when de-energized and at rest

3.2.11
synchronization
adjustment of an a.c. power source to match another a.c. source in frequency and phase angle

3.2.12
load power
power which is supplied to the load from the UPS

3.2.13
asynchronous transfer
switching of load power between two sources that are not synchronized. This transfer must happen with an interruption

3.3 Specified values

3.3.1
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[IEV 151-16-08]

3.3.2
tolerance band
range of values of a quantity within specified limits

3.3.3
deviation
difference between the desired value and the actual value of a variable at a given instant

NOTE This definition applies whether the desired value is constant or varies in time.

[IEV 351-12-15]

3.3.4
rated voltage
input or output supply voltage for which equipment is designed or specified

3.3.5
rated frequency
input or output frequency as declared by the manufacturer

3.3.6
phase angle
angle (usually expressed in electrical degrees) between reference points on one or more a.c. waveforms

3.3.7
crest factor
ratio of the peak value of a periodic waveform to its r.m.s. value

3.3.8
power
time rate of transferring or transforming energy or of doing work. (also called active power)

[IEV 111-13-30]

3.3.9
apparent power
product of the r.m.s. voltage U between the terminals of a two-terminal element or two-terminal circuit and the r.m.s. electric current I in the element or circuit:

$$S=UI$$

[IEV 131-11-41]

3.3.10
ambient temperature
temperature of the air or other medium where the equipment is to be used

[IEV 826-01-04]

3.3.11
total harmonic distortion
ratio of the r.m.s. value of the harmonic content as a percentage of the r.m.s. value of the fundamental component of the periodic function

3.3.12
recovery time
time interval between the moment a stabilized voltage or frequency leaves the steady-state tolerance band until the instant when this quantity returns to and stays within the steady-state tolerance band

3.3.13
stored energy time
minimum time during which the UPS will ensure conditions when the normal power fails starting with the energy storage means being charged

3.4 Input values

NOTE These definitions are only valid in the power conditioning mode (normal mode).

3.4.1
input voltage tolerance
maximum continuous input voltage variation in normal operation

3.4.2
input power factor
ratio of the input active power to the input apparent power with the UPS operating at rated input voltages at rated output power, and fully charged storage

3.4.3
high impedance mains failure
mains failure where the mains impedance as presented to the UPS input terminals is infinite

3.4.4
low impedance mains failure
mains failure where the mains impedance as presented to the UPS input terminals is negligible

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

3.5.3
rated load
load for which the system is defined

4 Symbols and abbreviations

$\cos \phi$	Fundamental portion of power factor
f	Rotary UPS output frequency in Hz
P	Active power
S	Apparent power
U_r	Rated output voltage of a rotary UPS
U_c	Rectified voltage
U_{ac}	Rotary UPS output voltage (r.m.s. line-line)
Z	Load impedance

5 Selection criteria

Complete application criteria should include the following features and shall be made available by the system supplier:

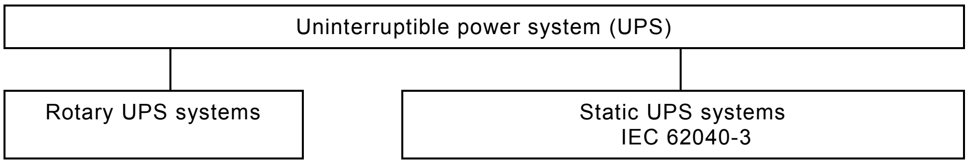
– rotary UPS load requirements;
– operating time required;
– starting capability of large electric motors in the load;
– fault clearing capability;
– input power quality;
– ambient temperature;
– reliability;
– maintainability;
– required floor space;
– parallel operation requirement;
– operating efficiency;
– reduction and/or isolation of voltage harmonics and other deviations from input to output;
– reduction and/or isolation of current harmonics and other deviations from output to input;
– environmental requirements (noise, vibration, dust, electromagnetic compatibility, etc.);
– degree of separation from the mains in power conditioning mode (harmonics, full galvanic isolation, etc.).

An input switching device shall be provided to isolate the rotary UPS from the incoming mains.

Means shall be provided to prevent reverse power flow, if required.

6 General description

Types of uninterruptible power systems are shown in Figure 1.



IEC 033/04

Figure 1 – Types of UPS systems

6.1 Rotary UPS

Rotary uninterruptible power supply as defined in this standard is achieved by a combination of electrical and when required RIC engines and generating sets.

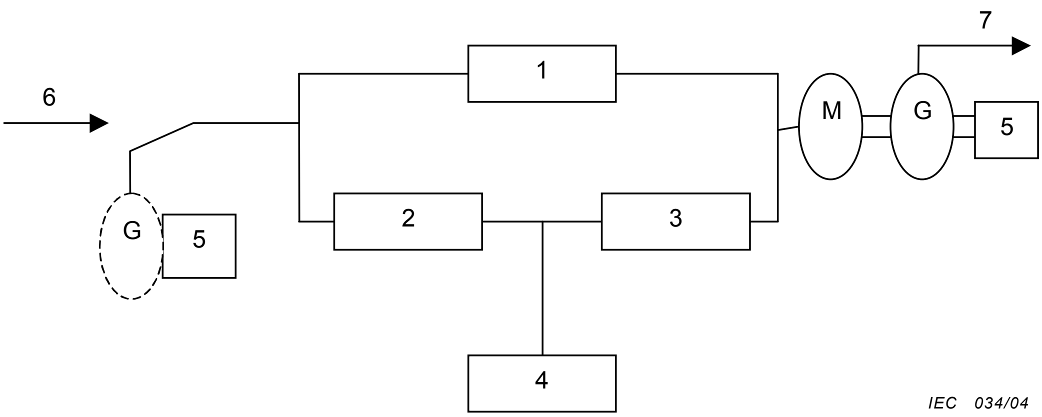
In order to achieve an uninterrupted supply of power during a short interruption period, a pneumatic, kinetic, electrochemical, or other such energy storage device is used. For extended periods of operation an RIC engine or generating set may be utilized to provide the energy supply. (See ISO 8528-1, subclause 6.5.)

6.2 Types of rotary UPS

Various configurations of rotary UPS systems are possible depending upon the application and performance requirements. It is important that the configuration shall be taken into account by the customer when agreeing upon the requirements with the manufacturer.

6.2.1 Series connected rotary UPS

Figure 2 illustrates a series connected rotary UPS.



IEC 034/04

Key

1	primary path	3	inverter	5	RIC engine	7	AC output	G	generator
2	rectifier	4	energy storage	6	AC input			M	motor

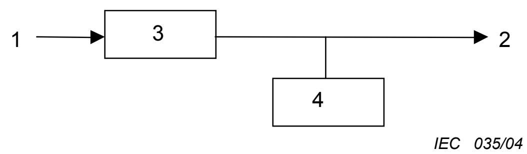
Figure 2 – Typical example series connected rotary UPS

In most series connected cases, two independent electrical machines (motor and generator) or a combination of both is used as the final output of the rotary UPS. In most cases the final output machine pair or combination machine is direct connected to the mains source with an alternate path to the mains through power converters allowing connection to a stored energy source. Direct connection provides higher efficiency and reduced input harmonics. Some series connected cases rely on the alternate path.

– Rotary UPS power supply to the electrical consumer is taken from the rotary UPS system, independent of whether the external power supply system is intact or has failed. In the event of a mains failure or if the power is outside the permissible tolerance limits of the input of the rotary UPS system, energy is provided from a short term stored energy source until a RIC engine can be started, if the installation is so equipped. When the installation is equipped with an engine, the required energy for continuity of the power supply to the electrical consumer is taken for a practically unlimited time from the engine (sufficient fuel supply assumed) (see also Clause 5). After restoration of the mains, supply power for the rotary UPS system is again taken from the mains system.
– The engine may be equipped with its own generator and transfer switch configured to supply power to the input of the series connected rotary UPS. The engine can also be directly connected by a clutch to the MG set of the series connected rotary UPS.
– Back feed to the mains during a short circuit of the mains or during rotary UPS transition modes must be prevented to maintain rotary UPS output power and prevent internal damage of the rotary UPS. In the series connected case with a single power path (i.e. rectifier to inverter to MG set) back feed prevention is provided by phase control of the rectifier. In series connected rotary UPS cases with a dual power path (i.e. static switch to MG set and rectifier to inverter to MG set) back feed is prevented by phase control of the sub-cycle static switch and the rectifier.
– In the series connected rotary UPS isolation protection of the consumer's load is provided by the electrical to mechanical and back to electrical power conversions of the final output MG set. The level of isolation protection depends on the MG set, insulation, air gaps, etc. The generator provides reactive power compensation and supplies the harmonics and unbalance as required by the load.
– In the event of mains failure or when exceeding the permissible tolerance limits of the electrical consumer, the power supply, practically without any interruption, will change over to short term stored energy and then to an engine when so equipped.
– Upon restoration of the stabilized mains, supply is effected synchronously and without interruption.

6.2.2 Line interactive rotary UPS

Figure 3 illustrates a line interactive rotary UPS.



Key

1 AC input   3 power system reactor

2 AC output   4 machine set

Figure 3 – Typical example of a line interactive rotary UPS

A machine set including a generator, energy storage means and an RIC engine if so equipped, is operated in parallel with the mains system.

