What is an uninterruptible power supply (UPS)?
Fundamentally, an uninterruptible power supply, or UPS, is a unit which maintains the electrical supply to a piece of equipment, or load, following the failure of the primary source of supply. The UPS is, therefore, installed between the source of the electrical supply and the load.

BS EN 62040-1:2003 defines a UPS as a combination of converters, switches and energy storage devices (for example, batteries), constituting a power system for maintaining continuity of load power in case of input power failure.

Are there different types of UPS?
Fundamentally, there are two categories of UPS – rotary systems and static systems.

Static
Static UPS systems deliver the output voltage derived from a stored source, e.g. a series of batteries through an inverter.

Rotary
Rotary UPS systems consist of one, or more, electrical rotating machines to provide the output voltage, e.g. a generator or multiple-synchronised generators.

Under normal circumstances, the electrical supply can be routed directly through to the load whilst the rectifier “rectifies” the a.c. supply to d.c. to charge the storage batteries.

In the event of loss of the electrical supply, d.c. from the batteries is inverted back to a.c. and will supply the load; the bypass switch opens and stops the inverted UPS supply from being routed back to the origin of the installation. This is known as a passive standby system.

The bypass switch can be used for another function. Should the electrical supply to the installation, or load, be non-sinusoidal, e.g. the harmonic content is such that the supply waveform is no longer considered to be sinusoidal, the UPS unit may be used as a “smoothing” device and clean up the supply for use on sensitive or vulnerable equipment and critical loads. In reality, the batteries will be charging whilst supplying the load. This is known as an active standby system. Operation in this mode will also compensate for dips or surges in the supply.

Static UPS systems are available in many different sizes, ranging from very small and simple to very large and complex. Small and autonomous systems are available providing circa 1kVA; large UPS units can be paralleled to provide, in excess of, 1MV A.
The rotary UPS system generally sits dormant until it is required. Control equipment will sense the loss of mains supply and switch the installation over to be supplied by the generator. Usually, there will be a period of time when the load is without a supply; this could be a period of seconds, even minutes, whilst the prime-mover starts and the generator attains full speed. This known as the automatic load transfer time. Figure 2, shows the layout of an installation with a back-up generator or rotary UPS.

The requirements of BS 7671

Isolation and switching

A UPS is a source of energy and, to comply with Regulation 460-01-01, a non-automatic means of isolation and switching should be installed to disconnect the source from the load. BS 7671 lists four types of switching – Isolation, Switching off for mechanical maintenance, Emergency switching and Functional switching. The concepts of isolation & switching are examined here:

The definition of isolation is:

Isolation

A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy.

The definition of a switch is:

Switch

A mechanical device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions, and also of carrying for a specified time currents under specified abnormal circuit conditions such as those of short-circuit. It may also be capable of making, but not breaking, short-circuit currents.

Regulation 460-01-02 requires that where an installation is supplied from more than one source, a main switch shall be provided for each source of supply and a durable warning notice shall be permanently fixed in such a position that any person seeking to operate any of these main switches will be warned of the need to operate all such switches to achieve isolation of the installation. Alternatively, a suitable interlock system shall be provided.

Characteristics of supply

As with any installation, it is a requirement of BS 7671 that the nature of the supply parameters are assessed, e.g. Ze (Ω) and Ip (A); UPS systems, which are a source of supply, are no exception.

Further, Regulation 551-02-02 requires that the prospective short-circuit current and prospective earth fault current shall be assessed for each source of supply or combination of sources which can operate independently of other sources or combinations.

Protection against electric shock

An important aspect of providing protection against indirect contact which can be readily overlooked by the designer is the need to ensure satisfactory operation of the relevant protective device(s) when the installation, or part thereof, is energised from a UPS. To be certain that the requirements of BS 7671 for protection against electric shock (and short-circuit) will still be satisfied, the designer must obtain full information for the alternative supply and make the necessary checks of the design, which will have been based upon the characteristics of the normal supply source.

Regulation 551-04-04 requires that where the conditions for automatic disconnection of Regulation 413-02 cannot be achieved for parts of the installation on the load side of the static inverter, supplementary equipotential bonding shall be provided on that side in accordance with Regulations 413-02-27 and 413-02-28. The resistance (R) of the supplementary equipotential bonding conductor between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts shall fulfil the following condition:

\[
R \leq \frac{50}{I}
\]

where: I is the maximum fault current which can be supplied by the static inverter alone for a period of up to 5 s.

Further, Regulation 551-04-05 states that precautions shall be taken or...
equipment shall be selected so that the correct operation of protective devices is not impaired by direct current generated by a static inverter or by the presence of filters.

Protection against overcurrent
Regulation 551-05-01 requires that where means of detecting overcurrent of the generating set is provided, this shall be located as near as practicable to the generator terminals. A generator control panel or UPS equipment may include self-protection, a feature of which is the rapid collapse of output voltage to the load. This will inhibit the operation of any fault protective device situated beyond the equipment terminals and the feature cannot be assumed to provide a fail-safe operational arrangement for the user. Safety of the system as a whole must be ensured by, if necessary, involving the equipment supplier.

