The UPS Handbook

Planning a UPS Installation

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11 Planning a UPS Installation

Introduction

This chapter assumes the need for a UPS system has been established.

There are now seven main stages which must be completed in order to achieve a successful UPS installation:

- sizing and selecting the correct UPS
- choosing a UPS topology
- reliability and availability considerations
- environmental considerations
- total cost of ownership considerations
- installing the UPS
- using and maintaining the UPS

In the text which follows, each of these points is expanded to provide comprehensive information on all aspects of UPS installation planning.

Sizing and Selecting the Correct UPS

Collating and Calculating Load Data

When planning a UPS installation it is important to gather as much information as possible about the proposed load and make allowances for future load expansion. Most items of electrical equipment have labels which carry information regarding the electrical characteristics of the item.

It is important to collate information for items of the proposed load – you may find the form *"Collecting Load Details,"* on page 209 useful.

In order to correctly size the UPS certain information about the load is needed - these include:

- voltage
- frequency
- number of phases
- load current, including any start-up (or inrush) current associated with motors and transformers
- power factor
- power consumption

Voltage

The ac supply voltage in Volts (V) is normally stated on the label or in the manufacturer's literature. In the UK, single-phase equipment will normally have a supply voltage of 230Vac and three-phase equipment will be 400Vac. Some equipment is designed for international use and the labelling may give a range of operating voltages.

Frequency

The ac supply frequency in Hertz (Hz) is normally stated on the label or in the manufacturer's literature. In the UK, equipment will normally have a supply frequency of 50Hz. Some equipment is designed for international use and again the labelling may give a range of operating frequencies.

Number of Phases

The number of phases will be either single (one) or three. If the equipment label or literature does not give a value, 230Vac devices can be assumed to be single-phase and 400Vac three-phase.

A three-phase UPS can supply three-phase and single-phase loads.
A single-phase UPS can **ONLY** supply single-phase loads.

Load Current

The device load current in Amperes (A) is normally stated on the label or in the manufacturer's literature.

Power Factor

In some electrical loads such as motors or computers, current flows into the equipment without being usefully converted to energy. This happens when the current drawn by the equipment is not in phase with the applied voltage.

Some equipment draws current which is always in phase with the voltage, however almost all the equipment likely to be connected to a UPS draws additional current which is not in phase with the voltage.

Power factor expresses how much of the supply current is in phase with the voltage and is effectively used.

Equipment which draws out of phase current has a power factor of less than 1.0. The power factor value will usually be between 0.8 and 1.0, and if no figure is stated it is traditional to assume a value of 0.8.

See *"Power Consumption,"* on page 201, for an example of how to use the power factor value.

Typically, loads have tended to present a lagging (inductive) power factor to its supply. Modern Switched Mode Power Supplies (SMPSs) within items such as blade servers have shifted this power factor to near unity, and in some cases to a leading (capacitive) power factor. Care must be taken to ensure that any potential UPS system can supply leading power factor loads without any form of derating. In addition, SMPS manufacturers have increased the efficiency of the SMPS itself but at the expense of increased harmonic content.

Power Consumption

It is useful to carry out a power audit of all the load items that are to be powered by the UPS and calculate the total load rating. The power consumption of the individual loads may be stated in Watts (W) or Volt Amperes (VA), but rarely both. Note that most newer UPS systems are rated in kW.

If the VA rating is not stated it can be obtained by:

- multiplying the supply voltage (V) by the load current (A) or
- dividing the power consumption (W) by the stated power factor (p.f.).

To calculate the VA rating for an item rated at 230V, 6A

VA Rating = 230 x 6 = 1380VA or 1.38kVA

To calculate the VA rating for an item rated at 240V, 130W

$$\text{VA Rating} = \frac{W}{pf} = \frac{130}{0.8} = 162.5\text{VA}$$

The VA rating will never be lower than the Watt rating as it is dependent on the Power Factor of the device (*See "Power Factor," on page 200*).

Measuring the Actual Load

Obtaining load details from product labelling will give a reasonable indication of the load power requirements but it cannot give an accurate view of the load variations over time. The only accurate method of establishing the load 'profile' is to perform a site survey.

Using label information gives an indication of expected load but takes no account of the load variation over time.

Many UPS suppliers offer a site survey service which may involve installing portable measuring and monitoring equipment to record information about the load over a period of time. The time the monitoring equipment is installed will be largely dependent upon the load applications. For example, there is little point in measuring the power demand of an office network after 5 pm or at a weekend when very few staff will have their PCs switched on.

Problem Loads

It is important to collate electrical data sheets for ‘Problem Areas’ to enable the UPS to be sized accordingly. UPS equipment is generally resilient but there are certain types of load which require special consideration when connected to a UPS and these include:

- blade servers
- lighting systems with high start-up current
- motors and compressors
- air conditioning equipment
- laser printers
- dimmable lighting systems

The items above can draw high, or pulsed currents during normal operation or start-up. This may overload the UPS or cause unintended operation, during start-up in particular, causing intermittent alarms or possible transfer between inverter and static bypass mode.

Consult your UPS supplier for advice concerning these types of load.

Blade Servers

Data centres are dynamic computer environments. In recent years the increasing mix of old and new computer technologies has caused the overall power factor of the computers/servers to shift towards unity. Furthermore with the introduction of powerful blade servers the overall power factor may even become leading.

This server evolution is becoming a big challenge for IT managers as most of the installed legacy UPS systems, with PWM (pulse width modulated) inverter switching, are designed to provide maximum power at lagging power factors. These UPS systems are approaching their kW power limits due to the change of loads from lagging to leading power factors, or may even shift into an overload condition. The majority of legacy UPS topologies that are installed in IT environments experience a typical derating up to 30% compared with modern transformerless topologies.

Derating of UPS topologies with leading loads

Legacy UPS topologies are designed to provide maximum kW power for lagging loads, typically at 0.8 power factor. If the load shifts from lagging to leading power factor, legacy double conversion UPS will derate substantially and hence reach or exceed their rated power.

The PWM inverter switching in most transformer-based UPS systems is slower and cannot avoid derating when supplying loads with leading power factors. Transformerless UPS with adaptive inverter switching do not experience derating at unity and small leading power factors.

Figure 11.1 shows typical values of power versus load power factor for both modern transformerless and legacy UPS topologies. Legacy UPS topologies (300kVA) typically provide 182kW at 0.90 leading power factors, which corresponds to 24% derating.

Transformerless UPS (300kVA) experience no derating up to 0.90 leading with respect to the nominal power at 0.8 lagging, and provide 270kW.

	300kVA Transformerless UPS	**300kVA Legacy double-conversion UPS**
Power Factor (load)	kW Rating	kW Rating
0.80 lead	231kW	152kW
0.85 lead	249kW	166kW
0.90 lead	270kW	182kW
0.95 lead	285kW	214kW
1.00	300kW	240kW
0.95 lag	285kW	240kW
0.90 lag	270kW	240kW
0.85 lag	255kW	240kW
0.80 lag	240kW	240kW

Figure 11.1: UPS Derating versus leading loads (300kVA)

Figure 11.2 shows that the transformerless UPS can provide substantially more power than equivalent legacy UPS. The 300kVA transformerless UPS provides up to 88kW more power for a 180kW load with 0.90 leading power factor, than equivalent legacy UPS, which corresponds to 44% of the total load value.

When new data centre power requirements are assessed it is very important to evaluate the power that the specified UPS can provide at leading power factors. The shift to leading power factors gives a clear advantage to transformerless UPS with respect to legacy UPS. Due to the substantial derating of legacy UPS when powering loads with leading power factors, in many cases it will be possible to specify a smaller transformerless UPS against a larger legacy double-conversion UPS.

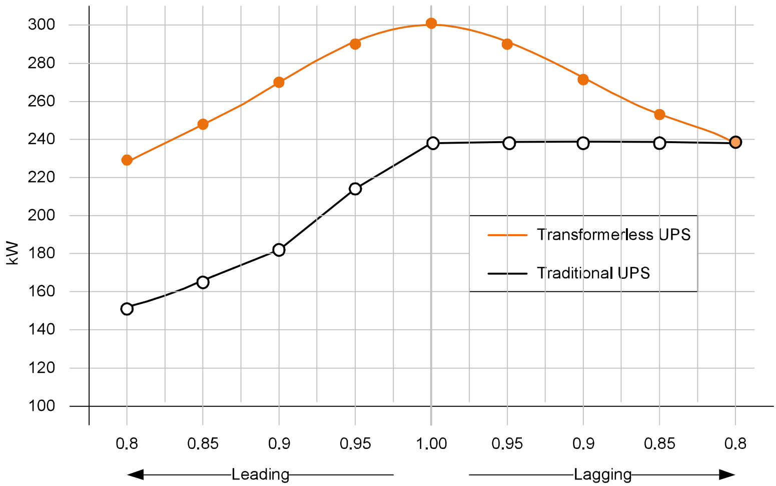


Figure 11.2: Power (kW) versus power factor

Figure 11.3 shows how two typical UPS topologies cope with blade servers with leading input power factor, which represents a major challenge for legacy double-conversion UPS (Assuming a 200kW load and p.f. = 0.9 lead).

	Transformerless UPS	**Typical legacy UPS**
UPS Rating	300kVA	300kVA
Available power at p.f. = 0.9 lead	270kW (UPS 74% loaded)	182kW (UPS 10% overloaded)
Losses at full load of 200kW (0.9 lead, non-linear)	9kW (95.5% efficiency)	25kW (89% efficiency)
Generator over-sizing factor	1.5	2.5
Special care should be taken when sizing the generator for leading power factor loads. It is recommended that advice is sought from the generator manufacturer. When the generator is supporting the UPS, the power factor presented to the generator is close to unity (typical for a transformerless UPS). However, if the UPS operates in bypass mode the leading power factor is presented directly to the generator terminals.		

Figure 11.3: UPS performance with blade servers (Assuming a 200kW load and p.f. = 0.9 lead)

It should also be borne in mind that, irrespective of the UPS topology, should the UPS system operate in bypass mode, the blade server load with leading power factor will be presented directly to the output of the standby generator — there is a risk that leading power factor loads could result in the generator automatic voltage regulator (AVR) losing full control of the output voltage.

As data centre loads move towards leading power factors the technical advantages of transformerless UPS, particularly in the output power range from 60 to 300kVA, become evident.

Harmonic Currents

Harmonic currents result only in undesired reactive power and not as active power and therefore the power factor for this type of load is poor. Nowadays, many equipment manufacturers include a power factor correction stage, without which a typical power factor can be 0.7 or less. Another typical characteristic for this kind of load is the high peak current. This is the peak (or crest) factor which is the ratio of the peak value to the rms value of an AC current in steady state. A factor of 2.5 can be regarded as typical for computer loads. For a normal linear load the corresponding value is only $\sqrt{2}$ or 1.42. It is important to pay attention to these factors when designing a network for computers and especially when choosing UPS equipment for this purpose.

To comply with the EU standard EN61000-3-2, all computer power supplies must, at least, include passive power factor correction (PPFC). PPFC can achieve a power factor of about 0.7 - 0.75.

When calculating with power vectors (apparent, active and reactive) the difference between the reactive power Q caused by phase shift and D (distortion) caused by harmonic currents must be observed. Instead of the power triangle formed by the vectors P, Q and S, a figure in three dimensions also including the reactive vector of D should be used. The relations within this configuration are given in Figure 11.4.

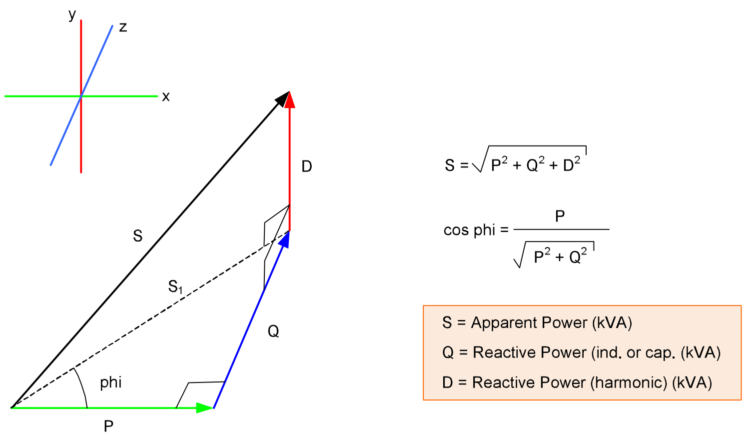


Figure 11.4: Three Dimensional Vector Diagram for Power Calculations

Neutral Current

If a balanced three-phase load is connected to a three-phase system the theoretical current flowing through the neutral conductor is zero, as it is equal to the arithmetic sum of the rms values of the three line currents

This is not usually the case when considering typical computer networks however, where very high neutral currents can be present even when the three line currents are equal.

When single-phase computer units, with their non-linear load characteristics, are connected to a three-phase network from lines L1, L2 and L3 to the neutral no current balance will take place as it would normally with linear sinusoidal currents. The situation is illustrated in Figure 11.5 which shows how the three line currents add-up into the neutral conductor. This results in a neutral current equal to the rms value of the three line currents and a frequency 150Hz.

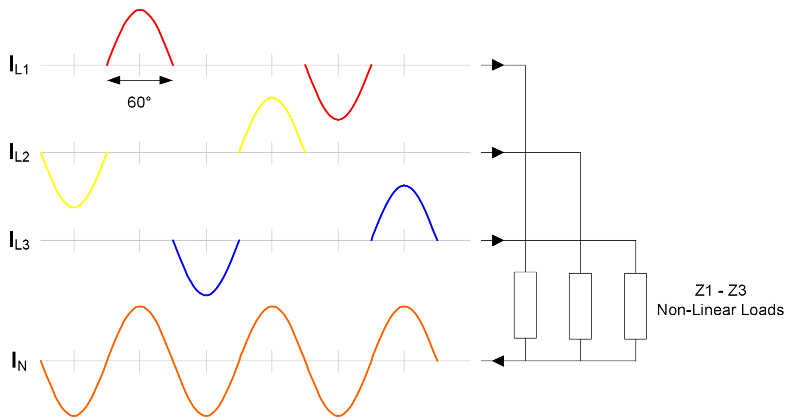


Figure 11.5: Currents in line conductors and neutral conductor

At its maximum this current will be as high as $\sqrt{3}$ or 1.73 times the line current. This maximum takes place when the line currents are of the same magnitude, which they generally are at the optimized loading of a cable.

