Technical Engineering Notes

UNINTERRUPTIBLE POWER SUPPLIES

Introduction

The fact that the mains supply is not always reliable has been brought into sharper focus by the increasing use of small computers in offices and at home. There are very few seasoned PC users who have not suffered data corruption as a result of disturbances on the mains supply, or even worse, complete loss of programmes from total mains blackouts. Although most of Europe has an exceptionally high quality main electricity supply we are by no means immune from problems as many in the UK can testify. They were cut off for periods lasting from 30 minutes to several days after the storms of October 1987 and January 1990. Equally inconvenient and sometimes more costly is damage to equipment caused by very high voltage surges such as those caused by lightning strikes. As a minimum they can activate overvoltage trips on equipment power units, at worst they can destroy banks of integrated circuits.

Traditionally equipment used in critical applications has been provided with back up systems to give varying degrees of immunity, typical examples are hospital operating theatres, air traffic control centres, large scale data processing installations, industrial process controls and secure voice and data communication systems. The high cost of providing no break power systems had not allowed proliferation to more mundane, but to the frustrated user, equally deserving applications.

However with new technology and higher production volumes, it is now possible to provide highly reliable back up power at a reasonable cost for almost any requirement.

Power Line Disturbances

It has been stated that as many as 1,000 variations can occur in 24 hours on mains supplies. Normally these are of a minor nature and do not interfere with the operation of equipment.

However, typical severe disturbances which occur on power lines are summarised as follows (see Fig. 29):

1 Voltage spikes and transients. These are caused by lightning strikes, nearby switching of highly inductive loads, automatic tap changing and power factor correction. The characteristics of these disturbances are high voltage peaks up to 2kV, and even occasionally to 10kV, with nanosecond leading edge, and less than 100µs duration.
2 Line voltage sags and surges. These are usually caused by switching on or off an high power equipment on the same distribution circuit. Amplitude may be ± 60% and duration up to 1 mains cycle.
3 Brown-out. An unplanned voltage reduction below the power company's specification, lasting several cycles. Causes lights to dim momentarily and TV pictures and computer CRT displays to shrink or even disappear. Local supply overloads and storms are main causes.
4 Blackout. Total loss of power caused by damage to power lines during storms, and sometimes from faulty cables and substation equipment.

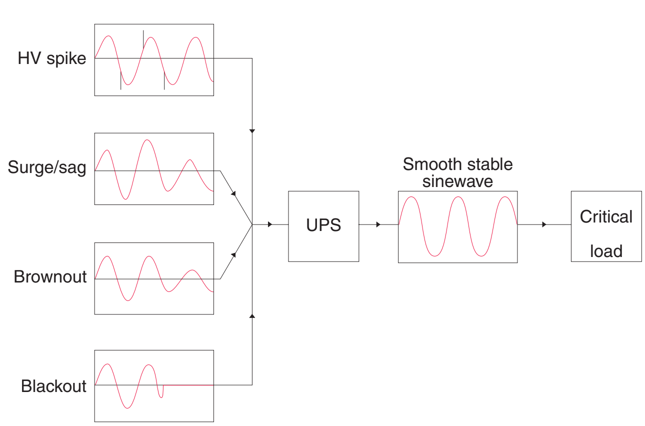

Fig 29 UPS isolates critical load from typical mains disturbances

UPS Systems

UPS is a term applied to an apparatus which is designed to give a continuous stable AC supply irrespective of variations and interruptions in the local mains electricity supply. It is sometimes used for AC/DC power supply units which have integral battery back up for one or more critical DC outputs. Since such systems do not have the general purpose nature, nor the isolation characteristics of AC/AC UPSs they should be classified as no break DC output power systems.

For UPS's a number of different system configurations are used, and a number of very different technologies, but from the users point of view they can be broadly separated into two categories; On Line and Off Line (Standby).

On Line Systems

A schematic of a typical On Line system is shown in Fig. 30. The load always takes its power from the output of a DC/AC inverter which in turn is powered from the output of a mains driven rectifier/charger. When the electricity supply fails the back up battery supplies DC power to the inverter. During normal operation the battery is float charged from the rectifier output.

The two main advantages of this system are:

1 No break in the supply to the critical load during change over between mains and battery power.
2 The load only ever sees pure power from the inverter output and is totally isolated from mains fluctuations and mains borne noise.