The energy storage and RIC engine may all be coupled on the same shaft, or realized as separate units with an indirect coupling (electrical, hydraulic, mechanical, etc.).

– Power is taken from the mains system, provided the voltage and frequency lie within the tolerance range specified for the mains system or electrical consumers.
– The rotary UPS system is also supplied with energy from the mains system. A certain degree of isolation between the mains system and the electrical consumer is achieved by means of an impedance (reactor). This is installed in the incoming feeder so that voltage deviations can be compensated to suit system requirements by the synchronous machine (s) that are connected in parallel.
– The power system reactor limits back feed in case of low impedance mains failure and allows independent control of output voltage. The generator provides reactive power compensation and supplies the harmonics and unbalance as required by the load.
– In the event of mains system failure or when exceeding the permissible tolerance limits of the electrical consumer, the power supply will change over to the synchronous converter machine or to the synchronous generator of the twin machine set.

The energy required for driving the rotary UPS is taken for either a limited time from the energy storage device or a practically unlimited time from an RIC engine (sufficient fuel supply assumed) (see also Clause 5).

Continuation of energy supply from the restored and stabilized mains is effected synchronously and without interruption.

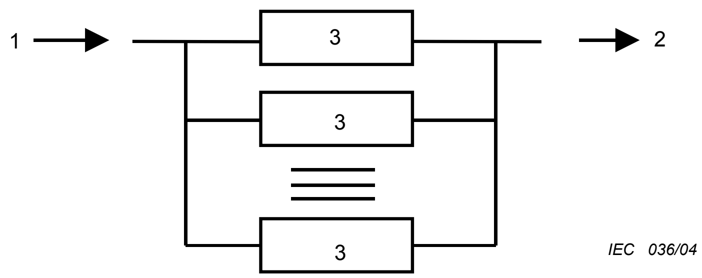
6.3 Parallel operation of a rotary UPS installation

6.3.1 General

Rotary UPS systems may be operated in parallel to increase power output, to increase availability, or to provide redundancy.

6.3.2 Parallel operation

Parallel operation of a rotary UPS system is illustrated in Figure 4. An arrangement of rotary UPS systems of identical rating is usual.



Key

1 AC input 2 AC output 3 UPS

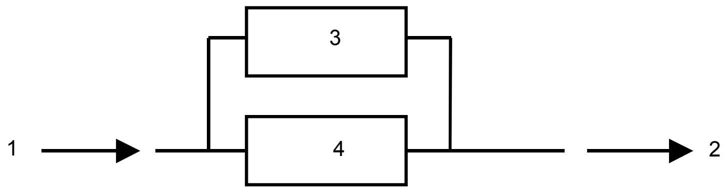
Figure 4 – Parallel operation of a rotary UPS

6.3.3 Redundant operation

Increasing the number of active rotary UPS units by at least one active unit to ensure full supply of electrical consumers in cases of maintenance or failure of a single rotary UPS unit (1 + n active redundancy).

6.4 Power system changeover with rotary UPS installations (bypass)

Bypass can be provided, to electrically isolate the rotary UPS, in case the nominal input and output frequencies are the same and where the average mains power availability is acceptable for the load. Bypass can be manual, automatic, or a combination of both. Bypass circuits may be individual or common in the case of parallel rotary UPS systems. See Figure 5.



Key

1 AC input 2 AC output 3 rotary UPS 4 bypass

Figure 5 – Bypass operation

Automatic transfer of electrical consumers supply to the mains system may be provided if a fault occurs in the rotary UPS system (passive redundancy).

Transfer is effected either with or without interruption depending on the rotary UPS system design. Mainly, however, transfer is effected without interruption.

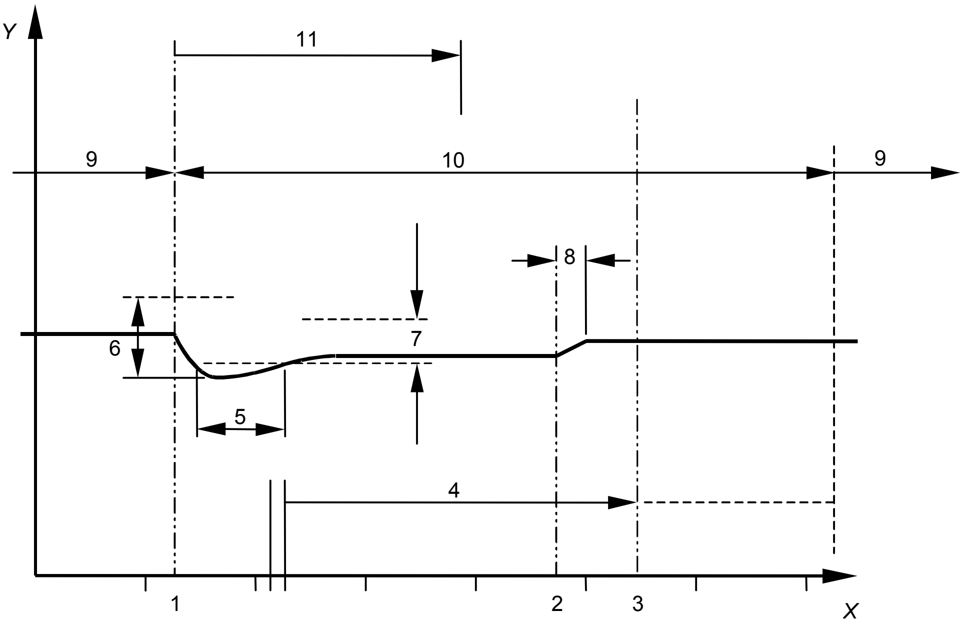
A transfer can be without interruption if a rotary UPS system and utility were synchronized, or with a short interruption if they are not synchronized. This transfer may be (temporarily) inhibited when the utility is not available or out of tolerance.

6.5 Enclosure protection

The equipment shall be provided with a surrounding case or enclosure constructed to provide a minimum degree of protection IP2X, (IEC 60529) to personnel against accidental contact with energized, hot or moving parts.

7 Modes of operation

Typical operation of a rotary UPS is shown in Figure 6.



IEC 038/04

Key

1 time of power failure
2 time of power return
3 time of synchronization
4 RIC engine if used
5 recovery time
6 dynamic limit values (Table 3)
7 steady-state limit values (Table 2)
8 synchronization
9 power conditioning mode
10 independent mode
11 stored energy time
X axis time *t* in seconds
Y axis output voltage frequency

Figure 6 – Illustration of rotary UPS operation

7.1 Power conditioning mode

A stable mode of operation that a rotary UPS finally attains when operating under the following conditions:

– normal power is present and within specified tolerances;
– energy storage means are being charged or fully charged;
– the operation is or may be continuous;
– the load is within its given range;
– the output voltage is within its given tolerance;
– RIC engine if provided ready to start.

7.2 Independent mode

The operation of the rotary UPS when operating under the following conditions:

– normal power is disconnected or is out of given tolerances;
– the energy is from storage device or RIC engine, if provided;
– load is within the given range;
– output voltage is within given tolerances.

7.3 Bypass mode

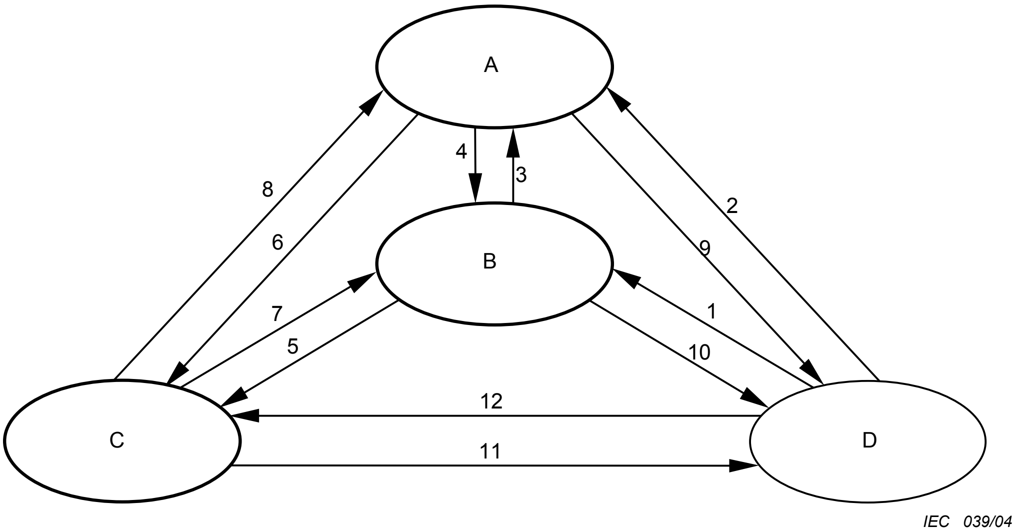
The state that the rotary UPS attains when operating the load supplied via the bypass supply.

7.4 Off mode

The state that the rotary UPS attains when de-energized and at rest.

7.5 Transitions

The 4 main operating modes and the 12 possible transitions are shown in Figure 7.