High peak line currents and the high current in the neutral conductor can cause over loading of feeders and transformers as well as voltage distortion (top-flattening of the sinusoidal voltage form) and common mode distortion. Special care is required – see *IEE Wiring Regulations 18th edition.*

In-Rush Currents

Some computer units have a built-in soft-start circuit but most are switched on directly causing a high inrush current. In the latter case the situation is similar to a momentary short circuit, where the current limitation will only be provided by the line impedance in the power supply.

Motors are the most common cause of inrush problems, typically drawing up to seven times their normal running current when started direct on-line, and up to three times normal current when soft started.

In-rush currents may also find their way through the neutral conductor and cause potential variations and transients affecting different areas of the connected computer network

Figure 11.6 shows typical in-rush current behaviour. These currents may have an amplitude of 15 to 20 times the nominal rms value.

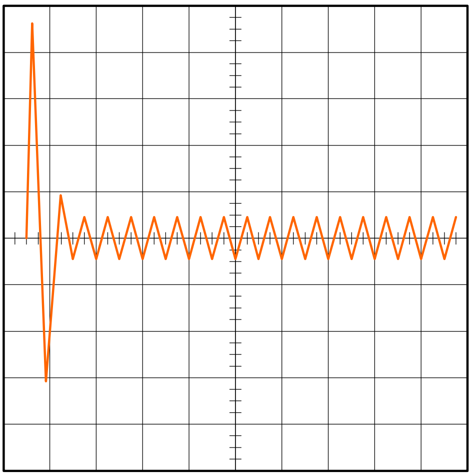


Figure 11.6: Typical Computer In-rush Current

Significant oversizing of the UPS system is required if high current loads such as laser printers and motors are to be powered.

Distributing the Load

If you are planning a three-phase UPS installation, once you have collected the load details, you must decide how the individual items of load will be distributed across the phases. Balancing the load evenly across the three phases is good practice as this allows the rating of the UPS to be fully utilised and presents a balanced load to the mains (or generator – if fitted) whenever the UPS is bypassed.

For example, a 60kVA three-phase UPS can supply up to 20kVA on each phase.

Most modern UPS have independently regulated phase voltages and do not require careful load balancing across the 3 phases in order to operate correctly. Even with these systems the load on any single-phase must never exceed 33% of the total UPS rating.

It is permissible to have single-phase loads, supplied by different phases of a three-phase UPS, in the same vicinity providing regulation 514-10-01 of BS7671 is enforced - see page 259.

Collecting Load Details

You may find it useful to use the following table to collect and collate load information.

Description	Voltage (V)	Frequency (Hz)	Phases	Current* (A)	Power		Power Factor
					W	VA	

** Steady running loads current.*
For dynamic loads, such as motors, start up currents need to be taken into account.

Site Capacity

It is essential that the capacity of the site's incoming mains supply and its cabling and switchgear is taken into account when planning any UPS installation.

If existing equipment is merely to be transferred to a UPS protected supply there may be only minimal increase in load, but if the site is to be expanded to include, for example, a new data centre, the load increase will be significant and the effect on the site's supply capacity will be important and must be considered.

Increasing the capacity of the mains supply to the site is likely to involve considerable expenditure so it is important, at this stage, to plan for the future.

It is beyond the scope of this book to give specific advice about increasing the supply capacity of a site, but the local electricity supply company will be able to give advice and guidance.

Future Requirements

When all the load information has been collected and collated, the required UPS capacity will be established. However, it is important to make some spare capacity contingency when sizing the UPS — 20% is typical.

However, just adding allowance to the measured or calculated capacity is not enough to cater for any future expansion plans and the topology of the UPS system is also an important consideration (*See "UPS Topologies," on page 19*).

Example

If the load measurement and calculation has resulted in a total load requirement of 120kVA (including a spare capacity contingency), and the critical load/ process dictates that a parallel redundant system is required:

- Instead of just considering an N+1 system comprising 2 off 120kVA UPS, a more cost effective solution may well be to specify, for example, 3 off 60kVA UPS or 4 off 40kVA etc.
- In a 2 UPS N+1 system, each unit can only ever carry 50% of its full load capacity while retaining redundancy and may therefore be operating at a low efficiency.
- In a 3 or 4 UPS N+1 system, each unit will be more heavily loaded while retaining redundancy and may well therefore operate at a higher efficiency (*See "Operating Costs," on page 241*).

The benefits of the N+1 system are:

- lower running costs
- smaller foot-print
- more easily expandable should the load grow

An N+1 system may be configured for future expansion by ensuring that suitable switchgear facilities are included during the initial electrical installation stages (*See "A Typical Paralleled UPS System Bypass Panel," on page 127*).

Alternatively, the selection of a modular UPS configuration enables a very expedient and cost-effective solution for future capacity upgrades (*See "Modular UPS Systems," on page 113*).

Choosing a UPS Topology

The topology chosen (*See "UPS Topologies," on page 19*) for a particular UPS installation is largely governed by:

- the size of the load
- the load type
- resilience and required availability
- CAPEX
- OPEX

Size of Load

The size of the load will influence which type of UPS may be chosen (*See "What is Available?," on page 13*).

Examples

If just one PC is to be supported:
The load is single-phase and likely to be less than 250VA therefore a 'Micro' UPS would probably be adequate and on-line, off-line and line interactive designs are available.

If an office network, or communications centre is to be supported:
The load may be either single or three-phase and is likely to be between 3 and 20kVA. It may require a battery backup or autonomy time of perhaps 30 minutes – in this case a 'Medium' sized UPS system is probably most appropriate. A UPS of this power rating is likely to be available only as an on-line design.

If a major data centre is to be supported:
The load will almost certainly be three-phase and may be between 30kVA and several hundreds of kVA. The load process may also require power redundancy and a standby generator to ensure absolute supply security even in the event of a lengthy mains failure. The only solution in this case is a 'High-Power' parallel system which is only available in an on-line configuration.

Load Type

The assessment of load type may overrule the UPS type chosen in the *"Size of Load,"* on page 212 section. If, for example, during the initial load compilation of calculation just one piece of three-phase equipment is required then this dictates that a three-phase UPS **must** be installed.

A single-phase UPS can only support single-phase loads.
A three-phase UPS can support **both** single and three-phase loads.

If a load that **must** be connected to the UPS is listed in *"Problem Loads,"* on page 202, then you must consult your UPS supplier as a special assessment will be required.

UPS equipment can support almost any type of electrical load but, installing a much larger UPS than was initially planned may avoid electrical disturbance to other connected loads and/or constant overload conditions and alarms if particularly 'hostile' loads are to be connected.

Consult your UPS supplier if any part of the planned load is listed in *"Problem Loads,"* on page 202

Load Process Requirements

The degree of mains supply protection demanded by the load process will often govern which UPS topology is chosen.

Examples

If the business processes must be protected for the majority of minor mains disturbances and interruptions but would not be adversely affected if it could be shut down in a controlled way should the interruption continue for an extended period, then a solution may be to install:

- a UPS with auto controlled shut down software facilities (*See "UPS Communications," on page 172*)
- an extended battery autonomy (*See "Additional Battery Cabinets," on page 146*)

If the supply to the critical load(s) may **never** be interrupted and the business process being protected **must** be available twenty-four hours per day, seven days per week, then the only viable solution is to install:

- an on-line UPS configured as an N+*n* parallel redundant system
- batteries to support the load during short mains failures
- a standby generator to protect the load during long outages

Summary

The choice of UPS topology is a complex one and depends on the particular business process and load to be supported.

Consideration must be given to:

- the size of the load
- the load type
- resilience requirements
- CAPEX
- OPEX
- financial cost to business of any down-time

In addition to the main criteria listed above, two additional items remain – will the chosen UPS fit in the space allowed for it, and can the equipment be easily transported into the chosen position?

These are discussed in *"Delivery and Positioning,"* on page 243.

Reliability Considerations

The overall cost of your UPS system can be affected by the reliability of the equipment you choose to install. The most important consideration when comparing manufacturers' reliability figures is consistency. Make sure that each manufacturer is performing calculations to the same standards and fully investigate any figures which differ drastically from the others.

The definitions which follow are generally considered to be the standard.

Term	Definition
Reliability	The reliability of a UPS system is the probability that it can perform its designed function (supply of interruption-free, clean power) during a certain time period.
Failure	Failure denotes the inability of a UPS to perform its designed function. A failure is caused by internal or environmental faults. *Note:* Faults usually cause a degradation of the system but do not always cause a system failure.
Faults/Errors	A fault is an anomalous physical condition e.g. design error, manufacturing problem, bad material, damage, fatigue etc. An error is a manifestation of a fault in a system where the state of the system differs from the intended state.
MTBF	Mean Time Between Failures is a measure of probability and is the average failure-free time between subsequent failures.
MTTR	Mean Time To Repair is the elapsed time from the error acknowledgement until repair is completed. MTTR depends on many factors such as size and quality of the service organisation and the availability of spare parts etc.

Availability Considerations

Power Availability Index

High availability is one of the most important issues in computing today. Understanding how to achieve the highest possible availability of systems has been a critical issue in mainframe computing for many years, and now it is just as important for IT and networking managers of distributed processing. A certain amount of mystery surrounds the topic of power availability, but consideration of just a few important points leads to a metric which IT managers can use to increase their systems and applications availability and make a rational price/performance purchase decision.

High Systems Availability

Availability is a measure of how much time per year a system is operational and available. Usually, companies measure application availability because this is a direct measure of their employees' productivity. With critical applications, or parts of critical applications, physically distributed throughout the enterprise, and even to customer and supplier locations, IT managers need to take the necessary steps to achieve high applications availability throughout the enterprise.

Power availability is the largest single component of systems availability and is a measure of how much time per year a computer system has acceptable power. Without power, the system, and most likely the application, will not work. Since power problems are the largest single cause of computer downtime, increasing power availability is the most effective way for IT managers to increase their overall systems availability. Power availability, like both systems and applications availability, has two components: mean time between failures (MTBF) and mean time to repair (MTTR). The two most important issues in increasing power availability are therefore increasing the MTBF and decreasing the MTTR of the power protection system.

Increasing MTBF

MTBF Definitions

MTBF figures for a UPS ($MTBF_{UPS}$) have little value unless they are given with values for the mains supply ($MTBF_{MAINS}$) and the Mean Time To Repair for the UPS ($MTTR_{UPS}$).

Value	Definition
$MTBF_{UPS}$	Calculated using of field statistics and on calculations of the MTBF of all the UPS component parts based on a recognised standard e.g. MIL-HDBK-217F. A high quality UPS will have figures in the region of: $MTBF_{UPS}$ Single UPS = 125,000 hours Parallel Redundant (1+1) UPS = 1,250,000 hours Parallel Redundant (4+1) UPS = 500,000 hours $MTTR_{UPS}$ = 6 hours $MTBF_{MAINS}$ = 50 hours (*Refer to Chapter* 2)
$MTTR_{UPS}$	Is the elapsed time from the error acknowledgement until repair is completed. MTTR depends on many factors such as size and quality of the service organisation, availability of spare parts, UPS diagnostic system etc.
$MTBF_{MAINS}$	Mains quality is an important factor when calculating $MTBF_{UPS}$ values. An average good quality mains supply has an $MTBF_{MAINS}$ = 50 hours (*Refer to Chapter* 2)
Bath Tub Curve	Displays failure rate as a function of time. There are three distinct periods on the curve: Early Failure Period Constant Failure Period Wear Out Period
Reliability Diagram	An event diagram which gives an answer to the question “which elements of the system must continue to operate in order to maintain the desired function and which may fail?” (redundancy).

Failure Rate (λ)

Failure Rate is the probability that a system which has operated to a certain time t will not fail in the following time interval (t, t + Dt).

$$\lambda = \frac{1}{MTBF}$$

MTBF is the average number of hours it takes for the power protection system to fail. The MTBF of the system can be increased in two ways: by increasing the reliability of every component in the system, or by ensuring that the system remains available even during the failure of an individual component. There is a finite limit to how reliable individual components can get, even with increased cost. Today, typical power protection systems that rely only on high component reliability achieve MTBF between 50,000 hours and 200,000 hours.

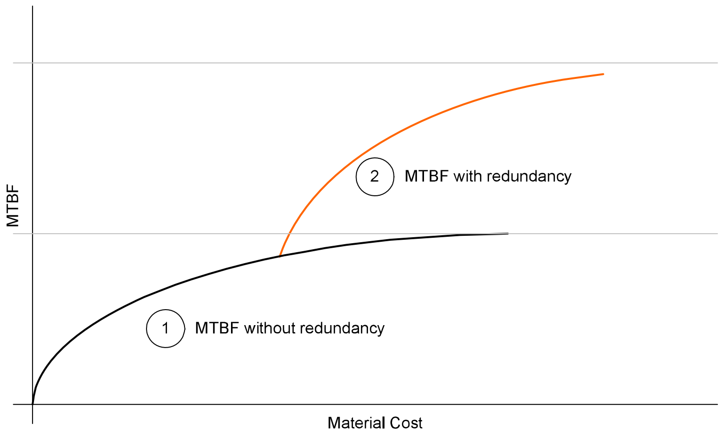


Figure 11.7: The diminishing returns of component reliability

By adding a level of redundancy to the system it is possible to achieve a three- to six-fold improvement in MTBF for power protection devices. Redundancy means that a single component of a power protection system can fail and the overall system will remain available and protect the critical load.

Of course, component reliability is a requirement of any system. However, Figure 11.7 shows the diminishing returns of increasing component reliability. Line 1 shows the plateau that occurs when MTBF is increased by using more reliable (and therefore more costly) components. Line 2 shows how redundancy, in addition to component reliability, can raise MTBF to the next plateau.