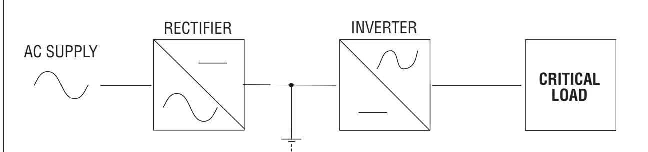

Fig 30 Schematic - online UPS

On Line UPS's must be very highly reliable - there is no point introducing an equipment between the AC supply and the critical load which is less reliable than the electricity supply. In the unlikely event that the rectifier inverter system fails, some UPS systems have an automatic static bypass switch to change over to direct supply from the mains as shown in Fig. 31. To minimise transient effects on changeover the inverter waveform should be synchronised to the mains. In the higher power systems (above 5kVA) it is normal to include a manual bypass switch to allow regular maintenance schedules to be undertaken

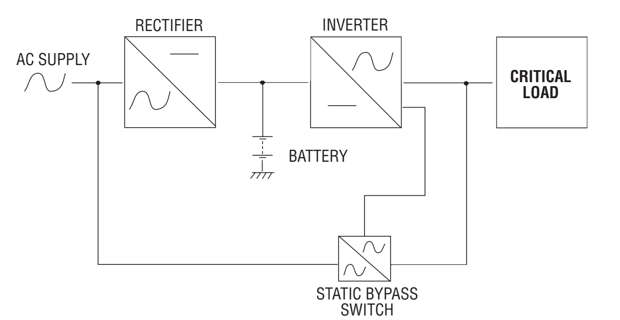

Fig 31 Schematic - online UPS with static switch

Off Line (Standby) Systems

Fig 32. shows schematically the interconnection of the main elements in a standby or Off Line UPS. The critical load normally draws power directly from the mains electricity supply, and in the event of a mains failure, the output of a battery driven DC/AC inverter is automatically switched in to supply power to the load. Mains failure would normally be defined as a drop in supply voltage to less than 85% of nominal value. Off Line systems are normally less expensive than On Line UPS because the inverter need not be designed thermally to run continuously at full rating. Also the rectifier is only required for battery charging, whereas in the

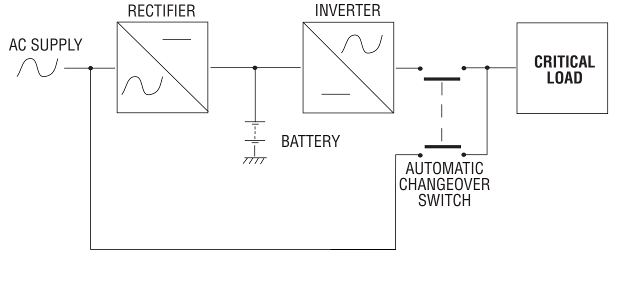

Fig 32 Schematic - offline (standby) UPS

On Line unit the rectifier has to be capable of supplying the inverter with full load power and float charge the battery at the same time.

There are several different configurations of Off Line systems, and there are hybrid systems incorporating certain features of both Off Line and On Line UPS's. For the prospective UPS user it is worthwhile identifying two broad categories, Active (or hot) standby systems and cold systems.

Active
The inverter runs continuously and is synchronised with the mains. This gives fast smooth changeover from mains to battery and allows continuous fault monitoring of the inverter during normal operation from the AC supply.

Cold
In these systems the inverter is only switched on after the mains failure is detected, thus a short interruption of 1 or 2 seconds is likely. These systems can only be used for non critical applications where a short break in supply is not important - emergency lighting is a good example.

Despite their considerably smaller size and lower cost, Off Line UPS systems are not as popular as might be thought. They suffer from the major disadvantage that they provide no mains isolation during normal operation so the computer system being backed up would still require a power line conditioner if isolation from mains transients and noise is desired. All Powerbox Off Line UPS systems provide filtering.

Technology
A number of alternative technologies are in use to implement the inverter section, which may be regarded as the heart of a UPS system. The essential circuit element in all static inverters was originally the SCR and these are still in frequent use in 10kVA plus systems. They have now been largely replaced in sub 10kVA systems by bipolar power transistors and more recently by MOSFET transistors, and very recently by GTO thyristors.

The simplest and least expensive UPS provides a square wave output at mains frequency. However these are not suitable for many applications, especially where the load is highly reactive. They are usually unable to supply the high peak current pulses demanded by a switched mode power supply without very severe power derating. Switched mode power supplies are now almost universal in microcomputer based equipment so the prospective user is advised to conduct a trial, or ask about the suitability of the UPS system before purchasing a square wave output UPS.

Some improvement of performance can be obtained using inverters with stepped square waves. With sufficient steps performance can approach that of pure sinewave inverters especially if output filtering is employed to get rid of the worst harmonics.

Where uncertainty exists with regard to the characteristics of the load, a Sinewave UPS is advised. There are several different ways of producing sinewave output inverters and some of these are discussed in the following paragraphs.

