

UPS Basics

Everything you ever wanted to know about uninterruptible power systems but were afraid to ask.

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Executive summary

Budgeting for electricity, securing adequate supplies of it and finding ways to use less of it are all common topics of conversation among data center operators. Ensuring that the power their IT resources rely on is both dependable and clean, sadly, can sometimes be an afterthought.

In truth, however, power sags, surges and outages are not only unavoidable but more than capable of damaging valuable IT equipment and bringing productivity to a halt. That’s why planning and deploying a robust power protection solution is absolutely vital.

An uninterruptible power system (UPS) is the central component of any well-designed power protection architecture. This white paper provides an introductory overview of what a UPS is and what kinds of UPS are available, as well as a comprehensive guide to selecting the right UPS and accessories for your needs.

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Why is power protection important?

No company can afford to leave its IT assets unprotected from power issues. Here are just a few of the reasons why:

- **Even short outages can be trouble.** Losing power for as little as a quarter second can trigger events that may keep IT equipment unavailable for anywhere from 15 minutes to many hours. And downtime is costly. Some experts believe the U.S. economy loses between \$200 billion and \$570 billion a year due to power outages and other disturbances.
- **Utility power isn't clean.** By law, electrical power can vary widely enough to cause significant problems for IT equipment. According to current U.S. standards, for example, voltage can legally vary from 5.7 percent to 8.3 percent under absolute specifications. That means that what utility services promising 208-phase voltage actually deliver can range from 191 to 220 volts.
- **Utility power isn't 100 percent reliable.** In the U.S., in fact, it's only 99.9 percent reliable, which translates into a likely nine hours of utility outages every year.
- **The problems and risks are intensifying.** Today's storage systems, servers and network devices use components so miniaturized that they falter and fail under power conditions earlier-generation equipment easily withstood.
- **Generators and surge suppressors aren't enough.** Generators can keep systems operational during a utility outage, but they take time to startup and provide no protection from power spikes and other electrical disturbances. Surge suppressors help with power spikes but not with issues like power loss, under-voltage and brownout conditions.
- **Availability is everything these days.** Once, IT played a supporting role in the enterprise. These days it's absolutely central to how most companies compete and win. When IT systems are down, core business processes quickly come to a standstill.
- **Availability is everything, but power costs must be managed.** The cost of power and cooling has spiraled out of control in recent years. Data center managers are typically held responsible for achieving high availability while simultaneously reducing power costs. Highly-efficient UPS systems can help with this goal, and products are available today that were not an option even a few years ago.

What is a UPS?

Put simply, a UPS is a device that:

1. Provides backup power when utility power fails, either long enough for critical equipment to shut down gracefully so that no data is lost, or long enough to keep required loads operational until a generator comes online.
2. Conditions incoming power so that all-too-common sags and surges don't damage sensitive electronic gear.

What are the main types of UPS?

UPSs come in three major varieties, which are also known as topologies:

Single-conversion systems

In normal operation, these feed incoming utility AC power to IT equipment. If the AC input supply falls out of predefined limits, the UPS utilizes its inverter to draw current from the battery, and also disconnects the AC input supply to prevent backfeed from the inverter to the utility. The UPS stays on battery power until the AC input returns to normal tolerances or the battery runs out of power, whichever happens first. Two of the most popular single-conversion designs are standby and line-interactive:

- *Standby UPSs* allow IT equipment to run off utility power until the UPS detects a problem, at which point it switches to battery power. Some standby UPS designs incorporate transformers or other devices to provide limited power conditioning as well.
- *Line-interactive UPSs* regulate input utility voltage up or down as necessary before allowing it to pass through to protected equipment. However, like standby UPSs, they use their battery to guard against frequency abnormalities.

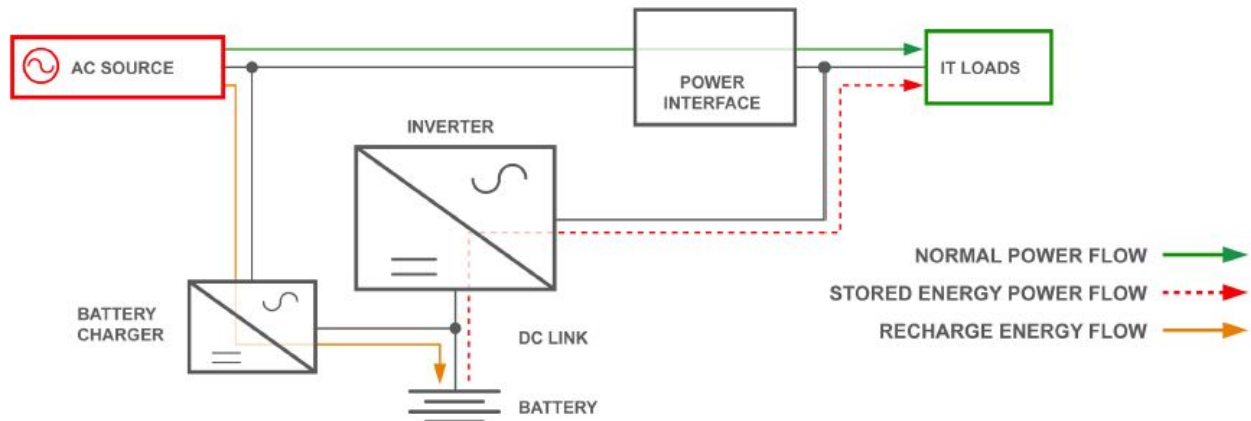


Figure 1. Internal design of a line-interactive UPS.

