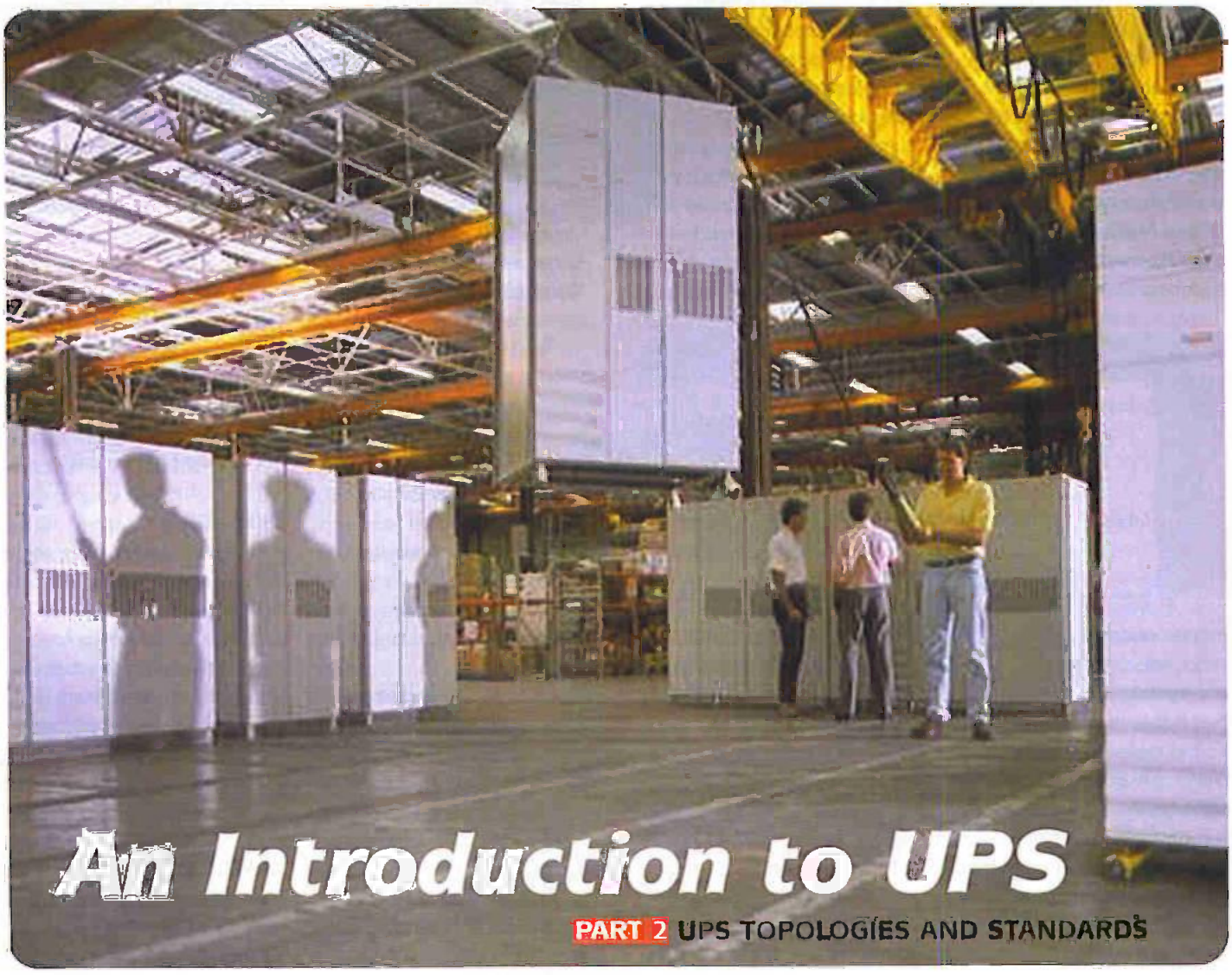
Powering THE INTERNET



An Introduction to UPS

PART 2 UPS TOPOLOGIES AND STANDARDS

Last month, Shri Karve introduced us to Uninteruptible Power Supplies and their relevance within the Internet Supply sector. This month he takes a closer look at the three types of UPS – Passive Standby, Line-interactive and Double Conversion – and explains why there was a need for the International Electrotechnical Commission, (IEC) to establish these standards.