PWM (Fig. 33)
The inverter based upon high frequency switching with pulse width modulation and output filtering to provide the final output sinewave is gaining considerable popularity. It consists of a transistor full bridge circuit which provides a series of rectangular pulses of varying width via an output transformer and filter. The output voltage is continuously compared with a constant amplitude constant frequency reference sinewave generated by an internal stable oscillator. The error signal is used to control the width of the pulse train to maintain the outputs sinusoidal waveform. Because of the high frequency switching the output transformer and filter components are relatively small. If a PWM inverter is combined with a switched mode rectifier/battery charger to make a complete UPS the overall size and weight reduction is dramatic when compared with other techniques using mains frequency transformers.

Advantages claimed for PWM UPS systems are low weight, small size, high efficiency, good dynamic regulation and the ability to cope with non-linear loads.The disadvantage is that the circuitry is complex and component stresses are high because of fast high power switching. The user needs to satisfy himself that

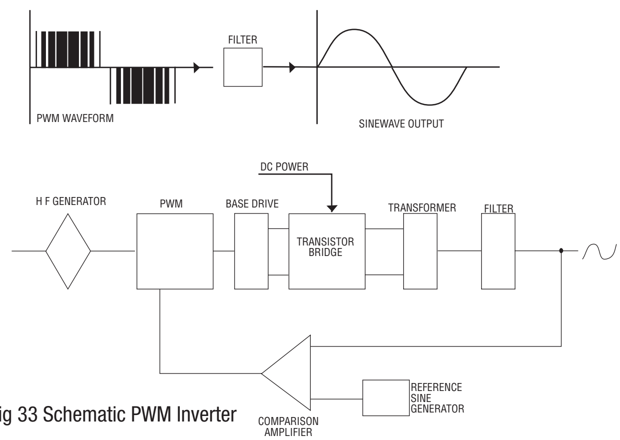

Fig 33 Schematic PWM Inverter

such designs are well established with a good history of field reliability, as demonstrated by the Powerbox range.

Linear Amplifier
Sometimes thought of as the classical circuit for low to medium power DC/AC inverters, the technique is viable for single phase UPS systems up to approximately 1kVA. Above this power level the amplifiers would be parallelled using a control circuit to ensure power sharing.

The schematic is straightforward (Fig. 34), a highly stable oscillator produces a pure sinewave at mains frequency. This is coupled via a pre-amplifier to the input of a low distortion linear power amplifier which provides the required output voltage via an output transformer. An additional output winding on the transformer provides negative feedback to maintain linearity.

The amplifier technology is very similar to that used in high power audio equipment (push pull class AB). Characteristics of this technique are low harmonic distortion (inherently good sinewave) and low output impedance which leads to trouble free operation in most applications. Because the circuitry is all analogue, temperature changes can cause frequency and amplitude drift. Also the power output stages must be kept cool for continuous reliable operation at full power. Ventilation is therefore very important.

Linear amplifiers are capable of providing short term surges of power well above continuous rating, also capacitive loads do not normally cause problems. However highly inductive loads can lead to low frequency instability (the same phenomenon as "motor boating" often experienced with audio power amplifiers).

Resonant Inverters (Fig 35)
Used mainly for low to medium power applications they consist of a current driven square wave inverter driving a resonant tank LC circuit in the secondary of the output transformer. Because the LC circuit is a high Q circuit designed to have a resonant frequency identical to mains frequency, this type of inverter produces a natural sinewave without additional filtering. The tank circuit is a reservoir of power with circulating current oscillating between the L and C, and the load demands its power from this reservoir. The inverter needs only to supply sufficient power each cycle to replace the power taken by the load and the small losses inherent in the LC

