

## Today's UPSs

What is the right power protection solution for a specific application? In configuring the most cost-effective and reliable means of protection, one must also consider all computerized needs against a range of available applications including the most appropriate UPS technology, control software, load size and battery time. Then there are the factors which, taken together, can serve as a solid foundation for an overall power protection strategy. Current considerations which may affect long-term satisfaction encompass UPS **configuration** (e.g., rack, tower, or desktop); **size** (accounting for the types of systems in use, the range of applications, as well as the number of nodes in one or multiple locations); **communication level** (from simple shutdown capabilities to highly intelligent, SNMP- and Web-based monitoring and control); **upgradeability**; and **support** (determining the scope and availability of service locations, as well as the supplier's reputation for reliability and support).

Fortunately, there are many kinds of equipment available to protect against power problems. Power conditioning and uninterruptible power supplies (UPS) are available for everything from a single PC to all the sensitive equipment housed in an entire plant. There are UPS products designed for specific applications - including industrial.

By matching all of these capabilities and options with current and future needs, the right UPS can be configured to protect almost any class of computing and networking equipment.

## UPS Topology Defined

### UPS Topologies: Double Conversion Protection

This alternative provides the highest levels of network protection, conditioning and UPS available. In a double conversion UPS, the inverter - a device that converts DC to AC - supplies conditioned power to attached devices. Most on-line UPSs supply five to 10 minutes of battery backup, which is more than enough for 98% of all blackouts. As studies show, these situations typically last no longer than two minutes. For the other 2% of blackouts, on-line UPSs are available with extended battery capabilities. On-line technology is often the best choice to protect critical applications - those systems that simply can not be "down."

### UPS Topologies: Offline UPS or Standby Power Supply

#### OFFERS MINIMAL POWER CONDITIONING

The simplest type of UPS is the *offline* topology, shown in Figure 1 below. Under normal operating conditions, AC power from the utility passes straight through the UPS to the critical load. A charger or "4-quadrant converter" converts AC power to DC to charge the battery. The inverter is used to convert the DC power from the battery to create AC power to support the load when the utility fails. Normally the inverter is operating in the stand-by mode, keeping the batteries charged. Should the utility power go out of specification, the inverter powers the load, drawing energy from the battery.

This topology is considered "single-conversion" because at any point in time, power is only being converted once (AC to DC, or DC to AC). In normal operation, a small amount of power is being converted from AC to DC to maintain battery charge. When input AC power goes out of specification, the inverter converts the DC power to AC to support the load. When the input power goes out of specification, there is a power disturbance in output voltage as the power failure is detected, the transfer relay operates, and the output inverter turns on to begin supplying the load.

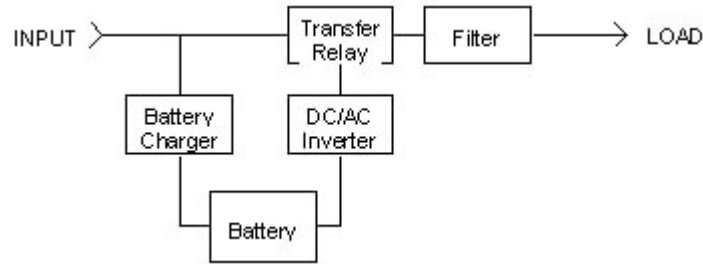


Figure 1. Offline UPS

The offline UPS can be made very inexpensively, and the efficiency is very high in normal operation. These products are typically found in home use or for powering individual computer workstations running non-critical applications that only require outage protection. Offline products sometimes have surge suppression and/or "buck and boost" circuits to compensate for high or low input voltage, but otherwise do not attempt to provide any significant input power conditioning.

The offline UPS is normally only applied to single-phase (workstation-level) non-critical loads. Its limitations, especially the generator incompatibility discussed in the next section, make it unsuitable for three-phase applications.