The Need For A New Standard

Mass-produced UPS first appeared on the market in the 1970s, essentially to meet the needs of large computer systems in terms of continuity and quality in the supply of electrical power. They then evolved to adapt to the vast increase in the number of sensitive loads and their diversification, due to the explosion in digital technology.

As a result, UPS were modified to meet the needs of applications such as mini and then microcomputers, industrial processes, instrumentation, telecommunication, etc.

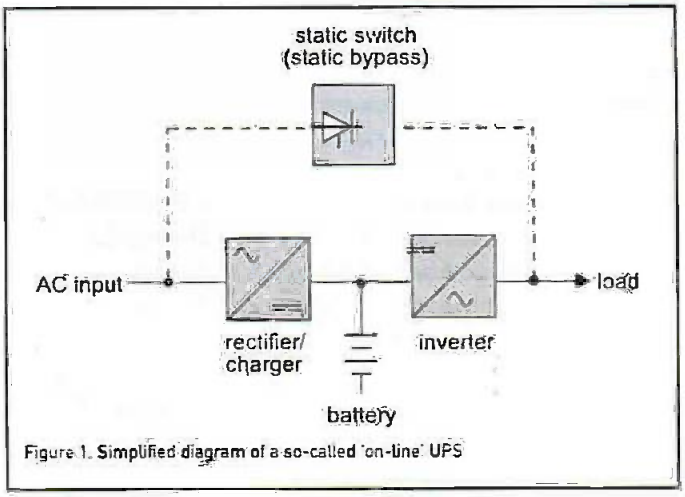


Figure 1. Simplified diagram of a so-called 'on-line' UPS

Adaptation to markets undergoing such rapid change necessitated a wide series of technological innovations and an extension of power ratings. Progress was made in both directions, toward lower and higher ratings, to meet the respective needs of microcomputers and the vital applications of digital telecommunication systems. That is why the term UPS today covers very diverse products ranging from a few hundred VA up to several million VA.

During this process of

adaptation and change, the techniques employed for UPSs became more diverse, depending on the type of application protected, its criticality and power level. At the same time, the description selected to qualify products was often confusing and even misleading to consumers.

Back in the 1970s, the term 'on-line' UPS was commonly used (see figure 1). It refers to a UPS topology comprising primarily: An input rectifier/charger that rectifies the AC-input supply voltage used to charge a battery as well as support an inverter; A battery supplying backup energy in the event of a utility power outage; An inverter that supplies power with a consistently high level of quality (frequency, voltage, etc. within tight tolerances); A static switch (static bypass) capable of transferring the load to bypass power without a break in the supply of power, thus enabling 'downgraded' operation of the load (i.e. not supplied with quality power via the inverter).

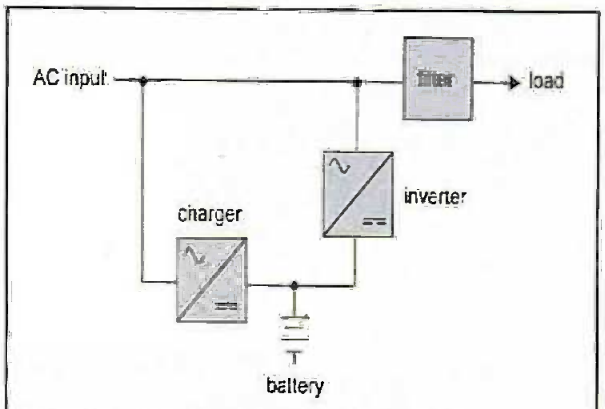


Figure 2. Simplified diagram of a so-called 'off-line' UPS

The standardisation bodies observed that the term 'on-line', which taken literally means 'on utility power', does not represent the true situation in this topology. The load is supplied by the inverter and not directly by the AC mains. The term was nonetheless fairly rapidly construed to mean a UPS supplying a load continuously via an inverter connected in series with the AC mains. This term concerns primarily high-power UPS (≥ 10 kVA).