Double-conversion systems

As the name suggests, these devices convert power twice. First, an input rectifier converts AC power into DC and feeds it to an output inverter. The output inverter then processes the power back to AC before sending it on to IT equipment. This double-conversion process isolates critical loads from raw utility power completely, ensuring that IT equipment receives only clean, reliable electricity.

In normal operation, a double-conversion UPS continually processes power twice. If the AC input supply falls out of predefined limits, however, the input rectifier shuts off and the output inverter begins drawing power from the battery instead. The UPS continues to utilize battery power until the AC input returns to normal tolerances or the battery runs out of power, whichever occurs sooner. In case of a severe overload of the inverter, or a failure of the rectifier or inverter, the static switch bypass path is turned on quickly, to support the output loads.

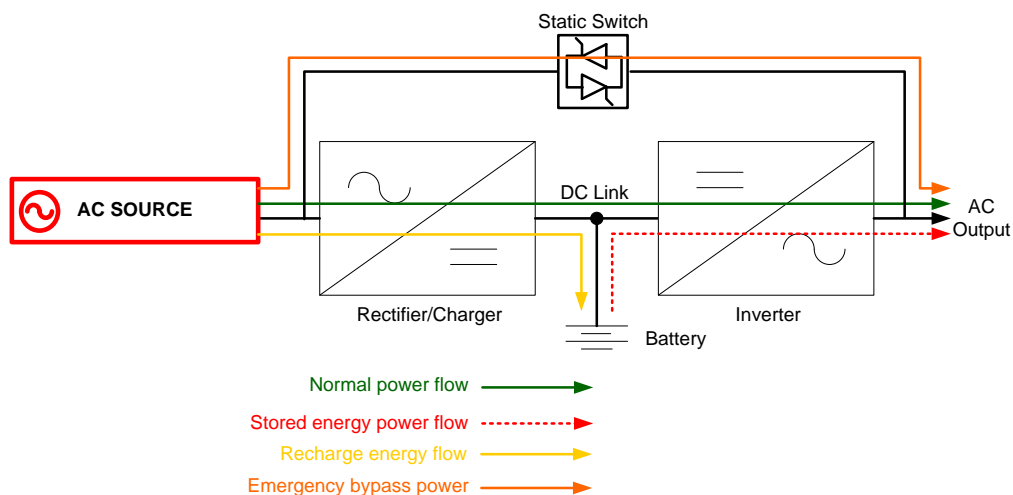


Figure 2. Internal design of a double-conversion UPS.

Multi-mode systems

These combine features of both single- and double-conversion technologies while providing substantial improvements in both efficiency and reliability:

- Under normal conditions, the system operates in line-interactive mode, saving energy and money while also keeping voltage within safe tolerances and resolving common anomalies found in utility power.
- If AC input power falls outside of preset tolerances for line-interactive mode, the system automatically switches to double-conversion mode, completely isolating IT equipment from the incoming AC source.
- If AC input power falls outside the tolerances of the double-conversion rectifier, or goes out altogether, the UPS uses the battery to keep supported loads up and running. When the generator comes online, the UPS switches to double-conversion mode until input power stabilizes. Then it transitions back to high-efficiency line-interactive mode.

Multi-mode UPSs are designed to dynamically strike an ideal balance between efficiency and protection. Under normal conditions, they provide maximum efficiency. When problems occur, however, they automatically sacrifice some efficiency to deliver maximum levels of protection. The end result is that data centers can save tens of thousands a year on energy without compromising data center performance or reliability. For more information on multi-mode UPSs, please see two additional white papers, “Which UPS is Right for the Job” and “Maximizing UPS Availability” at www.eaton.com/pg/whitepapers.

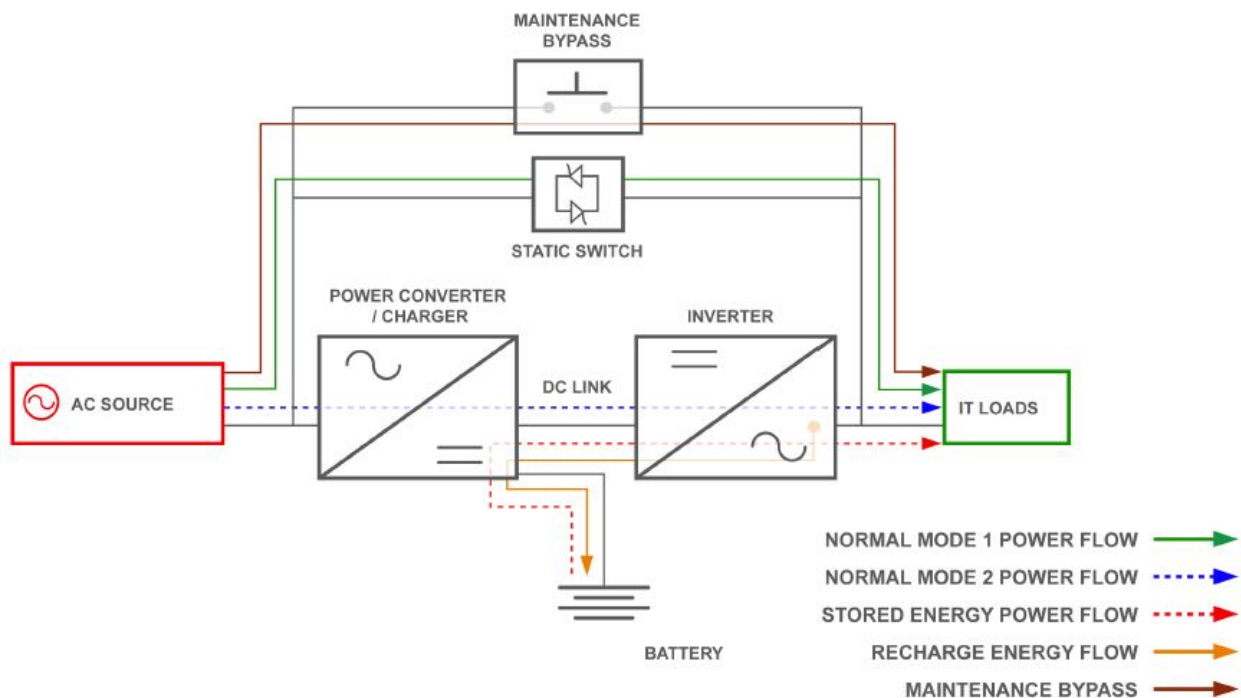


Figure 3. Internal design of a multi-mode UPS.

