TECHNICAL GUIDE

UPS

STATIC UNINTERRUPTIBLE POWER SUPPLIES

THE GLOBAL SPECIALIST IN ELECTRICAL AND DIGITAL BUILDING INFRASTRUCTURES

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INTRODUCTION

The circulation of **UPS systems** generally originates from an increasing dependence on electricity and the need to protect sophisticated equipment, data and critically significant processes for companies and for the daily life of each individual. Power electronics is included in the design and development of a static UPS with increasingly high performance levels which meet rapidly changing market demands.

There are a number of distinctive characteristics among the main players in the UPS market which should be taken into account before making a choice: the commitment to research and development, paying attention to energy consumption, having respect for the environment, searching for a reduction in operating costs, having a taste for the product aesthetics.

Factors linked to customer care and attention are also of major significance when making the choice, and include a complete offer of support services for the purchase, technical assistance, maintenance, periodic monitoring visits, and rapid intervention.

Finally, you must always bear in mind that there are essentially three fundamental UPS characteristics: safety, reliability, and availability.

This guide will illustrate the primary information and methodologies for choosing and dimensioning the UPS by effectively combining their different types with the variety of applications and loads that they will have to protect.

2- GRID FAULTS

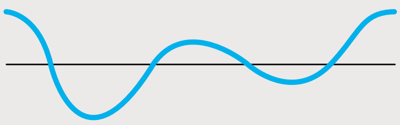
Nowadays, an uninterrupted and a good quality power supply is becoming an increasingly urgent need.

An increasing number of devices requiring power are playing fundamental and critical roles in the life of companies, for people's safety, for storing and processing data and for communications.

The devices which carry out these functions, on the other hand, are both sophisticated and sensitive and can be affected by supply network faults.

Incidents of an electrical nature that constantly threaten electronic equipment may be of different types, as can the impacts on whether charging is available (for example computer systems).

2.1. Types of faults

INTERFERENCE	DESCRIPTION	EFFECTS
 **Undervoltage (Brown-Out)**	Short-term drop in voltage levels. This is the most common disturbance (it even constitutes 87% of disturbances) attributable to the power supply and is caused by electrical devices starting up such as motors, compressors, lifts and hoists.	A reduction in the power required by a computer to function correctly, which results in the keyboard shutting down or unexpected system crashes, along with the data being processed becoming lost or damaged.
 **Blackout**	A blackout results in a total loss of power. It can be caused by an excessive demand for electricity, thunderstorms, ice on the lines, road accidents, excavations, earthquakes, etc.	The impacts it may cause involve data being lost, communications being disrupted, a lack of lighting, production lines being blocked, company activities being disrupted, a danger to people being posed, etc.

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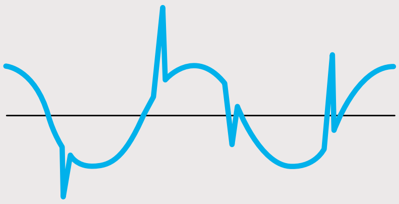
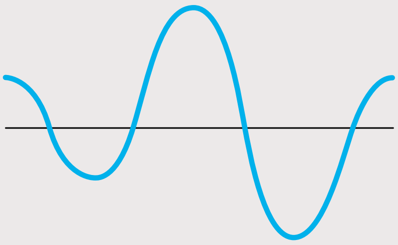
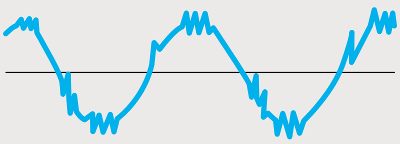
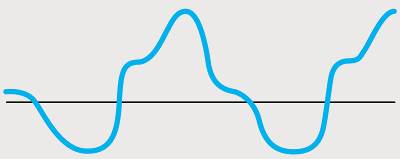
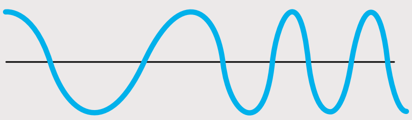
INTERFERENCE	DESCRIPTION	EFFECTS
 Spike	A spike, or a voltage transient, is a sudden surge in voltage. Spikes are generally caused by lightning and may also occur when the mains power returns after a blackout	It may affect electronic equipment across the network, serial lines or telephone lines, and may damage or completely destroy components and cause a permanent loss of data.
 Surges	This is a short-term voltage increase, which typically lasts 1/120 of a second. A surge can be caused by large-sized electric motors, such as air conditioning systems. Any extra voltage will be dissipated on the power line when these go out.	Computers and other highly sensitive electrical equipment require a variable voltage within a certain tolerance range. Any voltage value which exceeds the peak value or the effective voltage levels (the latter can be considered the average voltage) puts strain on delicate components and causes premature failures.
 EMI/RFI noise	The noise from electromagnetic interference and radio interference alters the sinusoid supplied by the supply network. It is generated by various factors and phenomena, including lightning, load switching, generators, radio transmitters and industrial equipment.	Any noise can be intermittent or constant and introduces transients, errors and issues in computer data, or in telecommunications; it can also result in malfunctions in various electrical devices.
 Parasitic and harmonious currents	These are generated by perturbations or atmospheric variations, by load variations, by current generators, by electromagnetic emissions and by industrial systems.	These disturbances cause errors in the execution of software programs, premature deterioration of computers and any data they contain, along with malfunctions in various types of electrical equipment.
 Frequency variations	These are generally present in energy produced by generating units.	These variations cause errors when making calculations, difficulties in interpreting magnetic media (discs, tapes, etc.), and various types of issues in electromechanical applications.

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2.1. The cost of power supply faults and the cost of downtime

While calculating the financial impact caused by network disturbances may appear complicated, production activities and the provision of services in the modern world are in fact strongly linked to the reliability of digital information systems to the extent that the unavailability of the latter corresponds to financial and social activities becoming blocked either partially or in full.

The following calculation can be made to get an idea of the costs of machine downtime caused by electrical issues that a company may experience:

a. multiply the time unavailable by the cost of the wages of the workers who are dependent on the system;
b. add any lost profit (total profit/period of unavailability);
c. add any costs of restoring the system which instead are dependent on the frequency of incidents and their severity levels;
d. add any costs (these are not always easy to calculate) related to a lack of service, customer and user dissatisfaction, penalties, compensation for damage and any related damage to image**.**

3- UPS TECHNOLOGY

Various expressions are used in the market to specify the types of static UPS, e.g.: Offline, Line-Interactive, Online Double Conversion, Digital Online, In-Line etc.
The majority of these terms are dictated more by commercial needs and choices than by the actual technology adopted.

Generally speaking, the three main construction types are: Offline, Line Interactive and Online Double Conversion.

3.1. Offline

The output is exactly the same as the input when there is a supply network. The UPS only intervenes when there is no input voltage, and powers the load by using the inverter which in turn is powered by the batteries.

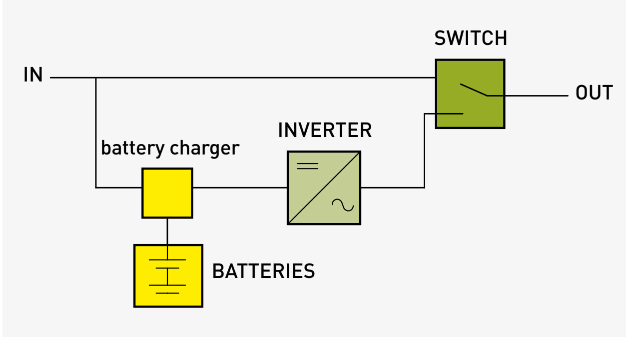
The primary functional blocks of this type of UPS are:

• **Switch:** in general, an electro-mechanical type with intervention times of between 5 and 10 ms.

• **Inverter:** a power converter that transforms the battery's direct voltage into alternating voltage. The complexity and performance level of this inverter may vary according to the model and the power, while the voltage generated can be pseudo-sinusoidal or sinusoidal with more or less intense harmonic content.

• **Charger:** a converter that transforms the alternating input voltage into direct voltage in order to charge the batteries when the UPS is operating on mains voltage. This circuit may be more or less complex and have higher or lower performance levels depending on the model and power.

Offline (VD)



• **Passive input filters:** there are occasionally passive filters that protect against overvoltages and high-frequency disturbances within the limits of the regulations governing electromagnetic compatibility (this is outlined below).

OFFLINE TYPES PROTECT AGAINST:

• Blackout
• Voltage sags > 10 ms
• Voltage fluctuations < 16 ms
• Overvoltages 4-16 ms

ADVANTAGES:	DISADVANTAGES:
Very low weight and size (for low power supplies)	There is no protection against the majority of disturbances caused by the mains
The efficiency level is very high during mains operation because the output is directly connected to the input	Network switching time - battery not empty
Low noise, cooling fans are often not required	In general, the inverter generates pseudo sinusoidal voltages
Low cost (for small power supplies)	Its compactness entails a very limited number of internal batteries, which means that the autonomy is generally low. It is often not possible to add external batteries.

3.2. Line-Interactive

The input and output are separated by a filtering and stabilising circuit when there is a supply network (AVR: Automatic Voltage Regulator); however, part of the disturbances or waveform variations which are possible at the input can also be found at the output.

As with the Offline types, the output is connected to the inverter when there is a power failure, the inverter being powered by the batteries.

The primary functional blocks of this type of UPS are:

• **Switch:** in general, an electro-mechanical type with intervention times of between 5 and 10 ms.

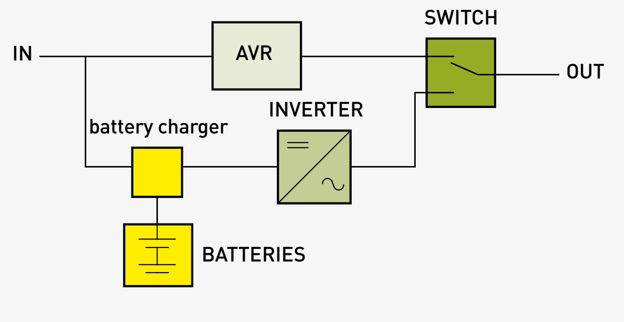
• **Inverter:** a power converter that transforms the battery's direct voltage into alternating voltage. The complexity and performance level of this inverter may vary according to the model and the power, while the voltage generated can be pseudo-sinusoidal or sinusoidal with more or less intense harmonic content.

• **Charger:** a converter that transforms the alternating input voltage into direct voltage in order to charge the batteries when the UPS is operating on mains voltage. This circuit may be more or less complex and have higher or lower performance levels depending on the model and power.

• **Automatic Voltage Regulator (AVR)**: a circuit which is generally made with a transformer with several outputs (corresponding to a different number of secondary coils) coupled to a switch, which connects, when the input voltage changes, to the output of the transformer with a voltage closer to the rated output of the UPS.

• **Passive input filters:** there are occasionally passive filters that protect against overvoltages and high-frequency disturbances within the limits of the regulations governing electromagnetic compatibility (this is outlined below).

Line-Interactive (VI)



THE LINE-INTERACTIVE TYPES PROTECT AGAINST:

• blackout
• Voltage sags > 10 ms
• Voltage fluctuations < 16 ms
• Surges
• Spikes

ADVANTAGES:	DISADVANTAGES:
Very low weights and sizes (for low power supplies)	There is no protection against frequency disturbances and strong voltage variations coming from the mains
Efficiency levels are high during network operation, while the AVR, which is a passive component, is interposed in between the input and the output	Network switching time - battery not empty
Low noise for small power supplies, where cooling fans are often not required	In general, the inverter generates pseudo sinusoidal voltages, although there are some models with sinusoidal output inverters
Low cost (for small power supplies)	Its compactness entails a very limited number of internal batteries, which means that the autonomy is generally low. It is often not possible to add external batteries.

3.3. Online Double Conversion

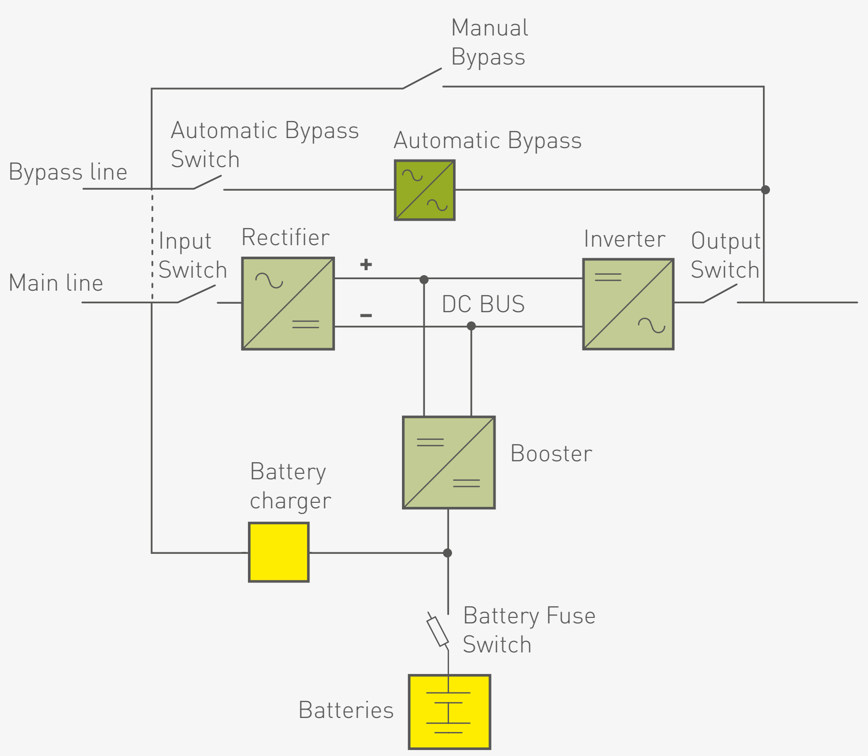
This typology is very different from previous ones.

The input is initially rectified and is then reconverted so that it alternates with an inverter.

The output voltage waveform here is completely independent of the input, all potential mains power disturbances are eliminated, and there is no transient time in the transition from mains to battery, since the output is always supplied by the inverter.

This type of UPS has an automatic bypass that guarantees power to the load by switching it directly on input in the event of overloads and any internal issues.

Online Double Conversion (VFI)



The following functional blocks can be identified inside the **Online Double Conversion UPS**:

- Rectifier:
- DC bus
- Inverter
- Booster (not always included)
- Automatic bypass
- Manual bypass (not always included)
- Battery charger
- Electrical distribution and disconnection

3.3.1. Rectifier (PFC)

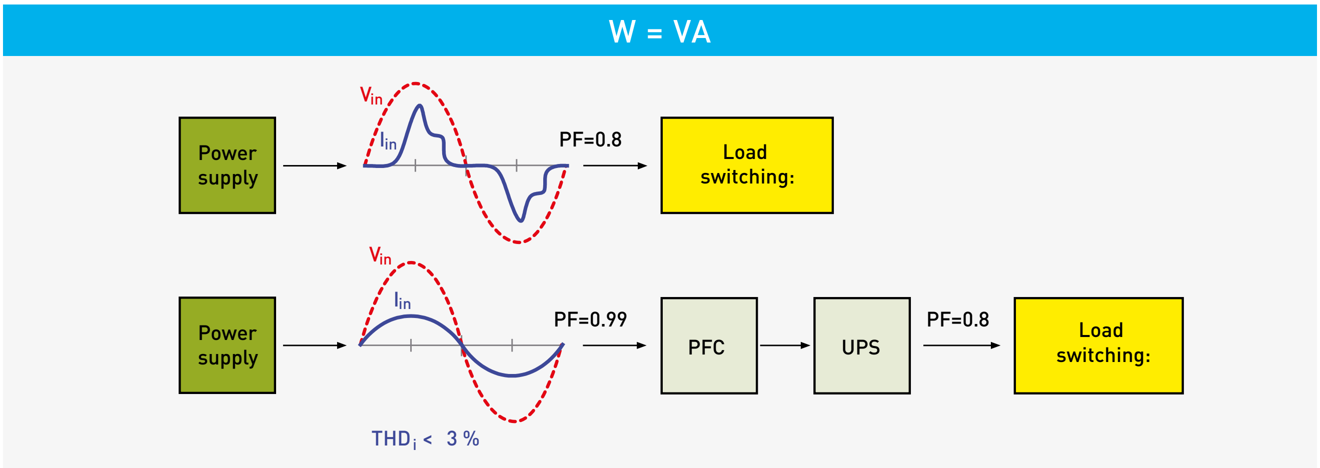
The rectifier circuit absorbs any alternating power from the power supply network and transfers it inside the UPS on the DC bus in order to power both the inverter and the battery charger.
It therefore acts a power converter with the task of stopping all disturbances from the network and ensuring there is a stable power supply to the internal UPS parts.

The rectifier is of a **PFC (Power Factor Corrector)** type in the latest generation UPSs.
The PFC rectifiers are able to absorb energy by minimising the harmonic distortion of the current (sinusoidal input current) and to keep the value of the power factor close to one (power factor corrector) by using high-frequency IGBT technology with triple level bridges.

In-depth study

Power supply factor and harmonic distortion

One input power factor virtually equal to one (PF = 0.99 already with a load equal to 20%), and a low harmonic distortion (THD <3%), guarantee a minimum impact on the network and a high level of energy efficiency, which results in energy management with reduced costs.
The further the power factor deviates away from the unit value, the greater the reactive power that is absorbed by the grid, with consequent tariff increases imposed by the operator. The correction of the power factor also involves a reduced oversizing of any upstream generator, which previously had to exceed the nominal power of the UPS by at least 30%, thus allowing for further savings as part of the construction of the continuity system.
A carefully controlled current absorbed by the network allows you to obtain a very low harmonic input current distortion level (THD <3%). Harmonic distortion caused by non-linear loads on the power supply lines, determines that any currents present in the system are higher than expected and that they include harmonic frequency components: a phenomenon that can be seriously underestimated due to the fact that these are currents which cannot be measured with standard portable instrumentation supplied to maintenance staff members.
It will remain the case that the conductors will operate at higher temperatures, causing a quantifiable waste of energy generally equivalent to 2-3% of the total load, even if the current remains within the overload protection device capacity.



3.3.2. DC bus

The **bus** in continuous mode is an energy storage tank that guarantees that the inverter has a continuous supply of power, even when switching power from mains to battery. The bus also supplies energy to the battery charger. The latest generation UPSs consist of advanced systems for overseeing and monitoring of bus energy levels in order to ensure that the inverter operates at full power even when there are highly distorting and variable loads.

