Uninterruptible Power Supplies

EUROPEAN GUIDE

CEMEP

Basic tools for a correct design of UPS according to standards

Uninterruptible Power Supplies

EUROPEAN GUIDE

BY CEMEP
European Committee of Manufacturers of Electrical Machines
and Power Electronics

CEMEP

FOREWORD

CEMEP UPS WG PRESENTATION

CEMEP is the European committee founded by the main professional associations in EUROPE involved in the Power Electronics field.

This organisation allows the Power Electronics manufacturers to coordinate their actions at a European level. The main topics are: market evolution, standardisation, promotion, connection with other products and professional groups.

Through CEMEP, the manufacturers speak with one voice and deal with the EU technical and environmental directives and other common industrial matters. The CEMEP organisation includes four working groups respectively in charge of:

- LV AC MOTORS
- HV MOTORS
- VARIABLE SPEED DRIVES
- UPS.

CEMEP UPS members are:

- FINLAND ➧ SET
- FRANCE ➧ GIMELEC
- GERMANY ➧ ZVEI
- ITALY ➧ ANIE/AssoAutomazione
- SPAIN ➧ SERCOBE
- UK ➧ GAMBICA

FOREWORD

WHY A EUROPEAN GUIDE ABOUT UPS?

High quality and availability of electrical power are now strategic requirements for all sectors of the economy. A breakdown can endanger the smooth running of a company and generate considerable financial costs. The failure of an electrical installation can be a serious human risk, for the operators as well as for the users.

As testified by the "blackouts" experienced by several countries in the recent past, and also by more minor power shortages, the frequency of supply problems continues to increase. This trend could be further accentuated with the deregulation of the electricity market and climate change in addition to the disturbances generated by the electric instal-lations themselves.

But solutions do exist to protect infrastructures, buildings and processes from any electrical supply failure. Among these solutions, UPS is one of the most commonly used today. Therefore, CEMEP decided to publish this new edition of its famous UPS Guide to provide UPS users with the most updated information about UPS functions and technological evolution. This information is based on the state of the art technology shared by all the European UPS manufacturers.

This CEMEP UPS Guide is most appropriate to those who want to:

- precisely evaluate their needs in power solutions,
- to choose the UPS that best answers these needs,
- and then to install, operate and maintain over the years their UPS in the most effective way.

We wish to thank the following experts who wrote this guide on behalf of all CEMEP UPS members: Mr BEAUDET, Mr CAPPELLARI, Mr CIPOLLA, Mr FINCK, Mr GALBIATI, Mr MASCAGNI, Mr PIAZZI, Mr RUETH, Mr SINIGALLIA and Mr SUSSET.

Antoine de FLEURIEU
CEMEP UPS - Secretary

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POWER PROBLEMS

1.1 DISTURBANCES IN DISTRIBUTION-SYSTEM POWER

Power distribution systems, both public and private, theoretically supply electrical equipment with a sinusoidal voltage of fixed amplitude and frequency (e.g. 400 volts rms, 50 Hz, on low-voltage systems).

In real-life conditions however, utilities indicate the degree of fluctuation around the rated values. Standard EN 50160 defines the normal fluctuations in the LV supply voltage on European distribution systems as follows:

- voltage +10% to -15% (average rms values over 10 minute intervals), of which 95% must be in the +10% range each week.
- frequency +4 to -6% over one year with ±1% for 99.5% of the time (synchronous connections in an interconnected system).

Practically speaking, however, in addition to the indicated fluctuations, the voltage sinewave is always distorted to some degree by various disturbances that occur on the system.

1.2 ORIGINS OF DISTURBANCES

Utility power

Utility power can be disturbed or even cut by:

- atmospheric phenomena affecting overhead lines or buried cables:
  - lightning which can produce a sudden voltage surge in the system,
  - frost which can accumulate on overhead lines and cause them to break,
- accidents:
  - a branch falling on a line, which may produce a short-circuit or break the line,
  - cutting of a cable, for example during trench digging or other construction work,
  - a fault on the utility power system,
- phase unbalance,
- switching of protection or control devices in the utility power system, for load shedding or maintenance purposes.

User equipment

Some equipment can disturb the utility power system, e.g.:

- industrial equipment:
  - motors, which can cause voltage drops due to inrush currents when starting,
  - equipment such as arc furnaces and welding machines, which can cause voltage drops and high-frequency interference,
- power electronics equipment (switch-mode power supplies, variable speed drives, electronic ballasts, etc.), which often cause harmonics,
- building facilities such as lifts which provoke inrush currents or fluorescent lighting which causes harmonics.

1 POWER PROBLEMS

1.3 REQUIREMENTS OF SENSITIVE LOADS

Digital equipment (computers, telecom systems, instruments, etc.) use microprocessors that operate at frequencies of several mega or even giga Hertz, i.e. they carry out millions or even billions of operations per second. A disturbance in the electrical supply lasting just a few milliseconds can affect thousands or millions of basic operations. The result may be malfunctions and loss of data with dangerous (e.g. airports, hospitals) or costly consequences (e.g. loss of production).

That is why many loads, called sensitive or critical loads, require a supply that is protected against distribution system disturbances. Examples:

- industrial processes and their control/monitoring systems-risk of production losses,
- airports and hospitals risks for the safety of people,
- information and communication technologies for the internet risk of halts in processing at a very high hourly cost.

Many manufacturers of sensitive equipment specify very strict tolerances (much stricter than those for the distribution system) for the supply of their equipment, one example being CBEMA (Computer Business Equipment Manufacturer's Association) for computer equipment.

1.4 COSTS INCURRED BY THE QUALITY OF ELECTRICAL POWER

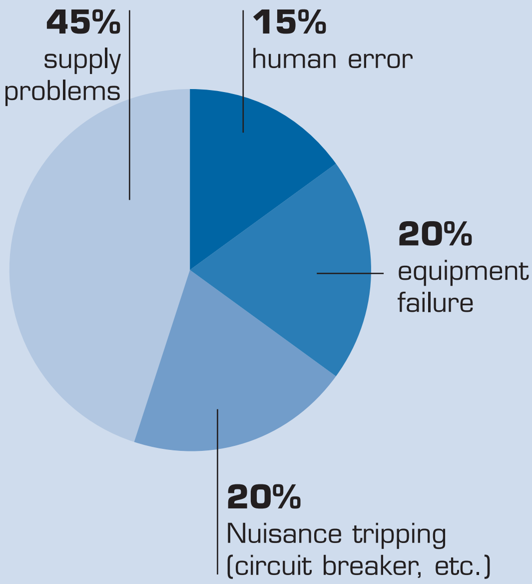
Over 50% of failures for critical loads are due to the electrical supply and the hourly cost of downtime for the corresponding applications is generally very high (fig. 1). It is therefore vital for the modern economy, which is increasingly dependent on digital technologies, to solve the problems affecting the quality and the availability of the power supplied by the distribution system when it is intended for sensitive loads.

SOLUTIONS TO POWER PROBLEMS

2.1 IN-BUILT PROTECTION

Numerous technical solutions exist and the user's choice must be made as a function of several parameters (cost, type of disturbance, characteristics of the equipment to be protected, the electrical distribution on site, criticality of the application to be protected, etc.).

(FIG. 1) **ORIGIN AND COST OF SYSTEM FAILURES DUE TO THE ELECTRICAL SUPPLY**



EXAMPLE OF HOURLY OF FAILURES
- mobile telephones - 40 kEuros
- airline reservation sustems - 90 kEuros
- credit-card transaction - 2.5 MEuros
- automotive assembly line - 6 MEuros
- stock-market transactions - 6.5 MEuros

2 SOLUTIONS TO POWER PROBLEMS

This document will cover all solutions from the simplest through to the highest performing or most versatile.

Some equipment includes in-built protection, but this is often reduced to protection against the most frequently encountered types of transients, brownouts or brief outages (using batteries or capacitors).

In addition, the solutions provided in everyday equipment are relatively ineffective and may simply boil down to protection (non destruction) of the device, a "clean" shut-down or the saving of essential data. They rarely enable the continuation of normal use of the sensitive equipment.

Indeed, to be able to continue operation in the event of a failure of the normal supply for more than 10 to 20 ms requires the instant switching in of a replacement supply using the energy stored in an inertia wheel or in a set of batteries.

It should be noted that today these two means remain the only ways of easily storing energy to replace a power source greater than several hundreds of watts. We will look at their functions and characteristics in the section dealing with uninterruptible power supply interfaces.

Software methods:
These methods are of course used in digital data processing equipment (computers, mainframes, plc's, telecommunication and process control equipment).

Their use is mainly limited to reducing or eliminating the consequences of a disturbance on the equipment or the application by using means such as:
- systematic and regular backing up of data to a permanent support that is insensitive to disturbances,
- automatic equipment shut-down and start-up procedures,
- auto supply monitoring by the machine to detect any disturbance which may be detrimental to its operation and warning the operator or restarting an interrupted sequence, or even taking a decision concerning the product currently being produced in a process (reject or restart).

Software methods are limited on machines working in real-time, networked with constant interconnection and data exchange, or for continuous processes for which the stoppage of the equipment during the process could be hazardous (e.g. in the chemical or petrochemical industries), or cause great loss of production or irreversible loss of information.

It should also be noted that these methods require additional programs and memory resources and can still lead to a lengthy stoppage of the application: outage can lead to the shut-down (although it would be "clean") of a production unit or a computer for several minutes or even more.

SOLUTIONS TO POWER PROBLEMS

Power problems
Solutions to power problems
European regulations
Technical standards
Configurations
Evaluation parameters
Communication
Options
Installations guidelines for medium and large UPS
Maintenance and services
Glossary

2.2 FILTERS, ISOLATING TRANSFORMERS, VOLTAGE REGULATORS

When in-built solutions have not been provided by the manufacturer or prove too costly to be included in each piece of equipment, the solution often involves adding an interface between the power network and the application or group of applications to be protected (centralized protection).

a) Filters

The filter is the simplest solution. It protects against magnetic or radioelectrical interference and atmospheric disturbances (it may be combined with a lightning arrester).

It has no effect on brownouts or frequency variations and does not protect against outage.

b) Isolating transformers

An isolating transformer equipped with an electrostatic screen enables the reduction of high frequency interference in common and cross-connected mode.

The attenuation level achieved will vary according to the quality of the transformer's design and manufacture. Here again, no protection is provided against other types of disturbances.

However, an isolating transformer enables earth leakage currents to be reduced in an electrical installation by localizing them to the circuits supplied power by the secondary. The use of certain coupling arrangements in three phase transformers also enables certain harmonic currents to be reduced in the primary (3^{rd} harmonic and multiples of 3).

c) Voltage regulators and network conditioners

A voltage regulator maintains the output voltage constant in spite of variations in its input voltage.

There exists mainly three types:

- ferro-resonant regulators,
- electromechanical regulators,
- static tapping switching conditioners.