How do I choose the right UPS for the job?

To ensure that you always end up with the right UPS for your needs, be sure to consider these eight issues during your selection process:

Topology

Question number one is should you get a single-conversion, double-conversion or multi-mode UPS? The answer depends largely on how important energy efficiency is for your organization relative to protection.

Single-conversion UPSs are more efficient than double-conversion devices, but offer less protection. That makes them a good fit for loads with a higher tolerance for failure. More specifically, standby UPSs (the most basic type of single conversion UPS) are generally the best option for smaller applications, like desktop and point-of-sale solutions, while line-interactive UPSs are typically preferable for smaller server, storage and network applications located in facilities with access to relatively trouble-free AC utility power.

Double-conversion UPSs, which provide the highest levels of protection, are less efficient but are usually the standard choice for protecting mission-critical systems.

Multi-mode UPSs, although they may be more expensive than either single or double conversion systems, are the best choice for companies looking to achieve an optimal blend of both efficiency and protection.

Single phase versus three phase

When the utility generates power, it is at the three-phase level. This type of power is available to almost all commercial and industrial customers, as they are typically large consumers of power. Three-phase power uses three separate “phase” wires, which allow higher power to be delivered to a single point or load. Most homeowners only have single-phase power available to them, as homes are typically small power users. Single-phase power is delivered through either one or two phase wires, which are derived from the utility three-phase power system using transformers.

Single-phase UPSs tend to be a sensible and economical option for simpler, smaller applications with low kVA requirements, which are typically seen in the home, small businesses and in remote or satellite offices where computing power is less than 20,000 VA. Three-phase UPSs are generally the preferred choice for high kVA applications, which are typically more sophisticated and have high compute densities. Large multi-story buildings, data centers and industrial facilities protecting high-power processes are typical three-phase UPS customers, as they need to distribute large amounts of power over relatively long distances.

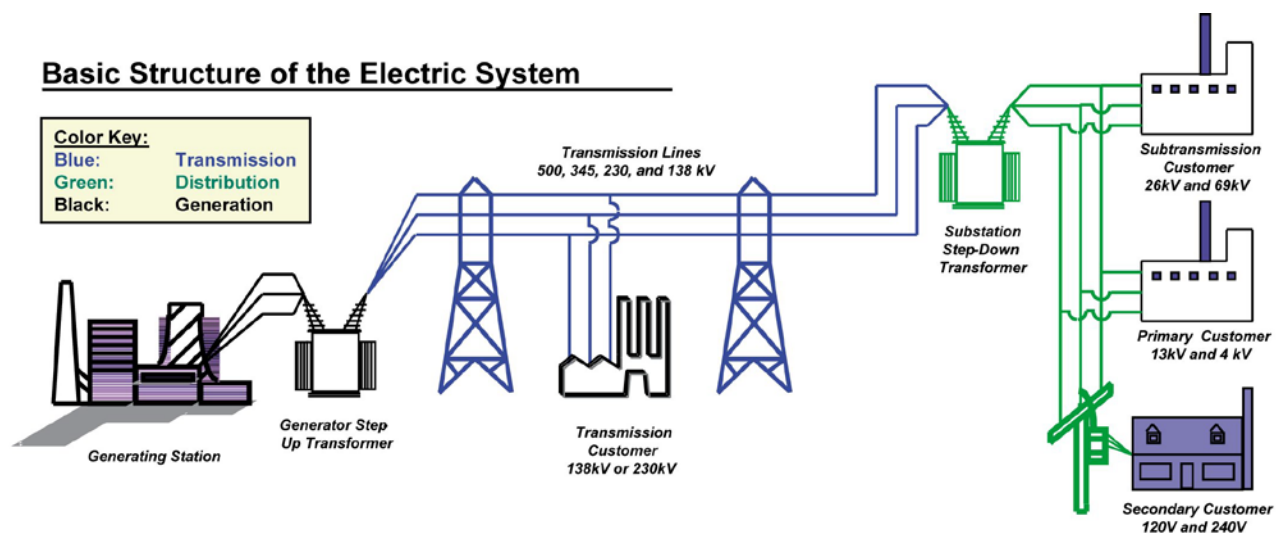


Figure 4. Three-phase power is generated and distributed to large commercial customers, with secondary customers, like homeowners, only receiving single phase power.

Rating

A UPS's rating is the amount of load, in volt-amperes (VA), that it's designed to support. UPSs are available with ratings as low as 300 VA and as high as 5,000,000 VA or more. Use this very basic procedure to determine the approximate UPS rating your organization requires:

1. Make a list of all the equipment your UPS will be protecting.
2. Determine how many volts and amps every device on the list draws.
3. For each device, multiply volts by amps to arrive at a VA figure.
4. Add all of the VA figures together.
5. Multiply that sum by 1.2, to build in room for growth.