3.3.3. Inverter

The inverter is the second power conversion circuit that transforms the DC bus direct voltage into alternating voltage to be supplied to the load.

The latest generation UPSs (in particular transformerless UPSs) include high-performance inverters based on high-frequency IGBT technology, which are capable of generating perfect sinusoidal voltages even on highly distorting loads, while continuing to maintain high efficiency values with particularly compact dimensions.

3.3.4. Booster

Some UPS models have a booster circuit that transfers energy from the batteries to the DC bus. This circuit increases the battery voltage so that it has adequate bus voltages for the inverter power supply. It is possible under these circumstances to have relatively low battery voltages (which is advantageous in terms of electrical safety).

The booster also makes the DC bus voltage independent of the battery voltage which will vary whilst discharging.

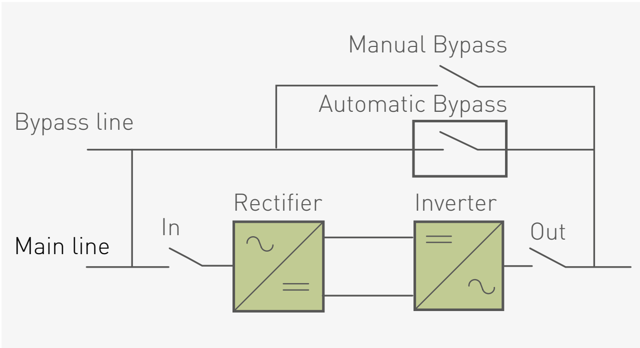
3.3.5. Automatic and manual bypass

There is an automatic bypass electronic circuit inside the **Online Double Conversion UPSs** which excludes the UPS power circuits in the event of an emergency (overloads, failures, etc.) by automatically connecting the load to the input mains. This circuit must intervene extremely quickly and be robust enough to withstand any overload currents.

A number of UPSs also have a manual bypass parallel to the automatic bypass which allows the load to be powered from the input mains during maintenance operations. The manual bypass is normally integrated into a medium/large size UPS (> 10kVA), while it can be included a an optional accessory for small size UPSs (<10kVA).

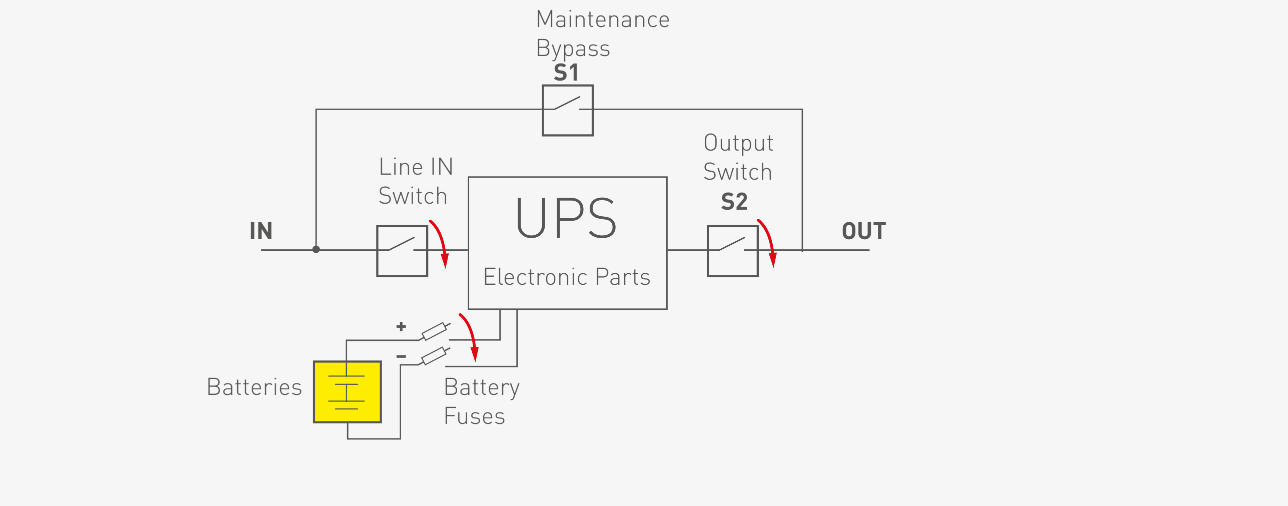
The UPS may have a dedicated input line for the bypass (both automatic and manual) for some applications, which varies from the input line that powers the rectifier. A maintenance bypass external to the UPS may also be provided under certain circumstances. In these circumstances, it is important that the bypass itself is only closed after the UPS itself is in bypass mode to prevent the external bypass from causing a short circuit between the UPS input and output.

This can be ensured by introducing interlocking systems between the external and internal bypass, or by clearly displaying the operating instructions on the external bypass control panel.



3.3.6. Electrical distribution and disconnection

Medium and large sized UPSs (to be wired inside the electrical panel) come equipped with a distribution panel which houses the disconnectors for the input, bypass, output lines and protection switches (these are normally disconnectors with fuses) for connecting the batteries.



3.4. Transformer-based and transformer-less online double conversion

The Online Double Conversion UPSs can also be divided into two further groups:

1. UPS with internal transformer

2. UPS without a transformer

3.4.1. UPS with internal transformer

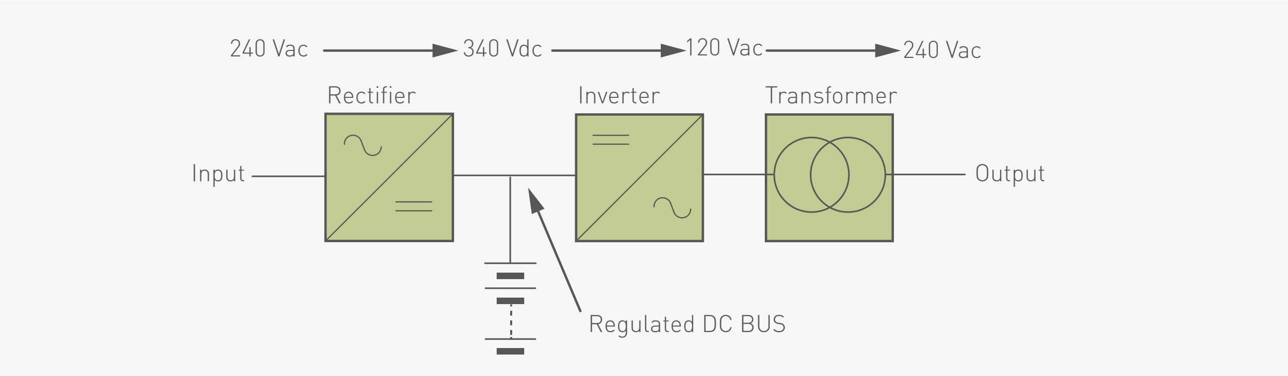
The first group is based on a classic topology which has been in use for several decades and still exists in some applications.

The inverter output in this type of UPS is connected to a transformer that increases the voltage up to the values required by the load.

It is generally possible with this UPS topology to have a three-phase delta input with no neutral.

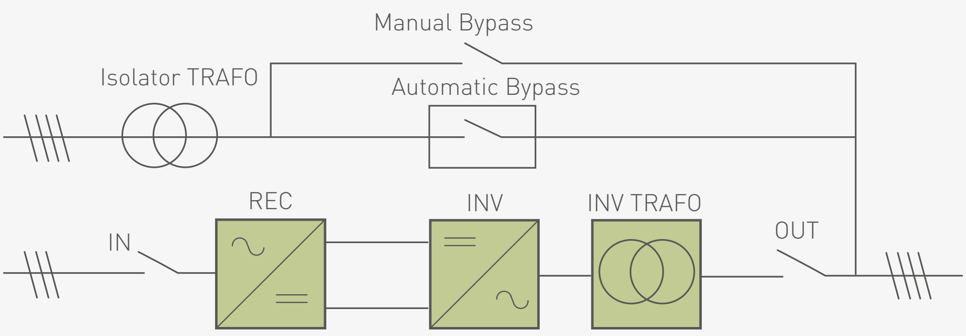
This topology was originally adopted for all power cuts; however, nowadays it is found mainly in large power supplies (> 200kVA).

The UPS block diagram with a transformer is shown below; the voltages are those of phase and are entirely indicative.



We should stress that this transformer does not necessarily guarantee galvanic isolation between the input and output; in fact, the input neutral is directly connected to the output neutral in the configurations where the ability to switch to bypass is required.

You will be required to connect an additional isolation transformer (with a 1:1 ratio) at the input to the bypass line to incorporate galvanic isolation in such cases, as is illustrated in the following diagram.



3.4.2. UPS without a transformer (transformer-less)

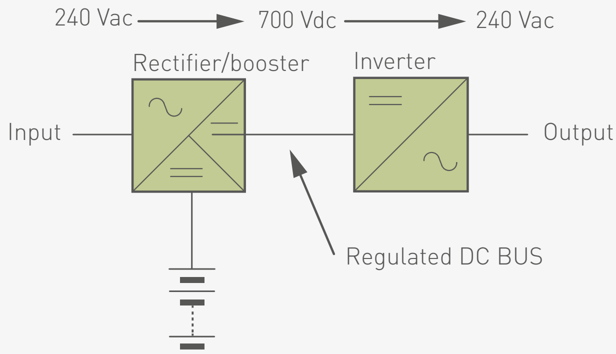
There has been a significant technological evolution in the field of semi-conductors over recent years, which has led to the creation of power components, such as IGBTs, with increasingly higher performance levels.

It was possible to achieve more accurate piloting and controls and have greater flexibility when converting energy with power conversion circuits (rectifiers, boosters, inverters, etc.) which are based on high performance static components.

In detail, today it is possible to create controlled rectifiers that allow for higher DC bus voltages and inverters which are capable of generating very low distortion voltages. This made it possible to avoid using the internal transformer with considerable advantages, such as the reduction in size and weight, the increase in efficiency levels, the reduction of noise, the reduction of harmonic distortion in the input current and a general reduction in costs.

Although transformer UPSs are still widespread, the current trend of UPS manufacturers is geared towards transformer-less technology, in particular for small and medium power UPS (up to 200-300kVA).

The UPS block diagram without a transformer is shown below; (the voltages are those of phase and are entirely indicative), where you can see that there is a booster circuit in the rectifier stage which allows the DC bus to retain a stabilised high voltage.



3.5. UPS in parallel

A number of **Online Double Conversion UPS** on the market can be connected in parallel.

The parallel of two or more UPS allows for redundant configurations, to reach higher power levels or to increase the power of an already existing system. The UPS inverters must be synchronised with one another to create the parallel, and this is normally achieved via special communication systems that connect the control logics of the two UPSs.

It is often necessary in large-sized UPSs to combine the UPSs with a special distribution panel that creates the parallel. It is important in parallel UPS configurations that the individual UPS bypass systems (both automatic and manual) are also synchronised with one another so that they can intervene simultaneously.

Sometimes it is possible that, in parallel systems, a centralised bypass is provided in parallel with all the UPSs and which excludes them all at the same time. It is also important under these circumstances that this bypass is synchronised with the bypasses inside all the parallel UPSs.

3.6. Modular UPS

The need for power supply continuity and maintenance and management facilitation have led to the birth of UPS with modular architecture over recent years.

Modular UPSs consist of multiple transformer-less Online Double Conversion UPSs (modules) that work in parallel within one single system.

The total power of the UPS will equate to the sum of the powers of the individual modules. It is easy to achieve redundancy or increase power in modular systems simply by adding one or more modules, and without having to connect multiple UPS in parallel. Furthermore, any faults in the power circuits in modular UPSs remain confined to one single module which is automatically excluded.

The lower the power of the individual modules (granularity), the lower the power lost in the event of failure and the more straightforward it is to replace the faulty module.

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3.7. The advantages and disadvantages of Online Double Conversion technology

ONLINE DOUBLE CONVERSION UPSS PROTECT AGAINST:

- Blackout
- Voltage sags
- Undervoltages (brown out)
- Voltage fluctuations
- Surges
- Spikes
- RFI/EMC noise
- Parasitic currents
- Harmonic elements
- Frequency variations

ADVANTAGES:	DISADVANTAGES:
Total independence of output voltage and frequency from input voltage and frequency, both in the presence of the mains supply and when operating on batteries	Higher costs than with other types
Mains/battery switching time null	Greater size and weight
High quality and stability of the power supplied to the load	Increased noise due to the need for forced ventilation
Minor impact on the input network, especially in models equipped with a PFC rectifier (the PFin is close to the unit, with a very low harmonic distortion of the input current)	Consumable components besides batteries (e.g. bus capacitors and fans)
Potential for achieving long autonomy by using additional batteries	
The ability to feed overloads by switching to automatic bypass.	
The potential for switching the load to manual bypass in the event of servicing the UPS in models where this is provided.	
High levels of efficiency during battery operation	

3.8. Functional components common to all UPS types

All of the UPS types seen previously include a command logic, a communication interface system, batteries and a battery charger.

3.8.1 Command logic

All UPSs require a command logic that coordinates the various functional blocks under different operating conditions (switching on, switching off, mains operation, battery operation, overload, end of autonomy, bypass, etc.). In addition, the command logic also manages the measurements of the operating parameters and alerts to the user.

The command logic may be more or less complex depending on the model and the type of UPS.

The latest generation UPSs have an advanced command logic which is based on a microprocessor or on a DSP.

In addition to managing the piloting of all the power circuits, these control circuits also control all of the UPS operating parameters, record all the system events and historical data, and allow you to easily perform diagnostics in the event of operating problems or anomalies.

The user can interact easily with the command logic to configure the UPS and monitor its operation using control panels with graphic and alphanumeric displays.

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3.8.2 Communication Interface

The communication interface allows direct connection with:

- **The computer (via serial and USB ports)**
- **Data networks (via TCP-IP, SNMP, Modbus communication cards)**
- **Other signalling and command devices (via logic level ports and clean contacts).**

The communication interface also comes equipped with special control systems in the UPS models that can be connected in parallel with each other (in particular the Online Double Conversion types) in order to create the parallel by synchronising the inverter outputs of two or more UPS.

3.8.3 Battery charger

The battery charger is an electronic power circuit that is tasked with charging the batteries during the UPS mains operation. The batteries in some instances are connected directly to the DC bus, meaning that it is the rectifier itself that functions as a battery charger. The battery charger is a separate circuit that draws energy from the network in parallel to the rectifier whenever there is a booster circuit between the batteries and the DC bus.

It is crucial that the batteries are charged and in good condition to ensure continuity of power supply in the event of a blackout. It is therefore necessary that a part of the energy absorbed by the UPS is destined to recharge the batteries as part of routine operation. This is an additional consumption that cannot be eliminated.

Advanced recharging systems (smart charge) are used to reduce the cost of recharging the batteries, and these are based on the direct measurement of the functional parameters (voltage, current, temperature) of the batteries and their variations so that the status of the battery can be assessed in real time. Charging follows a multi-phase cycle, the duration and intensity of which depends on the battery status.
This means that you have the advantage of rapid recharges, batteries that are always charged and monitored constantly.

In more advanced systems, the battery charger goes into stand-by once the full charge has been reached, blocking the recharge for a fixed time, after which the system carries out a quick check on the battery status before resuming recharging. Energy absorption levels are therefore maximised, limiting these to what is actually required by the current charge status of the batteries. In addition, the life of the batteries will also be extended as an additional effect.

An intelligent battery charging system (Smart Battery Charger)

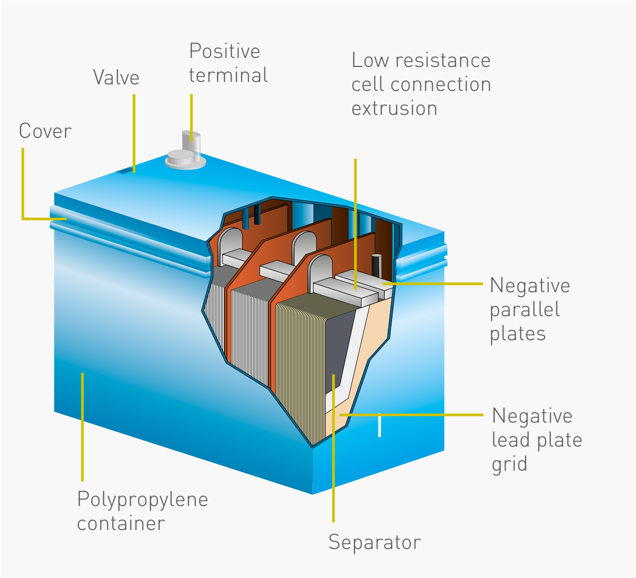
The intelligent triple-stage "Smart Charger" charging system, significantly extends the life of the batteries, even by as much as 50% and halves the number of replacements and environmental pollution due to their disposal.

4- BATTERIES

Batteries are essential for the UPS system: they ensure continuity of power supply by providing energy to the inverter (for the required period) when there is no power supply. It is therefore essential that they are always connected, functioning, and charged.

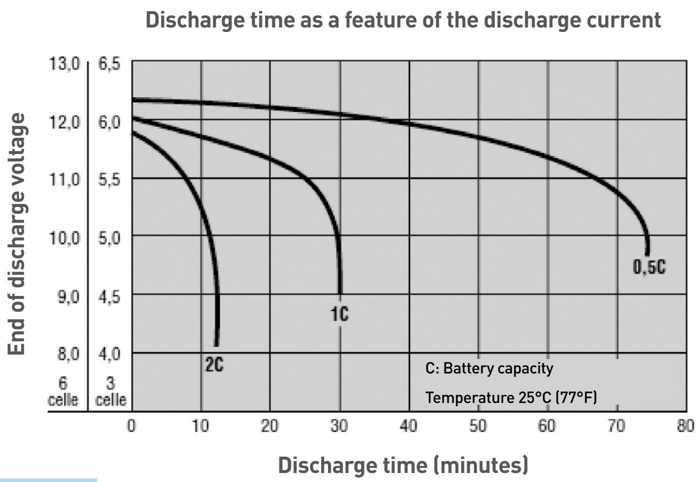
The batteries typically used in UPSs are sealed lead acid (SLA) and valve regulated lead acid (VRLA).

Nickel cadmium (NiCd) batteries, which are less sensitive to temperature, can be used In some special applications.