The criteria to be considered when evaluating the performance of regulators are the regulating range, the load variation response and the speed and flexibility of regulation.

Whilst regulators resolve problems of voltage variations, they are often ineffective against noise transients and frequency variations.

In response to this problem, the solution involves combining an isolating transformer and a voltage regulator: this is the so called network or line voltage conditioner.

Whilst they provide a good solution to major voltage variations and noise transients, conditioners are completely ineffective against outages (>10 ms) and frequency variations which only systems with "back-up" can remedy.

2 SOLUTIONS TO POWER PROBLEMS

2.3 DIRECT CURRENT POWER SUPPLIES

This solution is especially used in security systems, but also in telecommunications equipment and the supply of relays or contactors.

This supply comprises a rectifier and an energy storage unit:
- capacitors for back-up of less than 1 second,
- sets of batteries for greater back-up times.

This system is simple and cost effective, but it requires a device with a permanent direct current supply of a voltage of between 12 and 220V. In the case of a centralized back up solution, it will also require the installation of a separate direct current distribution circuit.

2.4 ROTARY SOLUTIONS

There are different variations of rotary uninterruptible power systems, but all of them use motor-generator sets with the generator output going to the critical load.
One version combines a motor and a generator with a highly simplified static inverter. The inverter filters out mains disturbances and regulates only the frequency of its output signal (generally in "square-wave" form) which supplies a regulated motor generator set. The motor-generator set generates reliable output voltage sinewave taking the inverter output frequency as a reference.
A second version combines a synchronous machine (regulator-generator), an induction coupling and a diesel engine with a free wheeling clutch.

These dynamic solutions are used in large installations (above 1000 kVA) and mainly for applications in an industrial environment.

The arguments often put forward in favour of this "dynamic" solutions are as follows: high short-circuit current, galvanic isolation and low internal impedance providing good tolerance to non-linear loads.

(FIG. 2) **ROTARY SOLUTIONS**

Solution / Disturbances	Isolating Transformer	Regulator	Conditioner	Synchronous generator set
Transients	✘		✘	✘
Sags/Brownouts		✘	✘	✘
Frequency variation				
Outage				✘
Blackouts				✘

SOLUTIONS TO POWER PROBLEMS

But the main disadvantages of the rotary UPS's are the high noise level (70 to 95 dbA), bearing replacement with long downtime, important dimensions and weight.

2.5 STATIC UNINTERRUPTIBLE POWER SYSTEMS

More than 35 years after they first appeared, uninterruptible power systems (UPSs) now represent more than 95% of back up power interfaces sold and over 98% for sensitive IT and electronics applications.

We will briefly recap on how they work, how they are used and the technical possibilities offered to users.

a) A review of how they work

Acting as an interface between the mains and sensitive applications, UPSs supply the load with continuous, high quality electrical power regardless of the status of the mains.
UPSs deliver a dependable supply voltage free from all mains disturbances, within tolerances compatible with the requirements of sensitive electronic devices.
UPS can also provide this dependable voltage independently by means of a power source (battery) which is generally sufficient to ensure the safety of individuals and the installation.

Static power supplies are generally made up of three main sub-assemblies :

- a rectifier-charger to transform the alternating current into direct current and charge the battery;
- a set of batteries (generally lead-acid type) enabling energy to be stored and instantly recovered as required over a 5 to 30 minutes period, or even more;
- a static converter to convert this direct voltage into an alternating voltage that is perfectly regulated and filtered in terms of voltage and/or frequency.

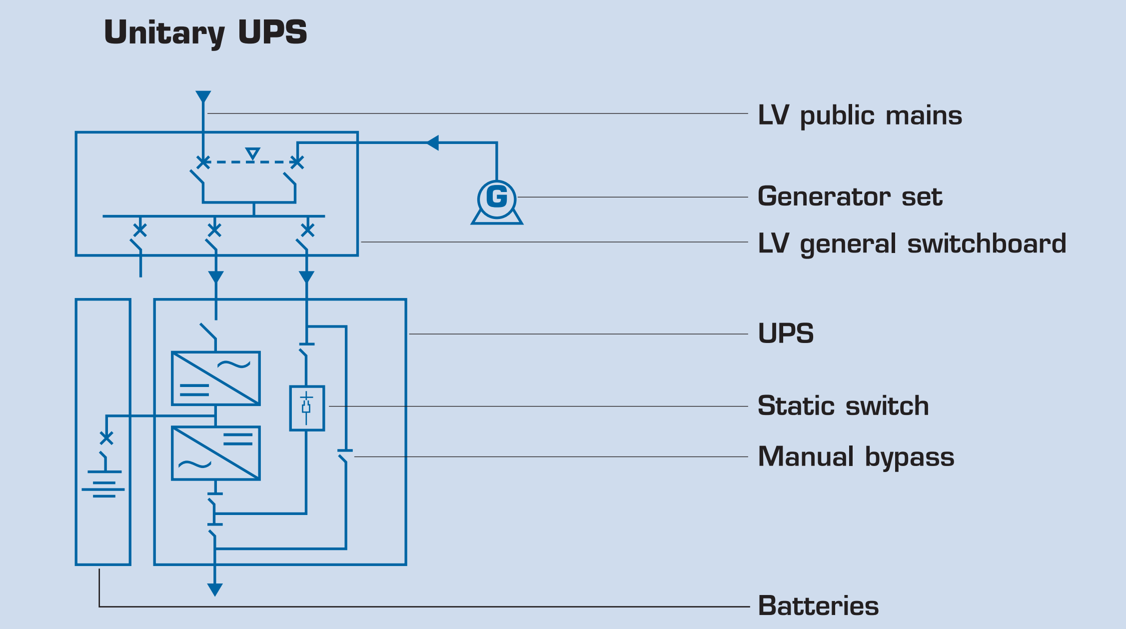
These three functions can be supplemented with additional features: a by-pass in the case of UPS overload or fault, a mechanical maintenance by-pass enabling the UPS to be completely isolated, as well as various options for signaling, maintenance, and even telemaintenance.

b) Use of UPS

Over many years, the UPS has become an integral part of high quality power distribution to the customer. Each of their components has been designed by the manufacturer to integrate perfectly with the site layout, whether a 250 VA supply for a personal computer in an office or a very complete 2000 kVA installation for a major tertiary sector data center or for the protection of a production unit.

The diagram shows an example of a low voltage electrical installation protected by a UPS. We can notice the inclusion of a generating set, a feature that is often seen as complementary to the static supply.

(FIG. 3) **EXAMPLE OF UPS INSTALLATION DIAGRAM**



Indeed, in the instance of a very long blackout, it will enable the back-up time provided by the battery to be extended, of course with the battery providing continuity of supply whilst the generator set is starting up and 10 or more minutes of back-up time should it not start up, during which time all the customer application shut-down sequences can be performed.

These technologies are complementary, as might be imagined, and indeed UPS systems manufacturers often work closely with generator set manufacturers during the design of large-scale installations to define together the machine characteristics (powers, operating sequences, etc.)

c) Parallel connection

In medium and high power installations, it is possible to combine several UPS in parallel:
- to make up a power supply greater than that available in the single chain,
- to increase the reliability of the supply by providing one or several redundant chains.

Very sophisticated layouts are possible in order to increase reliability or make the use and maintenance simplier.

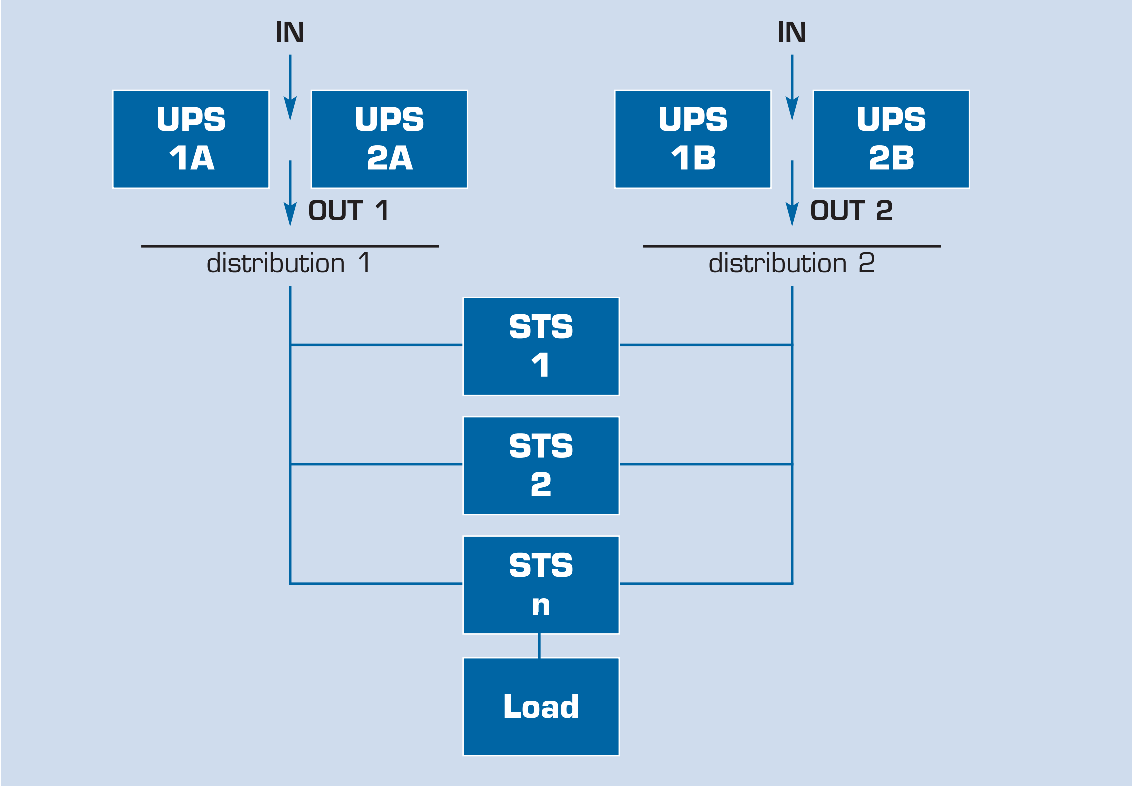
Different types of parallel connection are available.

d) Architecture with STS

Architectures with STS (Static Transfer System) provide dual power supply sources to critical equipments to enhance reliability and availability.

SOLUTIONS TO POWER PROBLEMS

(FIG. 4) **STATIC UNINTERRUPTIBLES POWER SYSTEMS (OR UPSS)**



The STS ensures automatic fast and seamless transfer between two or more independent power sources in case of preferred source failure. Often used with two separate UPS systems, STSs provide fault tolerant and redundant power supply at the point of use close to the protected loads. This concept protects mission critical applications not only from preferred source unavailability but also against most of failures such as, spurious breaker tripping, cable disruption, operating errors, etc... occurring in the distribution system between the power sources and the end user equipments.