The UPS you buy should have a rating equal to or greater than the final number you arrived at in step 5, unless you have more precise load data for the equipment you are protecting. Here are a few additional considerations to keep in mind:

- Relying solely on nameplate ratings may lead you to oversize the UPS system, so always use your equipment manufacturer's sizing calculator tools as well, if available. Most major manufacturers have Web-based or downloadable sizing tools that can closely estimate your equipment's power draw based on the configuration you are using.
- When deploying a centralized power protection architecture, you typically deploy larger kVA UPSs than you would deploy using a distributed power protection scheme.
- If your UPS will be supporting motors, variable-speed drives or laser printers, add more VA capacity to your requirements to account for the high power inrush that occurs when those devices startup. Your UPS vendor can assist in applying the proper UPS and rating for these types of applications.
- Companies that anticipate rapid near- or medium-term growth should use a multiple higher than 1.2 when building in room for growth in the procedure above. So should organizations that expect to upgrade their server hardware soon, as newer servers tend to have higher power requirements than older models.

Form factor

UPSs come in a range of form factors that fit into two master categories: rack-mounted and freestanding. The largest UPSs aren't available in rack-mounted form factors, so companies with substantial power requirements almost always use freestanding devices. For companies with more modest needs, deciding between rack-mounted and freestanding UPSs is largely a matter of data center design philosophy. Some organizations use rack-mounted UPSs in an effort to consolidate as much hardware as possible in their enclosures. Others prefer to maximize the amount of rack space available for servers by using freestanding UPSs. From a technical and financial standpoint, neither approach is inherently superior to the other.

Availability features

Organizations can utilize a variety of deployment options, technologies and services to increase the reliability of their power protection solution. Here are some of the most effective ones:

Redundant deployment architectures: Deploying UPSs in redundant groups can increase availability by ensuring that critical loads remain protected even if one or more UPSs fail. There are three main kinds of redundant UPS architecture:

- *Zone:* In a zone architecture, one or more UPSs provide dedicated support for a specific set of data center resources. That way if a UPS fails during a power outage, the impact is limited to the zone that device supports.
- *Serial:* In a serial architecture, multiple UPSs are connected end to end such that if any one UPS in the string fails, the others can compensate automatically.
- *Parallel:* Parallel architectures use multiple independent parallel-connected UPSs to achieve increased redundancy. If any UPS fails completely, the other systems can keep protected information technology equipment (ITE) loads operational.

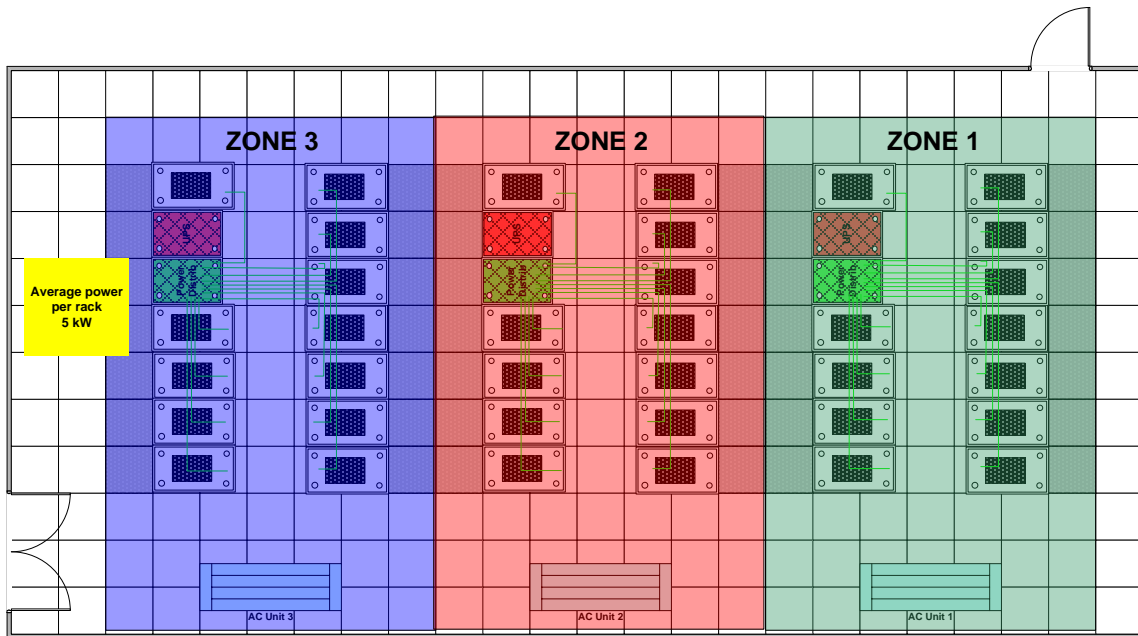


Figure 5. Zone protection uses separate protected “zones” and may use virtualization software to shift loads to other zones during failures or maintenance. Each zone has its own 60kW UPS system.