Key

A independent mode
B power conditioning mode
C bypass mode
D off mode

Figure 7 – Operating modes

7.5.1 Transition 1, starting the system with mains voltage present

Start-up may require the RIC engine or a pony motor to bring the rotating parts to speed before energy can be taken from the grid. With mains voltage and frequency within tolerance, the system enters the power conditioning mode.

The units of a multi-module system can be started sequentially, even when the total load is more that the first unit can supply when the excess load is supplied via the bypass from the mains.

NOTE Start-up (transitions 1, 2, or 12) is at least inhibited when an emergency OFF button is active.

7.5.2 Transition 2, start-up without mains voltage (black start)

This start-up method is only useful for systems with a permanent energy source, i.e. an RIC engine. Otherwise, the independent mode could only be maintained for a limited time. Black start is the ability to start using only internal energy sources like charged batteries and fuel. Internal energy sources that cannot be maintained during at least one day in “Off” mode are assumed as discharged at the beginning of the black start. The units of a multi-module system can be started (and mutually paralleled) sequentially, but loading shall be done in steps or after a sufficient number of modules is running.

7.5.3 Transition 3, disconnect from grid

At a mains failure, the system continues supply to the critical loads in independent mode. Detection of a mains failure might be different for a low impedance mains failure (based on under voltage for instance) or for a high impedance mains failure, where voltage and frequency on the rotary UPS input terminals initially might seem OK on some systems. High impedance mains failure detection can be based on frequency change, impedance measurement or phase change. The rotary UPS might open a switch to disconnect the system from the (failed) mains.

7.5.4 Transition 4, connect to grid

After a mains return, the system is synchronized to the utility voltage and connected to it.

7.5.5 Transition 6, transfer

Load is transferred from the rotary UPS to bypass in case of overload or internal failure.

7.5.6 Transition 7, 8, retransfer

Retransfer from bypass to (normal) power conditioning mode may be automatic, for instance after maintenance or initial start. Retransfer of load from bypass to generator is generally without interruption. Retransfer requires manual intervention when the transfer to bypass was due to internal errors.

The remaining transitions are numbered in the diagram but no further explanation is given. Their implementation depends on the type of rotary UPS, and not all may be possible.

8 Service conditions

8.1 Normal service conditions

Equipment that complies with this standard shall be capable of operating up to and from 0 to 1 000 metres altitude; from 0 °C to +35 °C; and in ambient relative humidity from 20 % to 80 % (non-condensing).

8.2 Operation at extended ambient

8.2.1 Ambient service temperature

A rotary UPS according to this standard shall operate under rated conditions in a minimum temperature range from 0 °C to +35 °C. Above this range, a de-rating in rated power of 1 % per °C up to 55 °C is used.

8.2.2 Ambient storage and transportation conditions

Rotary UPS equipment according to this standard can be stored non-operating under the conditions defined in 8.2.2.1 and 8.2.2.2, if no other conditions are given by the manufacturers instructions.

NOTE Storage duration may be limited due to recharging requirements of an included lead acid battery. The manufacturer should state these requirements on request.

8.2.2.1 Transportation/storage temperature

Rotary UPS equipment according to this standard shall be transportable in its normal shipping container,for example by aircraft or by truck, in an ambient temperature range from –25 °C to +55 °C. For stationary storage within a building, the ambient temperature range shall be from –25 °C to +55 °C. The battery manufacturer’s transportation and storage instructions shall be observed.

NOTE When a battery is included which contains an electrolyte, the duration of high or low ambient temperature may be limited due to a reduction of the battery life endurance.

8.2.2.2 Relative humidity

During transports and storage of a rotary UPS in its normal shipping container, the relative humidity can range between 20 % up to 95 %, non-condensing. The shipping container must be designed adequately, unless dry ambient conditions are guaranteed. Containers not designed for wet ambient conditions shall be marked by adequate warning labels.

8.2.2.3 Special transport conditions

These conditions are to be rated by manufacturer. Conditions may include liquids draining procedures, rotor locking, risk of freezing, shock, maintenance of (e.g. vertical) position, battery handling, etc.

8.3 Engines

Engines shall be rated according to ISO 3046 and ISO 8528-1 standard power. Engines employed for rotary UPS systems are designed to extend the bridging time in conjunction with stored energy devices as described in Annex A.

The practically unlimited bridging time is dependent on

– fuel supply;
– lubrication oil supply;
– maintenance interval.

8.4 Rotating electrical machines

Rotating electrical machines shall comply with IEC 60034-1 and IEC 60034-22.

8.5 Control logic

The rotary UPS system shall include necessary control devices to operate in all functional modes and transitions between these modes, within the specified tolerances of Tables 2 and 3.

9 Electrical service conditions and performance

9.1 General – all rotary UPS

Rotary based UPS offer the potential to provide additional fault clearing current capacity. To capitalize on this feature, the user should consider the sub-transient reactance of the output of the rotary UPS and the ability of the particular design to sustain this fault clearing capability for coordination with the particular load circuit protective devices used.

The output voltage waveform shall comply with the minimum requirements given in Clause 4 of IEC 61000-2-2 or Table 1 of IEC 61000-2-12 for linear load and up to a specified amount of non-linear load as defined in Annexes B and C. See Table 1.

Table 1 – Compatibility levels for individual harmonic voltages in mains power

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3		Even harmonics	
Harmonic order *n*	Harmonic voltage %	Harmonic order *n*	Harmonic voltage %	Harmonic order *n*	Harmonic voltage %
5	6	3	5	2	2
7	5	9	1,5	4	1
11	3,5	15	0,3	6	0,5
13	3	21	0,2	8	0,5
17	2	>21	0,2	10	0,5
19	1,5			12	0,2
23	1,5			>12	0,2
25	1,5				
>25	0,2 + 0,5 x 25/n				

Rotary UPS complying with this standard shall be marked and supplied with instructions for the installation and operation of the rotary UPS controls and indications.

9.2 Performance

The electrical performance of a rotary UPS shall comply with Table 2 and Table 3.

Rotary UPS systems depend upon the application. This subclause defines four performance classes and operating limit values for them, see ISO 8528-1.

Class G1 – basic lighting and controls;

Class G2 – similar to utility with small excursions, pumps, fans, hoists;

Class G3 – computers, telecommunication, and other sensitive loads;

Class G4 – special application.

The following limit values apply for any combination of

- temperature within normal operating limits;
- mains within steady-state operating limits;
- no load to rated load at rated power factor;
- single or multi-module systems.

Table 2 – Operating steady-state limit values for performance classes

Class		Frequency [a)]	Voltage [b)]
G1	Basic lighting and controls	±4 %	±8 %
G2	Similar utility lighting, pumps, fans, hoists	±2 %	±4 %
G3	Computers, telecommunication	±1 %	±2 %
G4	Special applications	AMC	AMC
AMC: Agreement between manufacturer and customer.			

a) Not including current compensation.

b) Ten seconds running average of the 3 line r.m.s. values.

Table 3 – Operating dynamic limit values for performance classes (note 1)

Class		Sudden phase shift	Frequency (note 3)	Voltage (note 2)	Recovery time
G1	Basic lighting and controls	No limit	±5 Hz	±30 %	5 s
G2	Similar utility lighting, pumps, fans, hoists	No limit	±3 Hz	±22 %	1 s
G3	Computers, telecommunication	2 %	±1 Hz	±15 %	0,7 s
G4	Special applications		AMC	AMC	AMC

NOTE 1 Transient values after

- change of load from 5 % to 100 % and vice versa in power conditioning mode;
- change of load from 5 % to 100 % and vice versa in independent mode;
- at mains failure and return;
- at transfer to, and retransfer from bypass, provided the bypass supply is at its nominal values;
- and during the addition/removal of one unit in case of redundant multi-rotary UPS system.

NOTE 2 Transient voltage lower limit applies from 10 ms after creation of a fused load fault when applicable.

NOTE 3 Frequency slewing rate outside the steady-state tolerance band should not be more than twice the transient frequency deviation limit per second in either direction (10 cycle average). Additionally, the duration of successive cycles should not differ by more than 2 % for class 3 in power conditioning and independent modes of operation.

AMC: Agreement between manufacturer and customer.

The output voltage distortion for all classes shall be less than the values stated in Table 3 for linear load, and up to a specified amount of reference for non-linear load.

Class G4 special application

Performance of class 4 applications is subject to agreement between manufacturer and customer. The agreement can include other tolerance limits or other conditions under which they apply.

10 Manufacturer technical declarations

10.1 General

The manufacturer shall declare the following list:

– net electrical output;
– output quality level (see G1, G2, G3, G4 of 9.2);
– net efficiency in power condition mode and stored energy mode at rated load, see 8.2.2;
– essential auxiliaries;
– battery recharge interval (if included) or restored energy time.