Architectures with several STSs supplying, each, different loads, enable automatic segregation of a faulty load if supplied by the same source, protecting the healthy loads from fault propagation effects.
They provide higher availability and easy maintenance without downtime or risk for the critical load.

e) User benefits

- Improved efficiency

The user is always interested in reducing the cost of operating his equipment. He keeps a close eye on power consumption, and therefore on the losses of the UPSs which are

SOLUTIONS TO POWER PROBLEMS

usually always in operation. Moreover, the losses must be paid for twice: kWh's consumed by the UPS plus additional kWh's for air condi-tioning.

This drove manufacturers of UPSs literally into a race against losses in which a few percent are won with every new advance in technology.

- Good supply of non-linear loads

For years, since the introduction of switch mode power supplies, the majority of electric loads, in particular computers, have been non-linear or "distortion-producing".

This means that the current waveform is not a sinewave and can have a high harmonic content (order 3, 5, 7, 9, etc.).

Such a current is also characterized by a high peak factor (2 to 3.5) and a power factor of 0.65 to 0.8.

Manufacturers quickly took all this into account in the design of today's UPSs, in particular by adopting PWM (Pulse Width Modulation) based inverters.

The output impedance of different sources as a function of harmonic frequency is revealing that the PWM inverter is the best solution: the output impedance is very low up to high frequencies and the output voltage distortion due to highly non-linear currents is negligible.

It can therefore be said that the problem of non-linear loads has been solved in the new PWM based UPSs and that derating is no longer necessary.

More recently, changes in power supply technologies have made the loads to have a higher and leading power factor up to 0.9.

- *Integration with communication and technical data management systems*

UPS operating parameters, data and alarms are converted to digital data and stored or displayed on the UPS screen. They can easily be transmitted to a remote site, i.e. a simple remote indicator unit or a complex centralized Building and Energy Management system (B.E.M). The B.E.M can process both energy management data (MV distribution, LV or engine generator sets) and data concerning the protection of power distribution installations.

The UPS is a key element in high quality electric power installations. The user can receive continuous information on the number of micro-breaks, the power consumed, the number of UPSs in operation and the current drawn per phase.

Microprocessors make it possible to establish communication channels between the UPS and the supplied computer, the computer network, the BEM or a remote location (e.g.

SOLUTIONS TO POWER PROBLEMS

maintenance department) through a communication support (the internet, the telecom network). In addition to the obvious power link between the UPS and the supplied computer system, a data link is increasingly established between the two. With the information sent by the UPS (duration of interruption, load, battery backup time, normal source restoral, etc.), the computer system can initiate automatic procedures (closing files, stopping peripheral devices, restarting), and of course, without operator assistance.

UPS communication features are compatible with the most common computer operating systems.

The UPS is frequently located closer to the computer system than the electrical panel, increasingly right in the office or the computer room next to the system to be protected.

- *Improvements in reliability and maintainability*

Equipment reliability has increased considerably over recent years due to better quality and improved performance of power components (transistors, thyristors), integration (integrated circuits, microprocessors, ASICs, etc.) which reduces the amount of components and more elaborate circuit designs.

Nevertheless, breakdowns do occur.

When a UPS breaks down, an accurate fault diagnosis and quick repairs are of utmost importance. Again, microprocessor-based systems offer major advantages including accurate diagnostics and identification of the faulty subassembly. The user receives a clear description of possible remedial action directly or via any communication network.

The remote diagnosis completed, fast repair is necessary. Crucial functions can easily be removed or drawn out and a module can be replaced within minutes.

3 EUROPEAN REGULATIONS

The two Directives applying to UPS are "Low Voltage 2006/65/EC", published in the Official Journal of European Union L374 on 27/12/2006, and "Electromagnetic Compatibility 2004/108/EC" (with the relevant amendments), published in the Official Journal of European Union L374 on 27/12/2006.

The Low Voltage Directive 2006/65/EC came into force on January 16th 2007; the transposition by Member States is not required since it results from the Council Directive 73/23/EC and its subsequent modifications according to Council Directive 93/68/EC.
The Directive 73/23/EC establishes the safety requirements for offering on the market electrically supplied materials, equipments and machines. Products satisfy the disposals of the Directive if they are consistent with the harmonized standards published in the Official Journal of the European Union or with the national standards, when the harmonized ones are not available.
The Directive 93/68/EC, effective since January 1st 1995, modifies the Directive 73/23/EC in order to fall into lines with the Directives concerning other sectors and make mandatory the CE marking on the products. For the CE marking on a product the manufactures must draw up a declaration of conformity and arrange a technical documentation to verify the conformity of the product to the requirements of the Directive. The manufactures must archive this documentation in the prospective of an inspection of the Authority of control and make the necessary action so that the manufacturing process ensures the conformity.

The Electromagnetic Compatibility Directive 2004/108/EC on the approximation of the laws of the Member States relating to electromagnetic compatibility repeals Directive 89/336/EEC.

TECHNICAL STANDARDS

CENELEC and *IEC* are the recognized standardization bodies, respectively at European and international level.

European UPS product standards are available and they are also recognized at national, European and international level; such a standardization guarantees the compliance with EC Directives.

The EN 62040-X series superseded the EN50091-X series and the IEC 61000-X-Y series superseded the IEC 1000-X-Y.

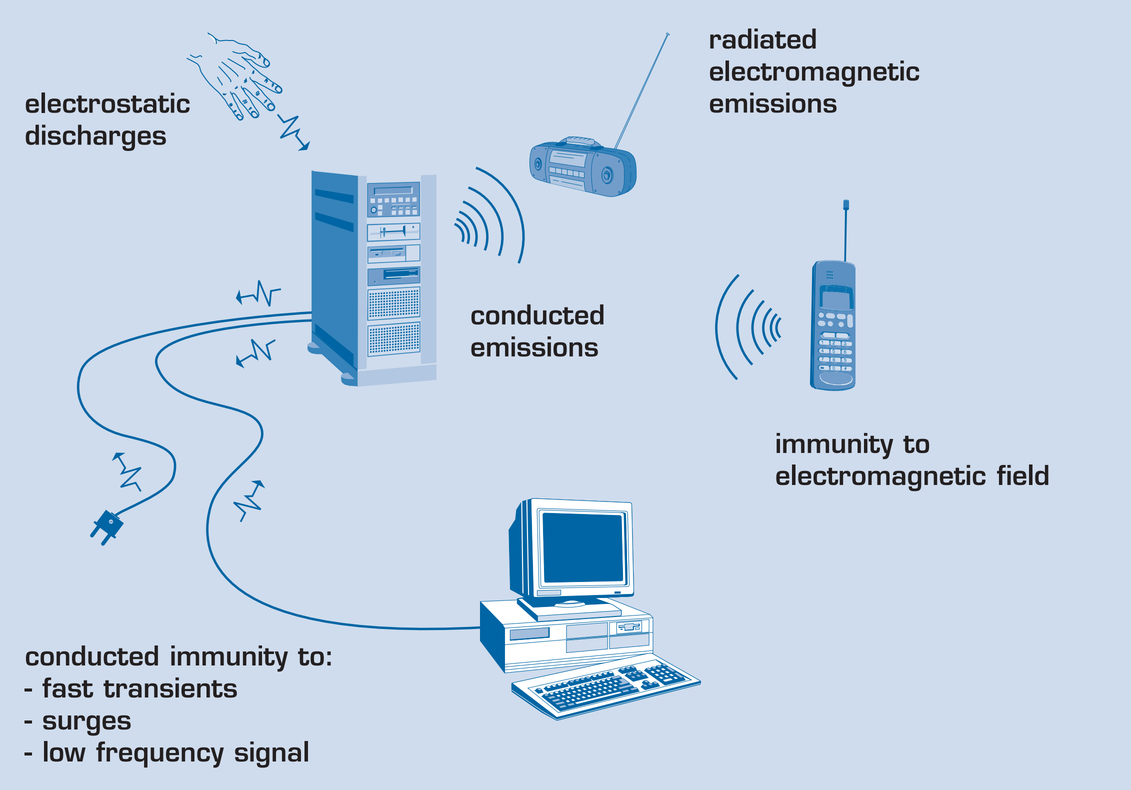
4.1 SAFETY

EN 62040-1-1 and EN 62040-1-2 are the reference standards prescribing the basic safety requirements for UPS used in operator access areas or used in restricted access locations.

4.2 ELECTROMAGNETIC COMPATIBILITY

It is the capability of the UPS to work without disturbances (immunity) and without disturbing (emission) other equipment due to electromagnetic disturbances on electric wires and radiated from the enclosure (see fig.5).
EN 62040-2 is the reference standard which defines the limits and testing procedures.

(FIG. 5) **IMMUNITY AND EMISSION**



4 TECHNICAL STANDARDS

4.3 PERFORMANCES

The reference document is the standard EN 62040-3. It is a guide for the best understanding between manufacturer and user as the performances to be declared and the relevant definitions and methods are defined.

4.4 OTHER STANDARDS

Other standards concerning UPS installation are here below listed:

- HD384/IEC 60364-X-X — for electrical installation of buildings
- EN 60439-1/IEC 60439-1 — low voltage switchgears
- EN 60529/IEC 60529 — for the degree of protection provided by enclosures
- EN 50272-2 — for Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries.

4.5 QUALITY SYSTEM CERTIFICATION

UPS manufacturers may follow a Quality System concerning their organization structure, procedures, methods and resource aimed at implementing quality management and policy.

The compliance with the reference standard of UNI EN ISO 9000 (V 2000) series is certified and continually audited by third accredited bodies and is assured by the Quality System towards customers, end users, suppliers and bodies outside the company.

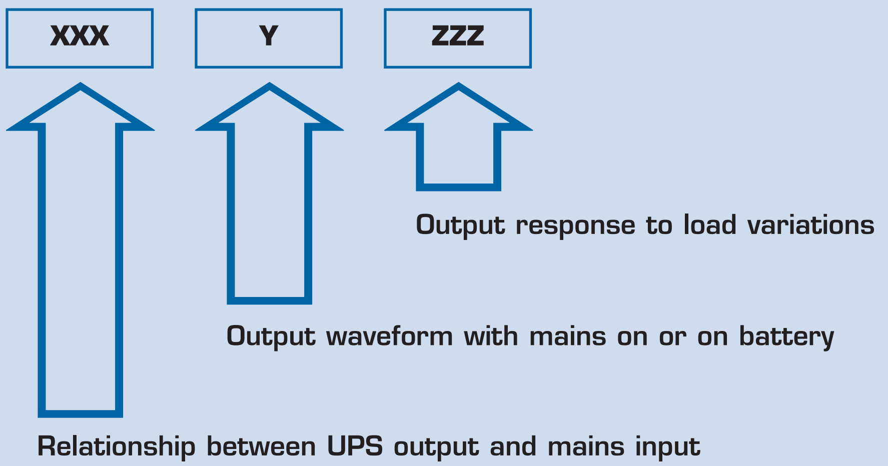
CONFIGURATIONS

A variety of UPS have 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 few watts to several megawatts.