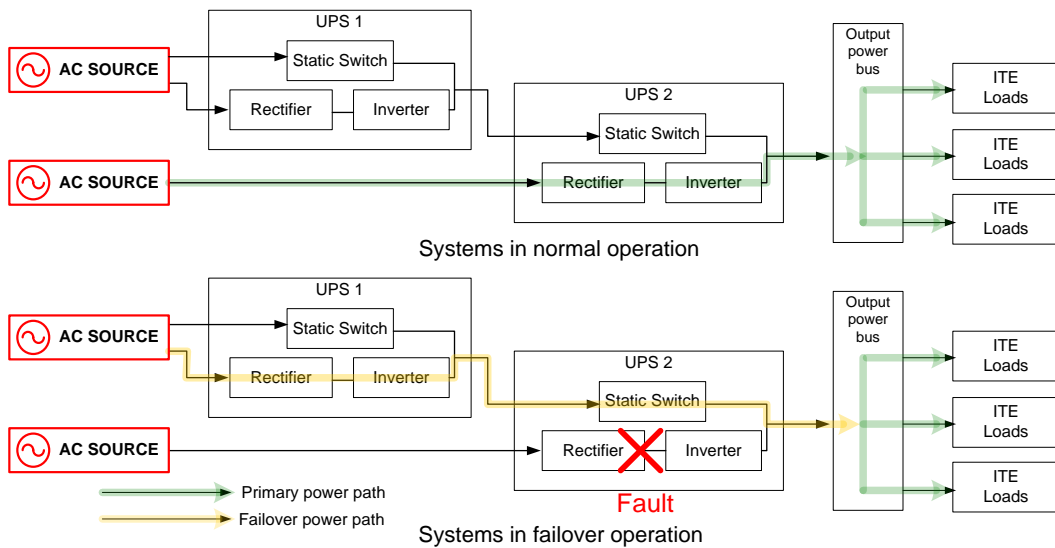


Figure 6. Serial (cascade) UPS architecture with changing power path if the UPS under load fails

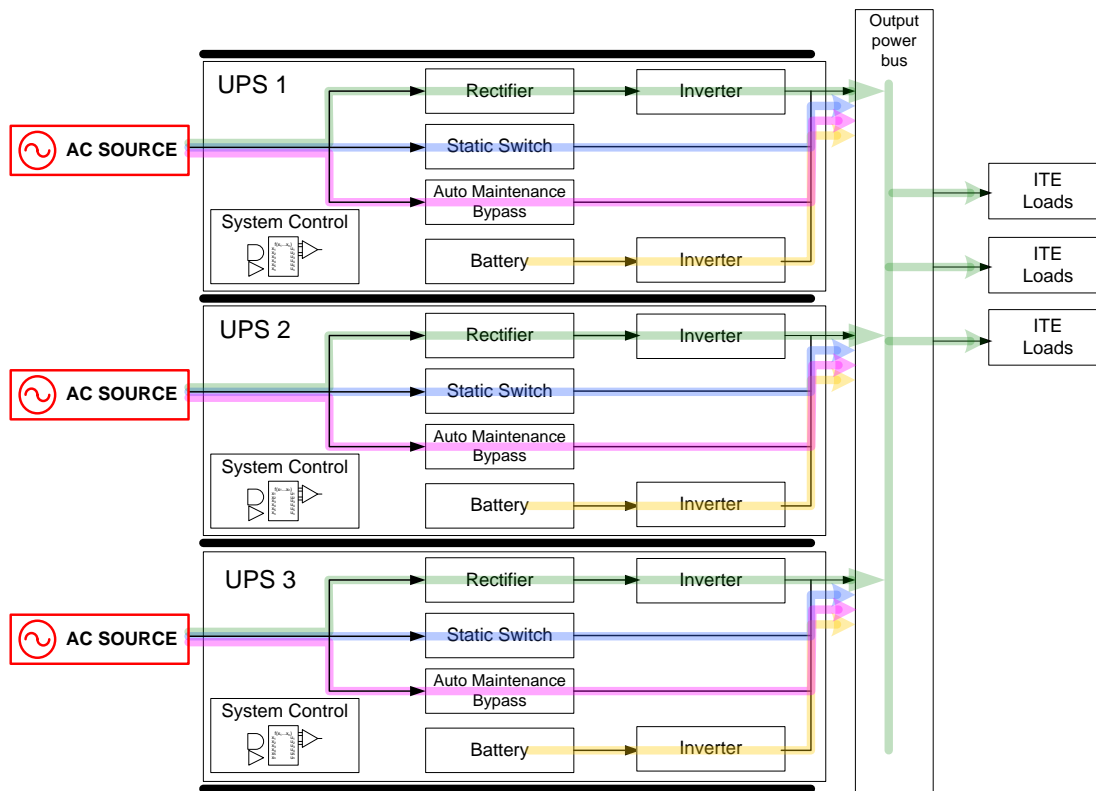


Figure 7. Parallel UPS systems all feed the output bus, so any single UPS module can be isolated for maintenance or in case of a failure. Parallel systems must be synchronized together to share the loads.

Hot-swappable components: Technicians can repair or administer a UPS that uses hot-swappable components without powering the UPS down, thereby exposing IT equipment to decreased risk of downtime.



Figure 8. Hot swappable battery modules allow service work to be performed while load equipment remains protected.

Extending battery runtime: A typical UPS battery provides five to 15 minutes of backup power. Organizations that need more than that can use supplemental external battery modules or cabinets to add as much as several hours of emergency runtime at full load.

Battery management: One of the most important parts of the UPS system is the energy storage system, which is typically a battery. Many UPS systems continually “trickle-charge” the battery, which has a tendency to degrade the battery’s internal chemical composition, reducing battery service life. While large banks of flooded electrolyte batteries for high power (greater than 500kVA) UPS systems need to have the battery trickle charged, most non-spillable (VRLA, see “UPS energy storage” below) batteries used in today’s lower kVA UPSs can benefit from a charging technique where the charger turns off and “rests” the battery. Some manufacturers have labeled this charging technique as Advanced Battery Management. This technique helps increase battery service life by as much as 50 percent. Batteries utilizing this technology last longer and are more reliable thanks to the UPS system’s three-stage charging technique, sophisticated sensing circuitry and an automated battery test routine that notifies the end user of deteriorating battery conditions that warrant replacement.

Remote monitoring: The best way to address UPS problems is to prevent them from happening in the first place. Remote UPS monitoring applications continually watch for warning signs of future trouble, such as deteriorating performance or an overheating battery, and send real-time notification when potential issues develop. That enables technicians to make repairs before serious breakdowns have a chance to occur. Data centers can perform remote monitoring themselves or contract with an external provider to do it for them.