10.2 Purchaser specification guidelines

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

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

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

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

10.2.1 Type of rotary UPS, additional features, and system requirements

a) Single
b) Multi-module (see 10.2.7 for additional information)
c) Bypass to prime 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 rotary UPS system isolators and tie switches
i) Compatibility with intended power system (i.e. earthed neutral, floating neutral)
j) Remote emergency power off (EPO) or emergency stop requirements

10.2.2 Rotary UPS input

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

a) nominal input voltage and voltage tolerance band desired;
b) number of phases and requirements for neutral lines;
c) nominal input frequency and tolerance band desired;
d) special conditions regarding, for example, super imposed harmonics, transient voltages, supply impedance, etc.;
e) limitations regarding, for example, inrush currents, harmonic currents, etc.;
f) stand-by power system rating;
g) supply protection requirements (short-circuit overload, earth faults).

10.2.3 Load to be supplied from a rotary UPS

a) Type – examples:
   – 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 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 the rotary UPS output

Information Notes – Rotary UPS output loading

The diversity of types of load equipment and their relevant characteristics are always changing with technology. For this reason, the rotary UPS output is characterized by loading with passive reference loads to simulate, as far as is 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 rotary UPS industry has generally specified rotary 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 C).

The effect on the output of the rotary UPS by non-linear loads in both steady-state and rotary 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

a) the higher peak to r.m.s. steady-state current values, 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 manufacturer/supplier and purchaser.

b) 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 rotary UPS employs electronic current limiting in normal mode of operation. This effect also applies to switching of transformers and other magnetic devices due to magnetic remanence.

These effects of high transient inrush currents on the load voltage may be tolerable where the load is sequence switched and are the first applied or may have no deteriorative effect on the loads already running.

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

Load voltage and frequency sensitivity, 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 rotary UPS topology for these applications should be investigated.

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

10.2.4 Rotary UPS output

a) Rated output power and power factor

b) Number of phases

c) Rated 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 adjustment range

g) Phase angle tolerance allowed (for three-phase or for single-phase centre tapped and single-phase rotary UPS supplied from two of a three-phase system)

h) Unbalanced load capability required (for three-phase or for single-phase centre tapped and single-phase rotary UPS supplied from two of a three-phase system)

i) Coordination between rotary UPS and load protective devices

j) Supply protection requirements (short circuit, overload, earth faults)

10.2.5 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

10.2.6 General application requirements and special service conditions

a) Efficiency at rated load conditions:

   the efficiency is the ratio of the net useful output power of the rotary UPS system to the total input power. To allow comparison, it is measured and specified in a steady-state under average climatic conditions. Efficiency is an economic or thermal parameter, and only of interest in those operating modes that can exist for more than 15 min with fully charged energy storage devices. The power consumption of all auxiliary systems needed to perform the normal task of the rotary UPS system is part of the losses. Eventual heating or air conditioning systems needed for wider climatic conditions are excluded. If energy is recovered, i.e. from exhaust gas or cooling water, it is a part of the net output power of the system

b) Ambient temperature range of operation

c) Cooling system (rotary 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 or storage conditions, limitations to space or weight

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

i) Future extensions of the rotary UPS system

j) Crest factor

   NOTE When applied to the load current of a UPS, one could say that the crest factor is solely a property to the load. In practice, this load crest factor is a result of both the load and the internal impedance of the source that supplies it. For instance, the same non-linear load can have a crest factor as high as 4 when supplied by a pure sinusoidal voltage from a stiff grid via the bypass, or only 2 when supplied by a rotary UPS. The (non-linear) load current shows short peaks centred at or around the peaks of the a.c. voltage at which time the d.c. side capacitors are charged. When supplied by a UPS, the output impedance of the UPS prevents such narrow peaks, and broader and lower current peaks will result having a lower crest factor.

10.2.7 Multi-module system configurations

a) Redundant rotary UPS

b) Non-redundant rotary UPS

c) Common system battery

d) Separate module batteries

e) Type of rotary UPS switches

f) Configuration of rotary UPS switches

10.2.8 Electromagnetic compatibility

a) Required emission standard and level category to which equipment shall comply

b) Applicable immunity standards and test level of which the equipment shall comply

Table 4 – Technical data sheets – Manufacturers declaration

Characteristic of equipment	Manufacturers declared values
Electrical output characteristics – steady-state characteristics – power conditioning mode and stored energy mode	
Rated output voltage Voltage adjustment class Output frequency (nominal) Rated output apparent power Rated output active power across linear load Rated output active power sinusoidal	.... V r.m.s. .... V ....Hz .... kVA ....kW ....kW
Short circuit capability % of full load running	See separate declaration
Overload capability	See separate declaration
Rated load power factor permitted – linear load Number of output phases Number of output leads	.... PF ....
Maximum phase angle variation (multi-phase only) Continuous unbalanced load capability	.... Degrees ....%
Output volts – DC component, linear load	 V
Electrical output characteristics – dynamic characteristics – power conditioning mode and stored energy mode (required class G4 only)	
Output voltage dynamic variation during transfer power conditioning/stored energy mode of operation and vice versa	See separate declaration
Output voltage dynamic variation due to load changes Slew rate Inrush current	See separate declaration .... Hz/s .... A
Electrical output characteristics – dynamic characteristics – stored energy mode	
Efficiency input/output	....%
Synchronization (if applicable)	
Mains matching synchronizer	Yes.. No
Stored energy mode of operation	
Duration of maximum permitted stored energy time at rated load	.... seconds/minutes/hours
Stored energy time (for integral batteries)	.... minutes at rated load
Restored energy time to 90 % charge (for integral battery) Battery rating and quantity (for integral battery) Battery recharge profile Battery cut-off voltage	.... hours ....x ....cells See separate declaration V

Table 4 *(continued)*

Characteristic of equipment	Manufacturers declared values			
Control and monitoring signals				
See separate declaration for complete list of indications and remote alarm/monitoring or interface devices				
Bypass characteristics				
Type of bypass	Manual	☐	Automatic	☐
Mechanical/static	Mechanical	☐	Static	☐
No break transfer/break transfer	No Break	☐	Break	☐
Break time/make time	..................ms		....................ms	
Maintenance bypass	Yes	☐	No	☐
Bypass protection fuse/circuit breaker	....		..............Rating	
Galvanic isolation fitted	Yes	☐	No	☐
Electromagnetic compatibility				
Immunity	State relevant National/International Standard and test levels			
Emission	State relevant National/International Standard and class			
Conducted a.c. mains	See separate declaration			
Conducted a.c. output	....dB			
Radiated – Electric field				
Radiated – Magnetic field				
Input harmonic currents				
Attenuation of mains borne radio frequency – input to output				

11 Testing

The following test methods are proposed for all performance tests.

Tests to demonstrate compatibility with safety and EMC standards are subject to local regulations and are not included within this list. (See ISO 8528-6.)

Type test or routine test is under consideration.

Unless otherwise stated, rated load is linear and symmetric, at rated power factor. Testing shall be done at ambient conditions between 15 °C to 25 °C. If the rated power factor is not declared, then power factor 0,8 shall be used. Unless otherwise stated, all tests apply for single units.

11.1 Static output voltage and frequency deviations

All 3 output line r.m.s. voltages and the output frequency shall be measured in the following situations, and compared to the steady-state values of the table:

a) resulting from steady-state voltage or frequency deviations from the mains;

b) resulting from variations of load:

   – symmetric linear load 0 %, 25 %, 50 %, 75 % and 100% rated load at rated power factor;

     NOTE If not stated, then power factor 0,8 should be assumed.

– unbalanced load;

  disconnect one of the three line connections from a rated, symmetric, resistive load, and measure the resulting output voltage unbalance.

  NOTE The remaining load is connected line-line for a rotary UPS system without neutral, or two times line-neutral for a system with a neutral connection. Note that the line currents in both cases are less than their rated values, and have different power factors.

– non-linear load;

– overload.

c) efficiency;

d) output waveform distortion;

e) steady-state non-linear load.

   Measure the steady-state harmonic components of the rotary UPS output voltage at 50 % and 100 % linear load, both line-line and line-neutral (low voltage if applicable).

11.2 Dynamic output voltage and frequency deviations

Output voltage and frequency shall be observed during the following tests. For three-phase systems without neutral, the line voltages shall be recorded for three-wire + neutral systems at recording divided by $\sqrt{2}$, or the real r.m.s. value per half cycle shall be used as the r.m.s. value. The frequency measurement shall use a frequency-to-voltage converter capable of measuring the frequency of each individual cycle, or at least the running average frequency over the last 5 cycles.

11.3 Input current characteristics

In power conditioning mode, at nominal mains voltage, at rated load, and with fully charged energy storage device.

– Input current harmonics

If the system has more that one power path, the input current harmonics shall be measured in all power path modes that can occur for more than 5 s.

– Input power factor

– Back feed

The voltage on the input terminals of the rotary UPS shall be recorded after a high impedance mains failure.

– Inrush current

11.4 Measurement of filter properties

11.4.1 From mains to output

The rotary UPS is in power conditioning mode without load or with light resistive load.

11.4.1.1 Voltage harmonics

Step 1: measure the input and output voltage harmonics. Measure at least the fifth and seventh harmonic in the line-line voltages, and if the rotary UPS has a neutral, also the third harmonic in the line-neutral voltages;

Step 2: connect enough rectifier load, as in Annex C, in parallel with the input terminals of the rotary UPS to at least double the level of input voltage harmonics to the rotary UPS. Then measure the same harmonics as in step 1;

Step 3: calculate the increase in magnitude per harmonic on the input side;

Step 4: calculate the increase in magnitude per harmonic on the output side. The filtering is the result of step 4 as a percentage of the result of step 3.