VRLA batteries are sealed hermetically, do not require any maintenance work, and have an internal gas recombination feature. In addition to ensuring a longer operating life, this feature also allows the UPS to be installed in rooms where people regularly linger.

This type of battery requires an air exchange that can be calculated according to the EN 50272-2 standard and for which the simplified formula can be seen below:



$$Q = 0.05 \bullet n \bullet I_{gas} \bullet CRT \bullet 10^{-3} [m^3/h]$$

Where:

Q = ventilation air flow in m3/h

n = number of battery elements

Igas = the current it produces, gas expressed in mA per Ah of the capacity allocated for the Ifloat buffer charge current (maintenance charge) or for the Iboost fast charge current

Crt = C10 capacity for lead acid elements (Ah), Uf = 1.80 V/element at 20° C
or C5 capacity for nickel/cadmium elements (Ah), Uf = 1.00 V/element at 20° C

The following values can be taken into account unless specified otherwise by the Igas battery manufacturer:

I_{gas}	Open vessel lead acid batteries	VRLA Lead acid batteries	Open Ni-Cd batteries
In buffer charge	5	1	5
In rapid charge (boost)	20	8	20

The EN 62040-1 standard indicates an Igas value, for the VRLAs, equal to 2 in the specific case where batteries are connected to a UPS.

4.1. Battery connections

Each battery has a nominal voltage value and a nominal capacity value (in Ah).

It is important to use batteries with the same voltage and the same capacity to ensure they function correctly.

The voltage across the series is equal to the sum of the voltages of the individual batteries when the batteries are connected in series.

The total capacity is equal to the sum of the capacities of the individual batteries when the batteries are connected in parallel.

The batteries are connected in series to reach the voltage levels required by the UPS. The battery series are connected in parallel in turn and so that they can reach the necessary capacity for the autonomy required.

E.g. using 12V 9Ah batteries:

- a series of 4 batteries corresponds to a total of 48V, 9Ah
- a parallel of 4 series of 4 batteries each, corresponds to a total of 48V 36Ah

Each UPS model has a specific DC voltage rating (Vdc) for the batteries, which implies that the number of batteries to be connected to the UPS in series must be the right number to have exactly this voltage value.

It will be possible to have one or more branches in parallel to achieve the required autonomy once the number of batteries in series has been set.

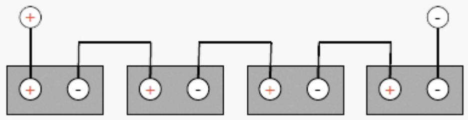
You cannot add branches in parallel indefinitely from a practical perspective, because you encounter very long charging times and the risk of current circulation caused by small imbalances between the large number of elements, in addition to those caused by space and cost issues.

This implies consequent issues with ageing and energy losses.

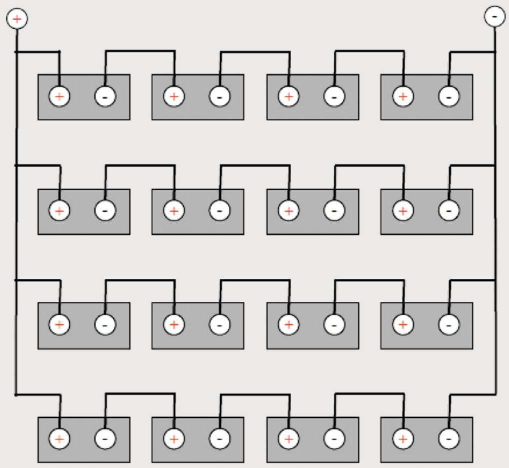
Further details related to the individual battery models are provided by the battery manufacturers themselves.

It is preferable as a general rule to use a few large batteries rather than a number of small batteries in case of long autonomy or high power.

An example of a series connection of four 12V 9Ah batteries, where there are 48V 9Ah in total.



An example of a series connection of four 12V 9Ah batteries, where there are 48V 36Ah in total.



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4.2. UPS autonomy calculation

It is normally the same UPS manufacturer that provides the autonomy values (in tables or as calculation software) for any UPSs that include internal batteries or involve already configured external battery cabinets.

It may be necessary under other circumstances to calculate the number of batteries to have a certain autonomy or, in contrast, to calculate the autonomy given by a set of already configured batteries. Nominal capacities in Ah normally refer to a 20-hour discharge period: this data is useful for a preventive evaluation; however, it is not optimal for accurately dimensioning autonomy times significantly in excess of 20 hours, as the autonomy period is not always equal to the ratio between the Ah and the discharge current.

The voltage and capacity of the batteries are not constant, but they do depend on the actual status of the batteries themselves, on the intensity levels, and the discharge duration.

This is why the battery manufacturer also reports other data and information in the technical data sheets. In particular, it includes curves and tables that indicate the duration of the discharge as a function of the power being supplied (it is considered constant during discharge) and the voltage obtained at the end of the charge (Vcutoff).

You can refer to these tables for UPSs, considering that the Vcutoff value is normally available in the UPS documentation, while the power to be taken from the batteries will be given by the load power supply divided by the DC/AC efficiency level, which is also specified by the UPS manufacturer.

The number of elements or blocks required for the desired autonomy can be obtained once these two values and the number of batteries to be connected in series have been identified.

Finally, it should be noted that, both UPS and battery manufacturers are offering software and applications more and more frequently to automatically make autonomy calculations.

Example:

UPS 40kVA, PF=1, Vdc=240Vdv, Vcutoff=1.70V/cell, DC/AC efficiency at 80% of charge $n_{80\%}$=95%

Charge 32kW, Autonomy 30 mins

Battery used: Vbat= 12V (formed from 6 cells in series of 2V), 40Ah

The power supplied by the batteries will be:

$$P_{bat} = \frac{P_{charge}}{\eta_{80\%}} = \frac{32{,}000\ W}{0.95} = 33{,}684\ W$$

From the constant power discharge table (at 25°C) taken from the battery data sheet:

F.V/time	2 mins	4 mins	5 mins	6 mins	8 mins	10 mins	15 mins	20 mins	30 mins	40 mins	45 mins	50 mins	60 mins	90 mins
1.60 V			1,794	1,636	1,373	1,263	968	788	577	463	421	387	335	244
1.65 V			1,673	1,534	1,303	1,205	944	763	564	454	417	386	334	240
1.67 V			1,624	1,494	1,275	1,182	935	753	559	451	415	386	334	239
1.70 V			1,549	1,430	1,228	1,143	916	737	**548**	442	409	382	332	236
1.75 V			1,422	1,321	1,149	1,075	877	704	530	428	399	374	325	231
1.80 V			1,302	1,217	1,069	1,006	825	675	507	410	383	361	314	226
1.85 V			1,188	118	996	943	773	639	486	396	364	337	296	222

We have established that each battery supplies 548 W for a 30 minute discharge, up to a voltage of a 1.70 V cell.
From the voltage Vbat allowed by the UPS, we can deduce that the single battery branch will contain:

$$\frac{V_{DC}}{V_{bat}} = \frac{240\ V}{12\ V} = 20\ \text{batteries}$$

So, to have 60 minutes, each branch will have to provide:

$$P_{branch} = 548\ W \times 20 = 10{,}960\ W$$

To supply the charge you will need:

$$N_{branches} = \frac{P_{bat}}{P_{branch}} = \frac{33{,}648\ W}{10{,}960\ W} = 3.07 \cong 3$$

Three branches of 20 batteries will therefore be needed, making a total 60 batteries, to have 30 mins of autonomy on a 32 kW charge.

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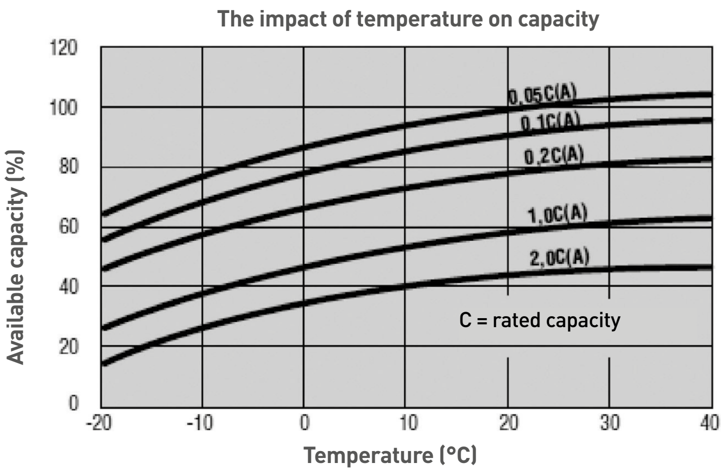
4.3. Battery life

Lead-acid batteries are able to supply high currents and work discontinuously, without necessarily totally discharging, and without suffering from the "memory effect" like other types of batteries do.

The battery manufacturers declare the "expected life time" of batteries. The most common cases for SLAs are: 5-6 years (standard life batteries) and 10-12 years (long life batteries). This data is indicative and refers to standard operating and environmental conditions that do not necessarily coincide with the actual operating conditions of the batteries.

Batteries are particularly sensitive to environmental conditions and method of use, given the chemical nature of the storage and supply of energy; in particular, high temperatures can drastically reduce battery life. In general, the nominal operating temperature of VRLA batteries is 20-25° C: the expected life will be halved for every 10° C increase in temperature.

THE IMPACT OF TEMPERATURE ON CAPACITY



The duration and intensity of discharges and recharges impact the life of the batteries with regards to how they are used.

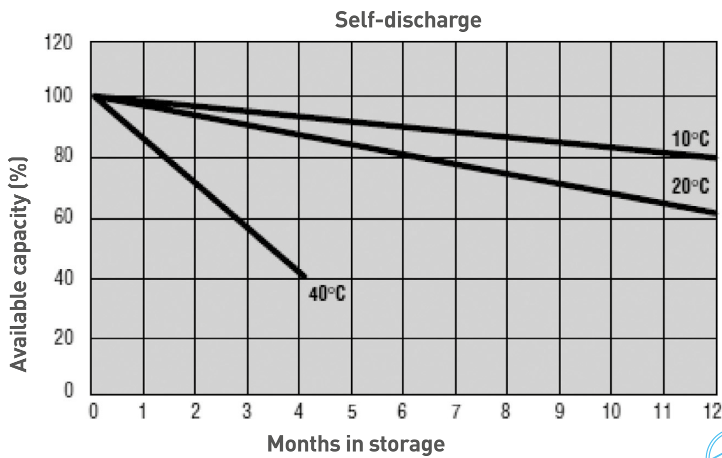
Currents which are too intense or too weak, very long and deep discharges, intense and prolonged recharges etc. may cause ageing and even damage to the batteries. The latest generation UPSs are adopting sophisticated battery management algorithms to overcome these phenomena. These algorithms optimise their use by dynamically controlling and adapting the voltages and currents in order to avoid deep discharges and ensure both effective and safe recharges.

The "intelligent" management of batteries allows for their status to be monitored continuously and reduces consumption related to their recharging, in addition to extending their life.

Batteries age and deteriorate, even if they are not used for a long period of time, because of the self-discharge phenomenon.

It is advisable not to leave the batteries disconnected for more than six months in order to prevent a permanent loss of capacity: even new batteries that are initially in good condition could present charging problems after this period of time has elapsed. In addition to self-discharge, the storage temperature also has a negative impact on the life of the batteries (self-discharge doubles with every 10°C increment in temperature).

SELF-DISCHARGE



4.4. Batteries inside the UPS

Modern UPSs make it possible to overcome this problem by managing to keep the batteries charged even when they are switched off (battery charge on stand-by). It is therefore sufficient to keep the UPS connected to the power supply, even if not in use, so that the batteries remain alive and active.

The UPS must always be connected to the batteries and report any disconnections or malfunctions promptly so that it is able to function correctly.

The latest generation UPSs have various automatic battery testing and monitoring functions and are able to alert the user about potential anomalies in order to prevent any issues even before the batteries have reached the end of their life.

In spite of this, it is still advisable to carry out periodic checks and maintenance on the batteries (at least once a year). It is also advisable to renew the battery system before the batteries have been fully exhausted.

It is also important to consider the recharge time when choosing batteries so that a certain level of autonomy can be reached: with the same nominal UPS power, the greater the autonomy, the greater the number of batteries and, consequently, the longer the recharge time.

It is advisable to calculate the autonomy based on the actual load to be protected rather than on the nominal power of the UPS so that you can optimise the choice of the number of batteries.

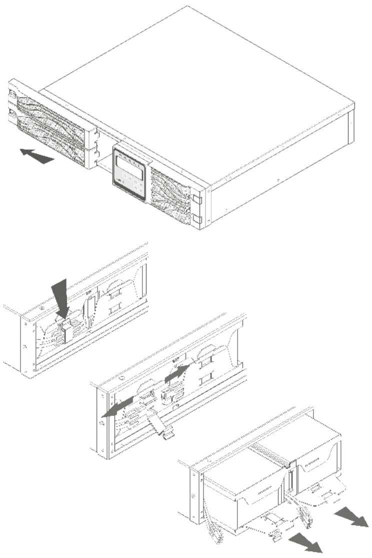
4.5. Batteries inside the UPS

The batteries are generally contained within the UPS itself in small power UPSs.

These batteries guarantee the minimum level of autonomy (normally known as "standard autonomy") which is usually around 5 minutes for very small UPS, such as Line Interactive types with a power lower than 1,000 VA, or 10 minutes for Online Double Conversion UPS with a power rating of up to 10 kVA.

Battery kit
(No.3 12V 9Ah batt)

UPS MegaLine 1-10kVA
internal battery cabinet



Internal batteries UPS Daker DK
Plus 1-2-3 kVA Online Double

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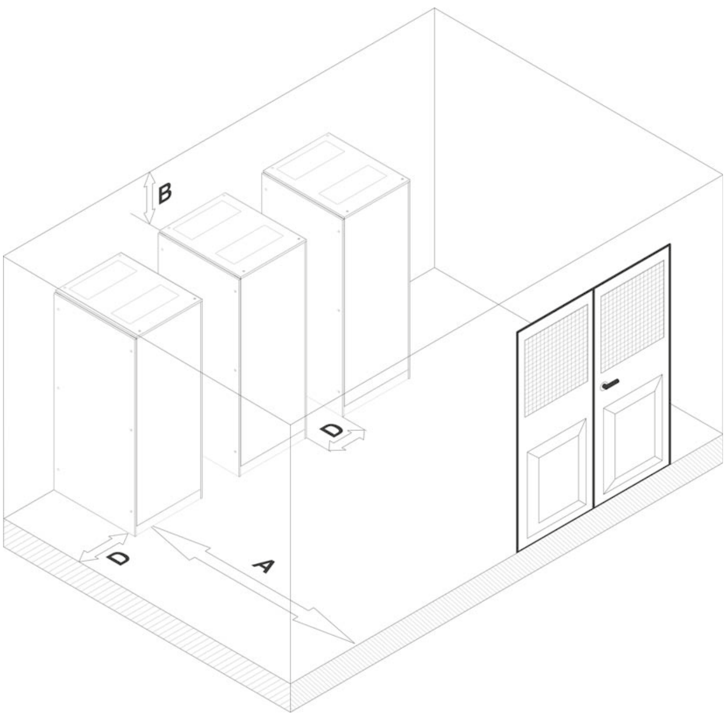
4.6. External battery cabinets

One or more external battery cabinets are used for autonomies higher than the standard specification or for medium power UPS that do not have space for internal batteries. The UPSs have a port dedicated to connection wiring with the external battery cabinet. The connection system must ensure that connections can be made easily in compliance with electrical safety standards.

The battery cabinets inside medium power UPSs (between 10 kVA and 100 kVA) where the DC currents and voltages are higher must include suitable disconnection and protection systems (normally fuses) to ensure safety and the ease of connecting several cabinets in parallel and connection to the UPS.

The capacity and the number of batteries can increase considerably even for low autonomies for UPS with power levels in excess of 100 kVA. The battery cabinets in these cases are large in size and very heavy.

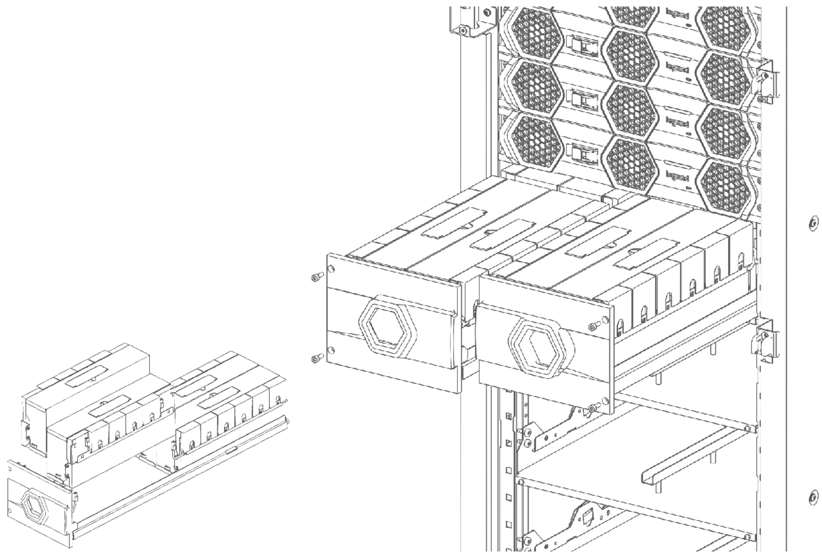
The currents involved are also high, therefore the wiring and the disconnection and protection systems must be dimensioned accordingly. The high-power battery cabinets are installed in dedicated rooms, preferably with air conditioning and adequate ventilation (EN 50272-2) and which can only be accessed by qualified personnel. It is preferable to house the batteries on open shelves, which can be inspected and maintained easily, in the case of battery spaces with many large capacity elements; access to these areas is reserved exclusively for experts and authorised personnel.



4.7. UPS with battery modules

In addition to the electronics in modular architecture UPSs (see related paragraph), the batteries can also be housed in specific modules, which allow for quick and easy installation and maintenance work. The battery modules can be housed both inside the UPS and in external cabinets.

Keor MOD modular UPS with internal battery modules



Battery drawers

Trimod HE modular UPS with internal battery modules

Battery drawer

External cabinet with battery modules for Trimod modular UPS

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4.8. Lithium batteries and other energy storage systems

Lead-acid batteries, in particular VRLAs, are undoubtedly the most common solution in the world of UPSs, in spite of their limited expected life and temperature sensitivity. This is thanks to the good quality to price ratio and ease of supply; there are also, however, other, alternative forms such as nickel cadmium batteries, super capacitors, and fly wheels (mechanical flywheels). The use of these devices is normally restricted to specific or niche applications.