The following classification is a part of the European standard EN 62040-3 which defines configurations of UPS by performances.

(FIG. 6) **CLASSIFICATION CODE**

The European standard EN 62040-3 defines the method of specifying the UPS performance and test requirements. This standard provides a three-part UPS classification:



The first part of the code defines the UPS topology:

VFI (output Voltage and Frequency Independant from mains supply):
where the UPS output is independent of supply (mains) voltage variations and frequency variations are controlled within IEC 61000-2-2 limits. When designed this way, this type can function as a frequency converter (see section 5.1-5.2 as example of this configuration).

VFD (output Voltage and Frequency Dependant from mains supply):
where the UPS output is dependent on supply (mains) voltage and frequency variations (see section 5.4 as example of this configuration).

VI (output Voltage Independant from mains supply):
where the UPS output is dependent on supply (mains) frequency variations but supply voltage variations are conditioned by electronic active/passive voltage regulating devices within limits of normal operation (see section 5.3 as example of this configuration).

5 CONFIGURATIONS

NOTE
IEC EN 61000-2-2 defines normal levels of harmonics and distortion that can be expected from Public Low Voltage supplies at the consumer terminals before connection of a given installation.

The second part of the classification code defines the output waveform during normal and storage mode of operation:
- S: sinusoidal (THDu < 8%),
- X: sinusoidal with linear load and non sinusoidal with non-linear load (THDu > 8%),
- Y: non-sinusoidal.

The third part of the classification code defines the output voltage dynamic response to load variations under three different conditions:
- change of operation mode,
- step linear load in normal and battery mode,
- step non-linear load in normal and battery mode.

For each of these conditions, the dynamic response ranks from 1 (no interruption) to 3.

The standard EN 62040-3 shows the main working functions of an UPS. UPS basic function is to supply continuous power to a load and can be carried out with different circuital architecture and relative operating modes. These typologies are described for example in the following sections.

5.1 UPS DOUBLE CONVERSION OPERATION

In normal mode of operation, the load is continuously supplied by the converter/inverter combination in a double conversion technique, i.e. a.c. - d.c. - d.c. - a.c.

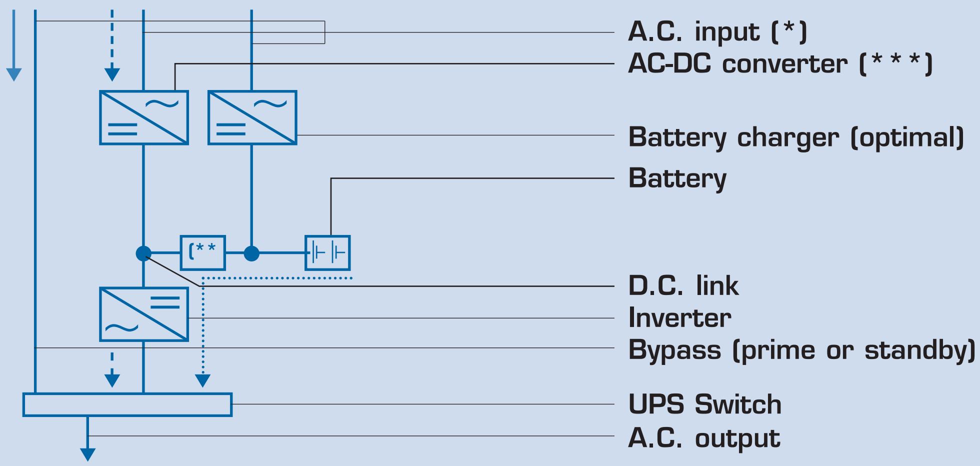
When the a.c. input supply is out of UPS preset tolerances, the UPS enters stored energy mode of operation where the battery/inverter combination continues to support the load for the duration of the stored energy time or until the a.c. input returns within UPS design tolerances, whichever is the sooner.

NOTE
This type is often referred to as an «On-Line UPS» meaning the load is always supplied by the inverter irrespective of the condition of the a.c. input supply. The term «On-Line» also means «On-the-Mains». To prevent confusion in definition, this term should be avoided and the above term used.

CONFIGURATIONS

(FIG. 7) **UPS DOUBLE CONVERSION OPERATION**

UPS double conversion operation with bypass



Normal mode
Stored energy mode
Bypass mode

(*) The AC input terminals may be combined
(* *) Blocking diode, thryristor or switch
(* * *) The converter may be rectifier, phase-controlled rectifier or rectifier-DC-DC converter combination

5.2 UPS DOUBLE CONVERSION OPERATION WITH BY PASS

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

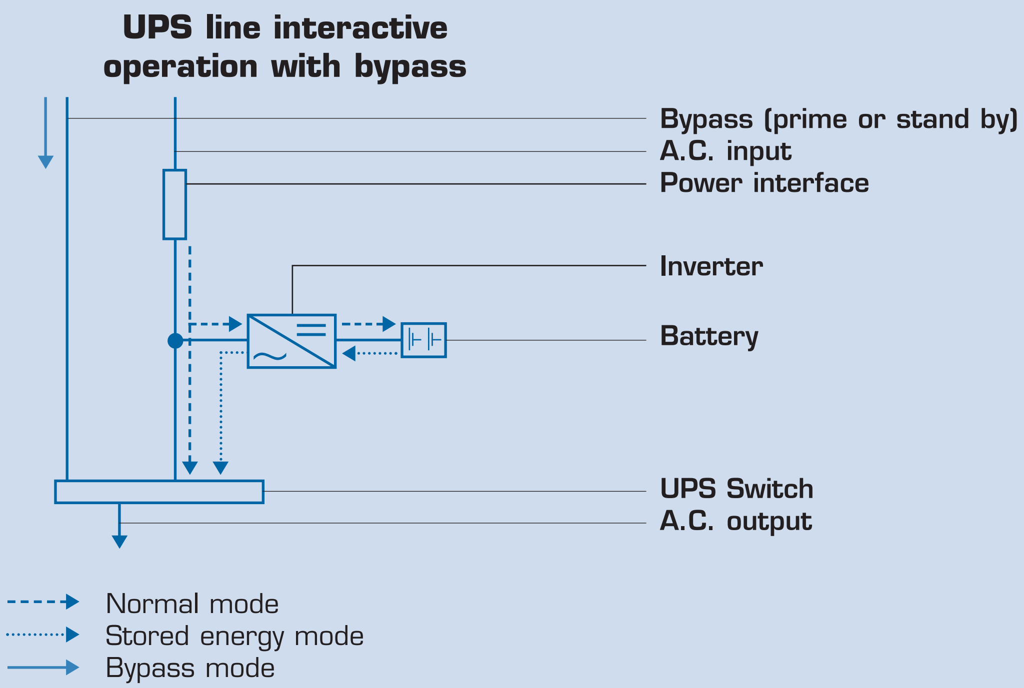
a) UPS failure;
b) Load current transients (inrush currents or fault clearing currents);
c) Overload;
d) Maintenance.

5.3 UPS LINE INTERACTIVE OPERATION

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

CONFIGURATIONS

(FIG. 8) **UPS LINE INTERACTIVE OPERATION**



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

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

5.4 UPS PASSIVE STAND BY OPERATION

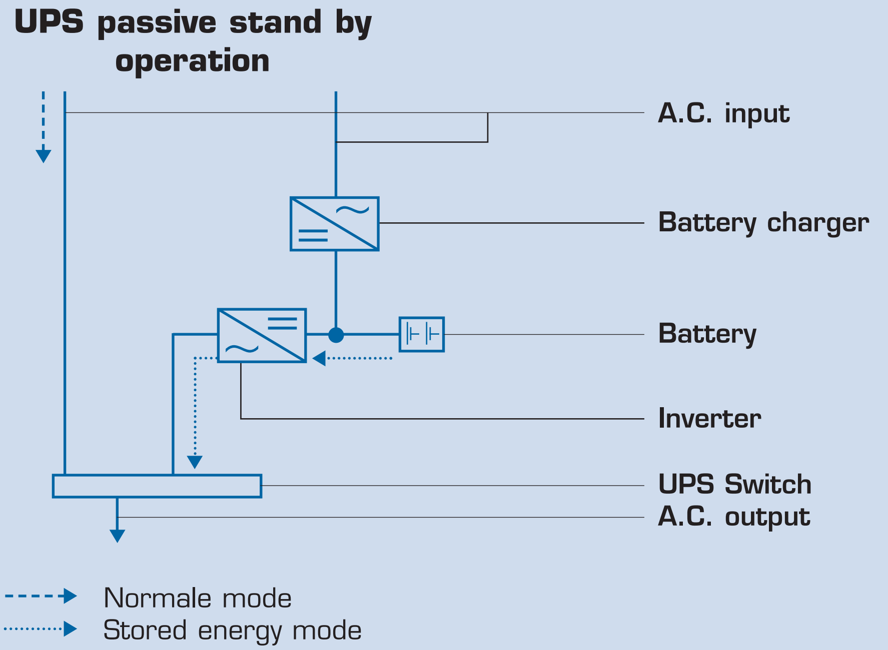
In normal mode of operation, the load is supplied by the a.c. input primary power via the UPS switch. Additional devices may be incorporated to provide power conditioning as voltage stabiliser systems. The output frequency is dependent upon the a.c. input frequency.

When the a.c. input supply voltage is out of UPS preset tolerances, the UPS enters stored energy mode of operation, when the inverter is activated and the load transferred to the inverter directly or via the UPS switch (which may be electronic or electromechanical).

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

CONFIGURATIONS

(FIG. 9) **UPS PASSIVE STAND BY OPERATION**



NOTE

This type is often referred to as an «Off-Line UPS» meaning electronic conditioned power is fed to the load only when the a.c. input supply is out of tolerance. The term «Off-line» also means «Not-on-the-Mains» when in fact the load is primarily fed from the mains in normal mode of operation. To prevent confusion in definition, this term should be avoided and the above term used.

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6 EVALUATION PARAMETERS

6.1 UPS ELECTRICAL SIZING

Knowledge of the following parameters has a key role in determining the UPS size.

6.1.1 APPARENT POWER (VA OR KVA)

It is defined as:

S = U x I for single-phase load
S = (UL1 x IL1) + (UL2 x IL2) + (UL3 x IL3)
for three-phase load

where:
U is voltage
I is the current absorbed by the load under normal load conditions (EN 62040-1-X)

This information is normally indicated on documents and/or load nameplates, though it may be shown as an oversized value.

Apparent Power of a UPS is specified in VA or kVA with the PF (power factor) specified under sine wave condition.

6.1.2 ACTIVE POWER (W OR KW)

It is defined as:

P = S x FP

where:
PF is the power factor.