Decreasing MTTR

One way that systems downtime can occur is when both the power protection system and the utility power fails. A shorter MTTR can decrease the risk that both of these events will occur at the same time. By driving the MTTR towards zero, it is possible to essentially eliminate this failure mode.

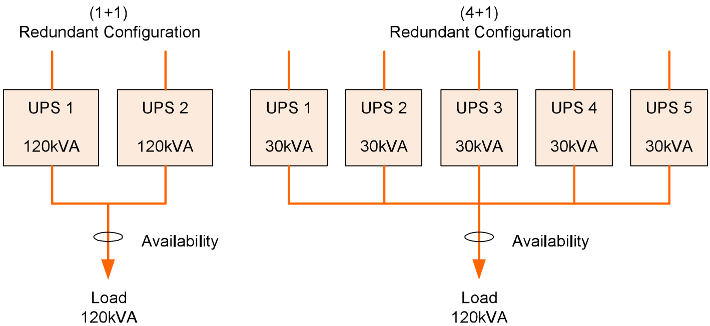
Adding hot-swappability to a power protection system is the most effective way of decreasing MTTR. Hot-swappability means that if a single component fails, it can be removed and replaced by the user while the system is up and running. When hot-swappability is used in conjunction with a redundant system, MTTR is driven close to zero, since the device is repaired when there is a component failure but before there is a systems failure.

Availability (A)

Availability is a useful measure (downtime per year) for systems subject to failure and repair; it is defined as the probability that the system is operational at time t.

$$A = \frac{MTBF}{MTBF + MTTR}$$

Sample Availability Calculations



This example compares the calculated Availability (A) of the two UPS system configurations shown above.

As stated previously the Availability (A) of a UPS is defined as:

$$A = \frac{MTBF}{MTBF + MTTR}$$

Taking sample figures from page 217:

Example 1	(1+1) Parallel Redundant Configuration Standalone UPS units	(4+1) Parallel Redundant Configuration Standalone UPS units
MTBF	1,250,000h	500,000h
MTTR	6h	6h
Availability	99.9995%	99.9988
Assumptions: • MTBF of the (1+1) system is higher than that of the (4+1). • MTTR is 6 hours for each configuration. • Results: Availability of the (1+1) system is higher than that of the (4+1).		

Example 2	(1+1) Parallel Redundant Configuration Standalone UPS units	(4+1) Parallel Redundant Configuration Modular UPS units
MTBF	1,250,000h	500,000h
MTTR	6h	0.5h
Availability	99.9995%	99.9999%
Assumptions: • MTBF of the (1+1) system is higher than that of the (4+1). • MTTR of the (4+1) system is shorter than that of the (1+1), achieved using rack mounted modular UPS units. • Results: Availability of the (4+1) system is higher than that of the (1+1).		

The examples show the importance of the MTTR figure if high availabilities are required. If a UPS module should fail in either of the samples shown, the systems are immediately non-redundant and rapid repair or replacement of the faulty UPS is essential.

Example 2 has a much reduced MTTR figure and hence higher availability as it uses modern, modular UPS units (See Chapter 6 and Chapter 7).

This pair of examples illustrates the move away from the, rather futile, search for a total reliability to the more easily attainable, fault tolerant system.

High Nines

In the previous examples the availability figures are shown as percentages. Recent attention to availability calculations has resulted in an additional expression; “high nines”. A lot of work in this area has been initiated by the Uptime Institute® (www.uptimeinstitute.com) and “high nines” has become an accepted standard to express availability.

“Nines”	Availability (%)	Down Time per annum
Two	**99**	87.5 hours
Three	**99.9**	8.75 hours
Four	**99.99**	52.5 minutes
Five	**99.999**	5.5 minutes
Six	**99.9999**	32 seconds

Data Centre Tier Rating

The availability figures given previously relate only to the UPS components, which, when considering a complete installation, can only give part of the picture. The Uptime Institute® has suggested a tiered approach to data centre availability and this specifies various system attributes for each tier. A comprehensive white paper, *“Data Centre Site Infrastructure Tier Standard: Topology”*, is available from their website and some extracts are included here: (*See “Further Reading,” on page 308*).

Tier Requirements Summary

Determining a Site's Tier Rating for Design Topology				
Tier Requirement	**Tier 1**	**Tier II**	**Tier III**	**Tier IV**
Minimum Capacity Components to Support the IT Load	N	N+1	N+1 After any Failure	N
Distribution paths – Electrical Power Backbone	1	1	1 Active and 1 Alternative	2 Simultaneously Active
Critical Power Distribution	1	1	2 Simultaneously Active	2 Simultaneously Active
Concurrently Maintainable	No	No	Yes	Yes
Fault Tolerance	No	No	No	Yes
Compartmentalization	No	No	No	Yes
Continuous Cooling	No	No	No	Yes

Tier I: Basic Site Infrastructure

The fundamental requirement

- A Tier I basic data centre has non-redundant capacity components and a single, non-redundant distribution path serving the critical environment.
- Tier I infrastructure includes: a dedicated space for IT Systems; a UPS to filter power spikes, sags, and momentary outages; dedicated cooling equipment; and on-site power production (e.g., engine generator, fuel cell) to protect IT functions from extended power outages.Twelve hours of on-site fuel storage for on-site power production (e.g., engine generator, fuel cell).

The performance confirmation tests:

- There is sufficient capacity to meet the needs of the site.
- Planned work will require most or all of the site infrastructure systems to be shut down affecting critical environment, systems, and end users.

The operational impacts:

- The site is susceptible to disruption from both planned and unplanned activities. Operation (human) errors of site infrastructure components will cause a data centre disruption.
- An unplanned outage or failure of any capacity system, capacity component, or distribution element will impact the critical environment.
- The site infrastructure must be completely shut down on an annual basis to safely perform necessary preventive maintenance and repair work. Urgent situations may require more frequent shut downs. Failure to regularly perform maintenance significantly increases the risk of unplanned disruption as well as the severity of the consequential failure.

Tier II: Redundant Capacity Components Site Infrastructure

The fundamental requirement:

- A Tier II data centre has redundant capacity components and a single, non-redundant distribution path serving the critical environment. The redundant components are extra on-site power production (e.g., engine generator, fuel cell), UPS modules and energy storage, chillers, heat rejection equipment, pumps, cooling units, and fuel tanks.
- Twelve hours of on-site fuel storage for 'N' capacity.

The performance confirmation tests:

- Redundant capacity components can be removed from service on a planned basis without causing any of the critical environment to be shut down.
- Removing distribution paths from service for maintenance or other activity requires shutdown of critical environment.
- There is sufficient permanently installed capacity to meet the needs of the site when redundant components are removed from service for any reason.

The operational impacts:

- The site is susceptible to disruption from both planned activities and unplanned events. Operation (human) errors of site infrastructure components may cause a data centre disruption.
- An unplanned capacity component failure may impact the critical environment. An unplanned outage or failure of any capacity system or distribution element will impact the critical environment.
- The site infrastructure must be completely shut down on an annual basis to safely perform preventive maintenance and repair work. Urgent situations may require more frequent shut downs. Failure to regularly perform maintenance significantly increases the risk of unplanned disruption as well as the severity of the consequential failure.

Tier III: Concurrently Maintainable Site Infrastructure

The fundamental requirements:

- A Concurrently Maintainable data centre has redundant capacity components and multiple independent distribution paths serving the critical environment. For the electrical power backbone and mechanical distribution path, only one distribution path is required to serve the critical environment at any time.
- The electrical power backbone is defined as the electrical power distribution path from the output of the on-site power production system (e.g., engine generator, fuel cell) to the input of the IT UPS and the power distribution path that serves the critical mechanical equipment. The mechanical distribution path is the distribution path for moving heat from the critical space to the outdoor environment. For example, chilled water piping, condenser water piping, refrigerant piping, etc.
- All IT equipment is dual powered and installed properly to be compatible with the topology of the site's architecture. Transfer devices, such as point-of-use switches, must be incorporated for critical environment that does not meet this requirement.
- Twelve hours of on-site fuel storage for 'N' capacity.

The performance confirmation tests:

- Each and every capacity component and element in the distribution paths can be removed from service on a planned basis without impacting any of the critical environment.
- There is sufficient permanently installed capacity to meet the needs of the site when redundant components and distribution paths are removed from service for any reason.

The operational impacts:

- The site is susceptible to disruption from unplanned activities. Operation errors of site infrastructure components may cause a computer disruption.
- An unplanned outage or failure of any capacity system may impact the critical environment.
- An unplanned outage or failure of a capacity component or distribution element may impact the critical environment.
- Planned site infrastructure maintenance can be performed by using the redundant capacity components and distribution paths to safely work on the remaining equipment.
- During maintenance activities, the risk of disruption may be elevated. (This maintenance condition does not defeat the Tier rating achieved in normal operations.)

Tier IV: Fault Tolerant Site Infrastructure

The fundamental requirements:

- A Fault Tolerant data centre has multiple, independent, physically isolated systems that provide redundant capacity components and multiple, independent, diverse, active distribution paths simultaneously serving the critical environment. The redundant capacity components and diverse distribution paths shall be configured such that 'N' capacity is providing power and cooling to the critical environment after any infrastructure failure.
- All IT equipment is dual powered with a Fault Tolerant power design internal to the unit and installed properly to be compatible with the topology of the site's architecture. Transfer devices, such as point-of-use switches, must be incorporated for critical environment that does not meet this specification.
- Complementary systems and distribution paths must be physically isolated from one another (Compartmentalized) to prevent any single event from simultaneously impacting both systems or distribution paths.
- Continuous Cooling is required. Continuous Cooling provides a stable environment for all critical spaces within the ASHRAE maximum temperature change for IT equipment as defined in Thermal Guidelines for Data Processing Environments, Third Edition. Additionally, the Continuous Cooling duration should be such that it provides cooling until the mechanical system is providing rated cooling at the extreme ambient conditions.
- Twelve hours of on-site fuel storage for 'N' capacity.

The performance confirmation tests:

- A single failure of any capacity system, capacity component, or distribution element will not impact the critical environment.
- The infrastructure controls system demonstrates autonomous response to a failure while sustaining the critical environment.
- Each and every capacity component and element in the distribution paths can be removed from service on a planned basis without impacting any of the critical environment.
- There is sufficient capacity to meet the needs of the site when redundant components or distribution paths are removed from service for any reason. Any potential fault must be capable of being detected, isolated, and contained while maintaining N capacity to the critical load.

The operational impacts:

- The site is not susceptible to disruption from a single unplanned event.
- The site is not susceptible to disruption from any planned work activities.
- The site infrastructure maintenance can be performed by using the redundant capacity components and distribution paths to safely work on the remaining equipment.
- During maintenance activity where redundant capacity components or a distribution path shut down, the critical environment is exposed to an increased risk of disruption in the event a failure occurs on the remaining path. This maintenance configuration does not defeat the Tier rating achieved in normal operations.
- Operation of the fire alarm, fire suppression, or the emergency power off (EPO) feature may cause a data centre disruption.

Simply put, the Tier topology rating for an entire site is constrained by the rating of the weakest subsystem that will impact site operation. For example, a site with a robust Tier IV UPS configuration combined with a Tier II chilled water system yields a Tier II site rating.

This very stringent definition is driven by senior executives who have approved multi-million dollar investments for an objective report of actual site capabilities. Any exceptions and exclusions footnoted in the approval documents will be quickly lost and forgotten. If a site has been advertised within an organization as being Fault Tolerant (Tier IV), it will be inconsistent to have to plan a site shutdown at any time in the future—regardless of any 'fine print' exclusions that diligently identified the risk. For this reason, there are no partial or fractional Tier ratings. A site's Tier rating is not the average of the ratings for the critical site infrastructure subsystems. The site's Tier rating is the lowest of the individual subsystem ratings.

Similarly, the Tier rating cannot be claimed by using calculated mean time between failures (MTBF) component statistical reliability to generate a predictive availability and then using that number to match the empirical availability results with those of sites representing the different Tier classifications. Statistically valid component values are not available, partly because product life cycles are getting shorter and no independent, industry-wide database exists to collect failure data.

Finally, this Standard focuses on the topology and performance of an individual site. High levels of end-user availability may be attained through the integration of complex IT architectures and network configurations that take advantage of synchronous applications running on multiple sites. However, this Standard is independent of the IT systems operating within the site.

Scope

This Standard establishes four distinctive definitions of data centre site infrastructure Tier classifications (Tier I, Tier II, Tier III, Tier IV), and the performance confirmation tests for determining compliance to the definitions. The Tier classifications describe the site-level infrastructure topology required to sustain data centre operations, not the characteristics of individual systems or subsystems. This Standard is predicated on the fact that data centres are dependent upon the successful and integrated operation of several separate site infrastructure subsystems, the number of which is dependent upon the individual technologies (e.g., power generation, refrigeration, uninterruptible power sources) selected to sustain the operation.

Every subsystem and system integrated into the data centre site infrastructure must be consistently deployed with the same site uptime objective to satisfy the distinctive Tier requirements.

Compliance with the requirements of each Tier is measured by outcome-based confirmation tests and operational impacts. This method of measurement differs from a prescriptive design approach or a checklist of required equipment.

Commentary on this Standard is in a separate section that provides examples for the design and configuration of facility systems for each Tier topology level. The commentary section also offers guidance in the application and implementation of the Tier definitions. In addition, the commentary section includes discussion and examples to aid in understanding Tier concepts as well as information on common design topology shortfalls.

Purpose

The purpose of this Standard is to equip design professionals, data centre operators, and non-technical managers with an objective and effective means for identifying the anticipated performance of different data centre site infrastructure design topologies.

References

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, ASHRAE Handbook—Fundamentals (Latest Version).

ASHRAE Thermal Guidelines for Data Processing Environments, Third Edition

Related Publications

Accredited Tier Designer Technical Paper Series

Further information can be found at www.uptimeinstitute.com.

Work by the Uptime Institute shows beyond doubt that traditional reliance on manufacturers figures does not always provide the best approach to system reliability and availability.

Traditional non-redundant, non fault tolerant UPS systems and solutions **cannot** provide reliable power supplies at the availability levels currently demanded by business critical systems.