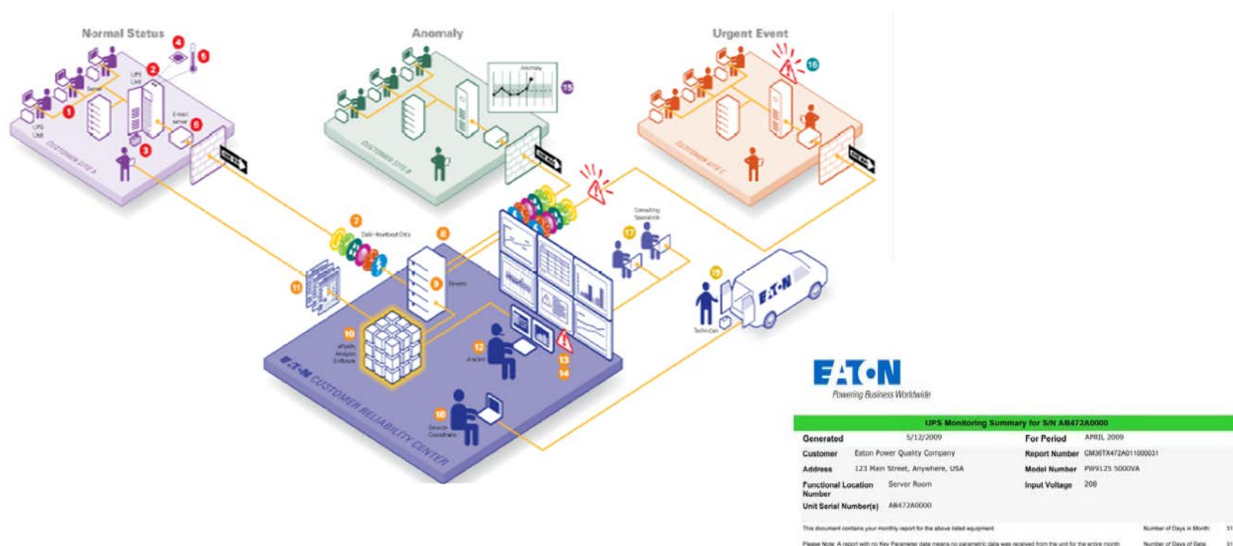


Figure 9. Remote UPS monitoring, which is provided as an option by some UPS manufacturers, allows them to keep a close eye on your power protection environment and send you alerts when they spot signs of impending trouble. The service may also include monthly reports on your UPS and its health.

Scalability and modularity

Implementing a robust power protection solution takes time and money. To get as much value as possible from that investment, companies should estimate their needs for the next three to five years when comparing UPS options. If you're likely to have significantly larger power requirements in that timeframe, choose appropriately larger UPS hardware.

Data centers with fluctuating needs or future requirements that are difficult to forecast can employ two strategies to increase the scalability of their UPS deployment:

- **Deploy UPSs in parallel:** Parallel UPS architectures boost scalability as well as redundancy. As their power needs increase, organizations can simply add more modules to existing UPS systems, rather than replace current devices with new ones.
- **Use modular UPS products:** Some newer UPSs feature modular designs that allow you to add capacity incrementally as requirements increase. For example, some such systems provide up to 50 or 60 kW of capacity in 12 kW building blocks that fit in standard equipment racks. As requirements increase, another 12 kW unit can simply be plugged in. Even the largest UPS systems can be made modular in 200 to 300 kW increments. That's a scalable and efficient approach to keeping up with escalating power needs that also lowers upfront capital spending and conserves data center floor space.

Software and communications

Even with a UPS, your IT system could still go down in case of an extended power failure or if the UPS gets overloaded for too long. Communication software can not only provide real-time notification of UPS status, but also lets you assign automatic actions to perform in case of a power event. This is extremely useful if your system operates continuously without users being present to manually shutdown affected equipment.

For the past 20 years, most UPS systems have come with software that would signal one or more servers that AC power was lost and that the UPS was on battery. If AC did not return and the battery energy was near depletion, the software would close all open applications to prevent any data loss. When AC power was restored, the system would automatically reboot, bringing the system back to its previous state. This solution was initially implemented on small PC servers protected by a single UPS, then moved to larger systems with an array of operating systems, many of which were proprietary to the IT equipment manufacturer. Communication was established through an RS232 serial port, or via relays to a simplistic control port.

As IT systems grew bigger in size and numbers, serial communication (be it RS232 or through a USB port) was replaced by network-based communication to enable communication between the UPSs and multiple servers. In this type of installation, the UPS is assigned its own IP address on the network and could be accessed remotely by all servers being powered by that UPS, so each server could be programmed to shut down or monitor the UPS for power issues.

As networks and UPS communication hardware and software became more complex, other automatic features were developed through power management software, including remote notification via email, pager or SMS, data accumulation allowing report generation and trending analysis, complex script programming to shut down a database or a program before stopping the server operating system and much more. With all of these advancements, the typical installation involved servers with single operating systems and with a single application running on each server.