Lithium-ion battery models have become more widespread in UPS applications over recent years. This technology, which was initially created for small portable electronic devices (laptops, smartphones and the like) is portrayed as an interesting alternative, especially for high-power UPS systems in highly technological applications such as data centres.

The main benefits of lithium batteries compared to classic VRLAs are: high energy density (they take up much less space with the same electric charge), low weight, and long life. The main disadvantages are the exceedingly high costs and the need for control and safety circuitry (this is required to manage the high energy density).

Lithium-ion batteries can be of various types and each has various levels of performance and usage; their choice must be made wisely considering, on a case-by-case basis, the demands of the application.

Finally, it should be noted that some VRLA battery manufacturers have launched new models of so-called "pure lead" batteries on the market in recent years. These batteries are equivalent to normal VRLAs, in terms of using them with UPSs; however, they do have lower sensitivity to high temperatures, higher energy density and a longer life expectancy, which makes them more akin to the performance of lithium-ion batteries.

These advantages do of course also result in them having a higher price than standard VRLAs.

5- UPS REFERENCE STANDARDS

The main standards governing the characteristics of the UPSs are shown below.

EN 62040-1 (ELECTRICAL SAFETY)

This standard outlines the basic safety requirements for UPSs. This includes the requirements of the general standard regarding the safety of electrical devices: EN61000-1. This standard is essential, since UPSs are, for all intents and purposes, power generators, contain high-voltage elements inside, and, in many cases, can generate high currents depending on their nominal power.

EN 62040-2 (ELECTROMAGENTIC COMPATIBILITY)

This standard defines the immunity and emission limits of electromagnetic disturbances that may affect UPSs. Particular attention should be paid to the limits of electromagnetic emissions because the UPSs include power converters (rectifier, inverter, battery charger, etc.) which often operate at high frequencies and may generate conducted disturbances on the input, output or battery cables., or emit waves that could disturb other equipment in close proximity to the UPS itself. The standard requires that these EM emissions fall within the limits permitted for various types of systems and applications.

This standard also establishes the level of immunity to electromagnetic disturbances which the UPS must have. Immunity is particularly important in cases where the UPS is installed inside systems where there are devices that can cause electromagnetic disturbances (e.g. industrial applications, telecommunications equipment, electrical workshops, etc...)

This standard also establishes, among the various requirements, the minimum level of immunity to overvoltage pulses between phases, neutral and earth.

EN 62040-3 PERFORMANCE CHARACTERISTICS

This standard concerns the performance level of the UPSs under various functional aspects: electrical, energy, environmental etc.

The standard describes - in detail and unambiguously - the procedures for carrying out laboratory tests on UPSs in order to obtain the nominal data and technical specifications that the manufacturer will report in the technical data sheets, manuals and in any commercial documentation for the product.

This standard also defines a classification of UPSs based on their performance level.

Standard for centralised power supply systems CEI EN 50171

The UPS is also required to comply with the EN50171 standard in the specific case of protecting safety equipment, in addition to complying with the 62040 series standards. This standard specifies the general requirements for independent centralized power supply systems for safety equipment. This standard applies to systems which are connected permanently to alternating current supply voltages not exceeding 1,000 V and which use batteries as an alternative source of power.

The term CPSS (Central Power Supply System) specifies a centralised and independent system for powering safety equipment such as, for instance: safety lighting equipment, electrical circuits for automatic fire-fighting systems, paging systems and safety alert systems, fume extraction equipment, carbon monoxide signalling systems or specific safety systems for particular types of buildings (for example those which are located in high risk areas). A UPS must meet not only the requirements of the product standards relating to the EN 62040 series when it is used to power these essential safety systems, but must also meet any additional requirements of the EN 50171 system standard.

The main additional features that the CPSS must include with respect to the UPS are:

- *the casings must be of adequate mechanical strength and be resistant to both heat and fire*
- *the chargers must be able to charge their batteries automatically after they have been completely discharged, so that they can provide a minimum of 80% of the specified autonomy within 12 hours from the start of charging. The charger must be designed so that a short circuit at the output cannot cause any damage.*
- *the inverters must be able to permanently handle 120% of the prescribed charge for the rated life. The inverter must be protected against damage to any components, other than fuses or other protective devices, caused by battery polarity reversal.*
- *batteries for centralised power systems (CPSS) must have a life declaration of at least 10 years at an ambient temperature of 20°C. Batteries for low power systems (LPS) must have a life declaration of at least five years at an ambient temperature of 20°C.*

5.1. EN62040-3 Classification

The classification of UPSs according to their performance level is shown in the table below:

EN 62040-3 CLASSIFICATION		
AAA	**BB**	**CCC**
Dependence of the output on the input	Output waveform	Dynamic output performance

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5.2. Dependence of the output on the input

The first three characters of the classification define the type of UPS according to the dependence between output voltage and current in relation to the input voltage and current:

- **VFI (Voltage and Frequency Independent)**: this is the UPS in which the output is independent of variations in the supply voltage (mains) and where any frequency variations are controlled within the limits stated under the IEC EN 61000-2-2 standard.
- **VI (Voltage Independent)**: this is the UPS in which the variations in the power supply voltage are stabilised by electronic/passive regulation devices within the limits of routine operation.
- **VFD (Voltage and Frequency Dependent)**: this is the UPS in which the output is dependent on the variation of the power supply voltage (mains) and on the frequency variations.

It is clear, with reference to the types of UPS listed above, that:

- the **VFI** class will include the **Online Double Conversion UPSs**. The output inside these UPS has been entirely rebuilt by the inverter regardless of the voltage and frequency values on input at the rectifier.
- the **VI** class will include the **Line-Interactive UPSs**. The output voltage inside these UPS is stabilised by the AVR at a constant value, regardless of the input voltage values; the frequency, on the other hand, remains unchanged as there is no circuit able to stabilise it.
- the **VFD** class will include the **Offline UPSs**. The output is directly connected to the input inside these UPSs, meaning that the voltage and frequency remain unchanged.

5.3. Output waveform

The second part of the classification code defines the output waveform during routine operation (first letter) and on batteries (second letter).

The letters can be S, X or Y with the following meaning:

- S: the waveform generated is sinusoidal, with total harmonic distortion THD% of <8% and harmonics within the limits indicated in IEC 61000-2-2 in all the reference linear/non-linear charging conditions.
- X: the waveform generated is sinusoidal, under the linear charging conditions as for class "S". The total distortion factor with reference non-linear charging is THD%> 8% if applied outside of the limits specified by the manufacturer.
- Y: the waveform generated is non-sinusoidal and exceeds the limits specified in IEC 61000-2-2. The type of waveform may vary from one product to another.

The output waveform is closely linked to the type of UPS and the type and quality of its internal circuits (e.g. inverters in Online types and inverters and AVR in Line-Interactive types).

It is possible, for example, to find Offline or Inteactive Line UPS on the market with simple inverters with pseudo-sinusoidal output (class Y), Line-Interactive with category S sinusoidal output and Online Double Conversion with high-performance inverters with THDv <1% (which are very common in category S).

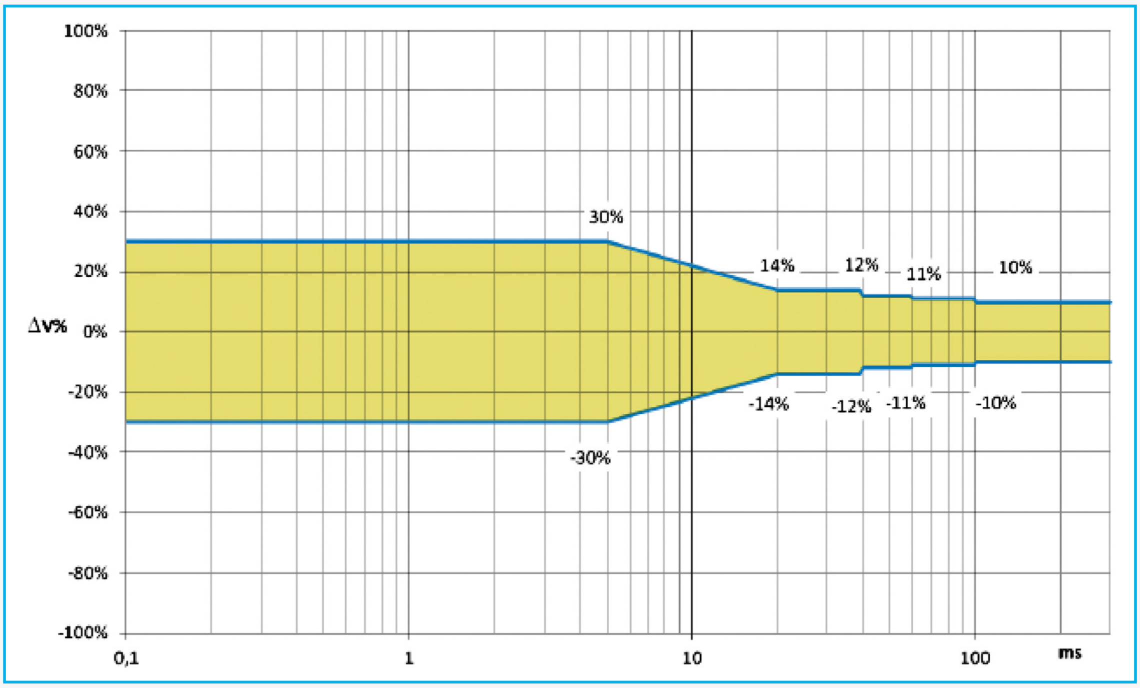
5.4. Dynamic output performance

The third part of the classification code defines the dynamic performance of the output voltage under load variations in three different categories:

- variation of the operating modes (routine and running off the battery);
- step-by-step linear load insertion in both routine and battery modes:
- step-by-step non-linear load insertion in both routine and battery modes.

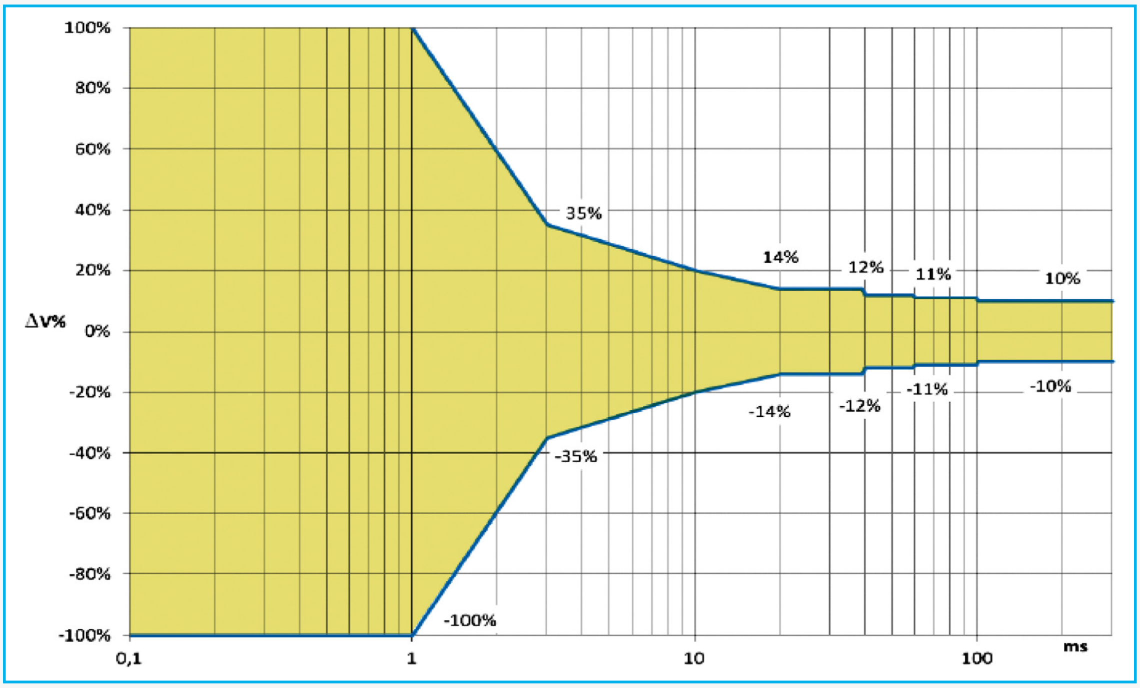
The dynamic performance levels can estimate the values 1, 2 and 3 for each of these conditions with the following meaning:

1 **The percentage variations of the instantaneous voltage values, compared to the nominal ones, fall within the area specified in the diagram below. No voltage interruption.**



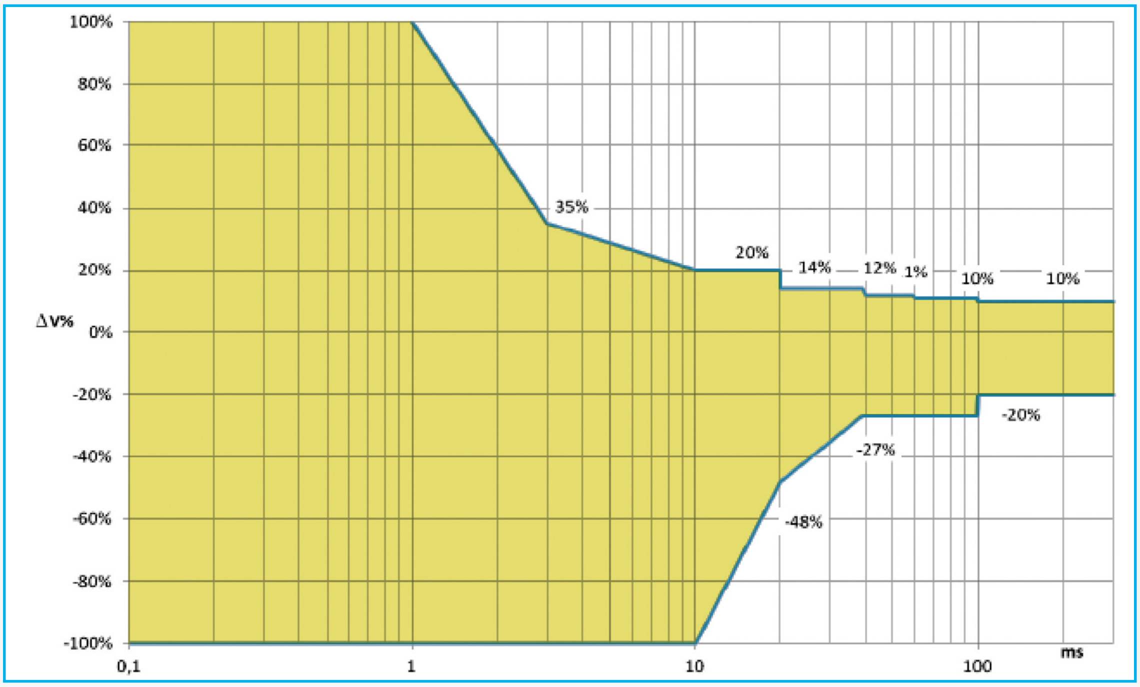
Dynamic characteristic of the output voltage of a UPS with performance category 1

2 The percentage variations of the instantaneous voltage values, compared to the nominal ones, fall within the area specified in the diagram below. The voltage is zero for a period of ≤1 ms.



Dynamic characteristic of the output voltage of a UPS with performance category 2

3 The percentage variations of the instantaneous voltage values, compared to the nominal ones, fall within the area specified in the diagram below. The voltage is zero for a period of ≤10 ms.



Dynamic characteristic of the output voltage of a UPS with performance category 3

The dynamic performance level is also closely linked to the type of UPS and the type and quality of its internal circuits (e.g. inverters in Online types and inverters and AVR in Line-Interactive types).

We should emphasise the fact that the standard indicates the minimum characteristics to be included in the various performance categories; however, with continuous technological evolution, the UPSs currently on the market may have higher performance levels than those specified by the standard.

Example:

VFD	**SX**	**322**	Offline UPS: output voltage and frequency dependent on the input. Output voltage: sinusoidal on mains, pseudo-sinusoidal on batteries. Mains-battery switching with sag ≤10 ms. Step load change to mains or battery with sag ≤1ms.
VI	**SY**	**311**	Line Interactive UPS: output voltage independent of the input. Output voltage: sinusoidal on mains, sinusoidal (distorted) (THDv> 8%) on batteries. Mains-battery switching with sag ≤10 ms. Step load change to mains or battery without sag.
VFI	**SS**	**111**	Online Double Conversion UPS: output voltage and frequency independent of the input. Output voltage: sinusoidal both on mains and on batteries. Mains-battery switching without sag. Step load change to mains or battery without sag.

6- TYPES OF LOAD

You will need to know the characteristics of the load that the UPSs must protect once the UPS types and performance categories have been defined.

The loads can be of various kinds, with different power requirements.

For instance, there are some particularly sensitive loads that require significant voltage and frequency stability, or loads that are entirely indifferent to the quality of the power waveform, loads capable of withstanding voltage sags or loads that only allow micro-interruptions lasting just a few milliseconds.

6.1. IT loads (ITIC curve)

UPSs are often used to protect electronic equipment, normally computer equipment: it is therefore particularly interesting to know the power supply characteristics which are required by these devices.