Power Availability (PA) Chart

The relationship between power availability, redundancy, and hot-swappability is easily explained by using the PA Chart, which categorises power protection systems in quadrants according to how well they meet the requirements of high power availability – redundancy and hot-swappability. As more components in a system become hot-swappable, the system moves from the bottom to the top of the graph (Figure 11.8), and as more components become redundant, it moves from the left to the right of the graph. IT managers can choose the solution that is right for them, depending on the need for high availability and the amount of money they want to spend.

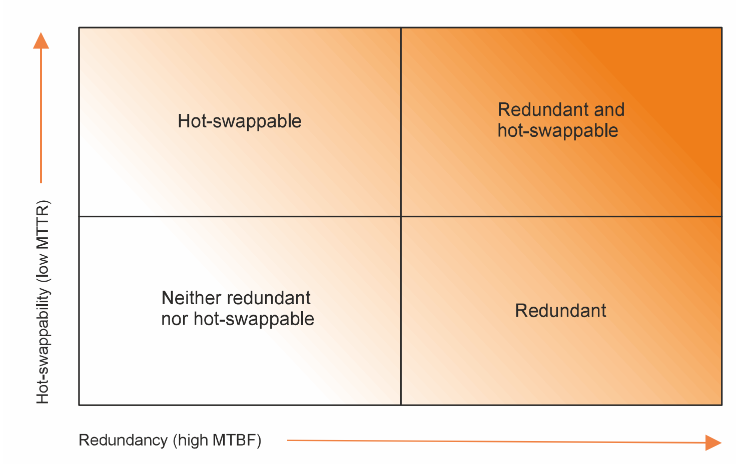


Figure 11.8: Systems categorised by how well they meet the requirement of high power availability

The PA Chart corresponds to the types of power protection systems available today as shown in Figure 11.9. The standalone UPS is neither hot swappable nor redundant. As shown in the table, a standalone UPS provides normal power availability because uptime is dependent on the reliability of the UPS itself.

The fault tolerant UPS is sometimes described as providing affordable redundancy. Systems of this type have redundant components but not all of the major components are hot-swappable. This type of system offers high power availability because the power protection system will continue to protect the load when a component fails. But because a failed component often results in the entire UPS needing replacement, this type of system can have serious drawbacks, including expensive and time-consuming repair with both systems downtime and a major inconvenience for IT managers. Fault tolerant UPS systems may have some hot-swappable components, such as batteries and a subset of power electronics, but in most cases a high number of critical components, such as the processor electronics, will not be hot-swappable.

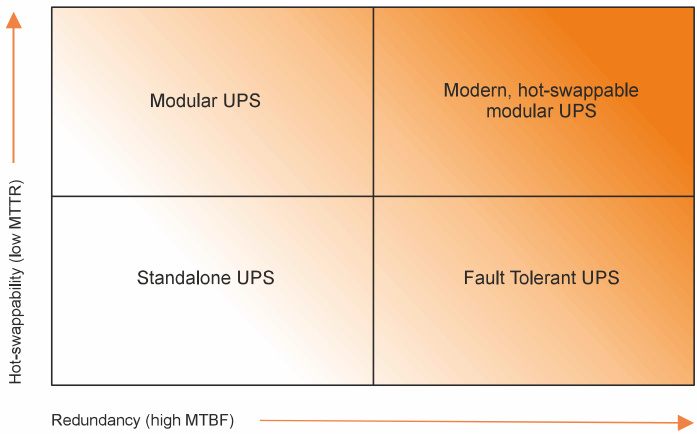


Figure 11.9: Types of UPS mapped onto the PA Chart

Like fault-tolerant UPS, modular UPS offer high power availability. Modular UPS have multiple hot-swappable components and are typically used for multiple servers and critical applications equipment. Many modular UPS also have redundant batteries. Their main advantage over fault-tolerant UPS is that all of the main components which can potentially fail can be hot-swapped, eliminating planned downtime due to a service call.

The modern, modular UPS offers the highest level of power protection currently available where the power electronics, batteries, and processor electronics are both redundant and hot-swappable. This system provides very high power availability and the highest level of protection for IT managers' critical loads.

Power Availability (PA) Index

The different types of power protection systems in the PA Chart can be measured linearly with the PA Index, according to the power availability they provide. The PA Index is a tool to explain the difference between power protection systems. Figure 11.10 shows each of the quadrants from the PA Chart mapped into a level of the PA Index.

Power Availability Index	Definition	Power Availability
PA-1	Not hot-swappable and not redundant	Normal
PA-2	Redundant but not hot-swappable	High
PA-3	Hot-swappable but not redundant	High
PA-4	All main components are redundant and hot-swappable	Very high

Figure 11.10: Quadrants of the PA Chart mapped into a level of PA Index

Figure 11.11 shows the relative power availability provided by each type of system. The PA Index maps directly into the PA Chart and makes the different characteristics of high availability power protection systems clear.

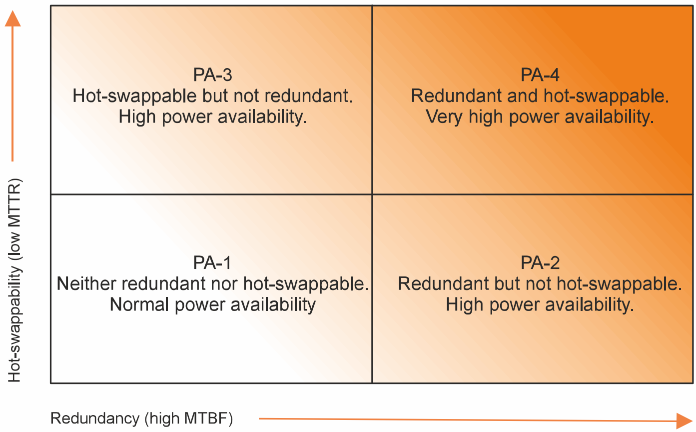


Figure 11.11: The PA Index mapped into the PA Chart

Summary

The PA Chart and the PA Index help to choose the right power protection system for high availability applications.

The standalone UPS, the modular UPS, and the modern, hot-swappable, modular UPS all offer real benefits in terms of power availability versus cost.

Although fault-tolerant UPS offer high power availability – and are marketed as such – they introduce serious drawbacks including a high MTTR and potentially significant inconveniences for IT managers.

The latest UPS designs are cost effective because they are:

- very efficient - kinder to the environment
- electrically very clean (low input current THD)
- quiet
- physically smaller
- have no requirement for 6/12 pulse rectification

Conclusion

Think about the future - installing a modular, upgradeable, UPS system may cost slightly more initially but will save significant costs in the future so before deciding on a particular UPS configuration, consider:

- possible future load growth – plan for upgrading at the start, consider installing several smaller paralleled UPS instead of one large single unit
- flexibility of smaller lighter units which can easily be moved when the company moves or expands
- a quality UPS should have a useful working life at least 10 years if it is well maintained (*See "System Maintenance," on page 268*)
- paralleling for ultimate reliability and high availability may prove to be a very good investment

Environmental Considerations

Heat

All UPS manufacturers will quote a maximum operating temperature for their equipment (typically +40°C). The air conditioning plant must have sufficient capacity to maintain the conditions stated. Obviously the overall efficiency of the UPS will have a significant effect on both the size and the operating cost of the air conditioning plant. -

If the UPS batteries are installed in the same room as the UPS, check the air cooling system is able to keep the ambient temperature at a level suitable for the batteries.
(*See "Energy Storage Devices," on page 133*)

Humidity

Again the UPS manufacturer will state maximum permissible relative humidity levels (typically 95%). Whilst most UPS equipment is well designed, high relative humidity levels may promote corrosion of cabinets and internal parts. Simple dehumidification equipment is available for sites where this may be a problem.

Audible Noise

The unit of sound intensity is the decibel (dB) and it represents the ratio between the sound level measured with a microphone and a reference sound level, 0dB, which is defined to be approximately equal to the threshold of human hearing. However as the human ear is less sensitive to very low and very high frequencies, an additional 'A' filter is applied when measuring background or other intrusive noises, hence the dBA unit used by all UPS manufacturers.

Typical audible noise figures for fully loaded UPS equipment range from 50dBA for 5kVA to 75dBA at 300kVA.

Figure 11.12 shows some examples of relative sound intensity.

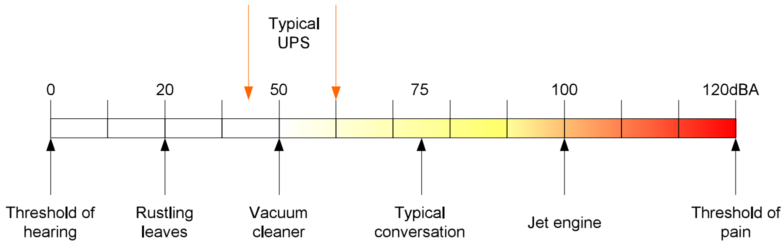


Figure 11.12: Relative Sound Intensity

The acceptable audible noise for any UPS depends on the application and installation location. Check the manufacturer's quoted level to ensure the installation will create the minimum disturbance.

Energy Use and Efficiency

Recent studies of the impact of energy use on the world climate and the anticipated arrival of legislation to improve the efficiency of such usage has led to increased public and corporate awareness of terms such as: Carbon Emissions, Greenhouse Gas and Global Warming.

Companies and Corporations, increasingly keen to emphasize their "green credentials", are including sound environmental practices in their operational policies and often include environmental achievements in Annual Reports.

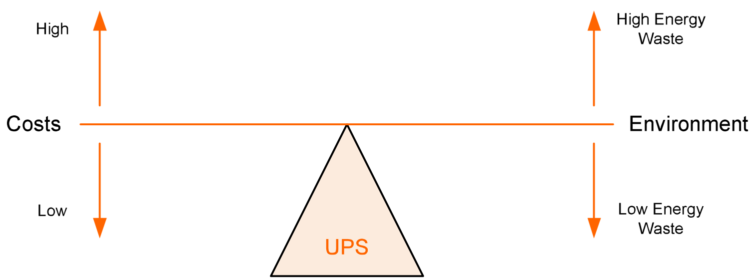


Figure 11.13: Balancing costs and environment

Carbon Emissions

The majority of the electricity generated in the UK is fuelled by the fossil fuels coal or natural gas, nuclear power or renewables.

Figures obtained from the UK Government Department for Business, Energy and Industrial Strategy for 2017 show:

- 45.2% Gas
- 23.6% Nuclear
- 23.4% Renewables
- 7.8% Coal

Saving Energy

Choosing the correct UPS system to support a connected critical load is not simply a matter of matching the output power to that load. The solution must also take into account, reliability, availability and expandability among others. Changes in the way UPS systems are designed and made have also highlighted the benefits to be gained by installing modular, transformerless units. These modern UPS provide new ways to save energy and thus cost over the lifetime of the system including rightsizing the UPS system over time, higher UPS efficiency for partial loads, lower cooling requirements and improved input power factor and input current total harmonic distortion.

Rightsizing

Rightsizing refers to selecting an appropriate UPS to support the load at any point in time. Until recently it was common practice to size a UPS to cope with the current load and any anticipated growth.

Example 1 - Traditional Approach

The graph in Figure 11.14 shows an initial expected system load of 35% of the data centre capacity and it is expected that the load will grow over 10 years to approach 90%. In the case shown a UPS system capable of supplying the projected 90% load is installed.

Although the UPS has supported the load, the shaded area on the graph shows it has been utilized very poorly and has been seriously oversized from the start.

In this example, the UPS system is never more than about 35% loaded and this has a serious impact on the efficiency.

A legacy UPS has a maximum efficiency of about 93% when fully loaded, dropping to about 90% at 50% loading and even less at the levels shown in the graph.

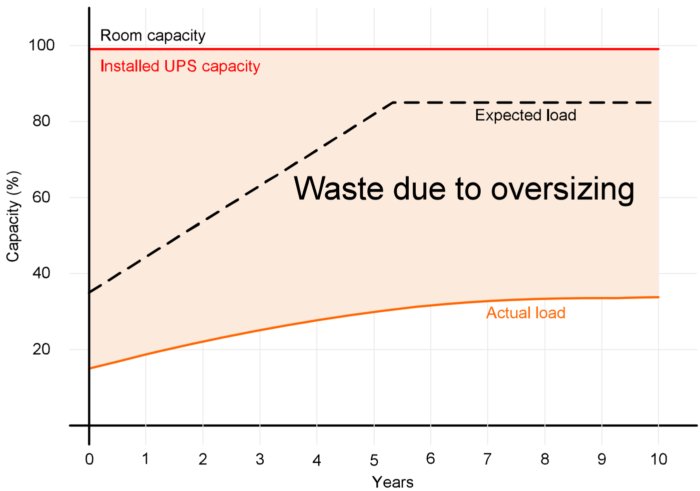


Figure 11.14: Traditional sizing method

Example 2 - Modular Approach

The graph in Figure 11.15 shows the same initial expected load and growth rate. This time the initial load is used as the UPS sizing start point and a modern, modular UPS is chosen. As the load grows, the UPS can be upgraded by adding modules (without increasing the UPS footprint) and the system utilization is greatly improved.

A modern, modular, transformerless design UPS has a maximum efficiency of about 96% when fully loaded and this drops to about 95% for loads between 25% and 75%.

Correct UPS sizing from the outset is vital to achieve minimum capital outlay and maximum power savings throughout the useful life of the system.