In the 1980s, the types of loads and the range of power ratings increased substantially and 'off-line' UPSs were developed, the term 'off-line' being simply the opposite of 'on-line'. This term is used to describe a topology (see figure 2) in which the inverter is not connected in series with the AC-mains, but rather in parallel in a passive standby configuration. It does not operate continuously, but only when the AC-input supply voltage goes outside tolerances.

This topology includes a filter whose function is not clearly defined and is occasionally presented misleadingly as a voltage-regulation function. It does not include a static switch (static bypass), with a result that load switching times are too long for some applications.

Again, the standardization bodies observed that the term 'off-line' (literally 'not on utility power'), does not represent the true situation in this topology. The load is primarily supplied directly with AC-input power supplied from the utility and the inverter action is demanded only sporadically, in the event of a problem with the utility power. Users nonetheless fairly rapidly adopted this topology and the term 'off-line', primarily for low-power UPS (£ 2 kVA).

In the 1990s, further techniques were developed. The term 'line interactive' is used for UPS implementing reversible inverters. However, the uncertainty created by the many versions of topologies exposed consumers to abusive tactics. For example, some UPS were termed 'in-line' and in some cases, the term 'on-line' was utilized in a very misleading manner. Over a period, this situation, which allowed a certain number of ambiguities and even outright fraud, played against the interests of consumers and penalized reputable manufacturers.

The need to establish a standard with clearly defined terms became unavoidable and that is why the International Electrotechnical Commission working group undertook to draft a standard on the types of UPS and the methods utilized to measure their performance. Cenelec, the European standardization committee adopted the contents of the IEC standard.

Standards IEC 62040-3 and ENV 50091-3 distinguish the following three types of UPS topologies – Passive Standby, Line-interactive and Double Conversion. These terms refer to UPS operation with respect to utility power, i.e. the distribution system upstream of the UPS. The standards define the following terms for input power: Primary Power – power normally continuously available which is usually supplied by an electrical utility company but sometimes by the user's own generation plant; and Standby Power – power intended to replace primary power in the event of primary power failure.

Practically speaking, a UPS has one or two inputs: The normal AC input (sometimes called Mains 1) is supplied with primary power; The bypass AC input (sometimes called Mains 2), when it exists, may also be supplied with primary power or, where possible, with back up power (for instance a separate cable from the same main low-voltage switchboard).

Passive Standby UPS

Normal Mode: The load is supplied with utility AC-input supply, generally via a filter / conditioner which eliminates certain disturbances and can also provide voltage regulation. The standards do not mention this filter and speak simply of a 'UPS switch'. They do, however, stipulate that 'Additional devices may be incorporated to provide power conditioning, e.g. ferro-resonant transformer or automatic tap changing transformers'. In this instance the inverter is on passive standby.