Example: step 1 shows a 5^{th} harmonic voltage component of 5 V r.m.s. in the input, and 2 V on the output. In step 2, the input 5^{th} harmonic was 10 V, and the output is now 2,2 V r.m.s. The attenuation is ((2,2 – 2,0)/(10 – 5)) × 100 % = 4 %.

11.4.1.2 Surges and transients

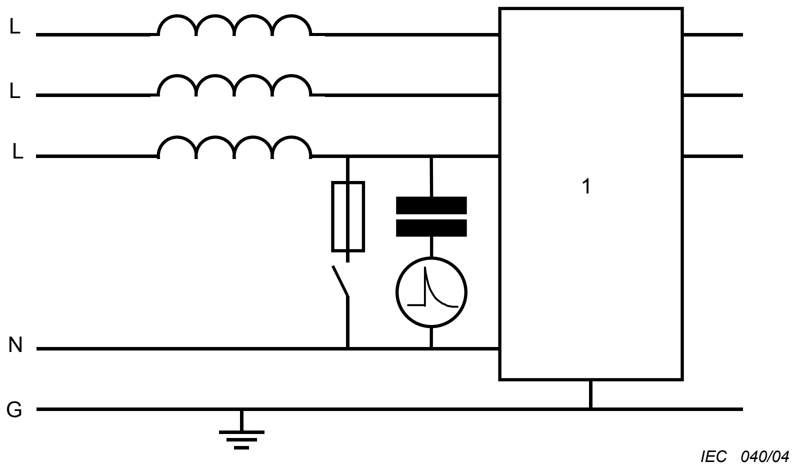
In order to isolate the applied surges to the input of the rotary UPS from the mains, a series impedance is required. The voltage drop over a suitable sized series inductor is approximately 5 % at the rated rotary UPS input current. For large systems, this impedance might be present in the feeder system.

Surges can be applied:

– between lines;
– from one line to neutral;
– or between ground and all input lines, including the neutral.

The test surge can be made in the following ways:

– first, the test surge can be made by creating a short circuit on the input side of the rotary UPS. The trapped energy in the upstream inductor produces a voltage surge when the fuse is blown. The typical surge has a rise time of approximately 0,3 ms and a peak value of 500 V;
– the test surge can also be made with a capacitive coupled standard surge generator. A typical pulse has a rise time of 1,2 µs to a peak value of 2,5 kV, and a decay of 50 µs. The coupling capacitor shall be large enough to conduct the pulse, yet small enough to limit line frequency infeed to the pulse generator.



Key

L line G ground

N neutral 1 UPS under test

Figure 8 – Surge test

The waveform on the input and on the corresponding output lines shall be recorded, and the maximum deviation from the (normal) sine wave is noted. The attenuation of the rotary UPS is the ratio of these maximum deviations on the input to output side of the rotary UPS.

11.4.2 From output to mains

The rotary UPS system in power conditioning mode reduces or eliminates the back feed of harmonic current components into the mains that originate from non-linear loads on the output of the rotary UPS. The rotary UPS is in power conditioning mode with non-linear load. The active power P taken by this load shall be at least 30 % of the rotary UPS rated active power. The measurement procedure for the input current harmonics is line current harmonics.

11.4.2.1 Line current harmonics

Step 1: measure the input current harmonics and output current harmonics with the non-linear load. (see above);

Step 2: measure the input current harmonics with a linear load of equal active power P;

Step 3: calculate the difference in input current harmonics between steps 1 and 2. The attenuation is this difference divided by the output current harmonics of step 1.

11.4.2.2 Neutral line current harmonics

Same for neutral line. Use 3 single-phase non-linear loads from Annex C.

11.5 System performance

11.5.1 Efficiency

Measure at load steps 0 %, 25 %, 50 %, 75 % and 100 % with stored energy fully charged, 25 % and 75 % are type tests. Efficiency shall be stated:

– Power conditioning mode efficiency

Measure with a linear symmetric load and at nominal mains voltage.

– Stored energy mode efficiency (fuel consumption)

11.5.2 Stored energy times

– Stored energy discharge time
– Stored energy recharge time

11.5.3 Multi-module rotary UPS performance

Such performance is applicable for parallel operating multi-module rotary UPS systems. The test is performed with at least two units in parallel operation with a linear symmetric load of at least 1,5 times the rated load of a single unit. All tests shall be done in power conditioning and in independent mode:

– Variation of voltage and frequency with load

Measure by switching on/off the load.

– Active load sharing

Record the lowest and highest active load per unit.

– Reactive load sharing

Record the lowest and highest reactive load per unit.

– Single unit failure test (if the system has a parallel redundancy)

Load short-circuit test. This is basically the same test as for a single unit. However, recovery is more critical as generators may lose mutual synchronism during the load fault.

11.6 Black start test

The ability of the rotary UPS system to start with no other power sources then the fuel and the starter battery (and an electronics battery if applicable). Black start is tested without load.

11.7 Environmental tests

– RIC engine start test at low temperature (see ISO 8528-1, subclause 14.1)
– RIC engine rated power test at the upper limit of ambient temperature that the RIC engine will operate
– RIC engine exhaust emission measurement according to ISO 8178-1
– Measurement and evaluation of mechanical vibrations of the RIC engine and any rotating electrical machine according to ISO 8528-9.

11.8 Audible noise

Measurement of airborne noise according to ISO 8528-10 at 0 % and 100 % load

– In power conditioning mode
– In independent mode

11.9 Testing

See Table 5 for a summary of testing.

Table 5 – Test methods for rotary UPS performance characteristics

Measured rotary UPS characteristic	Routine	Type test	Request only	Clause
Static output voltage and frequency deviations				
Resulting from steady-state V or f deviations of the mains			×	11.1
Resulting from variations of the load		×		11.1
Symmetric, linear load	×			11.1
Unbalanced load		×		11.1
Non-linear load		×		11.1
Overload	×			11.1
Efficiency	×			11.1
Output waveform distortion	×			11.1
Steady-state non-linear load		×		11.1
Dynamic output voltage and frequency deviations				
Resulting from variations of the load	×			11.2
Resulting from changes in operational mode		×		11.2
Change from power conditioning to stored energy mode	×			11.2
With a high impedance mains failure	×			11.2
With a low impedance mains failure		×		11.2
Change from stored energy to power conditioning mode	×			11.2
Change from power conditioning to bypass mode	×			11.2
Change from bypass to power conditioning or stored energy mode	×			11.2
Resulting from load side faults		×		11.2
Single phase fault		×		11.2
Three-phase fault		×		11.2
Input current characteristics				
Input current harmonics		×		11.3
Input power factor		×		11.3
Back feed		×		11.3
Inrush current (magnet and stators)			×	11.3
Measurement of filtering properties				
From mains to output			×	11.4.1
Voltage harmonics			×	11.4.1.1
Surges and transients			×	11.4.1.2
From output to mains			×	11.4.2
Line current harmonics		×		11.4.2.1
Neutral line current harmonics		×		11.4.2.2
System performance				
Efficiency at rated load	×			11.5.1
Power conditioning mode efficiency	×			11.5.1
Stored energy mode efficiency (fuel consumption)			×	11.5.1

Measured rotary UPS characteristic	Routine	Type test	Request only	Clause
Stored energy times				
Stored energy charge time	×			11.5.2
Stored energy recharge time	×			11.5.2
Stored energy discharge time	×			11.5.2
Multi UPS performance				
Active load sharing	×			11.5.3
Reactive load sharing	×			11.5.3
Single unit failure test	×			11.5.3
Redundancy test	×			11.5.3
Black start test (If applicable)	×			11.6
Environmental tests				
RIC engine start test at low temperature			×	11.7
RIC engine rated power test at the upper limit of ambient air temperature			×	11.7
Measurement of mechanical vibrations		×		11.7
Measurement of RIC engine exhaust emissions			×	11.7
Audible noise				
Measurement of airborne noise in power conditioning mode		×		11.8
Measurement of airborne noise in stored energy mode		×		11.8

12 Maintenance and product marking

12.1 Nameplate markings

The manufacturer shall provide nameplate markings to include the following minimum information in accordance with IEC 60034-1:

a) supplier's name;

b) model and/or part number designation or both;

c) serial number and or control number;

d) rated input voltage (input voltage tolerance);

e) rated input current;

f) rated input frequency;

g) rated output voltage;

h) rated output frequency;

i) rated output current;

j) rated output power and output kVA;

k) rated d.c. input voltage (required for rotary UPS with external battery);

l) rated d.c. input current (required for rotary UPS with external battery);

m) rated d.c. input voltage (optional for rotary UPS with internal battery);

n) rated d.c. input current (optional for rotary UPS with internal battery);

o) weight (optional);

p) performance class.