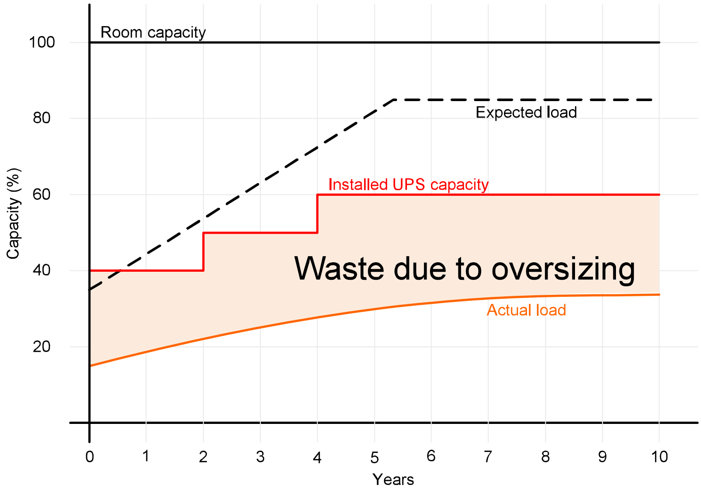


Figure 11.15: Modern sizing method

Manufacturers have acknowledged that in resilient, and hence redundant, UPS configurations the UPS units will never be operating at 100% of their capacity. For example in a single n+1 system with two UPS units operating in parallel and equally sharing the load their maximum operating percentage will be 50% of their individual capacity. Hence manufacturers have shifted the maximum efficiency performance to the actual point of use. Therefore each UPS now will be most efficient generating at 50% rather than at the usually stated 100%.

The concept of right sizing also brings into consideration the idea of granularity. With modern transformerless design UPS units, with their associated ‘flat’ efficiency curves, the question is “what load steps do I require for my critical IT system?”. For a small to medium-sized data centre, an IT room of say 200 to 500kVA, then the UPS system which increments in 50kVA modules may be ideally suited. However if the data centre is a large facility of several megawatts then large incremental steps of say 500kVA would be more appropriate.

Hence the concept of modularity takes into distinct meanings:

1. Withdrawable UPS modules contained in a frame.
   or
2. Large capacity stand-alone UPS units configured in a modular topology.

Whichever system is most suitable is a combination of facility size, granularity, coupled with high efficiency UPS units. The increased growth of transformerless designed UPS units is testament to the drivers of high efficiency and CSR to be environmentally responsible.

Partial Load Efficiency

There are, of course, many legacy systems in current operation which do not take advantage of the higher efficiencies afforded by the modern transformerless design. Although initial CAPEX may be a little lower, the OPEX's associated with an inefficient system design and transformer based UPS units will soon far outweigh any initial cost savings

The following table shows the comparative running costs for a parallel redundant UPS installation to support a load of 160kW (200kVA @ 0.8 p.f.) using both methods.

UPS Details	Legacy (2 x 200kVA) 200kVA N+1	Modular Transformerless (5 x 50kW) 200kW N+1
Load (%)	50	64
Efficiency (%)	91	97.2
Critical Load (kW)	160	160
Total UPS Input Power (kW)	176	165
Total UPS Heat Loss (kW)	16	5.0
BTU/Hr	54594.24	17060.7
AC Consumption (kW)	5.46	1.71
UPS Losses - Cost per Year*	£18,220.80	£5,694.00
Cooling Cost per Year*	£6,217.19	£1,942.87
Total Losses per Year*	***£24,437.99***	***£7,636.87***

** Costs based on 13.0 p/kWh*

Total Cost of Ownership

It is important to measure the total cost of ownership (TCO) in order to predict how the investment will be paid back. In the case of a data centre, the individual cost factors involved in protecting the investment include the necessary infrastructure for providing power, cooling and IT equipment protection.

Total cost of a UPS system depends not only on the purchase price but also on:

- capital cost including the purchase price and transportation costs
- building/footprint costs including installation cost, power density (kVA/sq m), and security concept (redundancy, availability)
- operating costs, including energy costs, cooling system energy losses, maintenance, training for maintenance, and spare parts stock
- upgrade costs.

The major contribution to the total cost of a data centre is usually an oversized or inefficient UPS system (*See "Rightsizing," on page 234*). Taking the case of a UPS system with a load of 80kVA, total costs and performance of a traditional UPS system are compared with those of an advanced modular UPS system. For optimum availability, a parallel redundant solution (n+1) is selected. A traditional parallel configuration of two 80kVA UPS is compared with an advanced modular parallel configuration of three 40kVA UPS (Figure 11.16).

Load: 80kVA	UPS Design	Configuration	Battery
Traditional		Parallel 2 x 80kVA (1+1) redundant	Mounted within UPS cabinet
Modular		Parallel 3 x 40kVA (2+1) redundant	Mounted within UPS cabinet

Figure 11.16: Comparison of configurations of traditional and modular

Capital Cost

Purchase Price

The purchase price of a traditional UPS system would typically be less than that of an advanced modular UPS system. However, the purchase price is not the only decisive factor when considering overall costs. The lower purchase price of traditional UPS technology must be offset against significantly higher operating costs in comparison with a modular system based on technology which reduces energy loss costs. The higher cost of the modular system is recovered within the first year of operation. A comparison of additional long-term costs also favours modular technology (*See page 238*).

Transportation Cost

A traditional UPS is built with an output transformer, which implies a total weight up to two or three times higher than that of a transformerless UPS system. This weight difference can increase transport cost by 100% or more (Figure 11.17).

System (80kVA, n+1)	Tot. Weight (inc Batts)	Gross Volume	Transport Cost
Traditional (1 +1)	~ 2 x 1150kg	2x (97x182x75)cm = 2.6m^3	226%
Modular (2 + 1)	~ 379kg	1x (73x197x80)cm = 1.15m^3	100%

Figure 11.17: Transport costs dependent upon weight and volume

Building/Footprint Costs

The traditional UPS system based on two UPS units typically needs two to three times the amount of floorspace in m^2 required for an advanced modular UPS.

System (80kVA, n+1)	Footprint	kVA/m^2	Installation Cost
Traditional (1 +1)	2x(97x75)cm=1.44 m^2	160kVA/1.44m^2 = 111	186%
Modular (2 +1)	1x (73x80cm=0.58 m^2	120kVA/0.58m^2 = 206	100%

Figure 11.18: Installation and footprint costs

Security Concept (Redundancy, Availability)

System availability is dependent on the mean time between failures (MTBF) and, even more, on time to repair in the event of a failure, mean time to repair (MTTR). In modular UPS systems, MTTR can be up to 12 times less in comparison with traditional UPS systems because a module can be quickly exchanged without load interruption, increasing the total availability of the UPS system to 0.999999 (6 nines).

Figure 11.19 illustrates how system MTBF and MTTR affect the availability of two seemingly equivalent systems and shows the MTBF of the non-modular system as being higher than the modular system simply because it comprises two rather than three UPS. If the MTTR of the non-modular and modular systems were the same (for example, six hours) then the non-modular system would have the higher availability (because of the higher MTBF). However the MTTR of the modular system is much lower at 0.5h and has a positive effect on the system availability.

	Traditional (1+1) redundant system	Modular (2+1) redundant system
MTBF	1,250,000h	8,333,333h
MTTR	6h	0.5h
Availability = $\frac{MTBF}{MTBF + MTTR}$	0.999995 (5 nines)	0.999999 (6 nines)

Figure 11.19: Comparison of system availability

Operating Costs

Spare Part Stock, Logistics and Exchange

Traditional UPS systems are not built as system-modules and therefore it is very difficult to propose a cost-efficient spare part package. For security reasons, often the most extensive and expensive spare parts kit will be selected. Even then, there is no guarantee that the spares kit will be effective or contain the part required for any or all failures which could arise, and there is a time overhead for stock management and logistics.

The hot-swappable technology of a modular system eliminates the complication of choosing the right spare parts kit. All that is required is a single replacement module, and even when there are different power ranges in operation, holding the highest kVA-rated module as a spare covers all eventualities. Trained personnel can swap modules within 15 minutes.

Through the use of spare modules, it is possible to save up to 50% on logistics and stock management costs.

Training Costs

If there are many different types of UPS systems within a company, training for each individual system is time consuming and costly. In contrast, modular systems over a wide range of output powers will have the same architecture and mode of operation.

The know-how gained by training on one UPS module system can be applied to other UPS module systems without additional training.

Upgrade Cost

Upgrading a traditional UPS demands extra space, costly cabling and involves taking the UPS off line during the upgrade.

With a modular UPS, the upgrade is performed by simply inserting the additional power modules into the rack. For example, three 20kVA modules may be replaced by three 30kVA modules, provided the system's distribution and frame has been specified for the maximum foreseeable requirement. Such upgrades can be performed without any interruption to the load, without increasing the footprint, and with no additional work on site. This flexibility makes upgrading a system very easy, and with very little additional cost.

Installing the UPS

Delivery and Positioning

The importance of planning the installation and delivery of the UPS system cannot be overstated. Having chosen a particular system and topology it is important to decide:

- will the system fit into the space reserved for it?
- is the proposed location suitable?
- how will the system be transported to the location?

Size & Weight

Improvements in UPS technology and design have provided much higher power densities which, when combined with the flexible installation options for modern parallel systems, make it much easier to find space for UPS systems. Also, because the most modern designs no longer need bulky and heavy input transformers, installation of very powerful UPS systems is no longer limited to the ground floor or basement plant room.

The manufacturer or supplier will provide details of space requirements and details of module weights in the UPS system specification. *See "Sample UPS Specifications," on page 310*.

> Be sure to consider possible future expansion when choosing a UPS location and if you can allow extra space over and above the manufacturer's recommended minimum, maintenance and service will be easier.

A UPS system is not just a big battery box. It contains electronic components similar to those found in computers and therefore requires careful handling when being transported. Additionally, large UPS equipment will be heavy and unwieldy and will require specialist contractors using 'air-ride' suspension vehicles and specialised lifting equipment to unload and position it. The UPS supplier should be able to recommend handling procedures and suitable contractors with experience in this field.

Choosing a Suitable Location

The choice of a particular installation location for the UPS depends on many things:

- how much space is available?
- can the floor safely support the weight of the equipment?
- will the installation cause continued inconvenience to the existing personnel and business?
- are the environmental conditions at the chosen location suitable?
- can access to the UPS equipment be made secure yet convenient?
- does the UPS comprise one module or several in parallel?
- what is the effect of the installation on existing air flow and air conditioning equipment?
- will the switchgear controlling the UPS be in the same area?
- can the chosen area safely accommodate the battery installation?

In general the location chosen for modern UPS can be summarised as follows:

Small UPS – less than about 20kVA, can be installed in a normal office environment although care should be taken to ensure that the additional noise and heat does not adversely affect the office environment.

Medium UPS – between 20 and 100kVA are designed to be installed in computer rooms.

Standalone UPS – greater than 100kVA, will often be located either in a separate UPS room or in an existing plant room.

Modular UPS – between 20 and 250kVA are designed to be installed in computer rooms or a suitable plant room.

Medium, Standalone and Modular systems must also include environmental control measures for managing dust, debris, temperature and humidity.

Floors and Cable Entry

The UPS cable entry method must be taken into consideration when planning the UPS installation on either a solid floor, such as a typical plant room environment, or a raised floor.

Most medium to large UPS require bottom cable entry but top cable entry configurations are available from some UPS manufacturers, removing the need for plinths or raised floors if cables are more easily run (in suitable supporting trays) above the UPS units.

Solid Floors

When installing the UPS with bottom cable entry on a solid floor, provision needs to be made to permit the input and output AC cables, and the battery DC cables, to run beneath the UPS for connection to the UPS terminals. This can be facilitated by either making a cable trench available within the floor or locating the UPS cabinet on a steel plinth. The height of the plinth needs to be sufficient to enable a satisfactory cable bend radius through 90°. This is particularly important for high power UPS using large cross sectional area cables. A steel plinth also serves as a convenient means of glanding steel wire armoured (SWA) cables to facilitate cable entry from above the plinth, as shown in Figure 11.20.

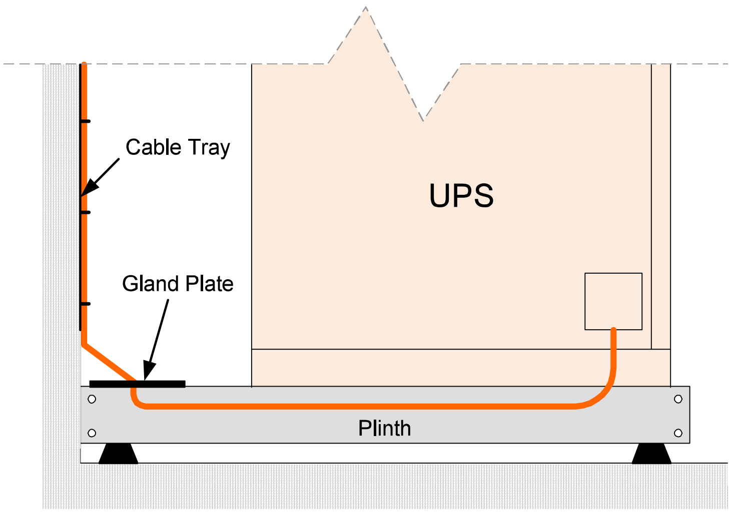


Figure 11.20: Cable Entry Using a Plinth

Top entry cabling configurations are available from some UPS manufacturers. This removes the need for plinths or raised floors if cables are more easily run (in suitable supporting trays) above the UPS units. Top cable entry may be included as a standard design feature, offering the customer a choice between top and bottom cable entry, or offered as a customer-selected option.

Some UPS manufacturers offer a side extension cable-way or busbar chamber to enable top cable entry but this tends to be costly and increases the UPS floor area.

Raised Floors

If the UPS is to be installed in a data centre, communications room, or similar type of environment then more often than not the floor is raised off the sub-floor to permit containment and access for computer equipment network and power cabling, and sometimes as a means to provide under floor cooling. A raised floor provides a convenient method for gaining bottom access to the UPS for the input and output AC cables, and the battery DC cables. However, the UPS equipment can be very heavy, particularly if the batteries are installed within the UPS or adjacent battery cabinets.