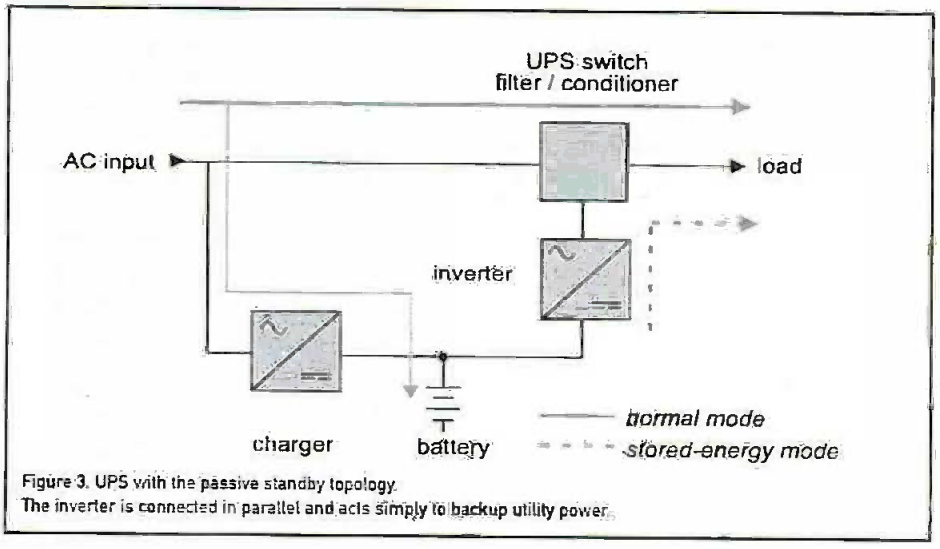


Figure 3. UPS with the passive standby topology.
The inverter is connected in parallel and acts simply to backup utility power.

Stored-Energy Mode: When the AC-input supply voltage goes outside the specified tolerances or fails, the battery and the inverter ensure continuity in the supply of power to the load with a very short switching time (generally < 10 ms). The standards do not mention a specific time, but do stipulate that 'the load is transferred to the inverter directly or via the UPS switch (which may be electronic or electro-mechanical)'.

The UPS continues to operate on battery power for the duration of the backup time or,

as the case may be, until the AC-input supply voltage returns to within the specified tolerances, at which point the UPS returns to its normal mode.

This topology is the result of a compromise between an acceptable level of protection against disturbances and cost. Practically speaking, because of its disadvantages, this UPS topology is used only for low power ratings (< 2 kVA). It cannot be used for frequency conversion.

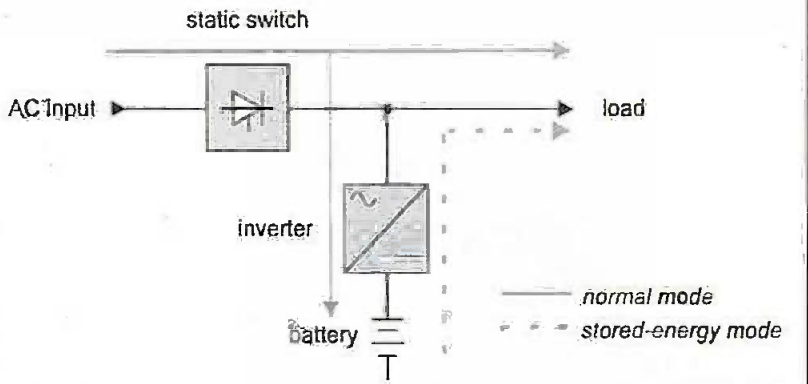


Figure 4. UPS with the line-interactive topology. The inverter is connected in parallel and acts to backup utility power. It also charges the battery. Through its reversible operation, it interacts with utility power.

Line-interactive UPS

Normal Mode: The load is supplied with 'conditioned mains power' via a parallel connection of the UPS inverter with the AC mains. The inverter is operational to provide output voltage conditioning and/or battery charging, whilst the output frequency is dependent upon the AC mains-input frequency.

Stored-Energy Mode: When the AC-input supply voltage goes outside UPS preset tolerances or fails, the inverter and battery maintain continuity of power to load. The switch (e.g. a static switch) disconnects the AC-input supply to prevent backfeed from the inverter. The UPS runs in stored-energy mode for the duration of the stored-energy time or until the AC-input supply returns to within UPS design tolerances, at which point the UPS returns to normal mode of operation.

Bypass Mode: This type of UPS may include a maintenance bypass. In the event of a UPS internal malfunction, the load may be transferred to the bypass input via the maintenance bypass.

This topology is poorly suited to sensitive loads with medium to high power ratings because frequency regulation is not possible. For this reason, it is almost never used at such ratings.

The so-called 'Boost/Buck', 'AVR' (automatic voltage regulation) and 'Delta Conversion' topologies all belong to the line-interactive category.

Double Conversion UPS

Normal Mode: The load is continuously supplied via the rectifier/charger–inverter combination which carries out a double conversion AC-DC-AC, hence the name of the topology.