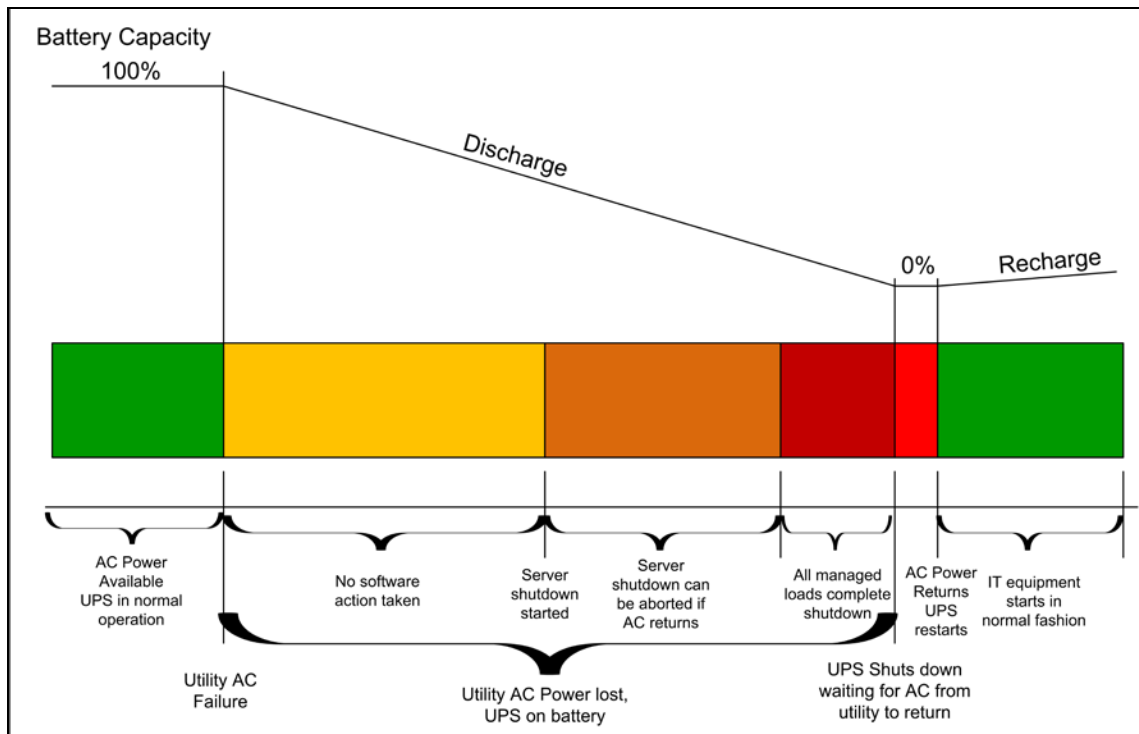


Figure 10. Typical UPS power management software can shut down impacted servers automatically and gracefully should a power outage threaten to outlast UPS battery capacity.

Virtualization is now bringing a new set of complexities, as the bond between operating system and physical hardware is no longer the standard. Some suppliers of UPS software must ensure that shutdown software agents are installed on each virtual machine as well as on the host machine. This can be quite tedious if the number of virtual machines is large, which is becoming the standard in many virtualized environments. Leading-edge UPS manufacturers have developed new software platforms that reduce this management complexity by integrating their software into virtualization management platforms like VMware's vCenter® or Citrix XenCenter®. In these environments, one single software installation can control and shutdown any cluster of servers. Another benefit is the enablement of automatic live migration of virtual machines in case of a power outage, as you are no longer limited to the option of shutting down the servers and stopping operations. Business continuity is now possible through this integration, which is not only available on vCenter but also on Microsoft SCVMM or Citrix XenCenter.

To summarize: logical and complete power management applications can help companies:

- Monitor and administer their UPSs from any location with Internet access
- Automatically notify key personnel of alarms or alerts
- Perform orderly, unattended shutdowns of connected equipment, or better, work with virtualization software to move virtual machines so as to maximize availability of key applications and hardware
- Selectively shut down non-critical systems to conserve runtime
- Analyze and graph trends, to predict and prevent problems before they happen
- Integrate with existing network and management systems via open standards and platforms