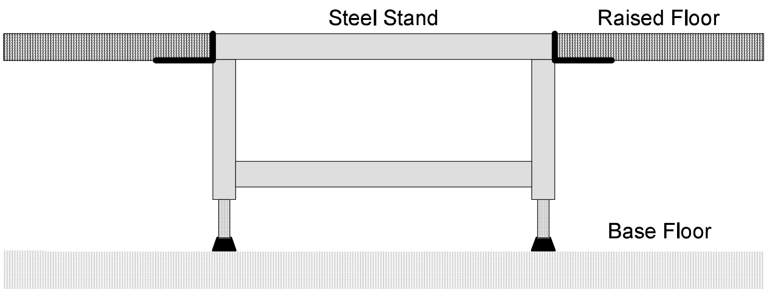


Figure 11.21: Raised Floor

To remove the potential stresses and single point loadings on the raised floor it is normal practice to locate the UPS cabinet, and if applicable the battery cabinet(s) on a steel stand that sits on the sub-floor within the floor void as shown in Figure 11.21. The height of the stand is adjustable so that it can accommodate any unevenness in the sub-floor and to ensure the top of the stand is accurately in line with the top of the raised floor. The stand would normally be provided with a rebate around the top periphery to support adjacent floor tiles which may need to be cut back into position.

Transporting the System

Having chosen a suitable location for the UPS system it is vital to survey the proposed site. If a specialist delivery contractor has been employed for the task they will usually undertake a site access survey before attempting to deliver any equipment.

Even if the location chosen for the installation could in fact accommodate an additional three or four UPS, access to the area may prove problematic.

Check the access route:

- Is the site easily accessible by road? Bear in mind the size of the delivery vehicle and the equipment required to off-load the UPS.
- Are all doorways large enough for the UPS equipment and any transportation equipment to pass through?
- Ensure the equipment can be moved along the entire route especially around corners
- Will the UPS need to be carried across soft or uneven surfaces?
- Are there stairs between the off-loading point and the final location?
- If the equipment must be transported using a goods lift, check that the lift has the required capacity
- Ensure that site staff are aware the equipment is being delivered and have made every effort to ensure that access along the route is unhindered on the day of delivery.

Electrical Installation

Installation Contractors

Electrically installing a UPS or protected power system is a specialised task and should only be performed by a qualified and experienced electrical contractor.

The supplier of the UPS equipment should be able to undertake the installation work or supply a list of suitable contractors who can provide references of previous installations.

Take the time to:

- Check the credentials of the staff who will be installing the equipment.
- Contact and investigate previous installations and discuss their work with the staff on the other sites.

It is important to ensure that the installation is carried out in strict accordance with the supplier's instructions and that it complies with local and national electrical installation regulations.

Installation Design

Small and medium sized UPS equipment will probably require very little installation work and minimal changes to the existing electrical wiring. However, if larger, high-power UPS equipment is being installed then careful consideration of the switchgear and cabling arrangements must be made.

Considerable time and therefore cost savings can be made by carefully planning the electrical installation to allow for possible business growth and the addition of extra UPS modules.

Using an integrated switchgear and busbar solution, such as that shown in Figure 7.26, on page 127, makes the installation process for a modern parallel free-standing UPS system much simpler by:

- providing a single point of entry for the incoming mains supply
- a single point of entry for the bypass mains supply
- a fully interlocked maintenance (or wrap-around) bypass circuit
- correctly sized busbars and circuit breakers
- co-ordinated protection for the load and UPS equipment
- straightforward connection of load distribution panels

Connecting the Critical Loads

In order to make best use of the UPS equipment and to ensure maximum protection of the critical load it is important to consider carefully how best to connect the load components.

Large ring circuits feeding many critical load devices are unsuitable as a fault on one device may cause the circuit feeding it to trip and consequently disconnect power to other pieces of important equipment.

Radial wiring with individual devices protected by their own circuit breakers is a far better approach – in this way a fault in one device will cause that device only to be disconnected and the remaining critical load elements will remain undisturbed.

To ensure satisfactory downstream discrimination for static UPS systems, it is generally recommended that sub-circuit protective devices are sized according to local regulations, as advised by an electrical contractor.

To avoid confusion, particular attention must be paid to the labelling of circuit breakers and fuses in the load distribution panels.

A selection of sample installation schematics is included in *“Installation Drawings,”* on page 259.

External Maintenance Bypass Switch

Whether it is a single free-standing UPS or a multiple parallel UPS system it is good practice to allow for a separate external maintenance bypass switch (sometimes referred to as a “wrap-around” bypass switch). Most modern UPS incorporate an internal maintenance bypass switch which permits the electrical isolation of the UPS components for maintenance or repair (see page 30, which illustrates the arrangement). However, it is desirable to allow the UPS to not only be electrically isolated but also physically isolated for a swap-out, or move, without disrupting the load. A suitably designed external maintenance bypass switch, as shown in the following figures, will facilitate this requirement.

Figure 11.22 and Figure 11.23 show examples of typical “single input” and “dual input” 3 phase external maintenance bypass switches

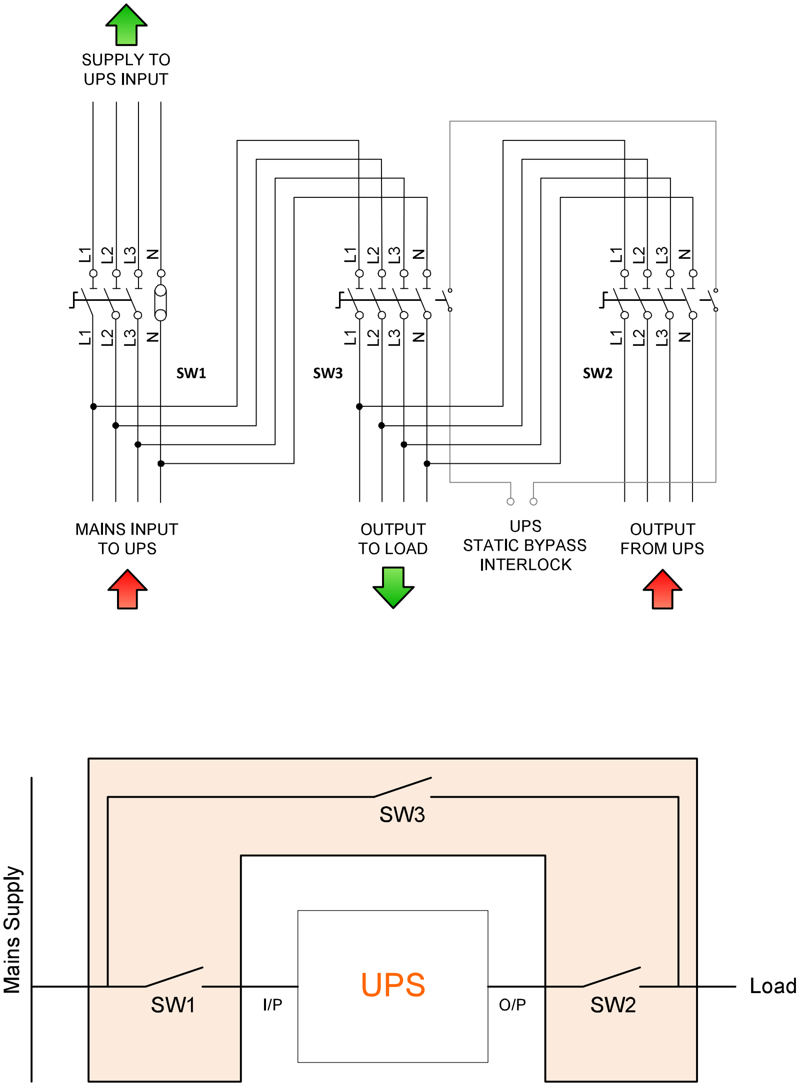
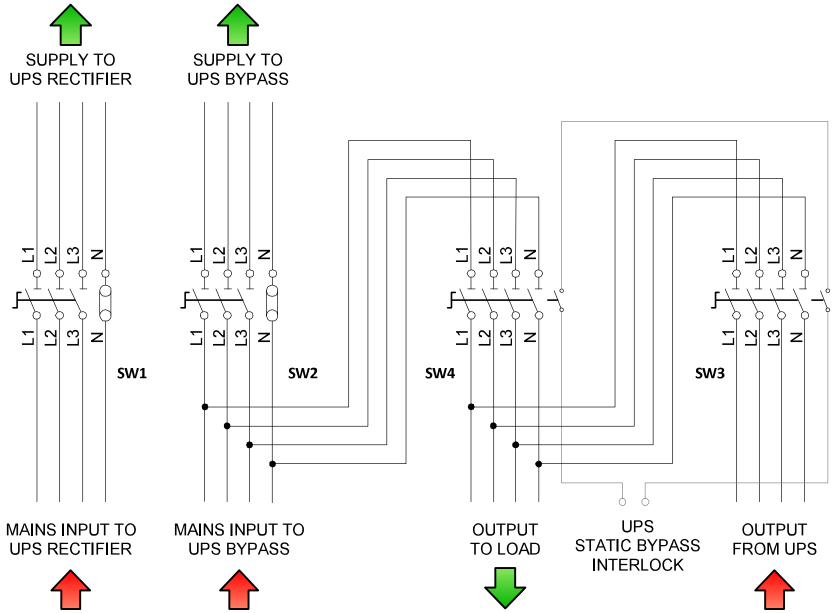


Figure 11.22: Single Input 3 Phase In/Out External Maintenance Bypass Switch



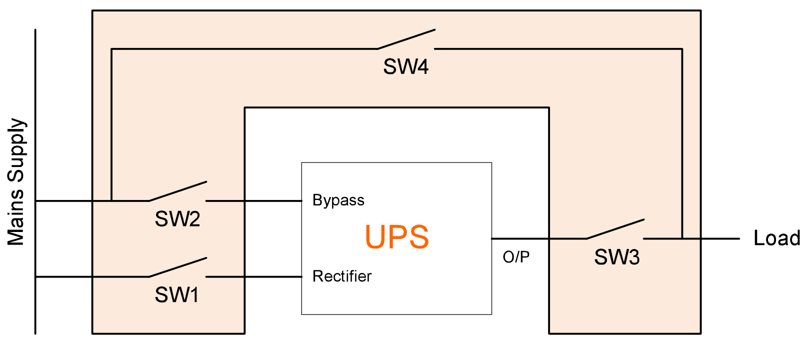


Figure 11.23: Dual Input 3 Phase In/Out External Maintenance Bypass Switch

Interlocking between ups and external bypass

If an installation includes an external bypass facility it is usual to incorporate some means of electro-mechanical interlock that prevents the external bypass switch from being closed while the inverter is on-line (and conversely prevents the inverter from being brought on line while the external bypass switch is closed). If the external bypass switch is closed while the inverter is on-line it will most certainly lead to inverter damage, and possibly load interruption.

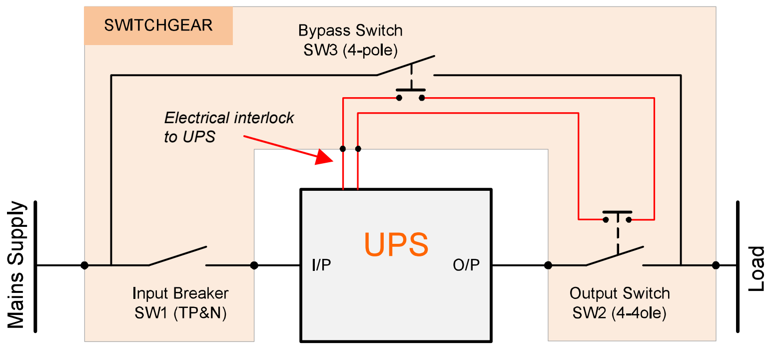


Figure 11.24: External Bypass Interlock

Figure 11.24 shows a basic external maintenance bypass installation. In this diagram the UPS input supply breaker (SW1), UPS output supply switch (SW2) and bypass switch (SW3) are contained in an external switchgear cabinet.

In this example, the interlock function is achieved by auxiliary contacts (n/o) on SW3 and SW2 such that if both these contacts are closed they present a short circuit to the UPS transfer control logic. This forces the UPS to transfer its output from the inverter to the static bypass if the inverter is on-line, and prevents it from being re-transferred back to the inverter for as long as the interlock remains active.

A typical manual switching sequence to close the external bypass would be:

1. At the UPS, transfer the load to (static) bypass.
2. Close the external maintenance bypass switch (SW3).
3. Open the external UPS output switch (SW2).
4. With SW2 open, the interlock is removed and the UPS output can be internally switched between inverter and bypass for testing, if required.
5. To totally isolate the UPS, open the external UPS input breaker (SW1).

Earthing

In any electrical installation correct earthing is essential for personnel safety and equipment protection. A protected power installation is no exception, it is essential to ensure that **all** earthing points within the system are connected to a properly planned and secure earthing system.

As a minimum a properly planned and secure earthing system for a computer and UPS installation must provide:

- protection against electrical shock
- a short, low impedance return path for fault currents
- a path for induced currents caused by high voltages such as lightning
- straightforward connection facilities for future expansion.

Most earthing installations are based on star or grid configurations.

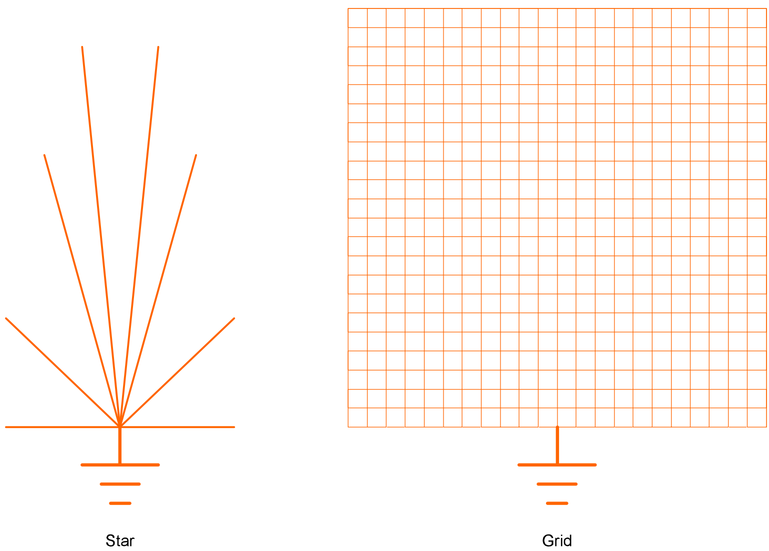


Figure 11.25: Basic Earthing Configurations

In the star system the earth conductor from the incoming mains supply is brought to a central point and radial earth conductors are distributed to each item of equipment.

