Liebert®

IT White Paper

EVALUATING THE ECONOMIC IMPACT OF UPS TECHNOLOGY

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Network Power

Summary

The sensitivity of electronic systems to power disturbances and the likelihood of interruptions in utility power make it easy to justify the purchase of an uninterruptible power supply (UPS) to protect business-critical systems. As a result, UPS systems have become standard in just about every data center and server room.

However, organizations that routinely go through an extensive review process for new technology systems may pay little attention to the type of UPS being installed to protect that system. That inattention can be costly because different types of UPS provide different levels of protection.

There are three types of UPS “topology” in use today: passive standby (offline), line interactive, and double conversion (online). As the topologies progress from passive standby to double conversion, the protection provided becomes more inclusive and more effective. Likewise, the acquisition cost of each topology increases. Making sound power protection decisions requires balancing the value of increased protection against the cost of that protection.

In cases where the systems being protected are important to the operation of the business, the cost of downtime and equipment damage that may result from inadequate power protection will almost always dwarf any differences in UPS cost. In this case, the most economical UPS system is the one that provides the highest level of protection.

According to a study by IBM, unprotected computer systems are subjected to more than 125 power disturbances in any given month.

The Value of UPS Protection

Any power interruption can shut down computer systems and have devastating consequences in terms of lost data, equipment damage, lost productivity and reduced customer service.

UPS systems deal with power interruptions in essentially the same way: they switch connected equipment to battery power. Uninterrupted operation of connected equipment is provided by the UPS battery system until utility power resumes or a backup power source is started and stabilized, at which point connected equipment is transferred to the backup power source. If a backup power source is not available, the UPS powers connected equipment as long as it safely can and then, using power management software in the UPS or connected system, executes a controlled shutdown to prevent data loss and equipment damage.

Some UPS systems can also protect connected equipment against power disturbances. According to a study by IBM, unprotected computer systems are subjected to more than 125 power disturbances in any given month. These disturbances include everything from low voltage conditions to spikes to waveform distortions.

By protecting critical systems from problems caused by power outages and power disturbances, UPS systems:

- Reduce or eliminate downtime;
- Eliminate data loss resulting from unexpected shutdown of computer or communication systems;
- Reduce downtime from equipment operating problems;
- Extend equipment life by filtering out disturbances that damage or degrade electronics; and
- Reduce power-related troubleshooting and support costs (i.e. restarting servers, re-installing applications, etc.).

Figure 1 shows the relative frequency of various power disturbances, while Figure 2 provides a description and illustration of each disturbance.

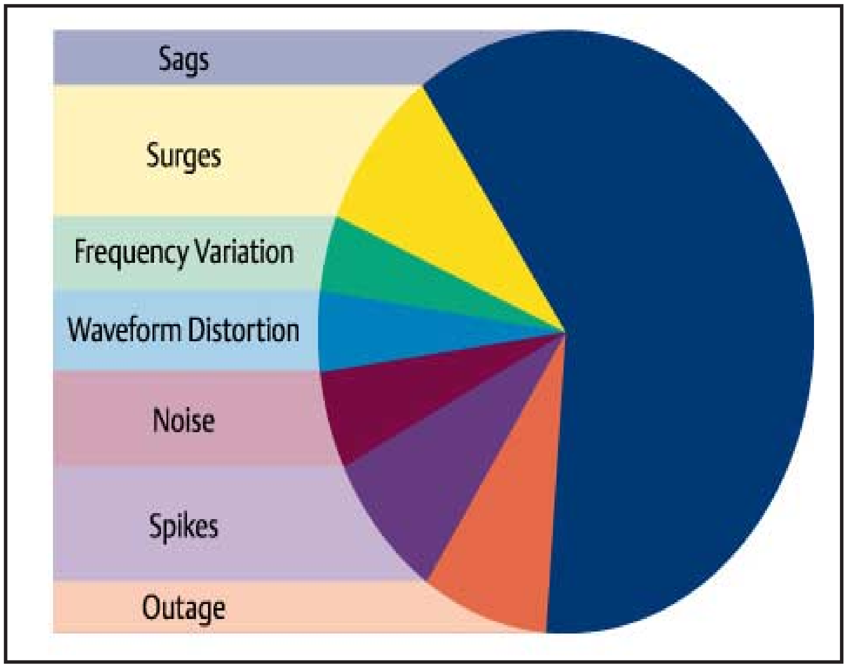

Figure 1. A full range of power problems, shown here by their relative frequency, can bring down a network without proper protection.