12.2 Label requirements

Warnings and instructions shall NOT be mixed. The warning label shall:

a) state the hazard;

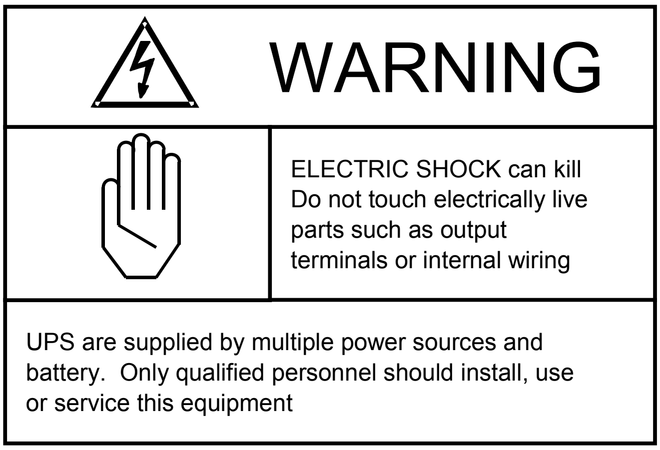
b) be conspicuous, clear, and concise;

c) describe the severity of the potential harm;

d) instruct the user how to avoid the hazard;

e) be permanently affixed to the product.

As a minimum, the electric shock can kill information shown in Figure 9, or its equivalent shall be placed on the rotary UPS.



IEC 041/04

Figure 9 – Warning label

12.3 Name plate marker

Equipment shall be provided with markings in order to specify:

a) input supply requirements;

b) output supply ratings.

For equipment 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 equipment, the marking shall be discernible after the equipment has been installed as in normal use.

Markings that are not visible from the outside of the equipment 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 should be attached to the equipment to clearly indicate the location of the marking where the equipment is operator installable. It is permitted to use a temporary marker.

The markings of input and output shall include the following:

c) rated voltage(s) or rated voltage range(s), in 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 "/".

NOTE Some examples of rated voltage markings are: rated voltage range: 220 V-240 V. This means that the equipment is designed to connect to any supply having a nominal voltage between 220 V and 240 V.

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

d) rated frequency or rated frequency range, in Hz.

e) rated current, in A.

For equipment 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.

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

– number of phases (1ϕ – 3ϕ) with or without neutral;
– output rated active power, in W or kW;
– output rated apparent power, in VA or kVA;
– maximum ambient operating temperature range (optional);
– stored energy time, in minutes or hours at an ambient temperature of 25 °C and rated active power (only for built-in batteries) (optional);
– manufacturer's name, trade mark or identification mark;
– reference to this standard;
– manufacturer's model or type reference.

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

12.4 Decals – labelling

The following instruction shall appear near to the point of connection:

‘SEE INSTALLATION INSTRUCTIONS BEFORE CONNECTING TO THE SUPPLY.’

12.4.1 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 rotary UPS, the manufacturer shall make available the necessary instructions.

The operating instructions shall be made available to the user.

NOTE 1 Such special precautions may be necessary, for example, d.c. connection of the equipment 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.

12.5 Maintenance

Means shall be provided to isolate the rotary UPS from input, output, and bypass. Means shall also be provided to electrically isolate batteries, if provided. Means shall be provided to verify that the machine is at rest for service purposes.

Annex A
(informative)

Typical energy storage devices

A.1 Energy storage devices

The machine set is the central component of dynamic UPS installations. Depending on its rotating parts, it stores energy, which can be delivered in the form of power within milliseconds. The duration of power output can be extended by a limited amount by adding energy storage devices like a flywheel or batteries. Power output capability can be extended for almost unlimited time by combination with an RIC engine.

Items to be taken into account when designing the energy storage devices for UPS installations are:

– power increase/power change (where applicable: in steps);

– allowed frequency deviation;

– allowed recovery time;

– installed inertia of electrical machines, clutches, and RIC engine if applicable;

– required back-up time.

A.2 Kinetic energy storage devices

Kinetic energy is stored in a flywheel. High-speed flywheels (10 000 to 50 000) rpm provide low torque during a relatively long time, whereas low speed flywheels (1 000 to 5 000) rpm can provide high torque during a short time, in the order of a few seconds and therefore are better matched to the use in rotary UPS systems.

Kinetic energy storage devices can be used in dual conversion UPS (where the energy flow in normal mode is converted twice into and from an intermediate form of energy), and in line interactive UPS, where the main energy flow is normally not converted. Where applicable, both solutions are shown in the following figures.

All systems can be combined with an RIC engine, either directly coupled to the generator, or as a separate diesel-generator set replacing the mains on the a.c. input side. Flywheel systems may include a pony motor to bring the speed of the shaft(s) near synchronous speed, or to charge the flywheel, or both.

Diesel engine, pony motor(s) and bypass circuits are not shown in the figures below.

A.2.1 Hard coupled flywheel storage

Rotary UPS systems with hard coupled flywheel are the simplest ones. The output frequency is proportional with the flywheel speed in stored energy mode when a normal generator is used. The allowed frequency deviation limits the speed variation of the flywheel so that only a small fraction of its stored energy can be used. During a power failure, the a.c. input must be disconnected from the grid to prevent back feed.

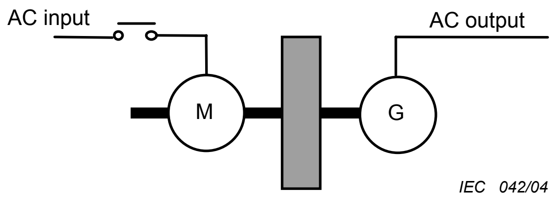


Figure A.1 – Dual conversion – direct-coupled flywheel

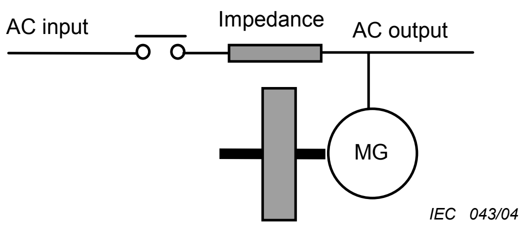


Figure A.2 – Line interactive – direct-coupled flywheel

A.2.2 Indirect coupled flywheel storage

When the flywheel is coupled to the motor/generator by a controlled ratio transmission, then much more of the flywheel energy can be used, even with negligible frequency variation on the output of the UPS.

Examples for a variable ratio transmission are:

a) a coupling with electromagnetic controlled-slip between flywheel and generator shaft;
b) synchronous motors coupled by a static frequency converter;
c) hydraulic motors coupled by a high pressure hydraulic link;
d) a continuous variable transmission (CVT).

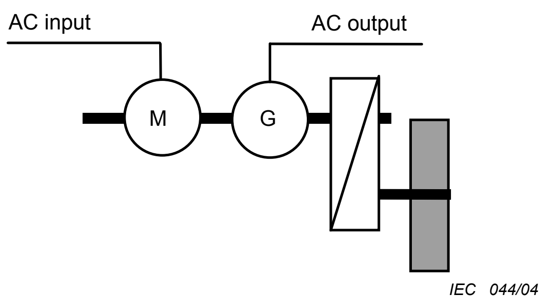


Figure A.3 – Dual conversion – indirect coupled flywheel

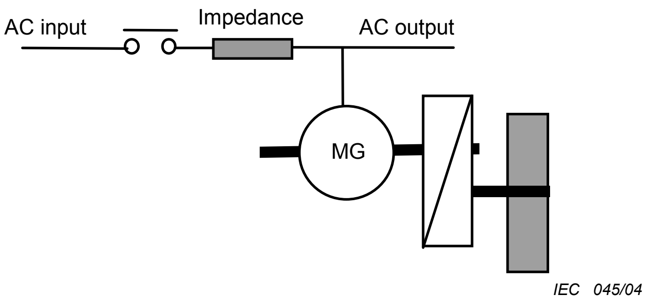


Figure A.4 – Line interactive – indirect coupled flywheel

Few variable ratio transmissions can transmit the full power in both directions. For economic reasons, the power in one direction is much lower, resulting in a time to charge the flywheel that is 10 to 1000 times longer than the typical discharge time.

A.2.3 Variable speed/ constant frequency generator

Constant output frequency with a decelerating direct-coupled flywheel is possible with a controlled-frequency supply of the rotor windings. (double fed a.c. machine). The excitation is provided by a frequency converter, feeding the rotor over slip rings. If the converter can convert energy in both directions, then the shaft speed can be from above to below the synchronous (d.c. exited) speed of the alternator.

An example is shown in Figure A.5 in the line-interactive form.

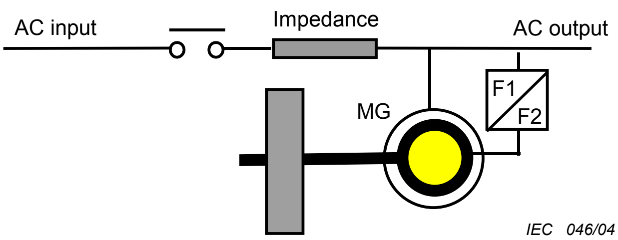


Figure A.5 – Double fed a.c. machine

A.3 Electrochemical energy storage devices

Another very common method to store energy is in batteries. Again, this can be done with dual conversion or line interactive designs, using a d.c. motor directly coupled to the battery, or with a synchronous a.c. machine, coupled to the battery over an inverter.