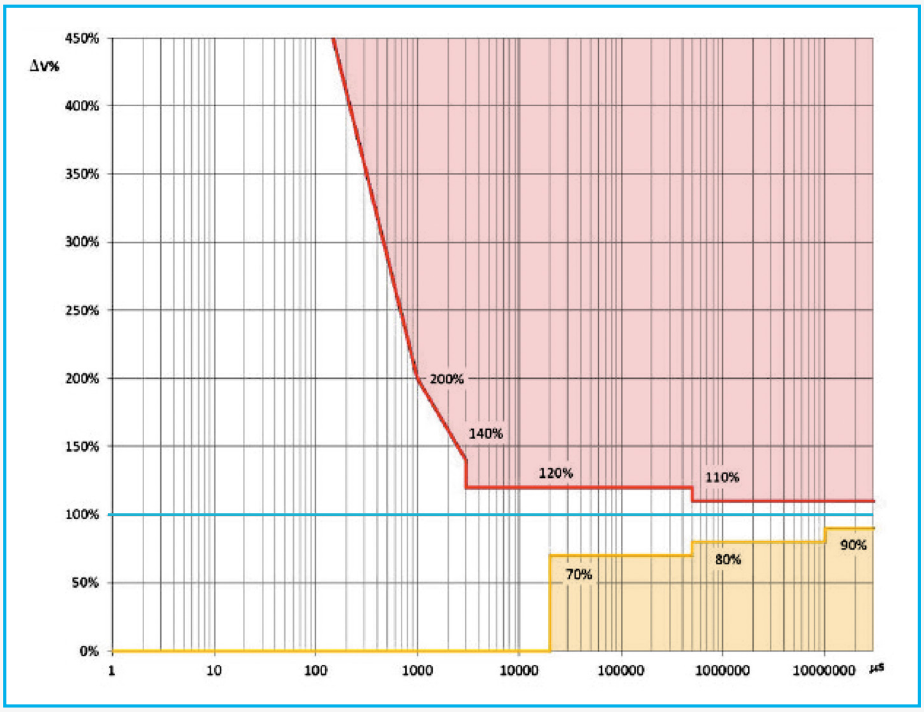
One of the few application notes acknowledged internationally in this respect is the ITIC (Information Technology Industry Council) curve, which represents the updated version of the well-known CBEMA (Computer Business Electronic Manufacturer's Association), which itself was also incorporated into the ANSI/IEEE "Standard 446 -1995" (IEEE Recommended practice for emergency and stand-by power for industrial and commercial applications").

The ITIC ex-CBEMA immunity curve (see the diagram) was generated with exclusive reference to Information Technology Equipment (ITE), i.e. substantially to PCs and similar devices, and is based on a simple evaluation in terms of amplitude (in addition to and less than the rated voltage) and the duration of any disturbance to the supply voltage.

These curves display the percentage voltage variations, with respect to the nominal value of 230V, and which is accepted by the powered devices as a function of the duration of these variations.

The white area in the diagram below represents all of the situations in which the device is not affected by the variation in voltage.

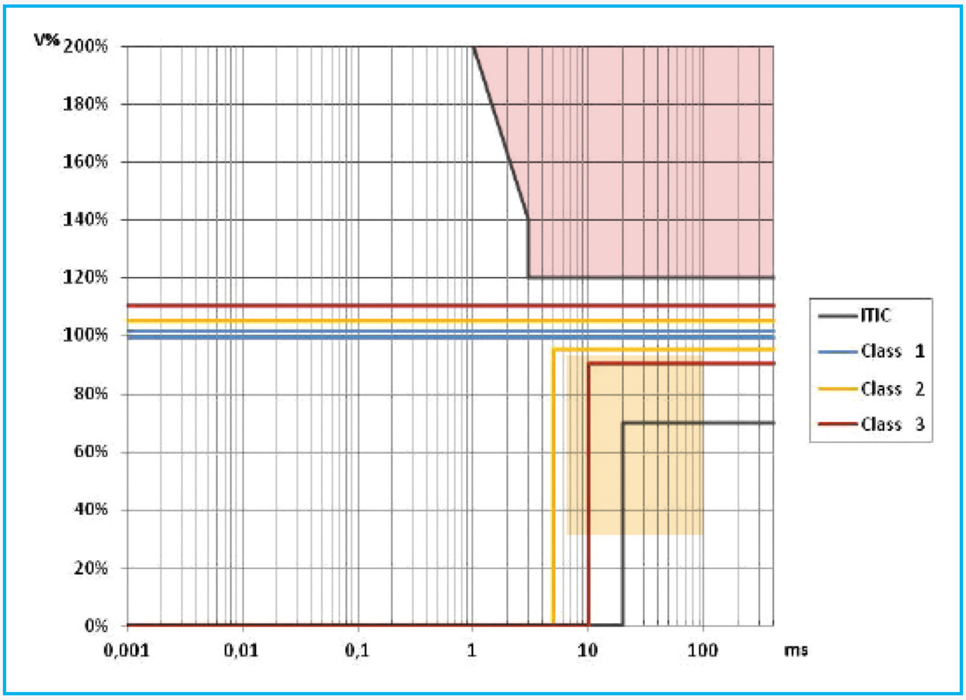
The coloured areas, on the other hand, represent situations in which malfunctions or even breakdowns may occur. In simple terms, it is obvious that the larger the voltage variation, the shorter the time in which the electronic devices are able to withstand any variation without consequences.



ITIC curve: the area in WHITE represents all of the combinations of variations in supply voltage and duration, in which the electronic device does not experience any changes in operation.

The area in RED represents the situations in which the device may become damaged, while the area in orange represents the situations in which the device may experience malfunctions or even be shut down.

It has been noted that all the dynamic performance categories fall within the permissible area of correct operation of the IT devices when comparing the ITIC curve with the performance categories specified under the EN62040-3 standard.



This specifically includes:

- **Class 1 UPS (Online):** these supply the IT loads with optimal power by having a much tighter voltage tolerance than that permitted by the ITIC curve.
- **Class 2 and 3 UPS (Line-Interactive or Offline types):** these can also protect the IT loads within the area permitted by the ITIC curve despite the voltage sag caused by mains-battery switching.

The IT loads are usually very stable with constant absorption and do not make any particular demand for the UPS power to be dimensioned. It should be considered, however, that these types of loads include the power supply stage at their input, which is typically a transforming and rectifying electronic circuit (e.g. switching power supply),

6.2. Non-IT loads

In addition to the IT loads, the UPS could be called upon to power other types of devices such as motors, lamps, coolers, industrial machinery, laboratory instruments, radio communications equipment etc.

More and more frequently, the types of loads mentioned are being controlled or powered by electronic circuits that can be likened to IT devices (e.g. numerical control systems, electronic power supplies, measurement and control devices, etc.); therefore, these applications fall into the category of devices described by the ITIC curve from a UPS perspective. "Non-IT/electronic loads" are all the devices in which there is no electronic control and power supply circuit powered directly by the UPS.

From a UPS perspective, non-IT loads to which particular attention should be paid can be divided into the following categories:

- Loads with high starting points
- Loads with repetitive absorption peaks
- Purely resistive loads
- Loads with a strong capacitive component
- Loads with harmonic currents
- Loads with potential back feed

6.2.1. Loads with high starting points

Loads such as motors, power transformers, lighting systems, etc. have high starting currents (even as high as ten times the rated current).

These starting currents lead to a peak of absorbed power greater than the rated power (steady-state). In this case, if the UPS is dimensioned for steady-state power, it will feel the current as an overload when starting up and potential scenarios are shown below.

Where there is an input network:

- In **Offline or Line-Interactive UPSs**, this overload can cause the thermal protections inside the UPS to intervene and to switch the UPS off.
- In **Online UPSs**, the load will be switched automatically to the bypass line; it is possible to set the UPS start-up in bypass mode in some models and then return to the inverter when the charge is fully operational.

In battery mode:

- The inverter will work in overload (by restricting the output current) for a certain time interval (depending on the intensity of the overload) in all types of UPS, and it will switch off by disconnecting the power supply to the load if the starting current does not run out within this period.

Only the **Online UPSs** can therefore supply peaks of considerable intensity thanks to the automatic bypass; however, this is only possible when using mains power. On the other hand, these will not be powered in battery operation if the peaks are of a duration and intensity in excess of the UPS overload capacity.

You will need to oversize the UPS so that you have a nominal power higher than the absorption peak level in order overcome this issue.

6.2.2. Loads with repetitive absorption peaks

These may for example consist of motors or other power devices which are activated repeatedly during their routine operations.

The situation is comparable to that of the starting peaks. The difference being that it is now not possible to take advantage of the bypass start-up in Online Double Conversion types, and it is also impossible to ensure a continuous power supply in battery operation.

The only solution is to opt for a more powerful UPS.

Load type	Initial current	Duration
Incandescent lamps	10÷20 In	0.1 ÷ 0.15 s
Halide lamps	2 In	3 ÷ 4 min
Fluorescent lamps	6 ÷ 8 In	< 1 s
High-pressure sodium vapour and mercury vapour lamps	1.6 In	4 ÷ 5 min
Asynchronous motors	4 ÷ 8 In	2 ÷ 20 s
Transformers	7 ÷ 12 In	< 1 s

6.2.3. Purely resistive loads

Purely resistive loads could be switched on and off repeatedly and fall into the category of loads with repeated absorption peaks. On the other hand, they do not require specific attention if they have constant absorption.

However, the resistive loads could sometimes be fed with non-symmetrical absorption (e.g. half-wave rectifiers, which absorb only in the positive or negative half-period). Some inverters may function in a non-optimal way in this case, which causes imbalance in the DC bus, which, could lead to the UPS being blocked if pushed to its limit.

The solution is also to oversize the UPS under these circumstances.

6.2.4. Loads with a strong capacitive component

Inverters are generally able to provide both active power and reactive power (the rated power of the UPS is actually always indicated in VA); however, there is a limit of reactive power that can be delivered imposed by the inverter architecture. The absorption of reactive power is normally indicated indirectly through the power factor of the load, which is defined as the ratio between active power (Watt) and apparent power (Volt Ampere).

UPS manufacturers usually specify the minimum values permitted for capacitive and inductive power factors (PF) of the load. The inverter weakens and is no longer able to provide its rated power if the values fall any lower. The weakening will become even more apparent in the case of capacitive loads.

There are a number of common UPS on the market that permit, without weakening, inductive PF> 0.8 and capacitive PF> 0.9 (in the most recent models capacitive PF> 0.8 is equal to the inductive one).

The solution is also to oversize the UPS under these circumstances, if the load is beyond the rated limits.

These situations are quite rare because the same electricity network operator normally imposes restrictions on the power factor of the loads, prescribing the use of power factor correction systems in the event of reactive loads.

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6.2.5. Loads with harmonic currents

These are also often referred to as non-linear loads: the absorbed current is not sinusoidal.

This type could also include IT loads which have, on input, switching circuits with strong harmonic absorption.

Current harmonics could make inverters with low dynamic performance levels unstable. These could be perceived by the UPS as overloads if the distorted current has peaks. A high harmonic content may also lead to an absorption of reactive power with low PF values.

The UPS could be oversized or you could opt for a UPS with high dynamic performance inverters under these circumstances (e.g. Class 1 according to the EN62040-3 standard), with low output voltage tolerances even on non-linear loads (e.g. THDv <1%), and with high crest factors (e.g. 3:1).

6.2.6. Loads with potential back feed

The typical example of these loads is motors with active braking.

The majority of UPSs (with the exception of special, specifically designed models) are not compatible (or are only partially and under certain conditions compatible) with this type of load; the back feed in some cases may even cause damage to the inverters.

The same electricity grid operators generally regulate the standards and conditions for re-feeding energy into the grid and any energy regenerated in modern machinery is usually managed by the same power supply and drive circuits as the motors that protect the upstream grid from the effects of the load. The problem remains in particular areas such as railway traction or heavy industry. The question always remains whether it is entirely necessary to use a UPS for these devices.

Where possible, good practice suggests using the UPS exclusively to supply logic and control circuits (effectively IT loads) on electrical loads that are not very sensitive to mains disturbances (e.g. motors, ovens, etc.). This significantly reduces the power of the UPS to be used.

7- POTENTIAL APPLICATIONS

Each type of UPS offers specific advantages, as highlighted in previous paragraphs.

Thus, by combining the functional characteristics of the UPSs, the characteristics of the loads being powered, and the environment in which it is being used, it is possible to list and group the potential applications for each type of UPS.

Offline	Line-Interactive	Online Double Conversion
- Small electronic loads - Home computer - Basic home applications	- Workstation - Internet stations - Telephone switchboards - Cash registers - POS terminals - Fax - Low power emergency lamp systems - Safety systems - Domestic and industrial automation	- Corporate IT network - Telecoms - Electro_medical - Any other potential application that requires continuous operation and high-quality energy ...

8- CHOOSING THE UPS

It is important to carefully evaluate the characteristics of the application you wish to protect in light of what has been said in the previous paragraphs, so that you can identify the UPS that best suits your needs.

As we have seen, the fact that a UPS has sufficient power to handle the actual load does not guarantee that you have made the right choice.

You will need to know the following basic parameters to dimension a UPS correctly:

- **APPARENT power:**

  this is the maximum output power available from the UPS expressed in VA.

- **ACTIVE power:**

  this is the maximum output power available from the UPS expressed in W.

- **Power factor (PF)**

  this is the ratio between active and apparent power (W/VA).

- **Autonomy:**

  this is the maximum time in which the UPS can deliver power when there is no supply.

- **Power supply parameters:**

  these are the number of phases, the status of the neutral, the voltage and frequency values of the power supply line, etc.

- **Output power supply parameters:**

  these are the number of phases, the status of the neutral, the voltage and frequency values of the UPS output line.

The input parameters must of course be compatible with the power supply and the output parameters must be compatible with the charges being powered and protected.

In-depth study

Rated power factor

The rated power of the UPSs is normally expressed in VA, and this is because the UPSs are able to supply both active and reactive power according to the power factor of the load.

The rated power factor of the UPS is often specified next to the rated power itself in VA. This value is not necessarily equal to the actual power factor of the load (which is due to the very nature of the load itself); however, it does allow you to know in what condition the UPS is able to deliver its maximum active power (in Watts).

For example, a 10kVA UPS with a PF = 0.9 is capable of delivering a maximum of 9kW.

In light of this, it is essential to know the actual active power absorbed by the load and, consequently, to choose a UPS that is able to supply this power.

UPS with nominal PF values of 0.7 and 0.8 were very popular in the past; however, with the natural technological evolution, UPS with a PF = 0.9 or even PF = 1 have become increasingly more frequent in recent times.

The problem of evaluating the maximum active power of the UPS with a PF = 1 no longer arises because the rated power in VA coincides with that in W.

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In addition to the basic parameters mentioned above, in compliance with the EN62040-x standards and the (EN62040-3) performance category, it is also useful to know the following additional technical data:

Input parameters:

- Input voltage tolerance
- Input frequency tolerance
- Input PF
- THDi % (harmonic content of the input current)
- Maximum input current
- Any absorption peaks when starting up the UPS
- Any protection on the input line including those inside the UPS
- Recommended protections to be placed upstream of the UPS
- Whether or not there is a dedicated input for the bypass line (only for Online types)
- Any overvoltage protection
- Whether or not there is any back feed protection

Output parameters:

- Output voltage tolerance
- Output frequency tolerance
- Frequency window for synchronising the output with the bypass line (only for Online types)
- DC/AC and AC/AC energy efficiency conversion levels (only for Online types) at various load percentages
- THDv% (output voltage harmonic content)
- Maximum output current
- Overload capacity
- Output current crest factor
- Short-circuit current
- Whether or not there is an isolating transformer
- Whether or not there is a manual maintenance bypass

Battery parameters:

- Battery type
- Expected life
- Number of cells
- Rated battery voltage
- Rated capacity
- End of discharge voltage per cell
- Charging time
- Charging method
- Rated discharge current
- Quantity and type of battery connection
- Any protection on the battery line included inside the UPS
- Recommended protection to be placed between the batteries and the UPS
- Sections and lengths of the battery cabinet and the UPS connection cables
- Technical data regarding any additional battery chargers

Mechanical and environmental data:

- Size
- Weight
- IP degree of protection
- Ventilation requirements and characteristics
- Cable input
- Whether or not there are any lifting eye bolts or wheels for handling
- RAL colour
- Thermal dissipation in BTU/h
- Operating temperature
- Storage temperature
- Relative humidity
- Maximum altitude without weakening

Communication and reporting:

- Type of control panel and display
- Measurements and reports visible on the control panel
- Diagnostic information, event memory and historical data available on the display or via software
- Communication ports (RS232, RS485, USB, logic signals)
- Possibility of connecting network interfaces
- Signal ports with clean contacts
- Any signal input ports
- Emergency Power Off (EPO) contact port
- Signal port for controlling the external back feed protection device
- Possible connection of environmental sensors (e.g. temperature and humidity)

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9- SYSTEM ARCHITECTURE

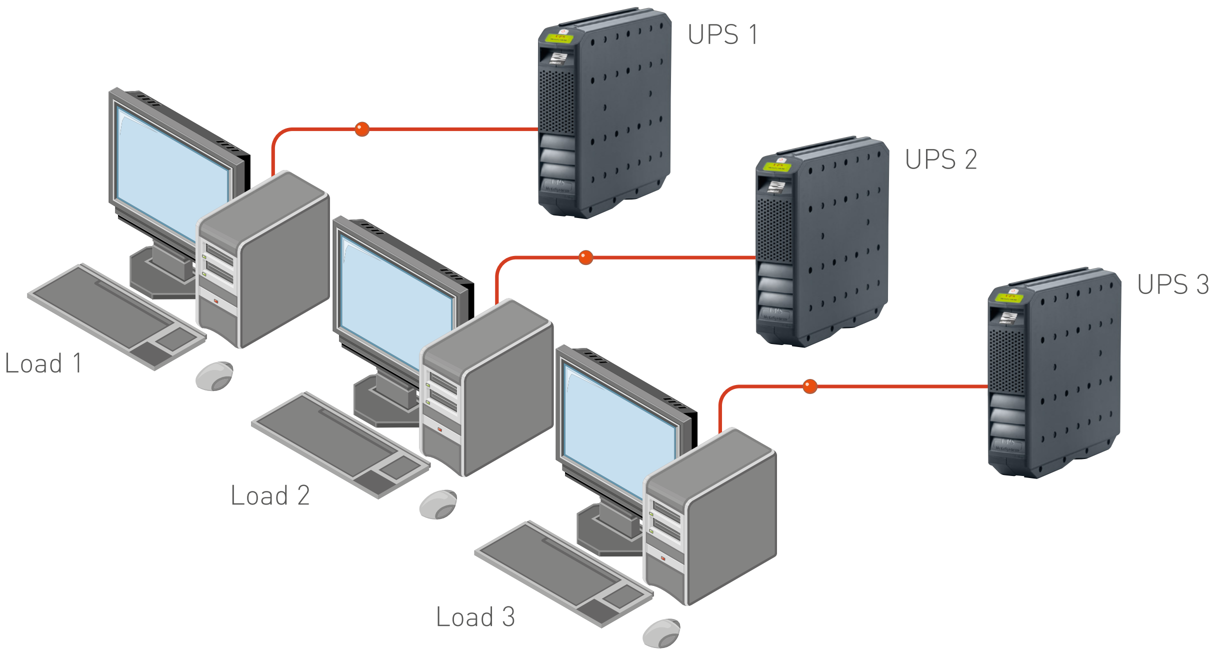
The safety, reliability and availability characteristics that a UPS system can guarantee are dependent not only on its intrinsic characteristics, but also on the way it is both used and managed. We are talking specifically about system architecture to describe how the UPSs (or their components) are installed and used in order to safeguard the devices.