In addition to outages, disturbances include:

- **Sags:** One of the most common types of disturbance, sags are short-term, low voltage brownouts triggered by equipment startup, lightning, utility switching or equipment failure. Unless compensated for by a UPS, sags can cause equipment operating problems and trigger sudden, unexpected shutdowns.
- **Surges/Swells:** Essentially the opposite of a sag, a surge is a short-term high voltage condition that occurs when power-hungry equipment is turned off. Surges can destroy sensitive electronic components.
- **Spikes:** Instantaneous jumps in voltage, spikes cause data corruption, lock-ups, processing errors and equipment damage.
- **Electrical line noise:** Small but rapid power fluctuations that cause aberrations in the smooth wave shape of the power line. Line noise can cause equipment operating problems, including data errors, software malfunctions and lock-ups.
- **Frequency variations:** Changes in AC frequency that are usually caused by backup generators taking over from utility power. They have the potential to shut down and damage computer systems.
- **Waveform distortion:** The most common type of distortion is the harmonic, which is a multiple of the standard power wave. Harmonics cause communication errors and hardware damage.

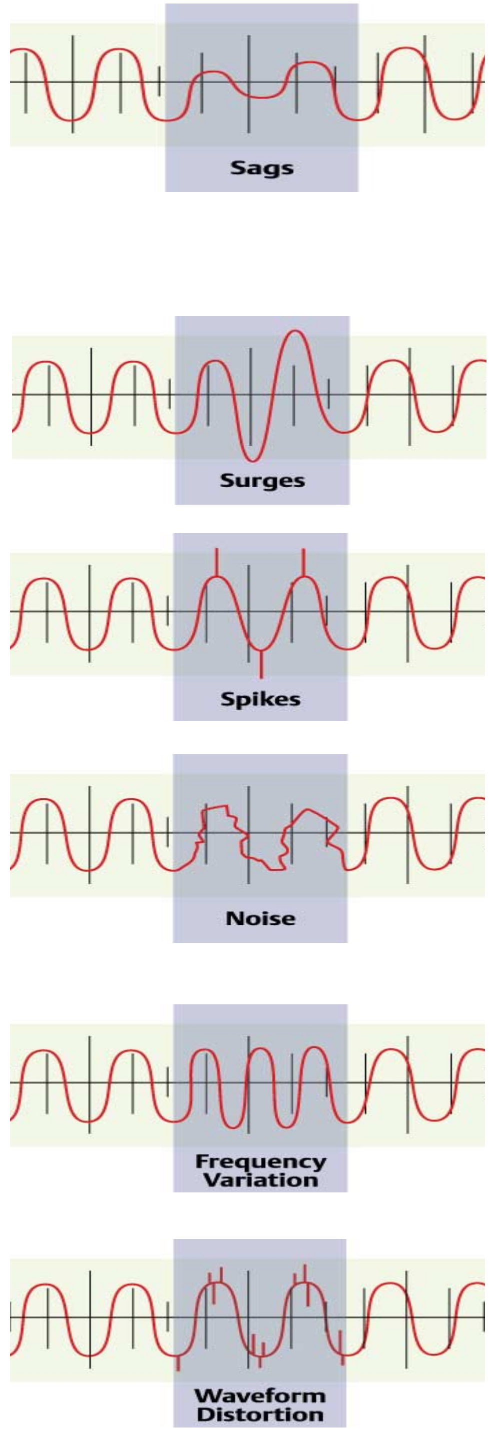

Figure 2. System protection must be ready to handle a wide array of power fluctuations. The illustrations show waveforms for typical 60 Hz AC power. The left and right unshaded areas show how the waveform should look; the shaded area shows how the disturbance distorts the waveform.