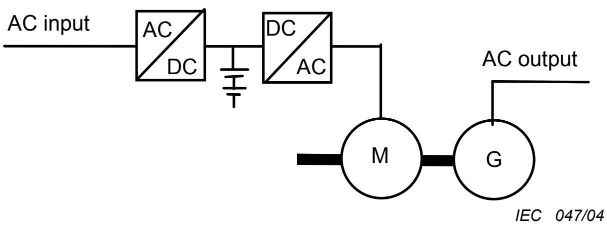


Figure A.6 – Dual conversion with battery

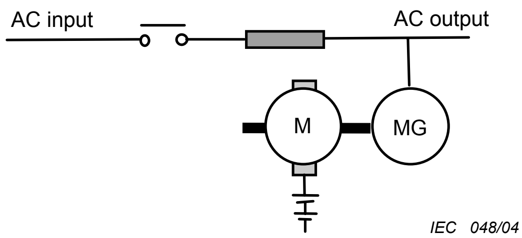


Figure A.7 – Line interactive with battery

The motor in Figure A.6 is an a.c. machine, so it can be fed directly from the a.c. input as long as the mains voltage and frequency are within suitable limits.

If this is not required, then the motor in Figure A.7 can be a d.c. type, directly fed from the battery.

The stored energy time for batteries is in the order of several minutes.

A.4 Further possibilities for energy storage

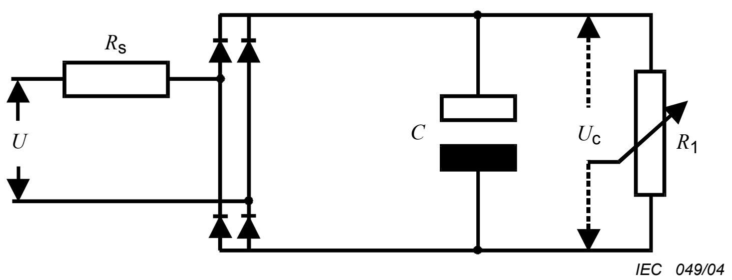
While the energy storage devices mentioned previously are widely used in practice, there are a number of other possibilities, for example, utilization of super conducting magnet energy storage (SMES), super capacitors, or compressed air.

Annex B
(normative)

Reference non-linear load – Single-phase

To simulate a single-phase steady-state rectifier/capacitor load, the UPS is loaded with a diode rectifier bridge that 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 B1, or formed by multiple equivalent loads in parallel.

Calculation and test method



U is the rated output voltage of UPS;

f is the UPS output frequency in Hz;

U_c is the rectified voltage;

S is the apparent power across a non-linear load – Power factor 0,7, that is, 70 % of the apparent power S will be dissipated as active power in the two resistors R_1 and R_s;

R_1 is the load resistor, set to dissipate 66 % of active power of the total apparent power S;

R_s is the series line resistor, set to dissipate 4 % of active power of the total apparent power S (the 4 % is according to IEC TC 64 proposal for voltage drop in power lines).

Figure B.1 – Single-phase non-linear load

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

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

Observing 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:

$$U_c = \sqrt{2} \times 0{,}92 \times 0{,}96 \times 0{,}975 \times U = 1{,}22 \times U \text{ [V]}$$

And the values of resistors R_s, R_1, and capacitor C will be calculated by the following:

$R_s = 0{,}04 \times U^2/S$

$R_1 = U_c^2/(0{,}66 \times S)$

$C = 7{,}5/(f \times R_1)$ [F]

For dual frequency 50/60 Hz, 50 Hz shall be used in the calculation.

The capacitance value used shall be not less than the calculated value.

NOTE The voltage drop in the diode bridge is neglected.

Test method

a) The non-linear test load 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) and rated output active power specified for the UPS under test.

d) After adjustment of resistor R_1, the 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, while performing all tests to obtain parameters required under non-linear loading, as defined in the various clauses.

Connection for non-linear loads to UPS

a) For single-phase UPS, the 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 non-linear load is used with 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 designed for single-phase loads connected line-neutral, three equal single-phase loads, connected line-neutral, shall be used up to 100 kVA UPS apparent and active power rating.

d) For three-phase UPS rated above 100 kVA, the loads according to Clause 3 shall be used, plus load according to Annex C.

Annex C
(normative)

Reference non-linear load – Three-phase

The reference load for all single and three-phase UPS systems up to 100 kVA is defined in Annex B.

For UPS systems rated above 100 kVA, the first 100 kVA of non linear load shall be applied as conforming Annex B, the remainder up to the full kW or kVA rating of the UPS shall be applied with the following circuit. This circuit is simple, and has typical and good defined input current harmonics (22 % fifth, 11 % seventh, 9 % eleventh, 7 % thirteenth). The power factor of the input current is 0,96, mainly due to these harmonics.

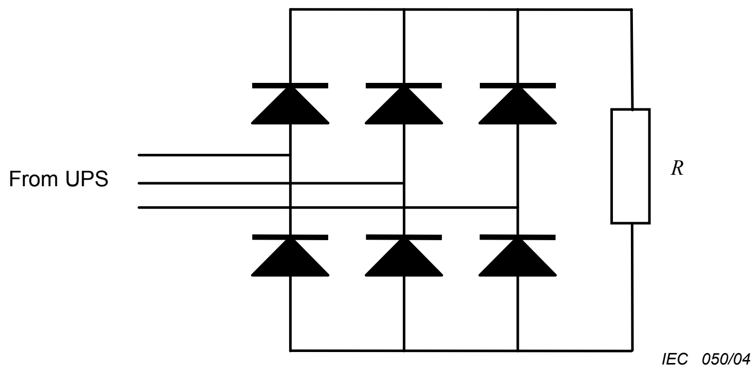


Figure C.1 – Three-phase non-linear load

where

U_{ac} is the UPS output voltage (r.m.s. line-line),

P is active power to be dissipated in the resistor R,

then $R = 1{,}872\ U_{ac}^2/P$

Example: A 480 V, 60 Hz UPS system rated 500 kVA at a power factor of 0,8 is said to accept 100 % non-linear load with sine wave output according to this standard. For the test, three line-neutral connected single-phase loads, each 33 kVA, 23 kW according to Annex B are connected, together with 400 – (3 × 23) = 331 kW of Annex C three-phase non-linear load (R = 1,303 Ω).

The resulting voltage distortion shall stay below the values of Table 3 (IEC 61000-2-2).

If the UPS is said to accept 50 % non-linear load, then both half of the single-phase and half the three-phase reference non-linear load shall be used.

Annex D
(normative)

Input mains failure – Test method

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

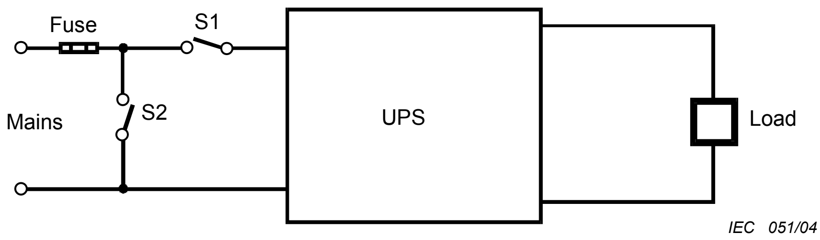


Figure D.1 – Input mains failure test method

Test D1 – High impedance mains failure

Normal mode of operation:

– S1 is closed;
– S2 is open;
– Open S1 to simulate the mains failure.

Test D2 – Low impedance mains failure

Normal mode of operation:

– S1 is closed;
– S2 is open;
– Close S2 to simulate the mains failure (fuse blown at ¼ load).

The fuse rating shall be according to 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 E
(informative)

Types of uninterruptible power systems (UPS) configurations

An uninterruptible power system (UPS), as described in this standard is an inertial power system. Its primary function is to provide specified continuity and quality of power to a user's equipment in 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 users equipment for a specified period of time when the utility is no longer available or acceptable.

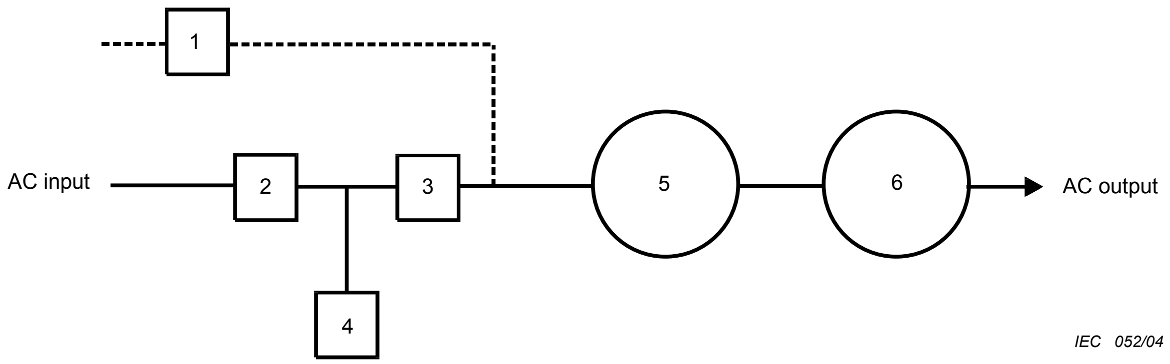
The user's equipment, typically referred to as the critical or protected load, may consist of one piece of equipment or may be a room or building full of equipment. It is the equipment that the user has determined needs to be provided with power that has a better continuity and quality than that power 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 that 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 has been developed to meet the users requirements for continuity and quality of power to 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.