The P or the PF value of loads is very seldom indicated, therefore a correct UPS sizing requires measurements of the P absorbed by loads. Experience shows that typical loads of computer equipment have a PF between 0.65 and 0.9.

The use of Power Factor Correction (PFC) on Switch Mode Power Supply (SMPS) input is more and more common for "high end" computer equipment (enterprise servers). These PFC rectifiers use mainly passive filters with capacitors and over compensate when the SMPS is lightly loaded. In this case the load will present a leading power factor to the UPS or other source (typically from 0,8 to 0,95 leading).
In this case, the user has to be sure that the UPS can supply such leading load, eventually with a derating or with a PF inductive correction system.
There is also the matter of supply source when the UPS transfers this leading load to the bypass supply, particularly when this source is a Generator Set. This parameter has to be considered when sizing the Gen Set to avoid instability of the latter.

EVALUATION PARAMETERS

6.1.3 CREST FACTOR

A linear load absorbs a sine-wave current which shows an effective value (Irms usually measured and declared) and a peak value (Ipk).

The Crest Factor is defined as:

CF = Ipk / Irms

The normal value for a linear load is CF=1,41.

Most loads applied to UPSs are non-linear loads (fig.12): they absorb distorted currents with a CF value greater than 1,41 and require therefore higher peak currents thus resulting in an increased distortion of the output voltage than equivalent linear loads. The value of the crest Factor (CF) is practically never indicated and it may be necessary to measure it specifically. Standard EN 62040-1-X, Annex M5, gives a reference non linear load as CF = 3, used for UPS testing. This value may be used in the absence of other data from the purchaser.

6.1.4 OVERLOAD

Overloads are temporarily required from load equipment that exceed the normal steady state value and are caused when one or more pieces of users equipment are switched on.

6.1.5 OPERATING PARAMETERS

In determining the size of a UPS, the following operating parameter conditions must be fulfilled:

S

The nominal Apparent Power of a UPS must be equal to or greater than the total S of loads.

P

The nominal Active Power of a UPS must be equal to or greater than the total P of loads.

WARNING: definitions such as “computer power” or “switching power” should not be considered for the correct sizing of the UPS and the battery (cf. § 6.9).

CF

It is necessary to verify that the UPS is sized for feeding non-linear loads with CF equal to or greater than the CF of loads as a whole and that the relevant output voltage distortion is compatible with the loads to be fed.

Overload

It is necessary to quantify overload and check that the UPS can sustain it, taking into account the overload capacity of the UPS.

6 EVALUATION PARAMETERS

If loads cause an overload greater than either the value or the duration allowed by the UPS, then two solutions are possible as follows:

- Use of a higher rating UPS;
- Acknowledge that under overload conditions users are automatically fed from mains power as long as requested through the changeover switch (if installed).

NOTE
A problem may arise if the mains power supply is missing or is out of tolerance: in this case the load may lose its supply. Where possible, switch on the load progressively, to avoid overload.

Operating temperature
If the temperature in the room is higher than the one declared by the manufacturer, the power of the UPS must be derated according to the indication of the manufacturer.

WARNING: UPS nominal performances should be compared at the same operating temperatures.

6.1.6 FUTURE EXPANSION
Once the UPS size has been established, it is recommended to add some extra power as allowance for future expansion:

- generally an extra power allowance of not less than 30% is regarded as adequate,
- opportunity to upgrade the power through the parallel system.

6.2 EFFICIENCY

6.2.1 EFFICIENCY DEFINITION
Efficiency η is the ratio between active output power and active input power of the UPS.

$\eta = P u / P i$

Energy dispersed as heat during UPS operation represents naturally an extra cost given by the thermal energy dissipated.

Because of heat dispersion it may be necessary, for medium-high power UPSs, to use extra electrical power for supplying equipments for air conditioning.

6.2.2 EFFICIENCY: THE IMPORTANT PARAMETERS
To avoid unpleasant surprises (high operating costs, inadequate ventilation or air conditioning) when talking about efficiency, a number of parameters must be considered as each UPS technology and topology presents certain advantages but also very different characteristics.

EVALUATION PARAMETERS

The main parameters to be taken into account are:
- topologies,
- load level,
- input voltage variations,
- type of load.

Regarding this last parameter, it is important to note that the loads supplied by UPS may have very different characteristics.
Loads are seldom linear (perfect sinewave) and non-linear loads have non-sinusoidal current with a high harmonic content.
This is particularly the case for computer hardware and medical and industrial equipment.
It is therefore essential to know the actual efficiency of a UPS when supplying this type of load, as certain converter technologies are very sensitive to non-linear loads.
The efficiency of different technologies will be compared using the non-linear load as defined in Annex E of standard EN 62040-3.

6.2.3 ENERGY COST

On a yearly basis, the cost of lost electrical power for a given load is given by:

Energy Cost = $Pu \times (1/\eta - 1) \times T \times c$

where

Pu is the active output power (kW) supplied to loads,

η is the UPS efficiency for that load level, and therefore not necessarily the nominal UPS efficiency,

T is the time taken, in hours of operation, in one year, at that load level,

c is the unit cost of electricity per kWh.

If air conditioning has to be taken into account, the energy cost will significantly increase.

6.3 INPUT CURRENT HARMONICS

According to the technology, a UPS may generate a distorted current containing harmonics that are multiples of the fundamental 50 Hz frequency.

The Options paragraph (§ 8.3) may be referred to for available procedures to reduce the input current harmonics.

6 EVALUATION PARAMETERS

6.4 NOISE

The presence of a UPS in the environment must be implemented in a way that will not alter living conditions. One must not forget that the average noise level, measured in accordance to the ISO 3746 standard, is equal to:

- 52 dBA in an office,
- 60 dBA in a computer room,
- 65/75 dBA in an electrical equipment room.

6.5 DIMENSIONS AND EASE OF MAINTENANCE

Compact size means:

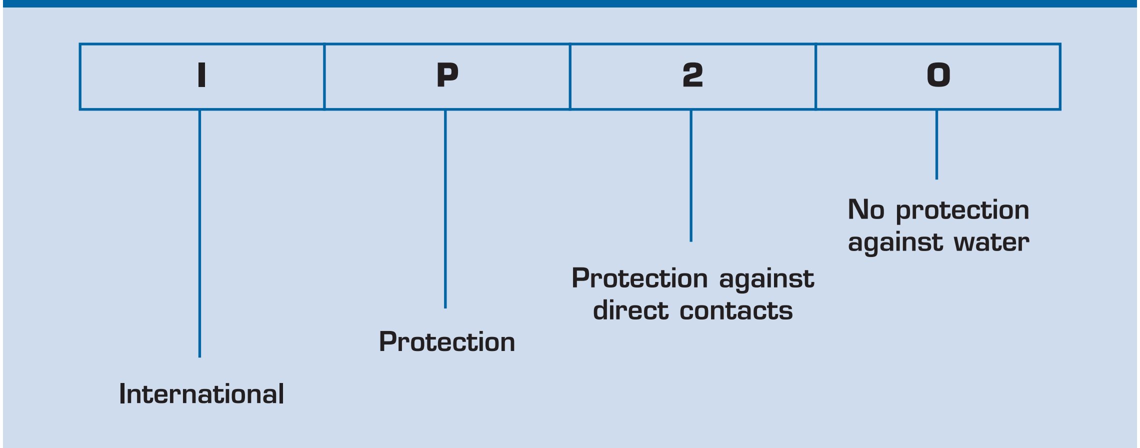
- reduced space required for installation, a factor that is important depending on cost per square metre of the area needed,
- easier and cheaper conveyance and installation of the UPS.

Adequate engineering may guarantee adequate maintainability even for small UPS size.

6.6 DEGREE OF PROTECTION

This means the safeguards laid out in the IEC EN 60529 standard "Degrees of protection provided by enclosures (IP Code)" against access to hazardous parts and against foreign objects (first characteristic numeral and optional additional letter) and against ingress of water (second characteristic numeral and optional supplementary letter).

(FIG. 10) **EXAMPLE OF IP**



6.7 RELIABILITY PARAMETERS

6.7.1 MTBF

MTBF (Mean Time Between Failures) is a parameter for evaluating UPS reliability. It represents the time estimate of satisfactory UPS operation between failures. MTBF

EVALUATION PARAMETERS

depends on various conditions like temperature conditions to which the equipment is subject, altitude, reliability of components used and their rate of use, on design features and, when applicable, redundant operation (systems in parallel).

6.7.2 MTTR

MTTR (Mean Time To Repair) is a parameter for evaluating easy repairing of UPS and therefore of the time it will be out of service for repairs. MTTR represents in fact the estimated repair average time and is largely affected by UPS design (easy replacement of parts and modules) and by on-board diagnostic equipment (easy troubleshooting). Note that the MTTR factor is dependent to on availability of spares on site when repairs are needed.

It must be noted that MTBF and MTTR values are informative only, as the range of these parameters may be quite large since it is subject to many associate factors.

6.7.3 AVAILABILITY

Availability is defined by the following formula:

A = (1-MTTR/MTBF)*100

6.8 BATTERY TECHNOLOGY

Batteries are normally supplied with the UPS and may be installed in the same cabinet: in this case, the supplier guarantees the UPS runtime specified for the apparent power of load and the power factor designed for.

Different battery technologies are available and described in the following table:

6 EVALUATION PARAMETERS

TECHNOLOGY	ELECTROLYTE	DESIGN LIFE IN YEARS AT 20°C	Igas	MOST COMMON APPLICATIONS	ADVANTAGES	SVANTAGGI
Valve Regulated Lead-Acid battery	AGM and GEL	3-5 (EUROBAT) Standard commercial	Floating: 1 In charge: 8	Consumer applications Toys Alarm systems PC-UPS	• Less involved maintenance • No specific room requirements • No topping up operations • High energy density • Extremely low gas emission • Reduced demands on the ventilation	• More sensitive to high temperatures, especially AGM type • Require good voltage stabilization chargers • No possibility to check or to see internally the cell • Limited shelf life
AGM = Electrolyte is absorbed into a fiberglass mat GEL = Electrolyte wille b ehold in the gel substance	Usually AGM	6-9 (EUROBAT) General Purpose		General use where safety and performance is not severe: • Emergency lighting • UPS • Alarm systems		
	AGM and GEL	10-12 (EUROBAT) High Performance		Applications with middle safety requirements: • Telecommunication • Power Generations • Power Distribution • UPS		
	AGM and GEL	12 and longer (EUROBAT) Long Life		Long life applications with high safety requirements: • Telecommunication • Power Generations • Power Distribution		
Vented Lead-Acid Battery	Free liquid	10-12 (DESIGN LIFE)	Floating: 5 In charge: 50	• Large UPS systems • General d.c. power supplysystems for the industry	• Easy to determine the state of a cell due to transparent container • Possibility to test the electrolyte density • Long storage periods are possible for dry charges cells • Long life	• Installation in dedicated rooms • Need of filling • Limited energy density • Gas emission
		Approx. 15 (DESIGN LIFE)		Applications with high safety requirements: • Telecommunication • Renewable energy • Emergency lighting • Power Generations • Power Distribution		
		Approx. 20 (DESIGN LIFE)		Applications with highest safety requirements: • Power Generations • Power Distribution		
Nickel- Cadmium	Free liquid	Approx. 20	Floating: 1 In charge: 50	some as vented lead acid but for more critical environments	• Possibility to test the electrolyte density • Long storage periods • Higher life • Less sensitive to Higher temperature	• Installation in dedicated rooms • Need of filling • Gas emission

*Battery life time on site may be affected by operational temperature, charge regulation & frequency and conditions of charge/discharge cycles

EVALUATION PARAMETERS

6.9 GENERAL CONSIDERATIONS ON THE MISLEADING CONCEPTS OF COMPUTER POWER

In the definition of the UPS rated power, the parametrical values, defined as "computer power", "switching power", "actual power", power at particular temperature values, etc…, are sometimes indicated.