There are various types of architecture, each with its own advantages and disadvantages to be assessed from time to time according to the demands and characteristics of the application being protected.

DISTRIBUTED ARCHITECTURE

Distributed architecture is used in cases where the application being protected is not particularly critical and where there are logistical difficulties (for example: several rooms, a pre-existing system, etc.).

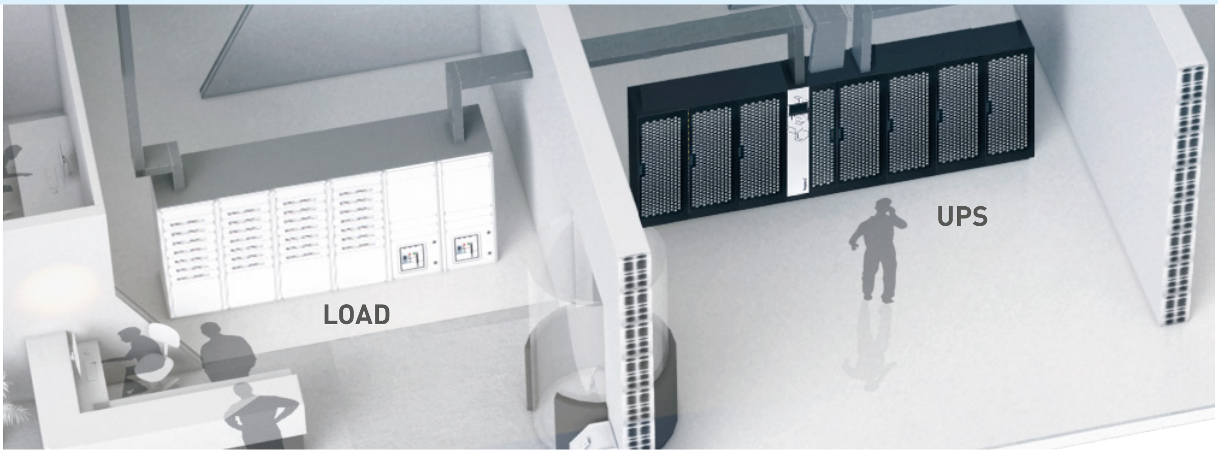
ADVANTAGES:	DISADVANTAGES:
Existing wall sockets can be used	Complex management and monitoring: a number of UPS located in different points
Dimensioning dedicated to the individual loads which require protection	Long and complex maintenance work: checking and replacing batteries on a large number of systems at different times.
Small independent UPS in close proximity to the loads to be protected	Emergency shutdown to be managed for each machine
Expansions or renovations dedicated to each single UPS station	Difficulty in implementing redundancy
Existing UPS can be serviced and used alongside new ones	Increased management and maintenance costs. Increased electricity consumption.



CENTRALISED ARCHITECTURE

Centralised architecture is based on the use of one single UPS to protect the entire load:

ADVANTAGES:	DISADVANTAGES:
One single system to install and manage (simpler and more cost-effective than a number of small systems)	A single system can constitute one single point of failure (distribution criticality). This can be avoided with redundant installations with a consequent increase in costs.
One single system to service (simpler and more cost-effective than a number of small systems)	The UPS is generally far from the load being protected.
A longer life time for both the UPS and for the batteries	Larger dimensions
Increased energy efficiency levels (lower electricity consumption)	Installation, wiring and autonomy expansion costs can be high
The UPS is normally located in a protected and safe technical area under optimal environmental conditions.	Specialist technical personnel are normally required for installation and maintenance work



PARALLEL CENTRALISED ARCHITECTURE

Parallel architecture is a centralised architecture that is based on the parallel connection of two or more UPS.

ADVANTAGES:	DISADVANTAGES:
Two or more UPS in parallel can offer total redundancy if they are dimensioned properly: the downtime of one UPS does not alter the operation of the other UPS which continue to protect the load	You will need to install two or more UPS, each with its own cabinet, its group of batteries and the input and output wiring: large size and high costs.
One single multi-UPS system to service (simpler and more cost-effective than a number of small systems)	The UPS is generally a far from the load being protected
Possibility of reaching high powers by adding the power of the UPSs in parallel.	You will need to create a parallel connection panel for the UPSs.
The possibility of expanding the power by adding one or more UPS in parallel	Costs for installation, wiring and autonomy expansion can be high
The UPSs are normally located in a protected and safe technical area under optimal environmental conditions	Specialist technical personnel are required for installation and maintenance work

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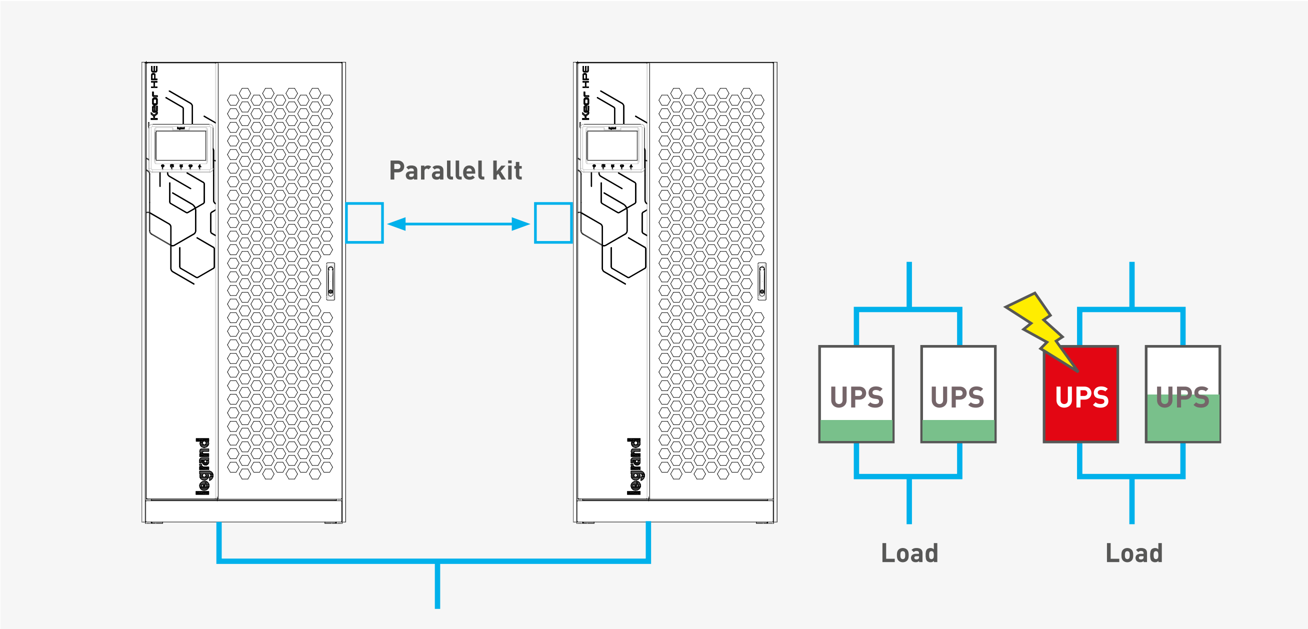
PARALLEL CENTRALISED ARCHITECTURE (CONTINUED)



One unusual feature of the parallel architecture is the synchronization of the bypasses: the parallel architecture must also take into account the synchronization of the static bypasses of each UPS along with any external manual bypass.

The command logic must instantaneously switch all UPSs connected in parallel to static bypass if a UPS has been switched to bypass, or if an external manual bypass has been shut off.

SYNCHRONOUS CENTRALISED ARCHITECTURE

Synchronous architecture is a centralised architecture, which is based on the connection of two UPS with outputs synchronised with one another (synchronism can sometimes be achieved between two groups of UPS connected in parallel):

ADVANTAGES:	DISADVANTAGES:
Two synchronous UPS can offer redundancy if suitably dimensioned and combined with an automatic switching system (ASS): the downtime of one UPS does not alter the operation of the other UPS to which the load can be diverted, which continues to be protected	You will need to install two UPS, each with its own cabinet, its group of batteries and the input and output wiring: large size and high costs.
One single multi-UPS system to service (simpler and more cost-effective than a number of small systems)	The UPS is generally far from the charge being protected
Greater flexibility; the option to divert the load to the second UPS in the event the first is undergoing maintenance	You will need to create a switchboard on the UPSs outputs
There is the option of powering the redundant inputs of the latest generation servers with the two UPS.	Costs for installation, wiring and autonomy expansion can be high
The UPSs are normally located in a protected and safe technical area under optimal environmental conditions.	Specialist technical personnel are required for installation and maintenance work

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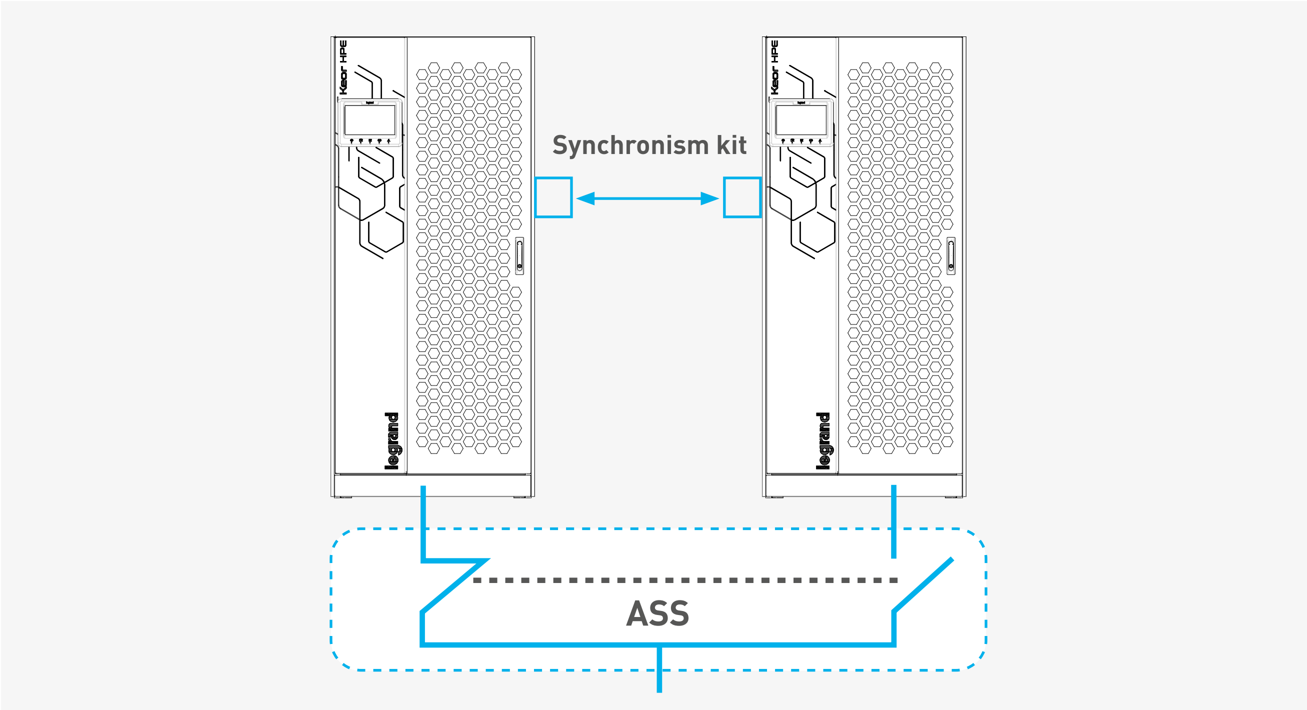

MODULAR ARCHITECTURE

Modular architecture is based on the use of a UPS consisting of several independent modules which all contribute towards powering the load. Modular systems are interesting in terms of protecting the hotspots of a company as they can easily provide redundancy and expandability.

ADVANTAGES:	DISADVANTAGES:
All the advantages of centralised architecture	The initial purchase cost may be higher than that of a conventional UPS
Ease of having internal redundancy by adding one or more modules	
Easier and quicker to both install and expand than the centralised solution	
Quicker and more straightforward to service and repair	
Reduced size compared to the centralized solution (in particular in the event of redundancy)	

GRANULAR MODULAR ARCHITECTURE

The granularity consists in having compact and low-power modules so that only a small part of the power is lost in the event of a single module malfunction; this architecture therefore allows for a high level of redundancy.

ADVANTAGES:	DISADVANTAGES:
Quicker and more straightforward installation, maintenance and expandability than the modular solution	The initial purchase cost may be higher than that of a conventional UPS
Ease of having internal redundancy and being immune to breakdowns. One single failed module results in a small loss of power when compared to the rated power	
Downtime minimised in the event of breakdowns for non-redundant configurations	
Greater levels of energy efficiency, reduced consumption	
Precise and optimal dimensioning: it is easier to get closer to the actual power of the load with small modules.	

10- INTEGRATION THE UPS IN THE ELECTRICAL SYSTEM

You will need to know the characteristics of the load itself and of the system in which the UPS will be installed in order to obtain a well-dimensioned uninterrupted power source for the load to be protected.

Particular attention should be paid to the following elements:

1. The maximum power of the load to be protected
2. Efficiency of the UPS to be used
3. UPS input circuit characteristics
4. Any additional energy sources (e.g. GE)
5. Any temporary changes in the network in the event of maintenance work

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10.1. Dimensioning the upstream line

The power that the privileged line must have is supplied as a minimum requirement by the sum of the power that the UPS supplies to the load plus any power absorbed by the UPS itself in order for it to function. This power can be calculated using the UPS efficiency - information that must always be provided by the manufacturer.

The declared efficiency does not normally consider the recharging phase of the batteries, which, are always charged during routine operation with the exception of the hours immediately following the return of the mains following a blackout. A UPS oversizing of approximately 20% more than the actual load is often simply applied and the upstream line is then dimensioned on the power of the UPS; thus, there is a safety margin both for the charging power of the batteries and for any load changes.

The presence of PFC in modern UPSs guarantees absorption with low levels of reactive and harmonic power; however, the possibility of switching to bypass for emergency or basic maintenance work must also be taken into consideration.

The absorption of the load which could have reactive and harmonic components must be considered under these circumstances. Attention must be paid specifically to the third harmonic and its multiples, which could generate homopolar currents in the neutral. Finally, the eventuality in which overloads are permitted caused by initial peaks or particular operating situations in which the UPS will switch to bypass mode, should also be taken into account.

UPS manufacturers will specify the absorbed current values, and, in some cases, will suggest the minimum cable section according to the absorbed current. Obviously, these are only mere indications as to the minimum values; for calculating the actual sections, it is necessary to consider the type and how the cables are laid and to apply the requirements of the standards with the related oversizing coefficients.

10.2. Choosing and coordinating overcurrent protection

Battery operation is not considered for upstream overcurrent protection.

The Offline and Line-Interactive UPSs normally possess low power and are connected to the electrical sockets using standard plugs, the sockets already being protected inside their starting panel. These UPS normally also have thermal protection or fuses inside them.

UPSs with Online Double Conversion (VFI) technology come equipped with a bypass circuit which automatically connects the load directly to the power supply in the event of a UPS failure or overload.

10.2.1. Overload protection

UPS manufacturers provide information relating to the overload capacity for both the inverter and the bypass line.

Both situations must be considered when choosing upstream thermal protection: the UPS will in fact continue to power the load from the inverter for a certain time in the event of an overload, depending on the intensity of the overload, at the end of which the UPS will switch the load to the bypass. The bypass will continue to supply the load within the limits specified by its overload curve.

The choice of thermal protection can therefore be made by comparing the time-current curves so that any protection intervenes only when the overload has already been transferred to the bypass and within the overload limits of the bypass line.

The same applies for thermo-magnetic switches and fuses.

10.2.2. Short circuit protection with thermo-magnetic switches

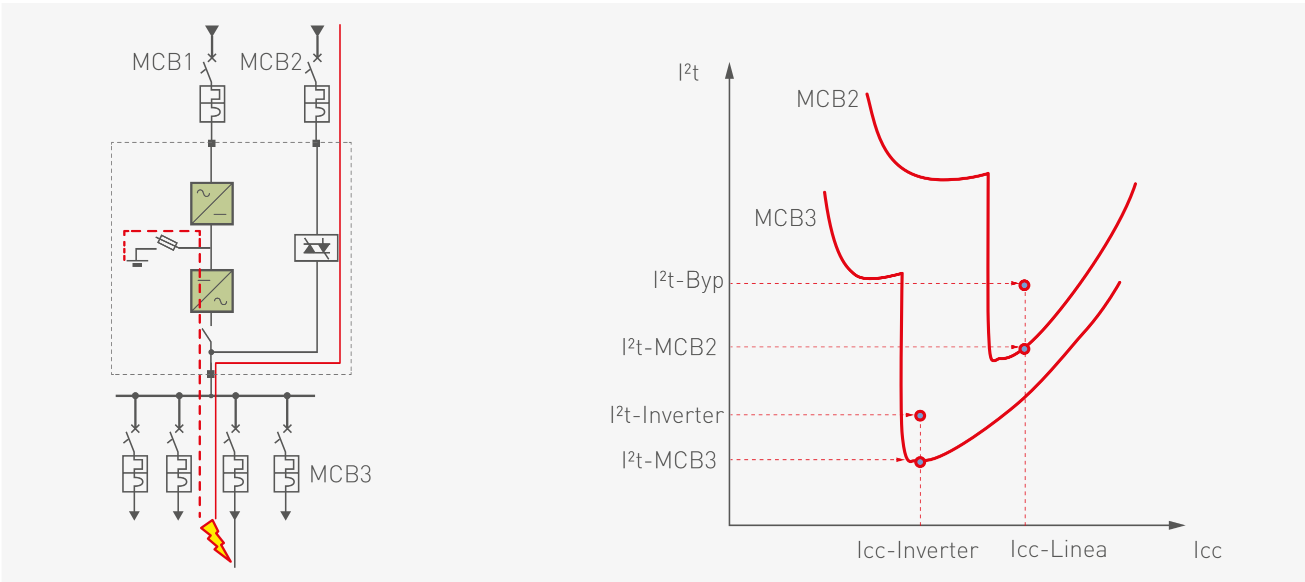
The UPS will immediately switch the output line to the bypass in the event of a downstream short circuit. For this reason, you will need to opt for the thermo-magnetic switch upstream and must take into account any feed-through energy that may be tolerated by the UPS bypass.