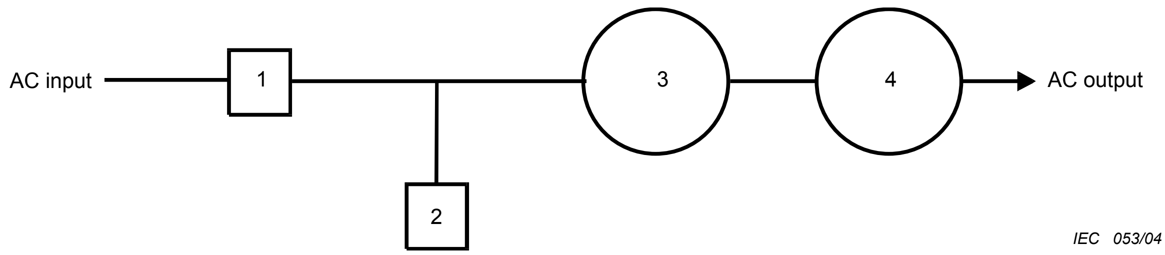
This annex explains some typical arrangements in use and the important characteristics of each of these. More examples of series connected UPS systems are shown in Figures E.1 and E.2. A line interactive example is shown in figure E.3. Other examples of UPS configurations are shown in figures E.4 and E.5.



Key

1 bypass
2 rectifier
3 inverter
4 energy store
5 AC motor
6 generator

Figure E.1 – Series connected type 1



Key

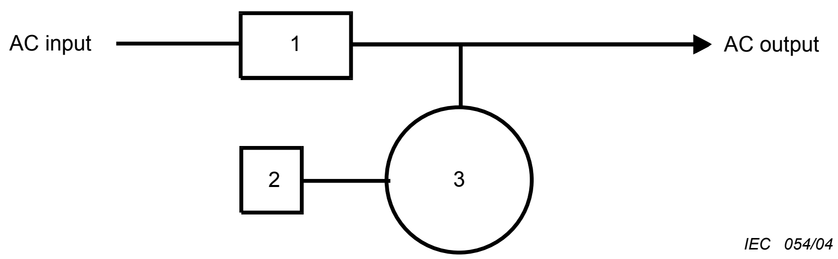
1 rectifier

2 energy store

3 DC motor

4 generator

Figure E.2 – Series connected type 2



Key

1 rectifier

2 energy store

3 generator

Figure E.3 – Line interactive

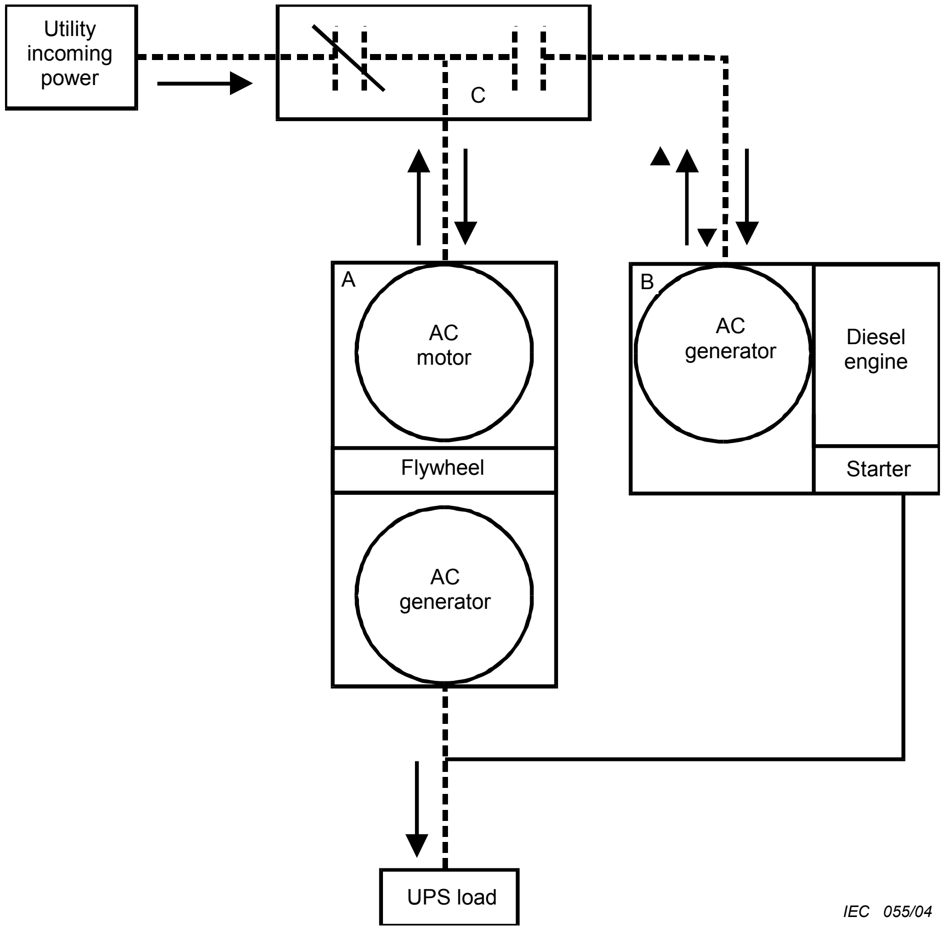


Figure E.4 – Typical UPS

In figure E.4, during normal 24 h running, the ‘A’ motor is connected to utility power, driving ‘A’ generator, which feeds power to the UPS load, and the flywheel, which stores kinetic energy.

Upon failure of utility power, ‘C’ control changes power sources (in less than 5 s) during which

– the ‘A’ motor, now driven by flywheel energy, momentarily becomes a generator and connects to ‘B’ generator, which momentarily becomes a motor, helping the engine to quickly accelerate;
– the ‘A’ generator, now also driven by flywheel energy, continues to feed the load and provides momentary power (rectified to d.c.) to crank the engine starter. Upon reaching full engine speed, the ‘B’ engine generator substitutes utility power and feeds the ‘A’ motor, which continues to drive the ‘A’ generator without affecting the UPS load;
– upon return of utility power, the ‘C’ control connects the ‘A’ motor back to utility power and stops the engine minutes later;
– initial system start-up uses ‘B’ engine generator power to accelerate the flywheel slowly. This process takes up to 20 min depending on the system’s capacity and eliminates high inrush current demand from the utility line.

The system consists of two similar a.c. squirrel cage induction motors and one a.c. synchronous generator mounted in-line shafts, normally horizontal and electrically connected as illustrated in Figure E.5.

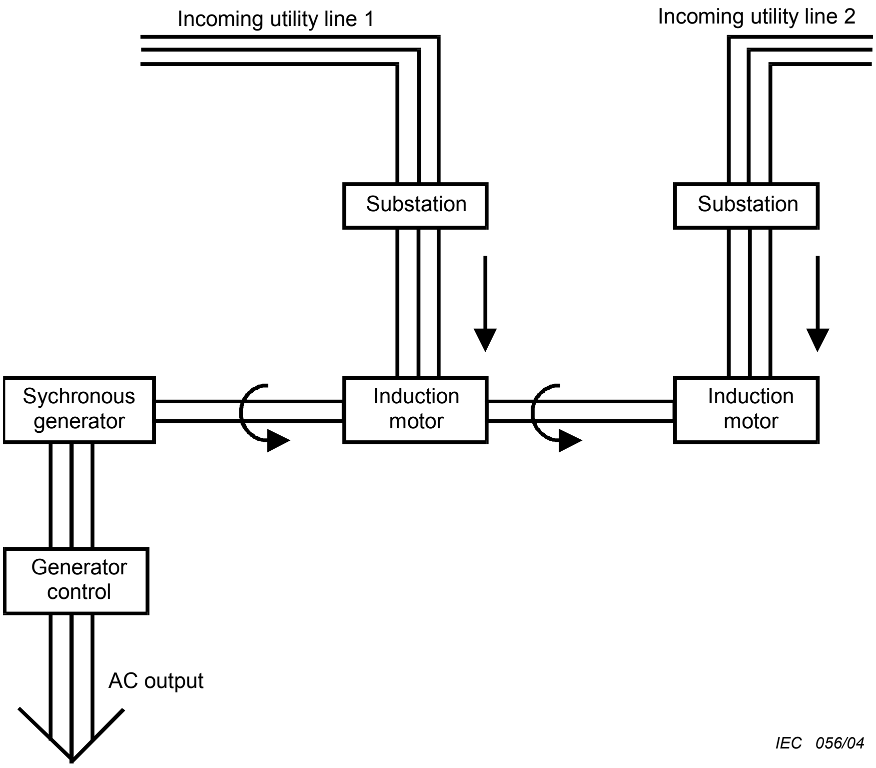


Figure E.5 – Typical switchless dual feed UPS

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