When using the grid arrangement, the earth from the incoming mains supply is connected to a grid or 'mat' of earth conductors which is installed to cover the entire installation area. Individual items of equipment may then be connected to the grid with very short conductors.

The grid system is more difficult to install, although rooms with raised floors have made it easier, but it does offer advantages over the star system:

- the whole grid is at near earth potential
- the grid offers very low impedance to all frequencies
- equipment connection to the grid is simple

However, the star system is much easier to install and is therefore the most common system in use.

Commissioning

Proper commissioning of UPS equipment by the supplier's trained and experienced personnel is essential. The small additional cost incurred is outweighed by the benefits of:

- complete check of system facilities and options
- complete warranty cover on all UPS equipment
- registration of equipment serial numbers with the supplier
- acceptance of environmental conditions
- the user being trained in the operation of the UPS

A sample of a typical commissioning method statement is given on the following pages.

Sample Commissioning Method Statement

General Instructions

If any corrective measures are required to commission the UPS they shall be carried out under warranty and costs will be borne by the supplier and/or the manufacturer of the UPS. If any corrective measures are needed as a result of shipping or installation damage they shall be made only after liability for the damage is clearly established.

Customer Information

- Record customer name and other customer details on the Commissioning Report (CR).

Unit Information

- Record unit type and serial number details from type plate located inside the door or at the rear of unit, and record on the CR.

Equipment Inspection

- Check the unit and options for external and internal damage. If any damage is found, record the nature of the damage on the CR and advise the customer.

Installed Options

- Identify what options the customer has also purchased with the system and record details on the CR.

Installation Checks

Common items

- Check and tighten all external connections to UPS, battery and load.
- Check phase rotation of AC connections and polarity of DC connections.
- Check all protective earth connections for proper installation and cable area.
- Check installation of service switch if fitted.

Rectifier/Converter, Bypass Line, Load

- Check that cable area and fuses are correct according to installation manual.
- Check that distribution fuses and cable area for distribution cables are correct according to connected loads.
- Record cable areas and fuse ratings in commissioning report.

Customer Interface/Options

- Check that the installation and connection of all optional features and facilities are made according to the installation manual and customer requirements.

UPS Power Up

The following activities will be performed with live voltage at the UPS input and output terminals. Ensure all company Health & Safety procedures and guidelines are fully complied with at all times.

Line Voltage Rect/Conv

- Connect line voltage to UPS Rect/Conv line and measure voltage.

Line Voltage Bypass

- Connect line voltage UPS Bypass line and measure voltage.

Unit Started

- Perform normal unit start up and check that unit is operating normally.

Output Voltage/Frequency

- Measure output voltage and check output voltage waveform and frequency.
- Confirm all calibrations are correct.

System Test

The following activities will be performed with live voltage at the UPS input and output terminals. Ensure all company Health & Safety procedures and guidelines are fully complied with at all times.

Front panel display and switches

- Check that all LED's illuminate:
- Check the MECHANICAL BYPASS switch. Transfer the load from the inverter via the static switch to the mechanical bypass switch. Check with an oscilloscope the UPS output voltage and check that the transfer is break-free.

Customer Interface

- Test for the correct operation of the following alarms (if fitted):
  - BATTERY LOW
  - LINE FAILURE
  - UPS BYPASSED
  - UPS ALARM

Line Failure/Synchronisation Test

- Look at the inverter output voltage and line voltage with an oscilloscope.
- Switch off the bypass line input then switch it back on.
- Check that the inverter synchronises with the bypass line after 10 sec. and that the phase angle is nominally zero degrees.

Starting Up and Shutting Down

- Start up and shut down the UPS following the procedures in the User Manual.

Function of Installed Options

- Test the function of each of the options installed.

Functional Test

- Perform a battery test and check discharge currents.
- Perform a mains failure test.

UPS Failure Test

- Check that the UPS transfers the load to the bypass line, when simulating trip of internal UPS fault. This test is only to be performed if there is no live customer load and the test can safely be performed on the UPS.

UPS Overload

- If possible, check that UPS transfers the load to the bypass when the load is >100%.

Operator Training

During the Operator Training sessions make sure that the operators are acquainted with the User Manual and use it as the training material.

Operating Principles

- Explain the operating principles of the UPS in general terms and in the UPS model specific terms. Explain also the function of all installed options.
  - Normal operation
  - Mains failure
  - Overload
  - Bypass switch (Static and Internal).

Safety Information

- Review the safety information as given in the User Manual and ensure that it is clearly understood.

Indications and Alarms

- Review the function and meaning of all indications and alarms.
- Review the function of computer interface and actions that shall be taken in the event of a mains failure.

Start and Stop Procedure

- Review and let operators perform a UPS start up and shut down procedure following the instructions in the User Manual.

Fault Diagnosis

- Review the fault diagnosis activities based on the fault indications from the front panel as described in the User Manual.

Responsible for Operation and Maintenance

- Record the name, title and telephone number of a person(s) responsible for the operation and/or maintenance of UPS in the CR.

Notes

- Record all relevant site/ unit comments in the notes section of the report and discuss each note with the customer.

Signatures

- Sign, and ensure that the customer signs the FSR and the Commissioning Report, and give a copy of the report to the customer.

Micro and Mini UPS (250VA - 2kVA)

In general the Micro and Mini sized UPS are supplied fitted with standard mains plugs and will not require specialist commissioning. In most cases these UPS are portable and are supplied 'ready-to-go' and simply require unpacking and connecting to the mains supply and the load. However, some suppliers will offer to deliver and install the equipment and spend some time explaining the operation of the system.

The output connectors on these small UPS are usually standard IEC sockets, so it is important to ensure that suitable cables for connection of the load equipment are available. *See "Desktop Systems," on page 13*.

Medium UPS (3-20kVA)

Medium sized UPS are designed to support complete office networks or communications centres. They are not usually portable and are connected to the mains supply by fixed wiring.

Some medium sized UPS (small single-phase units up to typically 6kVA) are connected to the mains supply using standard plug and socket arrangements and are put into service in the same way as the Micro and Mini systems.

Larger power ratings will require connection with fixed wiring and should only be commissioned by the supplier's trained and experienced personnel.

Large UPS (30-400kVA and above)

Large UPS equipment will be electrically installed with fixed cabling and dedicated input and output switchgear and must be commissioned by the supplier's trained and experienced personnel.

Load Bank Testing

To validate the correct operational performance, and the battery autonomy of the UPS system on-site and under full load conditions, a dummy load bank is sometimes utilised. This facility is normally only required on large UPS since the cost of the provision of a load bank and the engineer's costs become disproportional to the equipment cost for small and medium size UPS.

The load bank is normally resistive (unity power factor) and comprises heating elements and fans for cooling. Reactive load banks are also available (typically 0.8 lagging power factor) but tend to be much larger and heavier due to the wound inductive components. The load bank should be supplied with suitably rated cables, which allow it to be placed approximately 20 metres from the UPS terminals or output PDU. Allowance should be made to ensure the heat from the load bank can be safely dissipated and it should not be located in the vicinity of sensitive fire alarm and sprinkler systems.

If the load bank is being used to verify the specified battery autonomy it is good practice to only undertake the tests at least one week after the UPS has been commissioned to permit the voltage across the battery blocks to equalise and for the battery to be fully charged. For this reason UPS manufacturers do not normally include load bank testing as part of the standard commissioning procedures.

Three-Phase UPS Supporting Single-Phase Loads

On some occasions it is advantageous to support various single-phase loads across the output phases of a three-phase UPS. Whilst not essential, it is desirable to arrange the single-phase loads so that the loading on each of the UPS output phases is equal, or at least close to being equal. This is particularly important to avoid an unbalanced three-phase load being presented to a closely rated standby generator if, or when, the UPS switches to its bypass mode.

It is permissible to have single-phase loads, when being supplied by different phases, in the same vicinity providing local regulations are enforced, such as Reg 514-10-01 of BS7671 in the UK. This regulation generally states that:

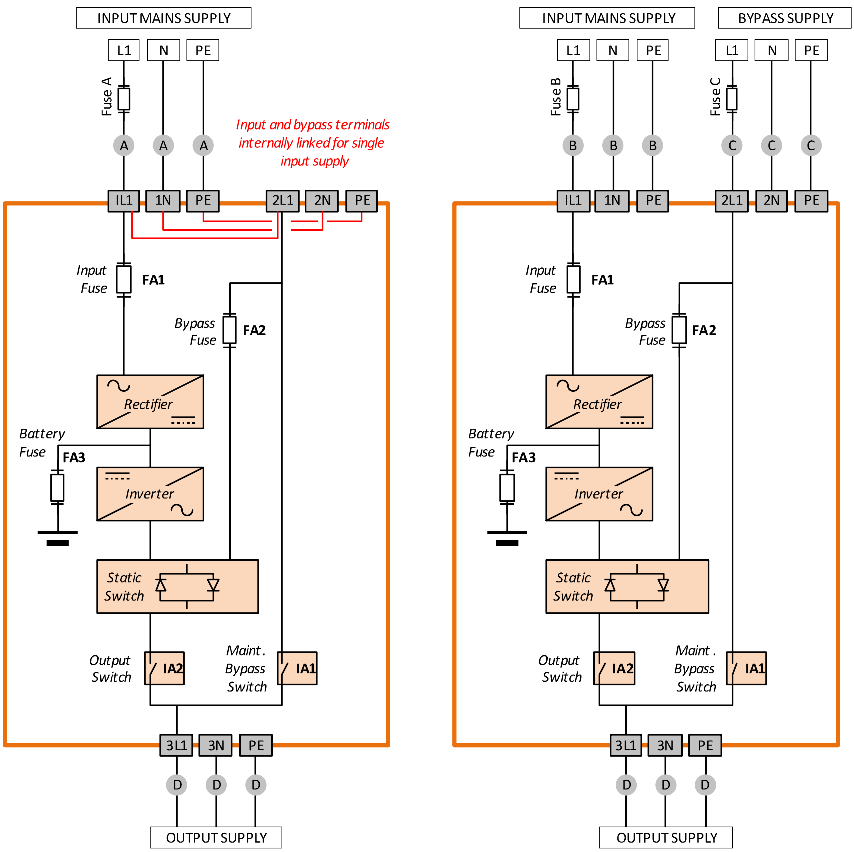
"Every item of equipment or enclosure within which a nominal voltage exceeding 230 volts to earth exists and where the presence of such a voltage would not normally be expected, shall be so arranged that before access is gained to a live part, a warning of the maximum voltage present is visible."

Installation Drawings

The following pages show some typical UPS installation drawings similar to those which your UPS supplier should be able to provide pre-installation.

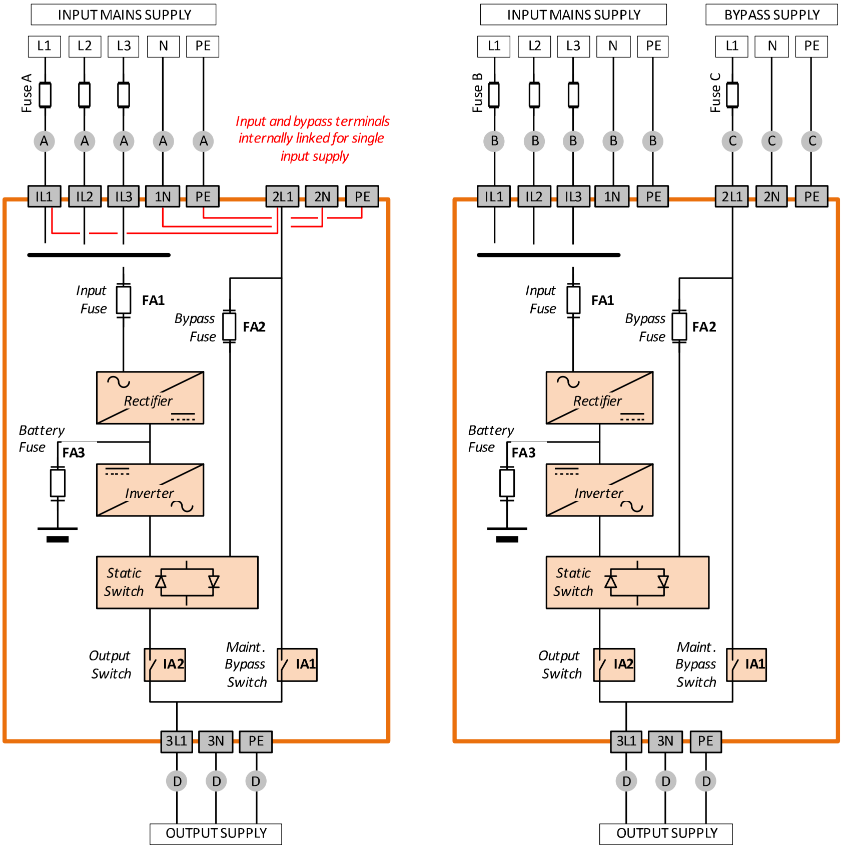
The drawings are shown as examples only and should not be used as references for a particular installation and any cable sizes shown are the minimum recommended.

Unless the UPS supplier is contracted to electrically install the UPS, its correct installation will be the sole responsibility of the electrical contractor.