Earth electrode
Regulation 551-04-03 requires that protection by automatic disconnection of supply shall not rely upon the connection to the earthed point of the distributor’s network when the generator is operating as a switched alternative to a TN system. A suitable earth electrode shall be provided. Clause 18.2.1 of BS 7430 states generator earthing calls for the provision of an independent earth electrode. It is necessary that the earth loop impedance at any point of the installation is low enough to ensure operation of the earth fault protection, and this should be taken into account when the earth electrode forms part of the earth fault loop. For independent earth electrodes associated with the local earthing of the star point of generating plant, it is recommended that the earth resistance should not exceed 20Ω.

Supplies for safety services
Safety services, such as fire alarm systems, sprinkler systems, etc., are often supplied by UPS systems as loss of supply to such equipment could result in loss of life. BS 7671 defines a safety service as an electrical system for electrical equipment provided to protect or warn persons in the event of a hazard, or essential to their evacuation from a location. BS 7671 recognises that UPS systems may operate in a parallel configuration. Regulation 566-01-01 requires that protection against short-circuit and against electric shock shall be provided whether the installation is supplied by either of the two sources or by both in parallel. Further, Regulation 566-01-02 requires that precautions are taken to limit circulation currents, particularly that of third harmonics or multiples thereof, in the connection between the neutral points of sources.

Harmonic distortion
Static UPS systems may create harmonics on the sinusoidal waveform. Other than selecting the use of low harmonic-producing equipment, there are two recognised methods of reducing harmonic content; install harmonic filters which are suited to the load of the UPS or increase the size of the neutral conductor. Regulation 524-02-02 requires that the neutral conductor is adequately sized to carry the maximum current likely to flow in it under normal operating conditions.
Small systems

Some small UPS systems, circa 1kVA, can be unearthed and effectively operate as an electrically separated system. Note that certain items of equipment require a reliable connection to the means of earthing to operate, i.e. filters within the switch-mode power-supplies of personal computers. Prior to connecting equipment to a UPS, it must be ensured that the equipment is suitable for operation in such circumstances. Regulation 413-06-03 requires that where only a single item of equipment is supplied in this manner, there should be no connection between the separated circuit and any other circuit, or to Earth. The flexible cable/cord supplying the load, which is liable to mechanical damage, should be visible throughout its length. It is preferred that a separate wiring system should be used for the separated circuit (although multicore cables without magnetic sheath or insulated conductors in an insulated enclosure are permitted if the rated voltage of the cables is not less than the highest voltage likely to occur and each circuit is protected against overcurrent). Every live part of each separate circuit shall be electrically separated from all other circuits to a standard not less than that provided between input and output windings of an isolating transformer to BS 3535.

Regulation 413-06-04 requires that no exposed-conductive-part of the separated circuit shall be connected to either the protective conductor of the source circuit, or to any exposed-conductive-parts of any other circuit.

Other considerations

Prolonged loss of supply

In the UK, some areas are more susceptible to power cuts than others, particularly rural areas. Should inclement weather bring down overhead power lines, for example, the mains supply could be interrupted for quite some time, perhaps days. A static UPS would not have the capacity to supply the load for a period of days but it would, however, provide enough time to allow back-up of information and data during the enforced power outage. This is known as the autonomy time. If the installation is located in such an area, a static UPS system could be used for short term power loss with a rotary UPS installed to provide an alternative long-term back-up source.

Storage batteries

Static UPS systems are usually equipped with storage batteries to meet the power requirements of the connected load; large loads require large battery banks. Small UPS systems may have maintenance free batteries but large banks will consist of one of two types of rechargeable battery, namely, lead-acid or alkaline. Lead-acid batteries are the most commonly used rechargeable battery, they are found in such applications as cars, motorcycles and electric vehicles. Note that the correct battery must be chosen for the particular application. Alkaline rechargeable batteries, such as nickel-cadmium, nickel-metal hydride and lithium ion, are widely used in small items such as laptop computers. Large capacity versions of these cells are now used in transport and UPS applications.

There are two different types of lead/acid and alkaline rechargeable batteries: valve-regulated (‘maintenance-free’) and vented. In valve-regulated batteries, any hydrogen and oxygen produced during charging does not escape but is converted back into water. Water cannot be added to these batteries as they do not need topping up. In contrast, vented batteries allow any hydrogen and oxygen produced to escape into the surrounding atmosphere and they require regular topping up with water. However, installation, commissioning and maintenance should only be carried out by a competent person trained in this line of work and experienced with the particular equipment.

Sources of further information

5) BS EN 88528-11:2004 Reciprocating internal combustion engine driven alternating current generating sets - Part 11: Rotary uninterruptible power systems - Performance requirements and test methods
6) BS EN 62040-3:2001 Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements

Thanks to Uninterruptible Power Supplies Ltd. for the images used http://www.upspower.co.uk