Stored-Energy Mode: When the AC-input supply voltage goes outside UPS preset tolerances or fails, the inverter and battery continue to support load power. The UPS runs in stored-energy mode for the duration of the stored-energy time or until the AC-input supply returns to within UPS preset tolerances, at which point the UPS returns to normal mode.

Bypass Mode: This type of UPS is generally equipped with a static bypass (often called a static switch). If this is present, the load can be transferred without a break to the AC bypass via the static bypass under the following conditions – UPS internal malfunction; Load current transients (inrush or fault clearing); Overloads; End of battery backup time. However, presence of a bypass implies that the input and output frequencies must be identical and that a transformer must be installed in the bypass if the input and output voltages are not the same. The UPS is synchronized with the source of the bypass AC supply to ensure transfer of the load without a break of power. Another circuit, called the maintenance bypass, is usually provided for maintenance purpose. Operation is carried out by a manual switch.

This is the most complete topology in terms of load protection, regulation possibilities and performance levels. It is in fact the 'on-line' topology presented at the beginning of this article. The standards state the term 'on-line' and advise that it should not be used. They recommend use of the term 'double conversion' which is a much more accurate description of the operating principle.

This topology makes possible no-break operation during load transfers from normal mode to the bypass mode and back, using the static switch. It also ensures total independence of the output voltage and frequency with respect to the input voltage and frequency. Due to their numerous advantages, double conversion UPS are used almost exclusively for the protection of critical application of higher power ratings (from 10 kVA and upwards).

Conclusion

For low power ratings (< 2 kVA), the three types of standardized UPS are all employed. For high power ratings, double conversion UPSs are used almost exclusively. Double-conversion UPS represents the vast majority of sales for medium to high power ratings (95% from a few kVA upwards and 98% above 10 kVA). This is because the double-conversion topology offers a large number of advantages in meeting the needs of sensitive loads at these power ratings, due primarily to the position of the UPS connected in series with utility power. What is more, this type of UPS has very few weak points, with the exception of the higher price, which is compensated by the superior level of performance that is often indispensable given the critical nature of the loads supported.

Part 3 Next Month

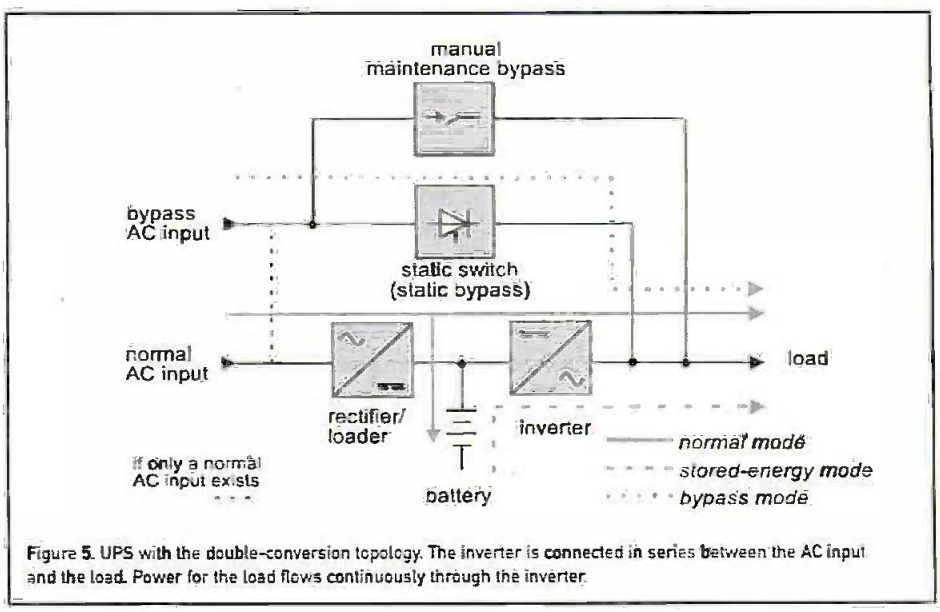


Figure 5. UPS with the double-conversion topology. The inverter is connected in series between the AC input and the load. Power for the load flows continuously through the inverter.