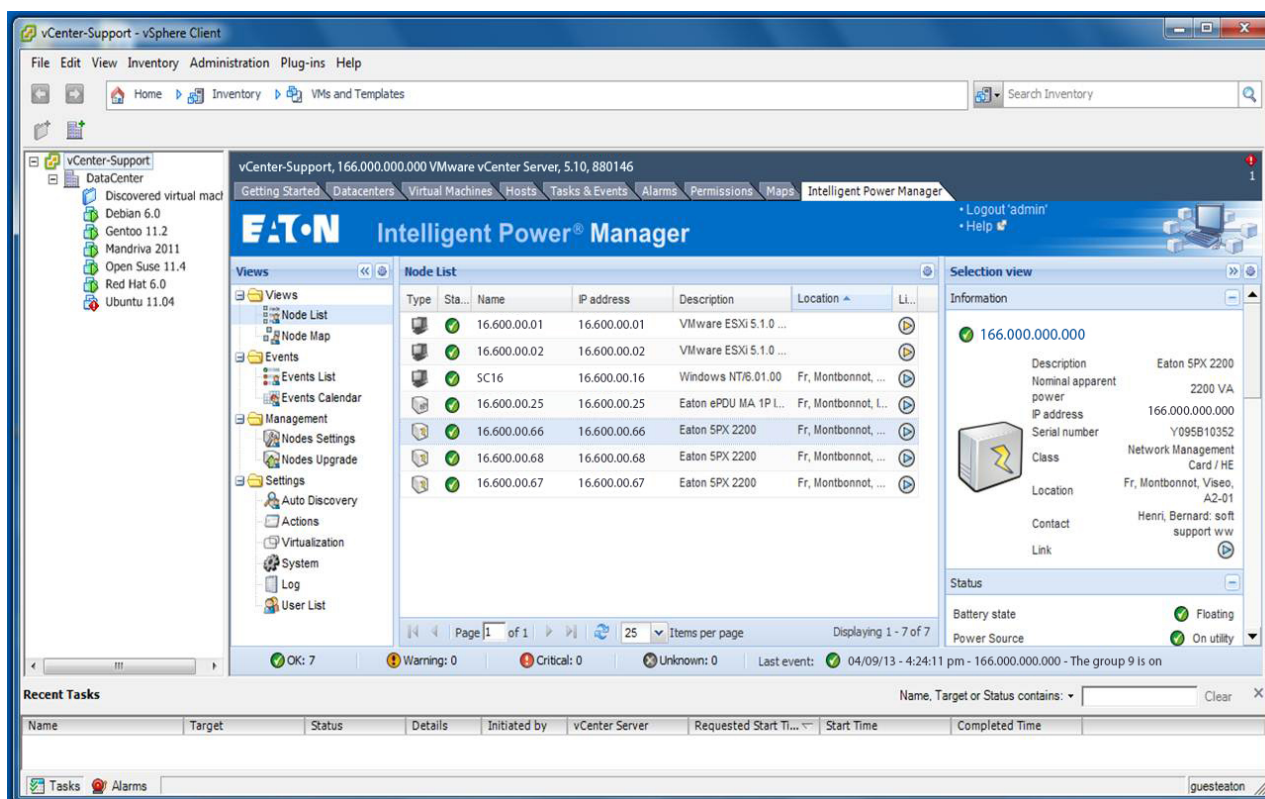


Figure 11. The UPS management software in this example plugs into the administrator's console for VMware vCenter, allowing the IT administrator to see and manage UPS-related events or alarms in the same system as their IT management tasks.

Services

With proper servicing, a well-made UPS can operate safely and reliably for as long as 20 years. Without proper servicing, even the best UPS is significantly more likely to fail when you can least afford it. Companies in the market for UPS hardware, therefore, should also choose an appropriate UPS service plan from a service provider with the experience, know-how and resources to provide comprehensive, high-quality support. For more information on selecting the proper services for your system, please see the white paper on "Choosing a UPS Service Plan" at www.eaton.com/pg/whitepapers,

What UPS accessories do I need?

A complete power protection solution typically includes more than just a UPS. Here are some accessories worth considering.

UPS energy storage

Most power protection solutions get their emergency standby power from either sealed batteries (also known as Valve Regulated Lead Acid, or VRLA, batteries) or flooded batteries (also known as Vented Lead Acid, or VLA, batteries). Sealed batteries tend to be less expensive, but also wear out sooner. Flooded batteries generally require specialized installation and maintenance. Deciding which kind of battery is right for you basically comes down to whether you're willing to pay more upfront for batteries that you won't have to replace as often.

Though lead-acid batteries are a proven technology well suited to the rigors of the data center, they're also bulky and heavy. Furthermore, due to the toxic chemicals they contain disposing of them is an expensive and tightly-regulated process. As a result, more and more companies are supplementing lead-acid batteries

with alternative standby power supplies, such as flywheels. A flywheel is a mechanical device typically built around a large rotating disk. During normal operation, electrical power spins the disk rapidly. When a power outage occurs, the disk continues to spin on its own, generating DC power that a UPS can use as an emergency energy source. As the UPS consumes that power, the disk gradually loses momentum, producing less and less energy until eventually it stops moving altogether.

On the plus side, flywheels are smaller and lighter than lead-acid batteries, easier to maintain and free of dangerous and ecologically-harmful substances. On the negative side, they typically deliver only 30 seconds of standby power. However, research shows that more than 95 percent of utility outages last just a few seconds, so using a flywheel as a complement to batteries during brief power interruptions can save data center floor space and lower maintenance costs, while also extending the life of your lead-acid batteries by reducing how often you use them.

Generator

During a utility failure, a UPS gives you the few minutes of time you need to shut down servers gracefully. These days, however, many companies can't afford to be without IT systems for the hours or even days that may elapse before electrical service is restored. Such organizations almost always include a generator in their power protection architecture. While UPSs provide brief periods of emergency power, generators draw on a supply of diesel fuel to keep IT systems operational for anywhere from 10 minutes to seven days or more.

When choosing a generator, look for one with 1.25 to 3.0 times the kVA rating of your UPS. The sizing process should be based on a number of factors, including UPS design, generator and fuel type, so seeking expert advice from the UPS and generator manufacturer is suggested.

In addition, be sure to maintain a supply of diesel fuel large enough to keep your data center operational for prolonged periods. During an extended power outage, demand for diesel can quickly outstrip regional supplies.

Power distribution units

An essential component of any power quality infrastructure, power distribution units (PDUs) distribute power to downstream ITE load equipment. Most companies use both floor-mount PDUs, which provide primary distribution to server racks, and rack-mount PDUs (also known as ePDUs), which distribute power to individual servers and other devices. PDUs can be equipped with optional devices like surge suppression and individual breaker (branch) monitoring systems to monitor energy use.

Conclusion

Businesses today invest large sums of money in their IT infrastructure, as well as the power required to keep it functioning. They count on this investment to keep them productive and competitive. Leaving that infrastructure defenseless against electrical dips, spikes and interruptions, therefore, is a bad idea.

A well-built power protection solution, featuring high-quality, highly efficient UPS hardware, can help keep your business applications available, your power costs manageable and your data safe. By familiarizing themselves with the basics of what a UPS does and how to choose the right one for their needs, data center operators can ensure that mission-critical systems always have the clean, reliable electricity they need to drive long-term success.

About Eaton

Eaton Corporation is a diversified power management company with 2010 sales of \$13.7 billion. Celebrating its 100th anniversary in 2011, Eaton is a global technology leader in electrical components and systems for power quality, distribution and control; hydraulics components, systems and services for industrial and mobile equipment; aerospace fuel, hydraulics and pneumatic systems for commercial and military use; and truck and automotive drivetrain and powertrain systems for performance, fuel economy

and safety. Eaton has approximately 73,000 employees and sells products to customers in more than 150 countries. For more information, visit www.eaton.com.

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