Such arbitrary parametrical values have no relation with apparent power and active power; they cannot be neither quantified nor defined and therefore must not be used for the correct sizing of the UPS (cf. Glossary).

6.10 BASIC DATA FOR UPS SPECIFICATION

The minimum information required to specify a UPS is as follows:

INPUT

- **Input type: single or three phase ________**
- Input voltage: 230-400 V-other (specify) ________
- Input frequency: 50-60 Hz-other (spec-ify) ________

LOAD

(nameplate ratings if available)

- **Output type: single or three phase ________**
- Load voltage: 230-400 V-other (specify) ________
- Load frequency: 50-60 Hz-other (specify) ________

- Apparent Power (VA) :________
- Power factor (): ________
- Active Power (W): ________
- Crest Factor (): ________
- Overload (%): ________

Brief description of the load:

- Information technology (computers, printers, …), lighting, telecommunication equipments, electromedical equipments…,
- Future expansion of power (%) ________

BATTERY

Back Up Time (min): ________
Battery type: sealed, open vent, NiCd
Life (years) ________

6 EVALUATION PARAMETERS

ENVIRONMENT

- **Operating temperature:**
- □ UPS room;
- □ Life (years): ________

COMMUNICATION

The UPS is becoming more frequently a part of a system of intercommunicating devices. Within such an environment, the UPS must become a peripheral of a system that can send information based on user needs. This must occur efficiently and in a secure manner, and often through microprocessor control.

The communication can be divided into two types: local and remote.

7.1 LOCAL COMMUNICATION

■ LIGHT INDICATORS

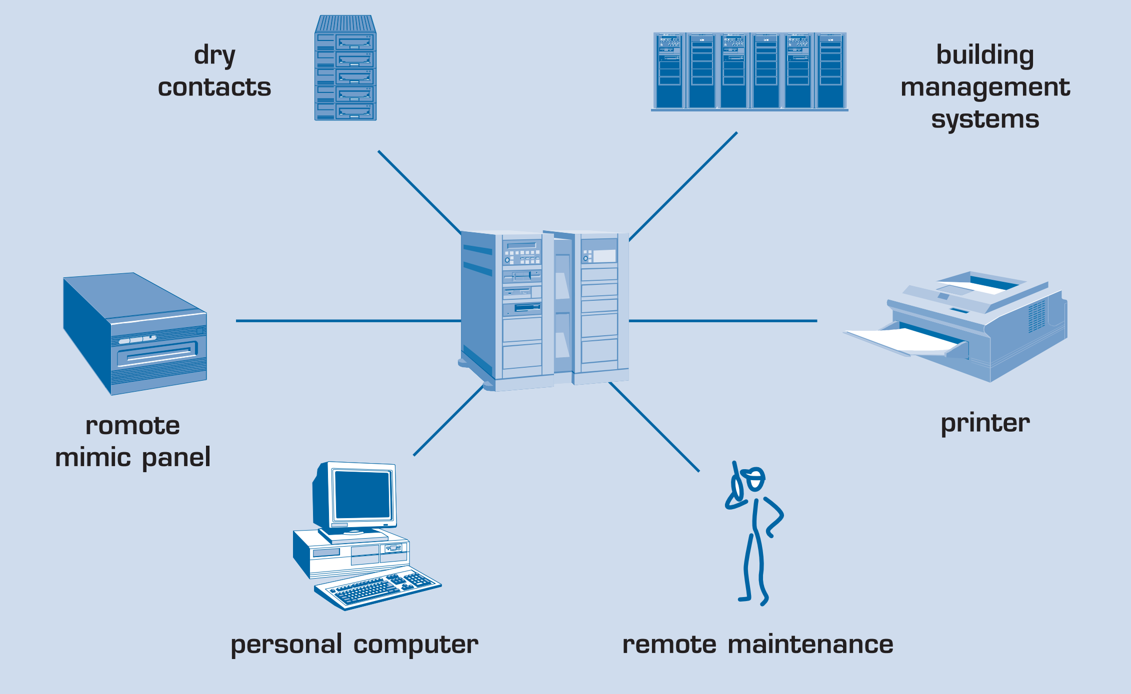
A simple warning light on the front panel of the device supplies gives an immediate indication of the UPS condition and is normally sufficient for small UPS ratings.

■ DISPLAY

For specific information about the UPS operating condition and its electrical parameters, it may be useful to equip the UPS with an alphanumeric display to ensure that the information supplied is clear. In addition, it is possible to implement special functions related to the use and diagnostics of the UPS. This solution is suitable for the UPS with higher ratings.

7.2 REMOTE COMMUNICATION

(FIG. 11) **DIFFERENT REMOTE COMMUNICATION**



7 COMMUNICATION

REMOTE REPORT THROUGH NO-VOLTAGE CONTACTS

If the operator does not have easy access to the UPS, it can be equipped with a remote signal for remote diagnostics of the main operating functions (at least "general alarm" and "battery operation"). This signal can be transmitted to information systems fed by the UPS, to a Customer's signal panel or to a signal synoptic panel supplied together with the UPS.

UPS/USER COMMUNICATION

By using dry contacts or a serial communication line, the UPS can be interfaced with the protected information user to ensure that operating systems are automatically shut down in case of a black-out and to transmit information about UPS status to operators.

SERIAL COMMUNICATION

For a more detailed remote diagnosis of the UPS, the information can be reported on an alphanumeric panel or directly on a Personal Computer. In these cases, the communication occurs through a standard serial line RS232, RS422 or RS485 guaranteeing a complete transmission of information through a simple twin-pair connection. The serial interface can also be used to report on a PC a much greater quantity of information than what is available locally and without any distance limits. The installer is free to use each communication device that is compatible with these standards: telephone modem, optical fibres or what else is necessary to reach remote plants.

NETWORK COMMUNICATION

Today UPS's have the capability to be connected to the network becoming a communicating element to the rest of the IT devices. When choosing a management solution for the physical infrastructure of IT networks, management of individual devices is necessary in order to have visibility of the many data points that are required for the reliable operation of network critical physical infrastructure.
Element management solutions offer the optimum approach as they manage a particular type of device and have the ability to assimilate and, more importantly, make manageable the large volume of data necessary for network availability. UPS Network interfaces provide management of an individual UPS by connecting the UPS directly to the network with a dedicated IP address, avoiding the need for a proxy such as a server. Embedded technology provides exceptional reliability and enables the UPS to reboot hung equipment. Each UPS can be managed individually via a web browser, Telnet, SNMP or via SSL and SSH. Notification features inform you of problems as they occur. For protected servers, the automatic shutdown software provides graceful, unattended shutdown in the event of an extended power outage.
Building Energy Management systems (BEM) frequently utilize networks separate from the IT network. These networks are frequently serial-based utilizing proprietary protocols or some level of standard protocols such as MODBUS or PROFIBUS.

COMMUNICATION BETWEEN UPS AND ASSISTANCE CENTER

UPS remote control can be extended and processed until it becomes a complement of the technical assistance service. It is possible to create a connection, using the normal telephone

COMMUNICATION

line, between the installed UPS and the assistance centre for an immediate alarm signal and a preventive control to ensure correct management of the UPS. The level of detail of the information on the single UPS can even include the recording of significant parameters for particular events.

8 OPTIONS

It is possible to improve the UPS standard version by adding options in order to respond to specific customer requests.

8.1 GALVANIC ISOLATION TRANSFORMER

The UPS can be supplied with a galvanic isolation transformer to change the neutral distribution system between input and output.

8.2 ADDITIONAL AUTOTRANSFORMER

When the mains voltage or the voltage required by the load has a different value from the UPS nominal value, an autotransformer for the voltage adjustment can be added.

8.3 SOLUTIONS FOR INPUT HARMONIC CURRENT REDUCTION

- Twelve pulse rectifier: the rectifier consists of a double shifted rectifier bridge that cancels the most important harmonic currents; cancellation is obtained through a combination of the harmonic currents by adequate phase shifting of the two rectifiers. For additional harmonic reduction an additional passive input filter may be provided at the input.
- PFC Rectifier (Power Factor Correction): the rectifier input current is switched and modulated to get a sinusoidal current absorption with very low harmonic content and a high input power factor. No significant input harmonic currents are generated by the rectifier.
- Active filters: they are mainly installed in parallel at the rectifier input. They actively cancel the input harmonic currents withdrawn by the rectifier avoiding them to circulate in the upstream supply circuit.
- Passive filters: usually capacitor/choke filters; they are installed in the front of the UPS providing a low impedance path to trap the main harmonics through a local circulation of the harmonic currents. It prevents the harmonics from circulating in the upstream supply power system circuit.

8.4 OTHER OPTIONS

Other options are available and can be agreed with the UPS manufacturer in order to optimise the installation.

Some examples of other options:

- Distribution panels
- Battery protection and monitoring
- Backfeed protection

9 INSTALLATIONS GUIDELINES FOR MEDIUM AND LARGE UPS

This section contains general technical information for the guidance of qualified personnel when installing UPS of the permanently connected type.

The manufacturer's installation instructions and national wiring rules should be adhered to, if they conflict with the following information.

9.1 POWER SYSTEMS

Most UPS are designed primarily for use on single phase/three phase power systems with an earthed neutral. For use on other power systems, i.e. impedant neutral or for single phase UPS for line to line operation, refer to the manufacturer or supplier for guidance on power system compatibility.

Isolating transformer options are generally available to enable conversion from these other power systems to earthed neutral operation. In some cases, you may be required to fit additional protective devices or switches in your supply installation.

9.2 CIRCUIT PROTECTION DEVICES

When using circuit breakers as protective devices a delayed action type should be used to prevent erroneous tripping due to the following:

a) UPS inrush currents. On switch-on a UPS may draw an inrush current up to 8 times normal full load current for a mains cycle. This may also occur if the UPS load is powered up in Bypass operation

b) Earth leakage currents due to the presence of EMC filters, at power-on, the instantaneous currents flowing to earth may not be balanced in all power lines and may cause differential type earth leakage detectors to operate.