The UPS manufacturer could also provide information regarding any protection to be placed upstream of the UPS, indicating the rated current and the type (curve) of intervention. Alternatively, the maximum feed-through energy value for the bypass circuit will be specified.

The thermo-magnetic switch will be chosen on the basis of the trip curve for feed-through energy, meaning that it intervenes for an energy value lower than that supported by the bypass. The downstream switch must of course be selective with respect to the upstream switch and must intervene initially by excluding the fault and leaving the UPS running on mains.

The transition to bypass will not be possible should a downstream short circuit occur when the UPS is running on batteries due to a blackout. The UPS inverter will limit the current to the maximum value under these circumstances which its components are able to supply and it will shut down. after a certain period of time should the short circuit persists.

The maximum current value provided by the inverter and the duration will vary according to the UPS model and power level; however, this current value is generally much lower than that of the short-circuit current that would occur where there is a power supply. In this case, the downstream circuit breaker will only be selective with the inverter if, in line with the short-circuit inverter current, it intervenes for I2t values lower than those supplied by the inverter itself.



10.2.3. Protection with fuses

All UPSs are already normally integrating fuse protection inside them to isolate any internal circuits in the event of a fault. It may be convenient in a number of situations to have fuse protection even outside the UPS, both upstream and downstream. The choice can be made in the same way as described for magneto-thermal protection by considering the specific static bypass feed-through energy inside the UPS.

The use of fuses on the bypass input in some situations may be useful due to their limiting power at high levels of short circuit currents. It may also be useful under other circumstances to use fuses on the loads downstream of the UPS, especially if you have multiple lines with IT loads, so that you can exclude any shortage in rapid time and make them compatible with the ITIC curve, i.e. times less than 10 ms; this avoids the risk of blocking IT devices on lines which are unaffected by shortages.

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10.3. Protection with a residual-current device

There may be a residual-current device in the upstream panel for low power Offline and Line-Interactive UPSs connected via standard electrical sockets that powers the line of the socket where the UPS is connected, therefore the same consideration must be made in the case of thermomagnetic protection.

The UPSs that require connection to the electrical panel generally include metal enclosures with an earth terminal (class I insulation) and they require differential protection in TT and TN-S systems to comply with the regulations governing low voltage systems.

If it is necessary to use differential protection upstream, you must take into account the fact that the UPS includes electronic power converters (inverter, rectifier, battery charger) and components in direct voltage (batteries, DC bus), which may generate pulsating and continuous currents to earth should there be any indirect contact. The simple AC type differential may therefore not be sufficient.

The electrical safety standard for UPSs EN62040-1 establishes that for UPSs with class I earth insulation the protection residual-current device:

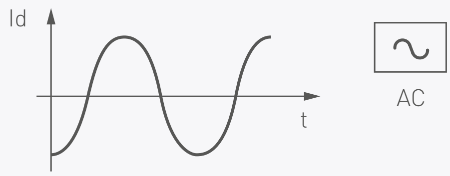
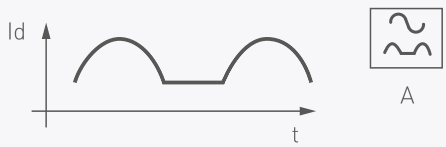
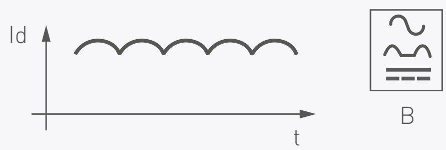
- must be type A for a single-phase UPS;
- must be type B for three-phase UPS or with three-phase input and single-phase output;
- may be of the AC type in the event that the UPS elements which could generate unidirectional currents towards earth have dual or reinforced insulation.

Residual-current device

In-depth study

Types of RCDs

Differential protection available on the market can be of varying types depending on the waveform of the leakage current:

LEAKAGE CURRENT WAVEFORM	TYPE OF SWITCH
	**AC type:** protection against sinusoidal leakage currents
	**Type A:** protection against sinusoidal, pulsating leakage currents
	**Type B:** protection against sinusoidal, pulsating and direct currents

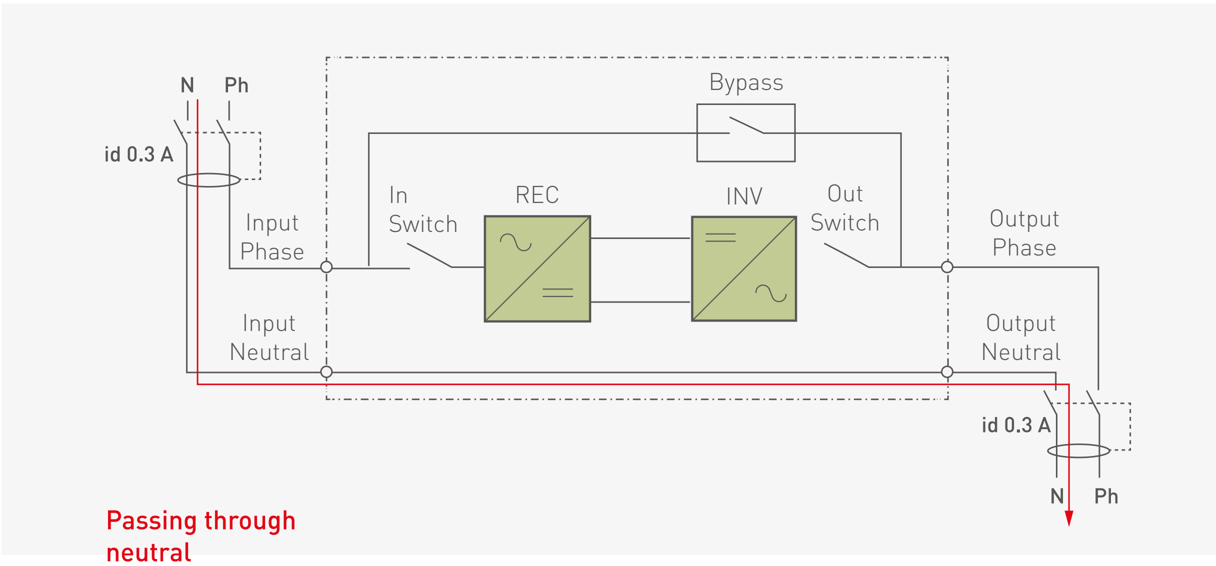
You must consider the fact that these have EMC filters inside which could give rise to small currents towards earth when using differential protection alongside a UPS; these currents, could cause the RCD to trip at an inopportune moment when added to any dispersion of EMC filters included in the load.

It is advisable in this respect to use differentials of at least 300mA upstream of the UPS.

If it is necessary to use differential protection on the load, it is important that the UPS does not alter the output neutral regime compared to the input equivalent.

You can of course ensure the neutral regime inside UPSs with Passing through neutral, in which the input neutral coincides with the output neutral.

The neutral is normally a passing through-type in transformer-less UPSs; therefore, protection is also guaranteed downstream. It is however important to ensure selectivity of the switches downstream with respect to the one upstream of the UPS.



10.3.1. Passing through neutral in transformer-less UPS

The neutral of the two inputs is common if the transformer-less UPS with Passing through neutral has dual inputs (one for the rectifier and the other for the bypass); therefore, it is not possible to use independent RCDs on the two lines because there could be a circulation of currents between the neutrals that cause the protection to trip at inopportune moments.

You will be required under these circumstances to use a single differential upstream of the two lines.

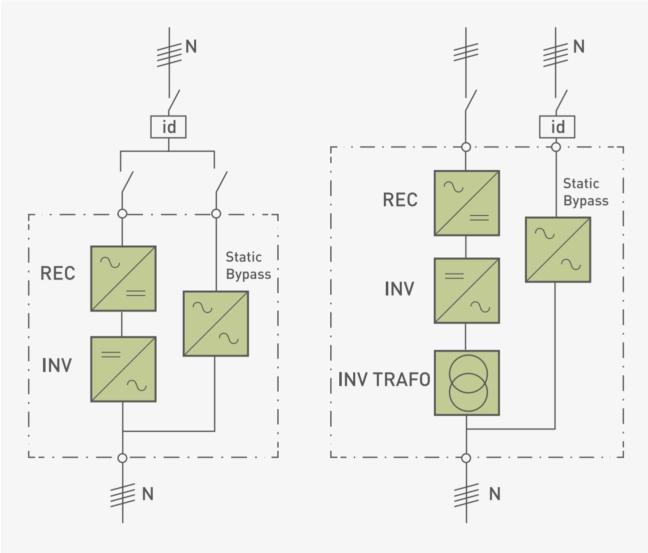
10.3.2. Passing through neutral in transformer-based UPS

Triple-phase UPSs with an inverter transformer may include a delta input rectifier (only the three phases without the neutral).

The passing through neutral here is generated by the connection in the neutral of the bypass line to the output neutral of the inverter transformer.

The differential must therefore be positioned upstream of the bypass line.

The RCD must not be positioned downstream of any isolation transformers when they are being used to create an IT system.

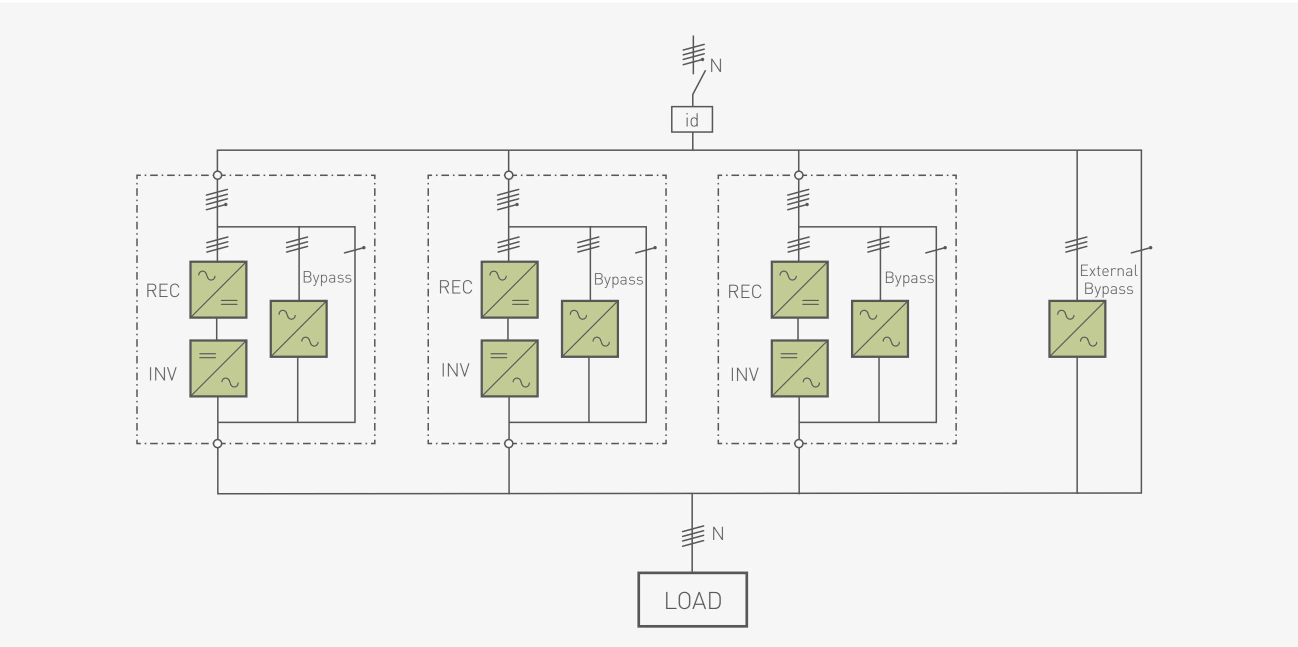


10.3.3. Passing through neutral in UPS connected in parallel

The neutral is of the passing through-type between the input and the output and through the bypass circuits of the individual UPSs, or through a centralized bypass in all parallel UPS systems.

In other words, the neutrals of the UPSs and the external manual bypass are all in parallel; this means that it is not possible to have any differential protection on each input line of the various UPSs, as these would trip at an inopportune moment.

In these cases, you will be required to position a single differential upstream of the parallel busbar on input to the UPSs, as shown in the diagram.



10.4. Dimensioning with generators

UPSs are often coupled to generator sets as shown in the following diagram.

The UPS guarantees an absolute continuous power supply by doing so in the event of a blackout by running on batteries during the generator start-up transient. The UPS will revert to routine operation powered by the generator itself once the generator becomes fully operational. The generator will be able to supply energy for several hours and in the meantime the UPS (if it is an Online Double Conversion UPS) will filter all possible disturbances from the generator, and supply quality energy to the load.

The PFC circuit will ensure that the UPS does not absorb any reactive power and that there are no current harmonics, which means that you will not be required to oversize the generator set, as was the case previously.

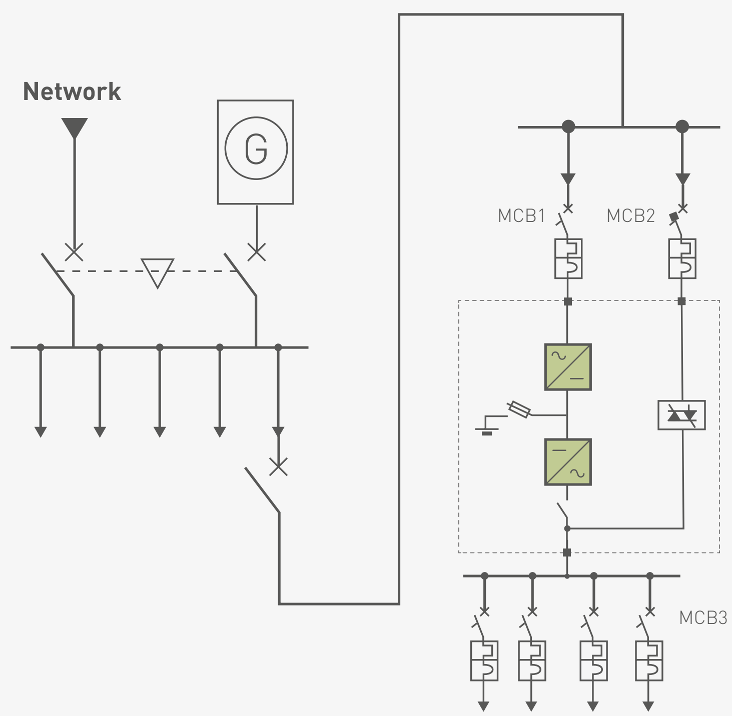
The factors to consider for dimensioning the generator, in addition to the rated power of the UPS, are:

- Any of the UPS starting currents (or any UPSs in parallel);
- The potential requirement to switch to bypass due to overload;
- Energy absorbed to charge the batteries.

The generator set must be able to supply energy even under the circumstance quoted above, by keeping the voltage and frequency levels within the tolerance limits permitted at the UPS input, and by preventing it from moving to battery.

UPSs often also have a dedicated signal port for connecting to the generator. This ensures that the command logic has been informed that the power supply originates from a generator and then implements various strategies (depending on the UPS model) to reduce any potential triggers and absorption.

The timed ramp start-up function (soft start - delayed walk-in) may be useful in parallel UPS systems, in which the UPSs absorb energy gradually (following a ramp) and do so at intervals staggered from one another. Here you will avoid passing the entire load to the generator in one single manoeuvre.



10.5. Back feed protection

The UPS behaves like an energy generator when in battery operation. It must be ensured for safety reasons, that there is no voltage upstream from the UPS even in the event of internal faults (e.g. an automatic bypass in short circuit).

A system must be provided with this in mind which detects the voltage backfeed and which carries out a disconnection (back feed protection) that isolates the UPS from the upstream system.

The back feed protection is built into the UPS and opens both the phase and neutral conductors in single-phase UPSs, which include an input connection with an electric plug: this ensures that there is no dangerous voltage on the plug poles.

Any back feed protection can be inside or outside the UPS when located inside the electrical panel in triple-phase or single-phase UPSs wired to the electrical panel. The UPS must be able to send a signal to activate the protective device should there be any external protection.

Any back feed is only isolated on the phases to ensure the equipotential earth connection in TN-C systems, where the neutral conductor coincides with the protective earth conductor. The back-feed protection isolates both the phases and the neutral in TN-S and TT systems,

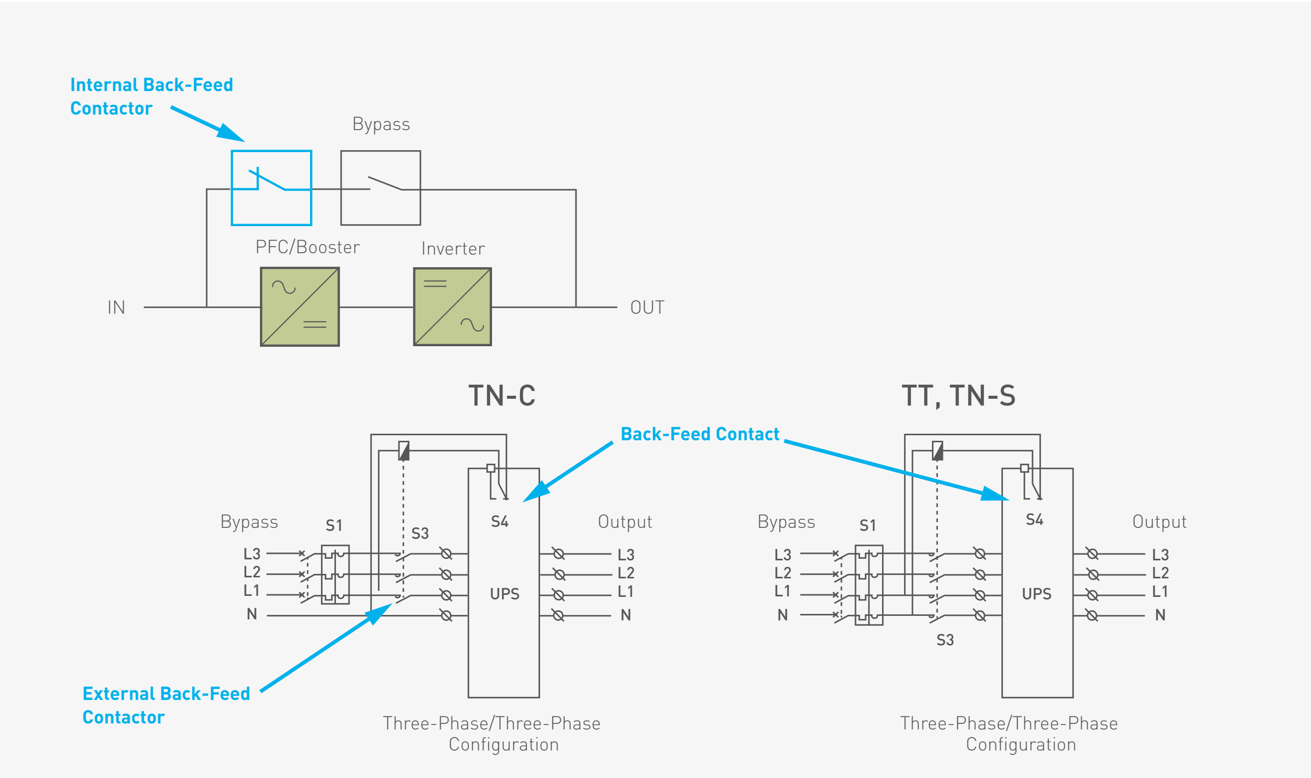
The system downstream of the UPS becomes IT, and nullifies any differential protection downstream of the UPS by disconnecting the input neutral in a transformer-less UPS with Passing through neutral.