#### UPS Topologies: Line-Interactive UPS

##### LIMITED POWER CONDITIONING

The next step upward is the *line-interactive* topology, shown in Figure 2 below. It resembles the offline product, but inserts a transformer or inductor in series between the utility power source and the load. This inline inductor enables the UPS inverter to "interact" with incoming power and provide a measure of power conditioning to the load. This "buck-and-boost" circuitry helps with high and low input voltage conditions.

Typically these 4-quadrant converters are constant-voltage devices. They adjust to shifting loads or varying input voltages by changing the output phase angle. Dynamic load changes cause power to be extracted from the battery. The resulting frequent hits on the battery can shorten battery life.

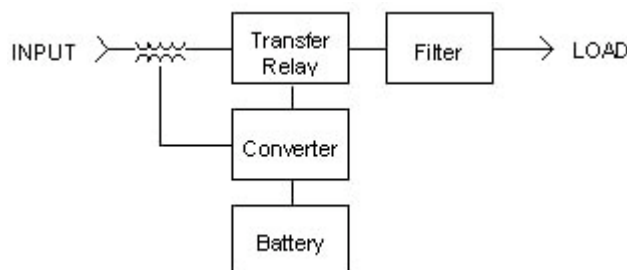


Figure 2. Line-Interactive UPS

Another limitation of line-interactive products is that they cannot completely isolate the critical load from the input line without operating on battery. Small perturbations in frequency and power quality can get passed directly to the critical load. Without electrical isolation, common-mode noise also passes right through to the load. Like the offline UPS, the line-interactive products can be inexpensive and efficient because they only support the entire critical load during power disturbances, and only for the duration of the battery. Compared to the offline UPS, the line-

interactive units pay a small efficiency penalty for the series inductor and for losses associated with their power conditioning functions. And like offline products, the line-interactive products usually have a small (but measurable) amount of voltage sag on at least one phase during the transition to battery power.

### Generator Compatibility

Generator interaction problems for offline and line-interactive UPSs are well documented. Offline and line-interactive products require stable source frequency and phase shift. Stable source frequency is required since the inverters must track the supply frequency to provide the voltage and current correction. Therefore the output frequency of the system is the same as the input frequency unless the UPS is operating on battery.

A classic operational problem is the starting of other loads on the generator causing the generator's output frequency to vary, which then causes the offline or line-interactive UPS to cycle on to battery operation. The problem is especially pronounced with natural-gas-powered gensets. This repetitive battery cycling can cause the battery to discharge completely, while significantly shortening battery life. Another potential problem is the generator instability that occurs when the UPS load is transitioned to the generator. The UPS load transfer causes the generator voltage and frequency to sag, causing the UPS to go back to battery operation. Soon thereafter, the UPS senses stable generator output, transfers the load back to the generator, then transfers back to battery operation when generator output dips again.

The solution requires that the frequency window ( $\Delta f$ ) and synchronizing slew rate ( $df/dt$ ) of the line-interactive UPS that defines a "power failure" be widened well beyond generally accepted critical load tolerances, which are  $\pm 1$  Hz for frequency window and 1 Hz/second for slew rate. In order to operate properly on gensets (i.e. to avoid going on battery too often), line-interactive products must be set to synchronize in a  $\pm 4-8$  Hz window and at a 4 Hz/second slew rate. These variations are passed on to the critical load.

These problems don't exist for conventional double-conversion UPSs. Double-conversion UPSs rectify the input supply and can accommodate large swings in supply frequency while continuing to provide regulated, stable output frequency, without the use of the battery. Further, the major double-conversion UPS manufacturers have developed input current distortion reduction techniques that greatly improve the compatibility of UPS with generators to allow closer load sizing. Double-conversion UPS products can be used with a 1.25x to 1.5x generator size without operational problems.