The double conversion UPS isolates connected equipment from the power source, eliminating the possibility that a power disturbance damages connected equipment.

Understanding UPS Topology Options

There are three types of UPS in use today: passive standby, line interactive and double conversion.

The **passive standby**, or offline UPS, monitors incoming power and switches to battery when an interruption is sensed. Passive standby systems are limited in their ability to condition power and do not work well with backup generator systems. Their use is typically limited to non-critical desktop systems. Liebert manufactures passive standby UPSs for non-critical desktop applications.

Line interactive UPS systems use a transformer or inductor between the power source and connected equipment to correct or filter variations in input power. This "interactive" approach allows the UPS to "buck-and-boost" incoming power as appropriate to eliminate sags and surges.

Line interactive systems rely heavily on their battery system to condition power, which can be a liability in many applications. They also do not isolate equipment being protected from the power source, creating the potential for equipment damage.

Nevertheless, they represent an appropriate solution for applications that require more power conditioning than passive standby systems provide, but are not business critical.

Liebert manufactures line interactive UPSs for non-critical desktop, small network and point-of-sale applications.

Double conversion is the technical name for the topology that has traditionally been referred to as "online." The name is appropriate because these systems convert incoming AC power to DC and then back to AC for delivery to connected equipment. This has a number of advantages:

- The UPS is always re-creating the waveform used by connected equipment, resulting in cleaner, more uniform power;
- The conversion of power within the UPS isolates connected equipment from the power source, eliminating the possibility that a power disturbance gets through the UPS and damages connected equipment;
- A wider range of power problems can be eliminated without using battery power, enabling longer runtimes during outages and increased battery life; and
- Connected equipment is always powered by the UPS inverter, eliminating the "switchover" effect that occurs in passive standby and line interactive UPSs when the UPS system transfers from utility power to battery or generator power.

Liebert has manufactured double conversion UPSs for over 25 years and offers a full range of double conversion UPS systems for applications that extend from single servers or switches to complete facilities.

Topology is primarily an issue for applications that require between 350 VA and 20 kVA, although you should not assume that all systems above 20 kVA are double conversion systems.

Calculating the Costs

Four factors should be considered when evaluating UPS costs: initial costs, operating costs, battery replacement costs and downtime costs.

Initial Costs
UPS acquisition costs typically increase as systems progress from passive standby to line interactive to double conversion. These costs can be evaluated by comparing the cost of similar capacity systems of different topologies, where possible.

For very small systems, the passive standby topology may be the only option available as other topologies would be too expensive to produce in small sizes. Likewise, for systems greater than 20 kVA, double conversion topologies should be standard because of the high downtime and replacement costs for the equipment being protected.

Therefore, topology is primarily an issue for applications that require between 350 VA to 20 kVA of protection, although you should not assume that all systems above 20 kVA utilize double conversion topology.

The key to evaluating initial costs is to ensure that differences in topology are considered when evaluating systems from different suppliers and that initial costs are used as the starting point, rather than the final determinant in the decision making process.

Energy Costs
Energy costs for a UPS system can be projected by evaluating the efficiency specification of the UPS system. This represents the percent of incoming utility power that is delivered to connected equipment, or conversely how much power is used by the UPS system itself. Higher-level topologies will consume more energy because they are more actively conditioning incoming power.

Battery Replacement Costs
Battery replacement costs are an important factor to consider when purchasing a UPS. Batteries are the weakest link in a UPS system and high temperatures and frequent discharges are their worst enemies.

While line interactive UPSs can switch voltage taps to correct sags and surges, some line interactive designs require a transfer to battery mode before changing voltage taps. The result is that line interactive UPSs often have a greater number of “hits” to the battery. The same is true for frequency variations; a double conversion UPS can correct for frequency variations without using the battery system while line interactive designs transfer to battery sooner, again resulting in more frequent battery usage.