This situation is however acceptable, as it is equivalent to a configuration with an isolation transformer downstream of the UPS.

This situation also occurs for a limited period of time (the duration of battery discharge), where the initial contact to earth is not dangerous.

Any danger only arises in the event of a second earth contact; however, this situation is very rare because both faults would have to occur during UPS battery operation with active back feed protection.

The two cases of internal and external back feed protection are illustrated below:



The issue of sustainability is now of fundamental importance for any business sector: it is a topic that has become increasingly integral to the corporate mission, and an objective that must coexist with the quality and performance levels of the product.

This is not only because the companies themselves are raising awareness of the issue, but also because it is the market which is demanding transparency and eco-sustainable products: even those who purchase UPSs are casting a more watchful eye over the environment and are questioning the environmental impact of the product they purchase, the materials that constitute it, how much it pollutes and how it performs during its usage phase and its destination at the end of its life cycle.

The circular economy

Creating a system that involves all stakeholders for sharing values, objectives and actions is essential in order to control and reduce the environmental impact on all economic and production processes, to reduce waste and environmental impacts, as well as transforming what would once have been called "waste" into new resources.

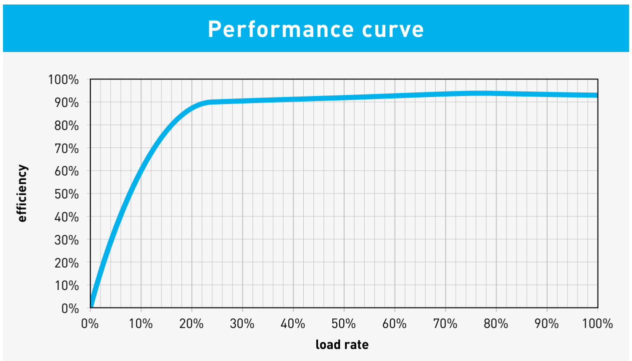
Monitoring these aspects impacts on the entire life cycle of the product, starting from the design of the new concepts and the specifications regarding the materials that constitute the UPS; this is possible with responsible planning and procurement processes ("green procurement"), with particular attention being paid to research and the use of innovative materials coming, in turn, from the circular economy and alternative raw materials, which may become resources with high added values, at the end of their product life, which are usable in other production cycles.

Energy efficiency and performance levels

The focus over recent years has been on the development of increasingly efficient UPSs, which allow high and incremental performance levels and returns with minimum energy loss.

The latest generation static UPSs pay particular attention to both the energy taken from the electricity grid and that supplied to the user, because the main cause of inefficiencies and energy waste is dependent precisely on the overall system efficiency level.

Efficiency levels are also linked to the percentage of system usage (this normally decreases at low percentages of use), therefore you are required to pay close attention to the exact dimensioning of the UPS, because any over sizing also has financially negative impacts on subsequent electricity consumption, in addition to incurring higher start-up costs.



Efficiency levels however are not only synonymous with high performance: efficiency is also eco design, namely the design of UPSs that lend themselves in a simple way to repairs, maintenance, separation of components and which therefore allow an increase in their durability and the potential for them to be reused and recycled at the end of their life.

Processes and products that represent an improvement in carbon emissions compared to the past are consistently being implemented even with regards to CO2 emissions.

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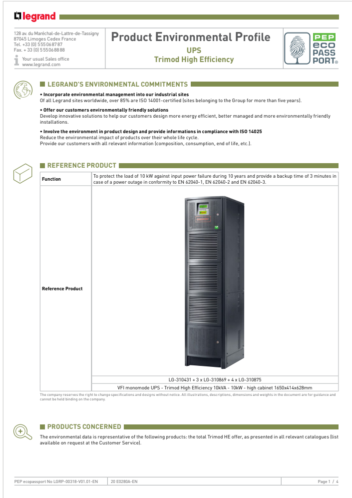
EPD/PEP

An EPD (EN: Environmental Product Declaration) or PEP (FR: Profil Environnemental Produit) is drawn up for each product in line with the ISO 14025 standard: this is a declaration that constitutes a type of environmental blueprint for the product.

The EPD is drawn up according to the analysis of the product life cycle: this examines the environmental impact of a product during its entire life, from highlighting the product specifications, to the choice of materials to be used and the destination of the product itself at the end of its life.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Product Environmental Profile
UPS
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LEGRAND'S ENVIRONMENTAL COMMITMENTS

- **Incorporate environmental management into our industrial sites**
Of all Legrand sites worldwide, over 85% are ISO 14001-certified (sites belonging to the Group for more than five years).
- **Offer our customers environmentally friendly solutions**
Develop innovative solutions to help our customers design more energy efficient, better managed and more environmentally friendly installations.
- **Involve the environment in product design and provide informations in compliance with ISO 14025**
Reduce the environmental impact of products over their whole life cycle.
Provide our customers with all relevant information (composition, consumption, end of life, etc.).

REFERENCE PRODUCT

Function	To protect the load of 10 kW against input power failure during 10 years and provide a backup time of 3 minutes in case of a power outage in conformity to EN 62040-1, EN 62040-2 and EN 62040-3.
Reference Product	LG-310431 + 3 x LG-310869 + 4 x LG-310875 VFI monomode UPS - Trimod High Efficiency 10kVA - 10kW - high cabinet 1650x414x628mm

The company reserves the right to change specifications and designs without notice. All illustrations, descriptions, dimensions and weights in the document are for guidance and cannot be held binding on the company.

PRODUCTS CONCERNED

The environmental data is representative of the following products: the total Trimod HE offer, as presented in all relevant catalogues (list available on request at the Customer Service).

PEP ecopassport No LGRP-00318-V01.01-EN | 20 E0280A-EN | Page 1 / 4

Digitalisation

New IT technology helps reduce the use of some paper documents in favour of a digital format: this means that any information can always be accessed anywhere from a PC or a smartphone and, at the same time, avoids the felling of numerous trees.

Digitalisation is also becoming an important driver of the circular economy, because it allows the use of tools for analysing performance data and for preventive diagnostics which are useful for optimising product life cycle and durability.

12- UPS MANAGEMENT AND COMMUNICATION

The UPSs are very often required to communicate remotely, to allow quicker and more effective diagnostics throughout the various phases of operation and rapid maintenance.

These functions can be obtained by equipping the devices with management software or network cards and by offering additional supervision services to ensure maximum safety and peace of mind for the customer.

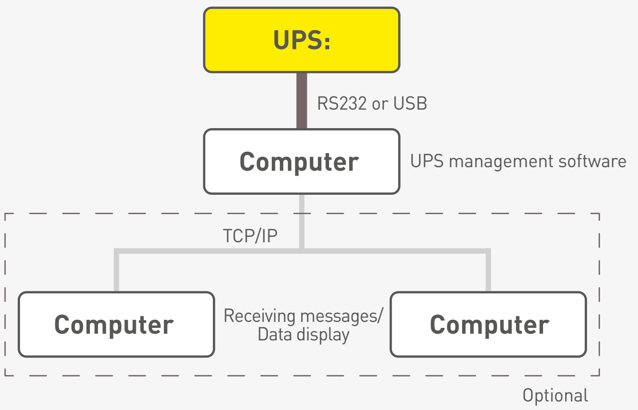
LOCAL PROTECTION

You can simply use an RS232 or a USB connection and install management software on the computer being protected to provide one single layer of protection.

This means that you will be able to view UPS data, alarm pop-up messages and to shut down the computer properly if required to do so.

You can view UPS data and receive alarm messages (e-mails or pop-up messages) on other computers as well if your computer is connected to an IP network.

The advantage of this type of management is that there are no (or very low) implementation costs. There is however a restriction imposed by the maximum length of the RS232 or USB cables; therefore, the UPS must be installed in close proximity to system being protected.

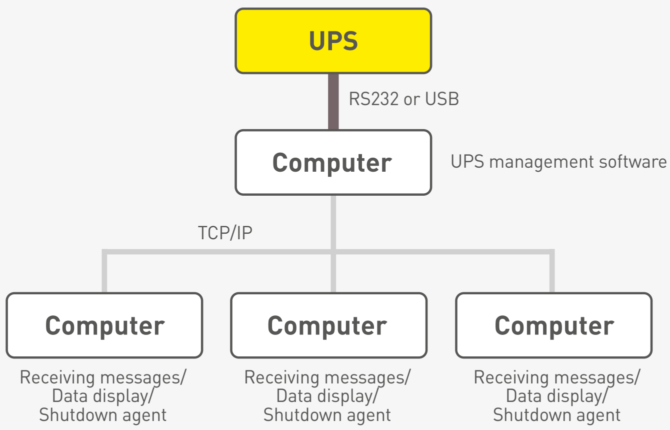


EXTENSION OF LOCAL PROTECTION

It is possible to use the solution described above in the event of a greater number of computers being monitored, by installing, however, a special software "agent" on the other computers that will receive and execute the shutdown commands sent by the computer interfaced to the UPS.

Implementation costs are also low here; however, in addition to the limitation of the maximum length of the RS232/USB cables, if the computer interfaced with the UPS switches off (failure, maintenance, update, etc ...), the management system is completely blocked.

As a result, you will no longer be able to receive alarm messages and shutdown commands, thus putting the integrity of the remaining computers at risk.



INTEGRATION IN THE IP NETWORK

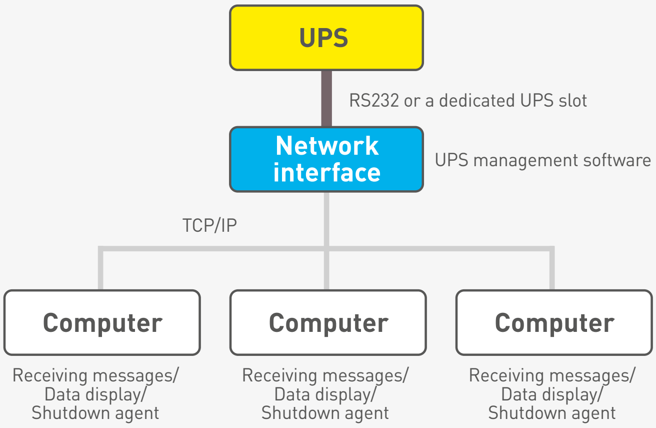
This type of installation requires the UPS to be connected to a dedicated network interface, normally known as the SNMP card. The network card is then connected to the IP network.

The UPS is managed directly from this network interface and is able to send e-mails and pop-up messages and to switch computers off and on again.

The protection of the various computers is ensured by installing a software agent on them which receives commands from the UPS network interface.

There a number of advantages to this solution, namely:

- the UPS can also be installed remotely from the systems it must protect
- the entire management is no longer dependent on a single computer, which effectively safeguards all of the connected devices.
- data can be displayed on any browser.



MANAGING MULTIPLE UPSS

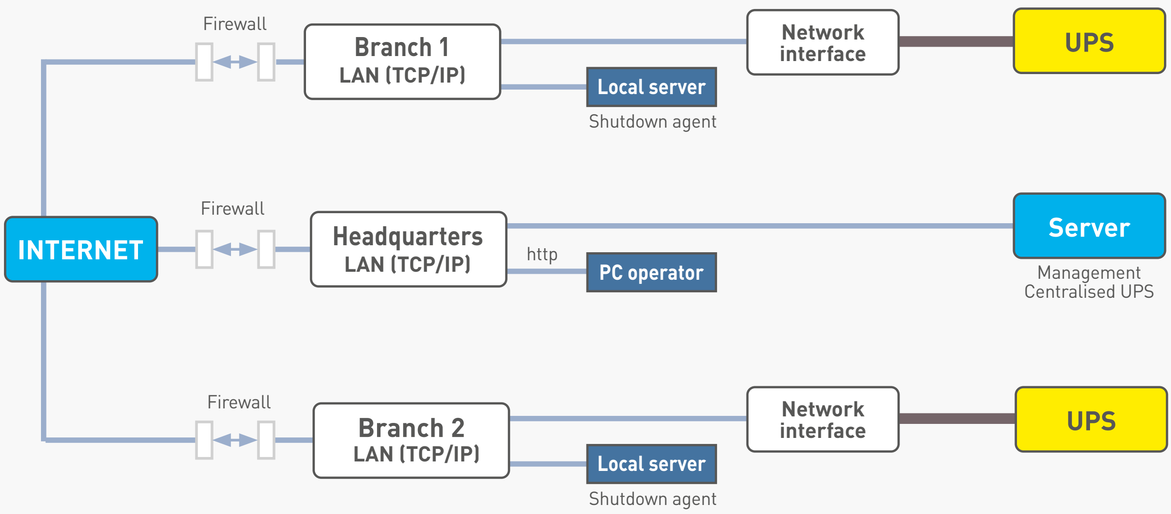
You will be required to use a software application to manage multiple UPS systems (of any brand) which is capable of continuously monitoring a large number of local or remote UPS systems, each of which is interfaced to a network card that supports the SNMP protocol.

This application continuously checks the status of each UPS, stores the alarms in a database and sends a series of pop-up messages and e-mails to the operators who are able to identify the UPS quickly that has generated the alarm and to make a full and efficient diagnosis of the problem, connecting via a standard browser.

A typical example of use of this application is represented by a credit institution:

- A UPS is installed in each branch and is monitored by a network interface. It both manages and protects the local network.
- The various local networks are permanently connected to the headquarters.
- The monitoring station is installed inside the main office and continuously monitors all of the UPSs.

The advantage of this solution lies in the use of a standard monitoring and alarm reception system that allows you to manage any UPS from one single location.



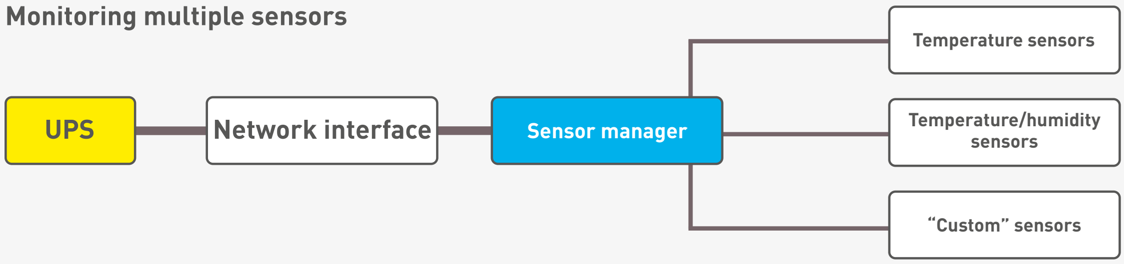
ENVIRONMENTAL MONITORING

There are situations in which UPS monitoring is not sufficient, in which you will also need to monitor the surrounding environment.
Using the network interface, it is possible to monitor the temperature and the humidity of the environment, using a special analogue sensor, or of a specific rack cabinet, and to send e-mails or execute commands on remote computers if the measurement exceeds the thresholds set.
It is possible to interpose a particular device in between the interface and the sensor itself that allows you to connect up to eight similar sensors should you need to use more than one sensor.

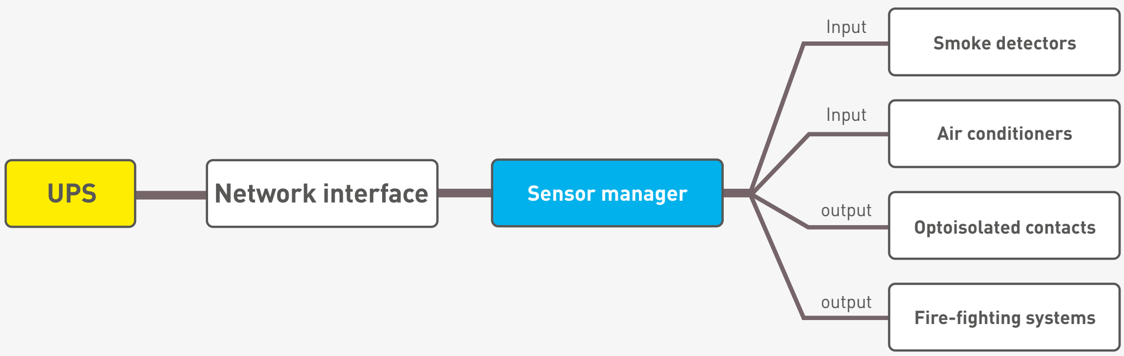
The historical data of the trend of the quantities measured by the sensors are stored in a special log file with the option of displaying them graphically or exporting them for subsequent analysis and archiving.
It is also possible to monitor the status of digital inputs (for example door-opening micro-switches or fault signalling contacts for the air conditioning system) and to control hardware devices such as, for example, light signals or sirens: it is also possible under these circumstances to send an e-mail or execute commands on remote computers.

Monitoring one single sensor

Monitoring multiple sensors



Monitoring digital inputs and hardware device control



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