9.3 BRANCH CIRCUIT PROTECTION AND DISCRIMINATION

When designing branch circuit protection for either the input or output wiring of the UPS, the guidance of the manufacturer/supplier should be sought, if proper circuit fault coordination is a requirement and details are not specified in the technical data sheets or installation instructions.

9.4 UPS OUTPUT CURRENT LIMITING

Dependent on the UPS technology, overload protection may be provided by internal electronic current limit circuits. It is a safety requirement, that when the output voltage falls below 50% of nominal rated output voltage, that the UPS must shut down within 5.0 seconds. (EN 62040-1-X, clause 5.6.1)

9 INSTALLATIONS GUIDELINES FOR MEDIUM AND LARGE UPS

9.5 NEUTRAL CABLE SIZING

If the load is non linear (usually the case for single phase power supplies) and connected to the output of a three phase UPS between phases and neutral, then it is likely that the neutral conductor will have to carry third harmonic currents, which are additive, for all the loads connected.

In this situation, the output neutral conductor should be increased in size in accordance with national wiring rules or IEC 60364-5-532.2.1 (HD 384). This may also apply to the supply neutral in some circumstances, such as in maintenance Bypass operation.

9.6 ISOLATION OF NEUTRAL

Many UPS types use the input supply neutral to reference the output neutral. When providing a means of supply isolation or input supply change-over circuits to the UPS, care needs to be taken to ensure that the input supply neutral reference is not disconnected whilst the UPS is in service.
This also applies to installations where the Bypass supply is separate to the normal input supply to the UPS and only one supply neutral is connected to the UPS for both supplies.

9.7 STAND BY GENERATORS

Stand-by generators are alternative supplies to the mains. Specify to the supplier of the generator that its load is likely to be electronic equipment to ensure that the generator regulation circuits can respond to and synchronise with waveforms having harmonic distortion and of the non-linear type.

9.7.1 CURRENT AND VOLTAGE DISTORTION

The sizing of the diesel generator is depending on several factors.
In addition to the nominal Power rating, the UPS Harmonic content of the current drawn by the UPS input is one of the most important parameter to be taken into consideration when selecting the generator.

The higher the current harmonic content, the higher is the risk of significant voltage distortion.

European standard EN 50160 and field experience suggest to keep the voltage distorsion lower than 8% to avoid malfunctions, derating and abnormal ageing of connected equipment.

9.7.2 CORRECT SIZING OF GENERATOR SET

Harmonic currents are often generated by the input stage (rectifier) of UPS if no particular attention or choice has been made. The harmonic current becomes a major concern for medium high power system or in case of a concentration of many smaller systems. The current distortion together with the output impedance of the source

INSTALLATIONS GUIDELINES FOR MEDIUM AND LARGE UPS 9

(transformer or generator set) generates and increases the global voltage distorsion of the source.

For a given harmonic current, the higher the impedance, the higher the voltage distortion.

The following parameters affect the voltage distortion:
1. maximum input power of the UPS,
2. line impedance,
3. impedance of the source (generator set),
4. the harmonic spectrum (level of each single harmonic (3^{rd}, 5^{th}, 7^{th}, 11^{th}, ..),
5. inrush current at the UPS's start up.

The solutions for decreasing the harmonics effects are:
a) to reduce the impact of the source impedance by increasing the rating of the Generator or improving performances (choose a generator set with a lower impedance). But this solution is not the most convenient in terms of cost;
b) to reduce either the level of upstream harmonic current generated by the UPS or harmonics in the connected loads (see chapter 6.3):
   - by selecting equipment with a low harmonic input current,
   - by providing additional and external extra filter devices.

NOTE
These devices may be either:
- active filtering technology,
- passive resonant filter tuned to cancel the worst harmonic ranks.

Generally this solution requires a careful network analysis taking into account resonance possibilities before installing.

Both solutions can be used separately or together.

9.7.3 SIZE OF THE GENERATOR SET

The best way to correctly size the generator set is to provide all the parameters specified above (§ 9.7.2, parameters 1 to 4).
In case some parameters are missing, the manufacturers suggest a “sizing ratio” that indicates the size of the genset according to the one of the UPS.
The sizing ratio can vary between 1.2 (including in average power necessary to recharge the battery) to 2.5 (depending on the input UPS stage technology).

The lower the total harmonic current distorsion (THDi), the lower will be the Total Harmonic Voltage Distorsion (THDv) and consequently the size of the Genset.

Usually ratings shall be confirmed by the generator set manufacturer as he is competent to confirm the adequate choice and rating.

9.7.4 INTERFACE UPS / GENERATOR SET

UPS can provide a communication and interaction with the generator sets. Different interfaces allow the UPS to modify the operating mode when the gen set starts. For example, by:

- inhibiting the battery recharge,
- increasing the input voltage and frequency tolerances,
- desynchronising the output from the input.

The UPS can also communicate the signals from the generator set (normally dry contacts) to a computer or computer network for remote monitoring or maintenance. In this case, the generator set can take benefit from the UPS intelligence and interfaces for improved diagnostic and monitoring facilities.

9.8 BATTERY INSTALLATION

Battery installations should comply with national rules and IEC 62040-1-X if the supplier provides no other information. Any requirements specified by the manufacturer for compliance with EMC regulations must be complied with.

Ambient temperature-Lead-acid battery design life is reduced by half for every 10 degrees rise above the design reference temperature of 20/25° C.

Whenever practicable, install in temperature controlled environments if optimum service life is required.

Batteries installed remotely from the UPS itself should be provided with protective devices suitably rated for operation on d.c. as close to the terminals as possible. A means of isolation should also be fitted to enable maintenance of the battery. If the battery consists of more than one battery string in parallel, then each battery string should have a means of isolation. This will allow one battery string to be worked on whilst the other string is still in service.

Proper ventilation shall be provided so that any potential explosive mixtures of hydrogen and oxygen are dispersed safely below hazardous levels. Ventilation shall be calculated per EN 50272-2 “Prescriptions for safety of batteries and installations”.

Standard EN 50272-2 deals in section 2 with Stationary batteries, generally used in applications with UPS. The norm describes the prescriptions for safety, including the protections against dangers generated by the electricity, the electrolyte and from the explosive gas. Other prescriptions are provided for keeping the functional safety on batteries and installations.

The Valve Regulated batteries (VRLA), best known as sealed lead batteries with internal gas recombination, can be installed into sites without particular prescription for Safety as the air flow needed for those batteries is very small.

INSTALLATIONS GUIDELINES FOR MEDIUM AND LARGE UPS

Cabling from external batteries to the UPS should be sized to not exceed the maximum recommended volt drop requirements specified by the manufacturer/supplier.

VENTILATION CALCULATION PER EN 50272-2
The quantity of air "Q" needed for the ventilation of a battery compartment should be calculated according to the simplified formula:
Q = 0,05 x n x Igas x Crt x 10^{-3} (m^3/h)
0,05 = v x q x s (v=hydrogen density, q=hydrogen generated; s=safety factor)
n = number of battery cells
Igas = current producing gas expressed in mA by Ah of capacity provided, for the floating recharge current (Ifloat) or for the boost charge current (Iboost). See paragraph 6.8 for Igas value
Crt = nominal capacity of the battery (Ah for single battery)
The formula for calculating the quantity of air "Q", changes according to the technology of the battery used (as indicated into the table in the paragraph 6.8).
The quantity of airflow for the ventilation should be insured preferably by natural ventilation or forced ventilation (artificial).
For the natural ventilation, the battery rooms or cabinets should have an air inlet and outlet with a free surface calculated with the following formula.

A = 28 x Q

Q = quantity of air for ventilation (m^3/h)

A = free surface for the air inlet and outlet (cm^2)

Example of calculation: for VRLA batteries with AGM technology (free lead batteries)

UPS: with 40 batteries 12V (6 cells 2V, per battery), with capacity 100Ah
Q = 0,05 x n x Igas x Crt x 10^{-3} (m^3/h)
0,05 m^3/Ah
n = number of batteries x Nb of cells = 240 battery cells (total number of cells)
Igas: 1 (mA/Ah) (for floating voltage)
Crt = 100 (Ah)
Q = 0,05 x 240 x 1 x 100 x 10^{-3} = 1,2m^3/h
A = 28 x 1,2 = 33,6cm^2

9.9 UPS REMOTE SHUTDOWN

UPS that are permanently connected to the mains supply, have provision for the connection of an external device to permit the remote shut-down of the load, and at the same time, prevent the UPS from continuing to operate in any operational mode, if an emergency situation, such as a fire, occurs in the building.

INSTALLATIONS GUIDELINES FOR MEDIUM AND LARGE UPS

This is a requirement of safety standard EN 62040-1-X and may also be a national requirement.

When using this option, additional contacts on this same device should also cause the interruption of the mains supply to the UPS to prevent operation of any automatic bypass circuits.

Alternative methods may be applied by using external devices when so permitted by local regulations.

9.10 UPS COMMUNICATION PORTS

Terminals and plug/socket connections on UPS intended to be connected directly to external Information Technology Equipment (I.T.E.) are "Safety Extra-low Voltage" (S.E.L.V.) circuits and must comply with IEC 60950 / EN 60950.

9.11 NON LINEAR LOADS

Typical non-linear loads usually found in the UPS industry, are those that consist of a rectifier and storage capacitor as normally found in any power supply. Power is only drawn from the mains or UPS when the supply voltage exceeds the d.c. voltage level on the storage capacitor.

The resultant current waveform does not follow the voltage waveform but occurs for up to 3.0 ms around the peak of the waveform. Its peak level can be between 2.2-5.0 times the r.m.s. value dependant on the supply source impedance and the waveform is rich in harmonic currents (see figure 12).

This type of current waveform can only be measured accurately with true r.m.s meters. If conventional average reading meters, corrected to read the normal r.m.s. a.c factors are used, it will result in a lower recorded value than the real r.m.s. value.
With this type of load, the r.m.s. current drawn and its peak value is dependent upon the supply source impedance as this limits the rate at which energy can be stored on the power supply capacitor each half cycle. Therefore it is not unusual to find that the value of the r.m.s. load current may be different in each of the UPS mode of operation if the output impedances differ. The UPS design normally takes this into account when the power rating is defined.

Equally, the voltage waveform may show signs of flattening at the peaks due to voltage drop across the supply source impedance, if the peak current value exceeds the normal sinusoidal square root of 2 peak to r.m.s. value.