Line interactive UPSs utilize transformers that provide the boost and buck function. Depending upon the UPS design, the internal batteries can be located close to the transformer resulting in heat radiating from the transformer, causing battery temperatures to rise. A general rule of thumb is that the life of a battery is cut approximately in half for every 20 degrees F that the battery temperature rises above room temperature.

In areas where power quality is erratic, double conversion UPSs can reduce battery costs by up to 75 percent.

Double conversion UPSs typically feature batteries housed in separate metallic enclosures that provide physical and thermal protection from heat sources. Additionally double conversion designs utilize high frequency transformers that are more compact and located away from internal batteries.

Double conversion systems also typically include over-discharge protection to improve battery performance management. When batteries discharge at low rates over a period of time, the depth of discharge is chemically deeper than a high rate of discharge. Over-dischage protection guards against the damaging effects of long-term deep discharge, further prolonging battery life.

In areas where power quality is erratic, double conversion UPSs can reduce battery costs by up to 75 percent. That alone can more than offset the differences in initial cost and energy costs of competing technologies.

Downtime Costs

Downtime costs are the least predictable – and most significant costs – associated with UPS protection. A single failure to protect computer systems from power outages or disturbances can cause revenue-sapping downtime, data loss, or equipment damage that dwarfs all other costs combined.

The remainder of this paper analyzes the different levels of protection provided by each UPS topology.

Protection Before, During and After Power Outages

All three UPS topologies are able to bridge brief interruptions in utility power, assuming the UPS batteries have been maintained as required. UPS topologies that rely more heavily on their battery systems for power conditioning (passive standby and line interactive) may not have the expected battery capacity during an outage, particularly if the outage is preceded by a period of power instability.

This was the situation Time Warner faced at its Manhattan data center during the major blackout of August 2003. This facility used a mix of Liebert double conversion UPSs and non-Liebert line interactive UPSs. When the blackout occurred, the batteries on many of the line interactive UPSs shut down before their rated backup time and could not support connected equipment while the back-up generators were started. They also had problems when the utility restarted with “dirty” power. They attempted to go to their already-spent batteries to condition this power and instead shut down, bringing down critical connected equipment with them. Even worse, when the incoming power lost its neutral and voltage jumped to 150 on one pole, they allowed this disturbance to reach the servers, destroying the power supplies on seven of them.

By contrast, the double conversion UPSs performed as required throughout these events.

Generator compatibility problems can create downtime and negate the investment in a backup generator.

Double-conversion UPSs are also more compatible with generator systems than other topologies, enhancing outage protection and eliminating the need for generator oversizing.

A common problems with other topologies operating with generators occurs when the UPS switches from battery power to generator power. This causes generator voltage to sag and this sag can cause the UPS to switch back to battery. The switch causes the generator voltage and frequency to return to normal, which is sensed by the UPS and connected equipment is switched back to the generator, creating another sag that forces the UPS back to battery. This cycle continues until the battery is no longer able to support connected equipment and an unexpected shutdown occurs – despite the continued operation of the generator.

Line interactive systems can compensate for this if they are configured with a wide output frequency window and high slew rate; however, this limits the UPS's ability to condition sags and frequency variations under normal operating conditions.

The General Monitoring company discovered first-hand the problems that occur when UPSs fail to synchronize with generators. During simulated outages, its generator would start up successfully and the building lights would come on using generator power, but the passive standby UPSs would stay on battery because they were unable to synchronize with the frequency of the generator. The company would run on battery power until the batteries were completely discharged, at which point the UPSs were often destroyed. Switching to double conversion UPSs eliminated these problems.

In summary, UPS topology affects outage performance in the following ways:

- Battery runtimes may be less than expected, increasing downtime and creating the potential for unexpected shutdown and data loss;
- Generator compatibility problems can create downtime and negate the investment in backup power; and
- There is increased risk of permanent damage to connected equipment that is exposed to surges and spikes.