### UPS Topologies: Line-Interactive with Power Factor Correction (including "Neo-Online" products)

#### MODERATE POWER CONDITIONING

In recent years, a few companies have introduced line-interactive 3-phase UPS products with power factor correction. These have enhanced power-conditioning features compared to offline and typical line-interactive products. These features come at a price however. Efficiency is lower, because of the active power conditioning. In fact, efficiency when powering non-linear loads (typical computer loads) is frequently less than that of double-conversion products. Complexity approaches (and sometimes exceeds) that of double-conversion products. Unfortunately, the marketing hype also exceeds that of double-conversion products. Some of these products are being touted as "online" - because their inverters are "on" all the time providing either voltage regulation or input power factor correction.

These are line-interactive UPSs in the classic sense, meaning that the series transformer and output inverter interact with the incoming utility voltage to alter the output voltage. Some products

have a small input inverter/charger (sometimes called a "delta" inverter) to modify the input voltage. The small inverter typically attaches to the DC bus, which it uses as a pipeline to exchange power with the output (main) inverter. The output inverter is used for both input power factor correction and outage protection.

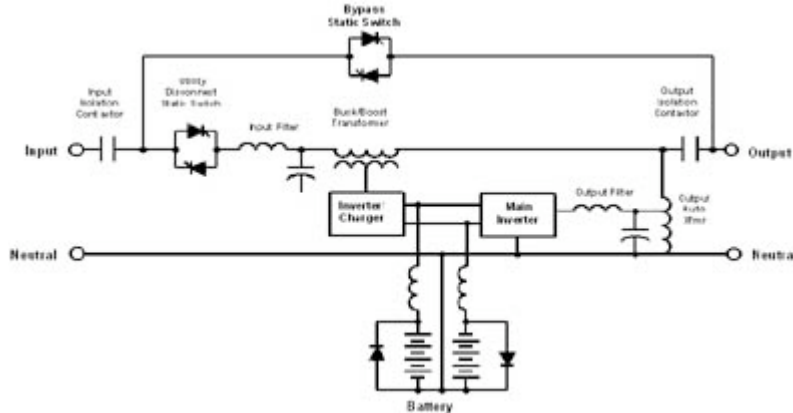


Figure 3. Line-Interactive UPS with Power-Factor Correction

In the normal mode (nominal input waveform, linear load on UPS), the input isolation contactor, the utility disconnect static switch and output isolation contactor are closed and utility power is directly supplied to the output. The input inverter operates as a charger and delivers a float charge to the battery system. The main inverter is off or idling under these ideal (unreal) conditions.

When the input voltage is present but not nominal, the delta inverter injects a voltage into the buck/boost transformer to add or subtract from the input voltage to create a regulated output voltage, similar to some electronic voltage regulators on the market today.

When the input power goes out of specification, the main inverter is activated to supply full output power and the utility disconnect static switch must be turned off to prevent backfeeding, similar to an offline UPS. Line-interactive UPSs using naturally commutated utility disconnect static switches are particularly susceptible to failure under certain input source faults; since they cannot turn off quickly, the inverter could be overloaded by the fault and will cause a shut down.

These units can also provide load harmonic current and input power factor correction. The main inverter operates to inject the required compensation currents -- both harmonic currents and fundamental frequency reactive currents. Whenever the inverters operate, either the voltage correcting inverter/charger or the harmonic current and power factor-correcting main inverter, there are additional losses that significantly reduce the unit efficiencies well below their advertised efficiency.

### UPS Topologies: The Double-Conversion UPS

#### FULL POWER CONDITIONING

The premium UPS topology is the true *on-line* or *double-conversion* product shown in Figure 4 below. Incoming AC power is rectified to DC power to supply the internal DC bus of the UPS. The output inverter takes the DC power and produces regulated AC power to support the critical load. Batteries attached to the DC bus are float charged during normal operation. When the input power is out of spec, the batteries provide power to the inverter and critical load.