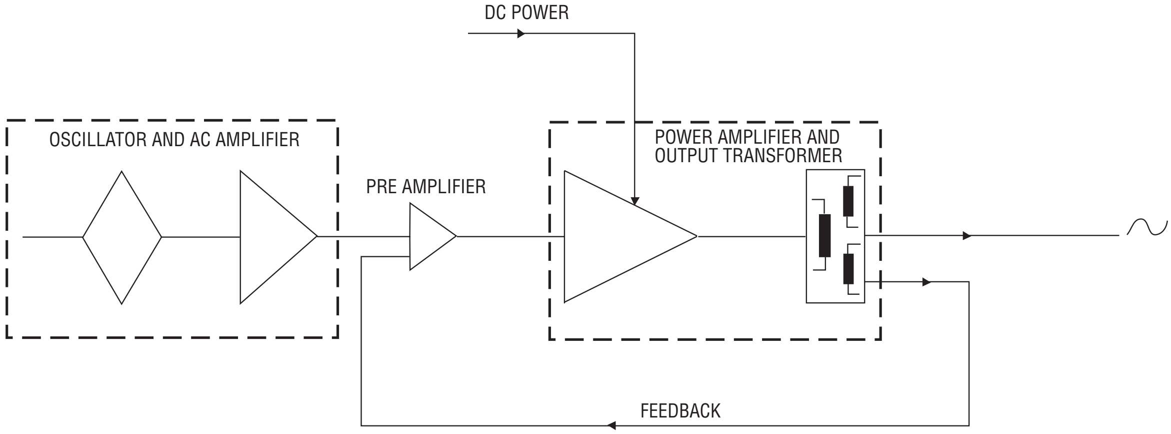

FIG 34 Schematic Inverter with linear power amplifier

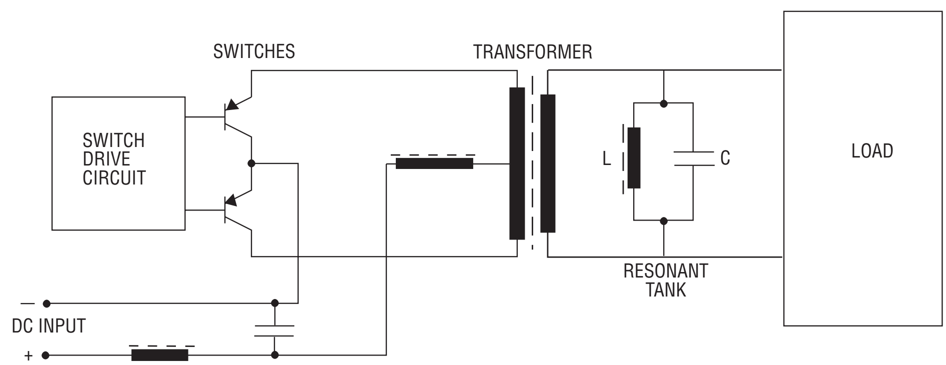

Fig 35 Schematic inverter using resonant tank output circuit

tank. At the resonant frequency the tank represents a very low impedance source to the load so has good capability to cope with dynamic and non-linear loads. Leading and lagging power factors are handled with equal ease.

To simplify the construction the resonant tank inductance is frequently designed into the transformer secondary. The term then used to describe the UPS is ferroresonant. Drawbacks of ferroresonant UPS systems is that they tend to be heavy and fairly large and the transformer produces considerable audible “hum” at mains frequency. The technique is however generally considered to be inherently the most reliable method for low to medium power UPS (up to 5kVA rating).

Installation

Installation of large scale UPS systems must be carefully planned with attention paid to ventilation of the system, special ventilation for the batteries if these are not fully sealed types, input fuses and/or circuit breakers for input protection of the rectifier/charger section, filtering to minimise the reaction of the rectifier circuits on the mains, and distribution and fusing of the output distribution network.

In the publication EN50091-1, which is the EU safety standard for UPS there are a number of requirements detailed which must be followed to ensure safe installation and compliance with the LVD. For instance the standard is particularly concerned with battery installation and care. Battery temperature is recommended to stay within +10°C to +40°C, but must not exceed the following limits:

	Minimum	Maximum
Lead/acid	-5°C	+55°C
NiCd	-20°C	+50°C

Batteries must have a separate or enclosed location. If internal to the UPS they must be in a separate bay or compartment. Adequate ventilation must be provided to prevent the build up of potentially explosive mixtures of hydrogen and oxygen (gases generated when batteries are being charged). Annex N of the standard gives methodes of calculating adequate airflow to ensure dispersion under various conditions.

Probably the major cause of breakdown of small UPS systems is overheating. When used in an office alongside microcomputer apparatus it is necessary to ensure that the ventilation is adequate and unrestricted. The UPS should not be sited in a position where it is in direct sunlight for long periods of the day, nor tucked away under a desk next to a radiator.

Acoustic Noise

In a normal office environment acoustic noise levels above 60 dbA would be intrusive, the target noise level should be below 55dbA measured at a distance of 1 metre.

Back up Time

The majority of low power UPSs are complete with battery capacity giving between 10 and 15 minutes back up time at full rating. This can normally be extended modularly up to several hours by the addition of external battery packs. Care must be taken to ensure that the charger is adequate to give sensible recharge times, otherwise the system has to be augmented by a separate higher power charger.

Audible and Visual Warnings

Most UPS incorporate a number of status and alarm signals which preferably have both visible and audible indicators.

Typically the minimum status signals are:

- Mains failure
- Battery near depletion
- System overloaded
- Support time remaining

Logic compatible outputs may also allow these signals to be polled by the computer system via the priority interrupt so that data protection routines can be automatically initiated.