SINGLE INPUT FEED				DUAL INPUT FEED				
Power (kVA)	Fuse A (A)	Cable A (mm^2)	Cable D (mm^2)	Fuse B (A)	Cable B (mm^2)	Fuse C (A)	Cable C (mm^2)	Cable D (A)
7.5	1 x 40	3 x 6	3 x 6	1 x 40	3 x 6	1 x 40	3 x 6	3 x 6
10	1 x 63	3 x 10	3 x 10	1 x 63	3 x 10	1 x 63	3 x 10	3 x 10
12	1 x 63	3 x 10	3 x 10	1 x 63	3 x 10	1 x 80	3 x 16	3 x 16

Figure 11.26: Typical 7.5-20kVA Single Phase In/Out UPS



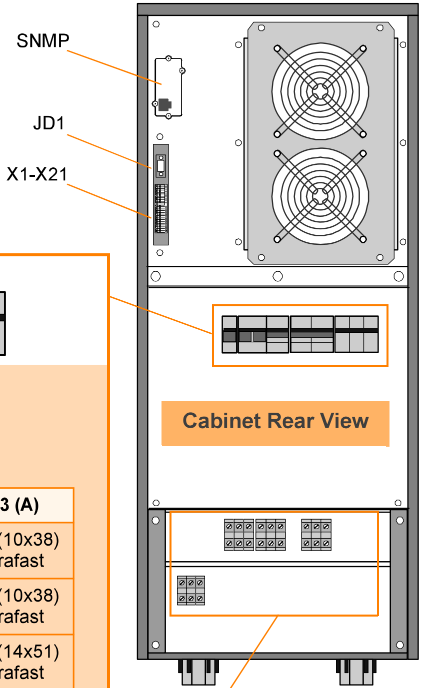
SINGLE INPUT FEED				DUAL INPUT FEED				
Power (kVA)	**Fuse A (A)**	**Cable A (mm^2)**	**Cable D (mm^2)**	**Fuse B (A)**	**Cable B (mm^2)**	**Fuse C (A)**	**Cable C (mm^2)**	**Cable D (A)**
7.5	3 x 40	5 x 6	3 x 6	3 x 25	5 x 2.5	1 x 40	3 x 6	3 x 6
10	3 x 63	5 x 10	3 x 10	3 x 25	5 x 2.5	1 x 63	3 x 10	3 x 10
15	3 x 80	5 x 16	3 x 16	3 x 40	5 x 6.0	1 x 80	3 x 16	3 x 16
20	3 x 100	5 x 25	3 x 25	3 x 40	5 x 6.0	1 x 100	3 x 25	3 x 25

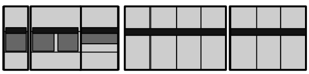
Figure 11.27: Typical 7.5-20kVA Three Phase In / Single Phase Out UPS

Customer Interface Connections

JD1 – Smart Port RS232 (Sub-D9P/F).

X1-X21 – Dry Port volt-free contacts on terminal block.





IA1 – Maintenance Bypass Switch
IA2 – Output Switch
FA2 – Bypass Supply Line Fuse
FA1 – Input Supply line Fuse
FA3 – Battery Fuse

	FA1 (A)	FA2 (A)	FA3 (A)
7.5	50A (14x51) Ultrafast	50A (14x51) GL/GC	32A (10x38) Ultrafast
10	50A (14x51) Ultrafast	50A (14x51) GL/GC	32A (10x38) Ultrafast
15	50A (14x51) Ultrafast	80A (22x58) GL/GC	32A (14x51) Ultrafast

Input/Output Power Connections

* In a 'single feed' (standard) installation terminals 2L1 and 1L1 are linked by cables fitted to the UPS side of the terminal blocks.
Terminals 2N and 1N are similarly linked.
When using a 'dual feed' supply these links should be removed and the bypass supply cable connected as shown in this diagram.

** The UPS internal battery is normally connected to the battery isolator switch (FA3). If an external battery cabinet option is used, the internal batteries are disconnected and the external battery cabinet is connected to the terminals shown in this diagram.

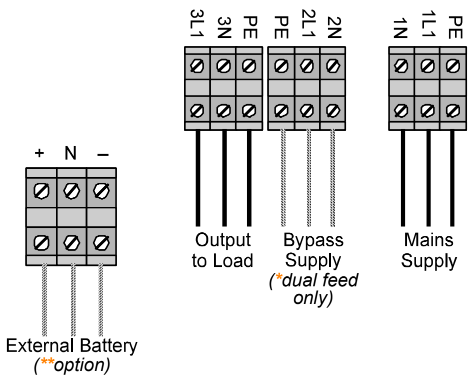
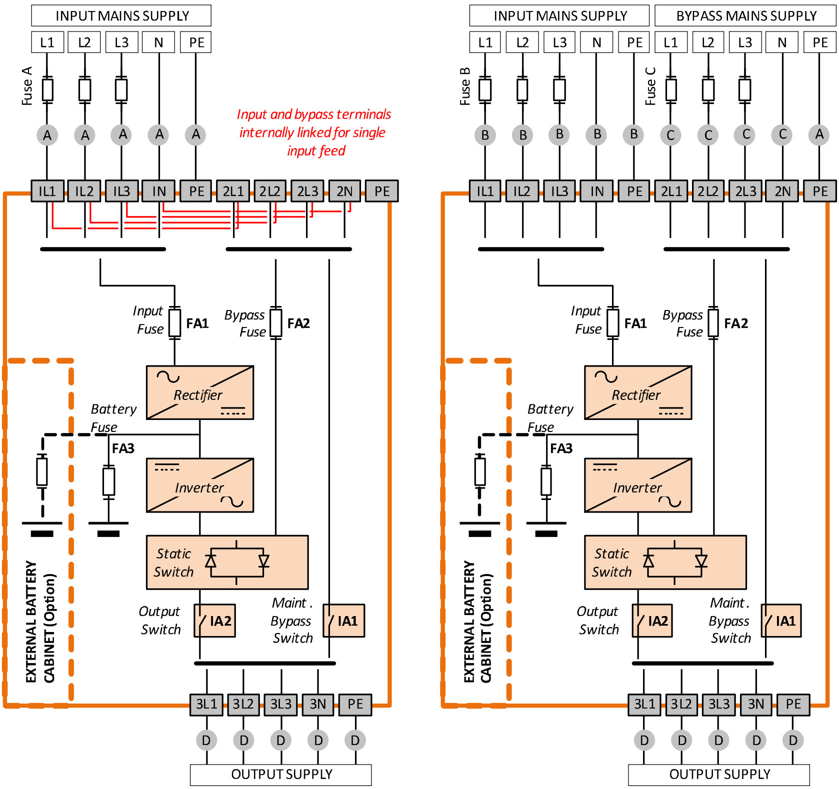


Figure 11.28: Typical 7.5-12kVA Single Phase Input Terminal Block



Power (kVA)	Fuse A,B,C (A)	Cable A,B,C,D (mm^2)
10	3x 20	5 x 2.5
15	3x 25	5 x 4
20	3x 40	5 x 6
30	3x 63	5 x 10
40	3x 80	5 x 25
60	3x 100	5 x 35
80	3x 125	5 x 50
100	3x 160	5 x 50

UPS Power (kVA)	Fuse A,B,C (A)	Cable A,B,C,D (mm^2)
120	3 x 200	5x 70
160	3 x 250	5x 120
200	3 x 350	5x 185
250	3 x 400	5x 240
300	3 x 500	5x (2x120)
400	3 x 630	5x(3x95)
400	3 x 630	5x (2x185)
500	3 x 800	5x (3x 150)

Note: External battery cables and fuses are bespoke to the installation

Figure 11.29: Typical Three-Phase Input/Output UPS

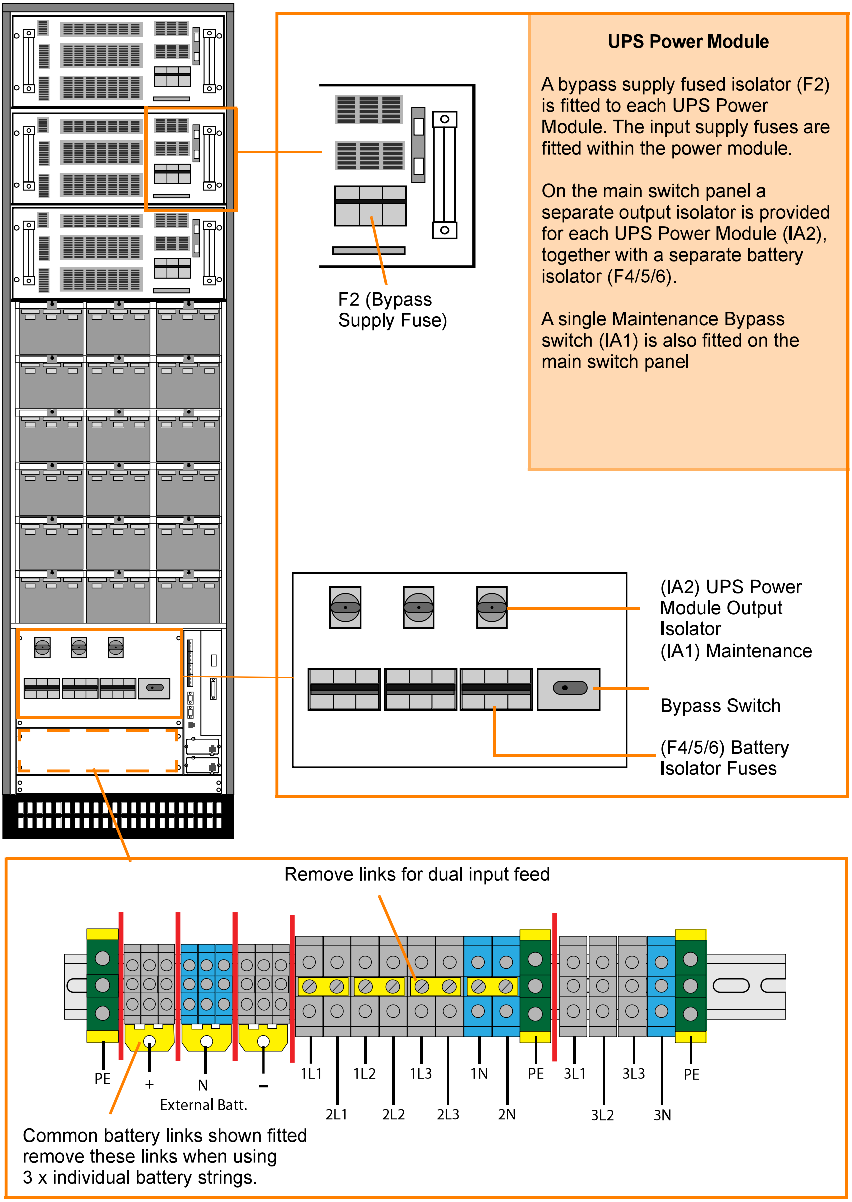


Figure 11.30: Typical 3 phase Input/Output UPS Terminal Block

Parallel Systems

Standalone, parallel, three-phase input/output UPS modules are installed in much the same way as a single free-standing module shown in Figure 11.26 - Figure 11.30 except that they also require some inter-module control cabling and, of course, paralleling switchgear.

In an N+1 parallel UPS system the cabling and protection for each module is the same as that used for single modules. However, the size of 'wrap-around' bypass cabling and the main output isolator will be dictated by the total capacity of the UPS system. When installing a parallel system consider the future and ensure that these items are sized accordingly.

Figure 11.31 shows a sample parallel system schematic.

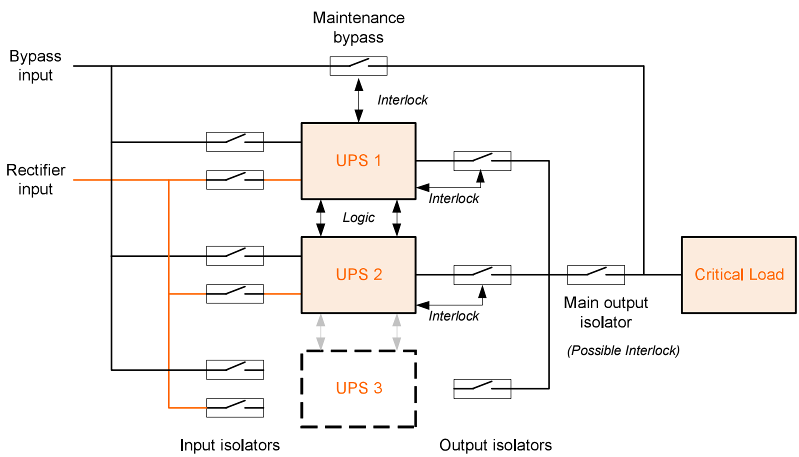


Figure 11.31: Sample Parallel UPS System Schematic with Spare Way Provided for Future Expansion (UPS 3)

Modular UPS systems lend themselves to paralleling much more readily since the inter-module control cabling and the paralleling switchgear is contained within the cabinet and requires only the insertion of the UPS module to facilitate communication and parallel connections.

Using and Maintaining the UPS

Responsibilities

Once the UPS is installed (and commissioned, if appropriate) it is important to ensure that someone is made responsible for the UPS and its associated equipment. This need not be an electrical technician, but should be someone who is invariably on-site and easily contactable and is typically the IT manager or facilities manager.

Establishing a central contact responsible for protected power provision is essential to ensure that:

- the UPS is kept in optimum condition
- the UPS or plant room is kept clean, dry, tidy and well lit
- alarms and indications are recorded, logged and reported correctly
- the UPS is correctly maintained
- someone on site knows where the UPS is located

For small UPS systems, access to the UPS user manual and the phone number of the UPS supplier is all that is typically required. However, for medium and large UPS systems that require routine maintenance, a higher degree of user system awareness is required.

Service and Maintenance

Typically medium sized UPS systems are covered by a service and maintenance contract and this should be considered essential for large systems.

Information regarding the correct care of UPS systems and detail regarding service and maintenance contracts is given in Chapter 12.

UPS equipment should only be operated by trained and experienced personnel as high voltages are present within the UPS cabinets. Also the company maintaining the UPS equipment should be able to confirm that their service personnel are fully trained by the manufacturer and that they have full and unrestricted access to spare parts.

Summary

This section has discussed, in some detail, the steps required to achieve a successful UPS installation.

The correct selection, delivery and positioning, electrical installation, commissioning and maintenance of a UPS system may not be straightforward. There are a large number of diverse skills required to complete all aspects of the installation successfully and within the available budget. The UPS end user may choose to handle all aspects of the installation or they may appoint a consultant or experienced electrical contractor to act for them. Alternatively, there are some UPS suppliers who can offer ‘turnkey’ solutions and the end user may want the security of knowing that the original specifier, supplier and installer will be responsible for the continued operation of the UPS system.