When sizing distribution cabling it may be necessary to increase the cable size to allow for the higher voltage drop caused by high peak to r.m.s. load currents to avoid this loss of

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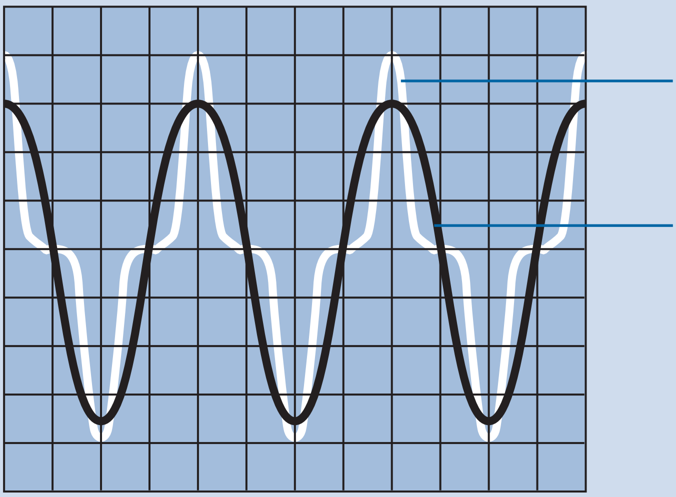
peak voltage and consequently a lower mean d.c. in the load power supply, unless the power supply has a wide operational voltage tolerance. This applies especially in areas where the nominal mains voltage is often at the lower tolerance level for long periods due to peak demands on the supply network in your location.

(FIG. 12) **NON LINEAR LOAD: CURRENT AND VOLTAGE**



10 MAINTENANCE AND SERVICES

When it comes to choosing a UPS, one of the most critical factors is the technical support that the manufacturer provides to current and future customers. Here are some of the services which should be considered when installing a UPS:

- pre-sales support,
- installation and initial start-up,
- maintenance contracts,
- after-sales support,
- remote supervision,
- training.

10.1 WHY IS SERVICE ESSENTIAL?

To meet their needs, systems no longer require just a product, but they require a solution.

The solution is a combination of services and product. The services include pre-sales guidance, site assessment, maintenance of the UPS and its environment and so on.

10.2 PRE-SALES SUPPORT

10.2.1 LOAD ANALYSIS

Before choosing a UPS, the load to be protected must be clearly defined. The presence of peak or start-up inrush currents may have a significant effect on specifications. The service technicians, equipped with harmonic analysers and storage oscilloscopes can help customers to establish the required output and avoid costly, oversized specifications.

10.2.2 ELECTRICAL ENVIRONMENT ANALYSIS

The service technicians help customers in the following ways:

- to determine which protective circuit-breakers should be placed on the various connections, in line with the current rating and short circuit current at the point of installation,
- to assess the cross section for the connection cables, as a function of heating and the permissible voltage drop,
- to meet the requirements set by international standards with regard to neutral systems and the protection of persons.

MAINTENANCE AND SERVICES

10.3 INSTALLATION

The service technicians assist in reviewing all the key installation tasks.

Key tasks are as follows:

- access possibilities,
- equipment unloading,
- upstream mains connection,
- distribution switchboard connection,
- battery connection,
- air conditioning/ventilation.

10.4 COMMISSIONING

In order to ensure compliance with standards and accepted practice the UPS manufacturers recommend that initial start-up be carried out by its own after-sales service for the medium and large size UPS.

The following operations are carried out by the engineers:

- validation of the measurements made during production testing,
- on load test,
- battery discharge test,
- training for site personnel,
- full job report.

The following key points should be checked with the customer:

- in the event of it being necessary to stop data processing for initial UPS start-up, when should this be done? In the evening, on weekends, etc.
- if loads are not available, who will provide the test loads?
- who will be responsible for coordinating the various suppliers and/or contractors involved?

10.5 MAINTENANCE CONTRACTS

The justification for a UPS installation is that it supplies “clean”, uninterrupted current. To purchase this type of installation is to recognise that the protected application is vitally important. It is therefore essential to consider the complete cost of an eventual UPS failure, however unlikely.

To do this, it is necessary to take account of the cost of repairing the equipment, but also expenses related to down time, during which the critical application is not protected, or perhaps not even supplied at all.

The aim of the maintenance contract is to keep this risk as low as possible.

10 MAINTENANCE AND SERVICES

Thanks to regular battery checks (for site contracts) it also implements preventive maintenance and extends the working life of the battery investment. The manufacturers have developed a wide range of maintenance contracts, which are designed to suit all types of individual requirements.

Contracts vary, from an entry range contract including routine visits, but excluding parts and labour, to all inclusive contracts with a guaranteed response time.

The range, which is completely adaptable, enables customers to get the most out of their maintenance budget, in line with specific requirements, both in terms of response time and preventive maintenance.

10.6 AFTER-SALES SUPPORT

A warranty that the manufacturer alone may supply

Although the manufacturers recommend maintenance contracts as the best way of keeping an installation in perfect working order, it also provides high quality, on site troubleshooting services:

- requests for service received by phone,
- short response time thanks to large number of after sales centres,
- rapid repairs thanks to modern technology used in the equipment and the high professional standards of the after-sales technicians.

10.7 TELEMAINTENANCE

Comprehensive and preventive insurance

Remote supervision is a service provided by some UPS manufacturers in the framework of their maintenance contracts.

A direct link between the UPS installation and the maintenance team draws on a combination of two manufacturers assets:

- the “intelligence” of products and their communication capabilities,
- the excellence of the maintenance service, carried out by high level specialists.

In the event of a breakdown, the maintenance team is immediately alerted. It makes a diagnosis, informs the customer and, within the framework of the maintenance contract, takes action without any risk of human error or loss of time.

10.8 CUSTOMER TRAINING

Regardless of which type of UPS is installed, customer training must be carried out.

MAINTENANCE AND SERVICES

There are several training courses:
- basic information dispensed during initial start-up, which comprises basic operating instructions for the UPS and suggestions for using the user manual;
- a training course covering UPS operation and maintenance. This course is designed for those responsible for these tasks.

- UPS operating principles,
- the ON-LINE design,
- characteristics of the various units,
- initial start-up and connections,
- overall installation diagram,
- user interface for entering commands,
- start-up procedures, on, off, by-pass and diagnosis,
- location and study of power sub-assemblies using block diagrams,
- control electronics presentation,
- using the indications and alarm messages,
- UPS environment,
- batteries: technology, choice, maintenance and installation,
- neutral system of the installation.

10.9 SERVICES BY THE UPS MANUFACTURER

The manufacturer of your UPS is the only one to be able to guarantee best maintenance owing to their key competences:

Expertise: cumulated advantages of design, manufacture and maintainance for technical support and logistics.
Traceability: full traceability of the UPS since its conception.
Availability: continuous availability of the spare parts with a guaranteed origin for all UPS still in service.
Know-how: guarantee of interventions on site by the manufacturer's expert.
Speed: commitment on time of repair.
Performance: benefit from the manufacturer's latest technologies and solutions.
Guarantee: the manufacturer is in the best position to be able to propose the guarantees expected by clients.
Vigilance: remote monitoring by the manufacturer of your feeding system.
Environment: UPS manufacturers remain firmly committed to upholding the highest environmental standards and continue to adhere strictly to all European Union Directives.

10 MAINTENANCE AND SERVICES

With the UPS manufacturer, your partner throughout the life of your power supply system, you don't evaluate the services on an apparent cost but on the global cost. Thus, you will benefit from the advantages of maintenance by the manufacturer:

- controlled technical stops of your process
- minimal time of repair
- maintenance of your system performance
- support to operating your system
- analysis and advice
- conformity to the standards.

Moreover the manufacturer expertise reduces the risk of expensive downtime and provides the benefit of spare parts and intervention without cumulated margin.

GLOSSARY

BEM (Building and Energy Management) system: system used to control and monitor all building utilities and systems from a central location.

CENELEC: Electrotechnical Committee for Electrical and electronic standards. It writes the European standards for electric and electronic equipments. Manufacturers can follow the CENELEC standards (EN) in order to comply with the European Directives.

Computer Power: In the definition of the UPS rated power, the parametrical values, defined as "computer power", "switching power", "actual power", power at particular temperature values, etc., are sometimes indicated. Such arbitrary parametrical values have no relation with apparent power and active power; they can be neither quantified nor defined and therefore must not be used for the correct sizing of the UPS.

Electromagnetic compatibility (EMC): possibility of a device to operate normally when installed near other devices, given the disturbances emitted by each device and their mutual sensitivities.

EN: European Norm. For electrical and electronic items, they are the European standards written by CENELEC.

Ethernet: International standard for digital network communications between devices, complying with the OSI (Open Systems Interconnexion) 7-layer model issued by the ISO.

European Directive: A law made by the European Union which must be incorporated into national laws of member states. There are horizontal directives, concerning all kinds of products and vertical directives, written only for specific kinds of products. Presently, for the electrical manufacturers there are two important vertical directives outlining the requirements for UPS products: 2004/108/EEC for EMC (Electro Magnetic Compatibility) and 2006/65/EEC for safety.

Harmonic distortion, total (THD): ratio between the r.m.s. value of all harmonics of a non-sinusoidal alternating periodic value and that of the fundamental.

Harmonic distortion, individual: ratio between the r.m.s. value of an nth order harmonic and the rms value of the fundamental.

IEC: International Electrotechnical Committee. Standard committees from different countries in the world contribute to define the IEC standards.

IGBT: the Insulated Gate Bipolar Transistor is a bipolar transistor controlled by a MOS transistor which offers advantages in terms of voltage control and very short switching times.

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IP rating: this indicates the safeguards laid out in the EN 60529 standard "Degrees of protection provided by enclosures (IP code)" against access to hazardous parts and against foreign objects (first characteristic numeral and optional additional letter) and against ingress of water (second characteristic numeral and optional supplementary letter).

Linear load (non linear load): a load can be defined as "linear", when the absorbed current has the same shape as the supply voltage.
A load can be defined as non linear, when the ratio voltage/current is not linear.
When a non linear load is supplied with a sinusoidal voltage, the current is a pulse.
For the UPS, a standard non linear load is defined by the european Norm EN 620140-1.

Noise level: acoustic decibel level (dBA) representing the sound power of a source measured according to standard ISO 3746.

PFC: Power Factor Correction.

Preferred Source: Power supply selected as normal source to supply the load.

RS 232C (Recommended Standard 232C): standard defining digital communication circuits between devices.The main features of this type of communication are:
- synchronous and asynchronous transmission,
- communication over public switched telephone network and short local networks,
- point-to-point communication via 2-wire or 4-wire media.

RS 422A (Recommended Standard 422A): for communication in a disturbed environment or over long distances, standard RS422A offers a differential operation option with a balanced voltage insuring superior performance.

SNMP: Simple Network Management Protocol used for data communication over computer networks of the Ethernet type.

STS: Static Transfer System.

Typical back up time: in defining the runtime, the definition of "typical emergency runtime" is often used, which has nothing to do with the emergency runtime based on a 100% load value.

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European Committee of Manufacturers of Electrical Machines and Power Electronics