Without the right protection, downtime, equipment failure and customer dissatisfaction can all occur creating economic losses that are preventable.

Protecting Against Power Disturbances

Differences also exist in how well each topology protects against power quality problems.

Sags

Sags or brownouts are the most common problem UPS systems must protect against. Passive standby UPSs will go to battery when input voltage goes outside a window of approximately +/- 15 percent.

Line interactive UPSs utilize their transformer to regulate output voltage

Line interactive and passive standby systems provide no protection against waveform distortions. These distortions pass through the UPS to connected equipment where they can cause communication and operating errors.

when the input voltage varies within a window of approximately +25 / -35 percent. If low voltage conditions persist, they can lower the UPS output voltage, stressing the power supplies of connected equipment. If the input voltage then drops to the point where the UPS must go to battery, the switchover effect occurs (a 4 to 6 ms break in power). This would not affect equipment under normal operating conditions but may cause an already-stressed power supply to shutdown.

Double conversion UPSs operate over a similar input voltage window as line interactive designs; however, an online UPS tightly regulates the output voltage typically to within +/- 3 percent of nominal – even during extended low voltage conditions. In addition, the double conversion system does not create a switchover effect when switching to batteries.

Surges/Swells/Spikes

All three UPS topologies can include built-in surge suppression capabilities; however, it is recommended that dedicated surge suppression systems be installed upstream from the UPS to eliminate overvoltage conditions before they reach the UPS. Only double conversion UPSs prevent surges and spikes from reaching – and damaging – connected equipment.

Electrical line noise

Line interactive and passive standby systems typically provide the capability to filter a certain amount of line noise; more extreme cases may cause the UPS to oscillate between battery and utility power. Double-conversion UPSs eliminate line noise during the conversion of power to DC and then back to AC.

Frequency Variations

Both line interactive and passive standby UPSs protect against frequency variations by transferring to battery power. Since frequency variations are typically created by backup generators, this can cause generator compatibility problems.

Waveform distortion

Line interactive and passive standby systems provide no protection against waveform distortions. These distortions pass through the UPS to connected equipment where they can cause communication and operating errors. Waveform distortion can also degrade the reliability of electrical components, lowering the MTBF for equipment exposed to them. Double conversion UPSs naturally eliminate waveform distortions as power is converted within the UPS.

In summary, these performance differences can create the following problems:

- The UPS may go to battery more frequently to correct disturbances, increasing operating costs and exposing sensitive electronics to the switchover effect;
- Equipment may be exposed to damaging surges and spikes; and
- Equipment may be exposed to power disturbances that can create operating problems and shorten life.

Matching UPS Technology to Application Requirements

When evaluating UPS technology, organizations are faced with the prospect of balancing the cost of the extra protection delivered by higher-level topologies against the benefits of that protection. Following are four examples of "typical" UPS applications in the 350 VA to 20 kVA range that illustrate how this balance can be accomplished.

Example 1: Protecting Stand-Alone Design Stations

Objective:

Bridge brief power interruptions and eliminate power-related data loss for eight design stations in a design firm.

Primary Costs to Consider:

- Lost productivity of designers unable to work because of power outages or equipment damage
- Lost data resulting from sudden shutdown of design stations due to power interruptions or disturbances
- Equipment replacement costs resulting from power-related damage

Situation:

Each station requires approximately 1 kW of protection. Compatibility with a backup generator system is not required.

Recommended Approach:

Double conversion systems may not be cost-effective in non business critical standalone applications requiring 1 kW or less of protection. Consequently, if every workstation is going to be protected by its own UPS, the decision is between line interactive and passive standby systems. Because the value of the equipment is relatively high and it is involved in revenue generating operations, line interactive systems would be preferable to passive standby systems.

An alternate approach would be to protect all workstations with a single double conversion UPS. The cost per kW of UPS protection goes down as the size of the UPS increases so this configuration may provide a higher degree of protection at about the same cost as eight smaller line interactive units. It also has the advantage of simplifying maintenance.