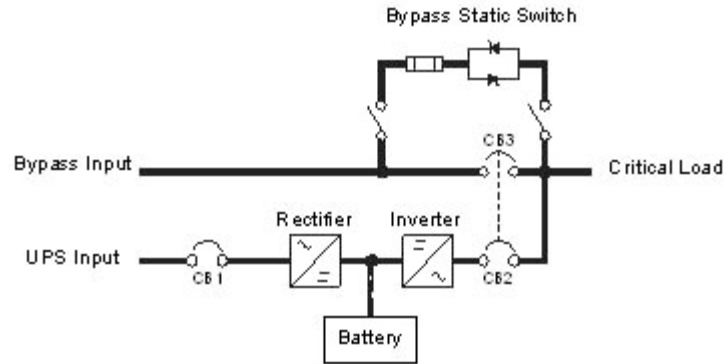


Figure 4. On-Line UPS

Some advantages of this configuration include.

- The critical load is completely isolated from the incoming AC input power.
- The critical load is always being supplied by the output inverter, which is always being supplied from the internal DC bus. When input power fails, there is no transitional sag in the output voltage because the inverter is already operating on DC input.
- The input voltage and frequency may fluctuate, but the double-conversion UPS doesn't care, since the rectifier is only making DC power to feed the DC bus. For example, a Liebert Series 600 UPS can operate indefinitely and even recharge its batteries with input voltage at 15% below nominal. It can continue to operate, without discharging the batteries, through voltage sags of 20% below nominal. Likewise if input frequency is fluctuating in and out of specification, the rectifier will continue to make DC power and the output inverter will continue to make 60 Hz power without using the battery.
- The output inverter usually contains an isolation transformer that can produce a separately derived neutral. This enables the UPS to be electrically isolated and provide common mode noise protection for the load. All Liebert three-phase UPS products have output isolation transformers as standard.
- The double-conversion UPS is inherently dual-input, meaning that it has separate inputs for the rectifier and bypass circuits. The customer may request a single-input model as a convenience for installation, but dual-input UPS products are incrementally more fault-tolerant.
- In a certain manufacturer's three-phase UPS products, the output inverter can synchronize to any internal or external reference source while operating in the normal mode (without using the battery). In normal operation, it will sync to its own bypass source. When operating on system batteries, it will normally sync to its internal reference clock. However, a true double-conversion UPS can be used in a dual-bus power system, where the UPS will sync to the designated reference source in all operating modes: on utility, on batteries, or on the backup generator.
- A fault on the input line causes the UPS to go to battery power, but the UPS rectifier will not allow power from the DC bus to flow upstream.
- This design is very mature and very well understood. It has been applied successfully to every imaginable application. All of Liebert's medium and large three-phase UPS products are double-conversion topology and have achieved million-hour critical bus MTBF.

## Conclusion

All UPS topologies can provide outage protection, and can play a role in today's power protection industry:

- The Offline UPS is a low-cost solution for convenience-level protection against power outages. Single-phase workstation applications only.
- The Line-Interactive UPS provides adequate performance and some power conditioning for small network applications. Single-phase workstation and non-critical server applications.
- The Line-Interactive UPS with Power-Factor Correction provides better power conditioning for small network applications than standard line-interactive technology. Suitable for single-phase workstations and non-critical server applications. Not suitable for facility-wide three-phase applications.
- The Double-Conversion UPS provides the best performance and protection against all power disturbances. Recommended for all critical single-phase and three-phase applications, particularly high-availability, 24x7 applications.

### **Solutions, Not Simple Answers**

In the final analysis, there are no hard and fast rules. As the systems, which are our productivity tools of today, grow and change in size and complexity, power protection devices must also be flexible enough to meet those changing needs. The growing popularity of the decentralized work environment means power protection must be more widespread and reliable than ever before. The task of identifying what is worth protecting and what level of protection is the most cost-effective for an organization is not simple. Not only must one take into consideration today's critical demands, but one must also configure solutions that will function tomorrow. Is it critical? The direct and hidden costs associated with "fixing" what amounts to the lifeline of a business over and over again, is too great a risk to ignore.

Because today's complex computing and networking systems are so crucial to business operations, businesses need UPS systems to deliver the clean, uninterruptible flow of power today's equipment demands. Networks can't afford to be down, and network managers will find that UPSs are an important tool in keeping their networks up and running.