Example 2: Protecting Remote Servers

Objective:

Protect remote servers and other equipment outside the data center from power-related downtime and operating problems.

Primary Costs to Consider:

- Lost/reduced productivity resulting from unreliable network services
- Support costs for rebooting or troubleshooting systems
- Damage to equipment from spikes and surges

Situation:

Applications typically require from 750 W to 20 kW of protection. Extended runtimes may be required to compensate for lack of a backup power source.

Recommended Solution:

With overall network utilization increasing, servers outside the data center are now being asked to achieve the same levels of availability as those inside the data center.

Double conversion UPSs are available in sizes as small as 2U and provide better protection against power quality problems and more effective isolation of connected equipment. They also support longer battery runtimes and are required if remote systems are to approach the level of availability of systems in the data center.

A double conversion UPS with a communications card for remote monitoring and an external bypass option to support continuous operation of connected equipment during UPS service, would deliver the best protection for this application.

Example 3: Protecting IP Telephony Devices on the Network Edge

Objective:

Protect edge-of-network equipment from power-related downtime and operating problems to support deployment of IP telephony.

Primary Costs to Consider:

- Lost/reduced productivity resulting from unreliable network communications
- Lost revenue from customer impact of unreliable network communications
- Support costs for rebooting or troubleshooting systems
- Damage to equipment from spikes and surges

Situation:

To be successful, IP telephony must match the high reliability standards of the traditional phone system. The power protection system is instrumental in accomplishing this. Power disturbances can create packet losses that disrupt communications. Power over Ethernet increases the impact of a power outage at the Intermediate Distribution Frame (IDF) and users expect to have phone service in the event of an outage. Space in the IDF is often limited.

Recommended Solution:

Line interactive UPS systems have been considered a viable option for some edge-of-network application in the past, but higher availability standards required by IP telephony and increasing sensitivity of network devices have shifted the balance more decidedly toward double conversion UPSs.

Double conversion UPSs, now available in sizes as small as 2U, support longer battery runtimes and eliminate the switchover effect that occurs when passive standby and line interactive systems switch to battery. Some communications devices are so sensitive to power interruptions that the switchover can cause a shutdown.

A double conversion UPS with extended battery capacity is required for this application. A communications card in the UPS to support remote management is also a requirement for this application. At minimum, the system should include a maintenance bypass, although actual UPS redundancy is becoming more common on the edge.

Example 4:
Protecting a New Rack in a Small Server Room/Data Center

Objective:

Provide power protection for a new equipment rack being added to a small server room.

Primary Costs to Consider:

- Server downtime can disrupt business operations across the organization, reducing productivity and impacting customer service
- Lost data may be irreplaceable
- Increased demands on limited IT resources for power-related maintenance and troubleshooting

Situation:

The room currently houses three racks requiring 2 kW of protection each. Each rack includes a rack-mounted line interactive UPS system. Business growth will likely drive the need for more racks in the future and the possibility exists that a backup generator will be added at a later date.

Recommended Solution:

All the servers in the room could be considered business critical and could benefit from the increased protection provided by a double conversion UPS. In addition, the business is at an ideal stage to transition from rack-scale protection to room-scale protection. Up to about 3 racks, rack-scale protection makes sense, but above that the challenge of managing multiple UPSs – and maintaining multiple battery systems – becomes cumbersome. The double-conversion system also simplifies addition of a backup generator at a later date. A scalable double conversion UPS, like the Liebert Nfinity would provide cost-effective protection today and can be easily expanded to accommodate future growth.

Conclusion

Like all technology purchasing decisions, organizations must balance costs versus benefits when selecting UPS technology. Understanding the differences in UPS topologies and how these differences affect performance is key to matching the UPS system to the application. Although it may be tempting to drive down initial costs and select the least expensive UPS system, this is rarely a sound long-term strategy. In most cases, the benefits of increased protection will significantly outweigh differences in system costs.

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Printed in U.S.A. 0704 WP404