Selecting UPSs

FOR MISSION CRITICAL PROJECTS

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A well-designed and properly applied UPS can protect critical loads from power quality anomalies.

The purpose of a UPS is to prevent undesired power features of the power source from affecting critical loads. Undesirable power features include power anomalies, such as outages, blackouts, sags, surges, brownouts, transients, and harmonics. These power anomalies supplied from the power source can be detrimental to the availability and reliability of your critical loads.

Voltage swells, sags, or transient impulses can interrupt sensitive electronic processing, cause lights to flicker, and can even cause permanent harm to sensitive critical electrical equipment. A UPS can provide protection from power anomalies including:

Surge or Swell: A surge or swell is a substantial increase or surge in voltage lasting a small fraction of a second. A surge is defined as an anomaly that lasts greater than 0.5 of a waveform cycle or 8.33 msec. Surges can be caused when large current-drawing equipment and motors such as air conditioners are switched off.

Transient: A transient is a power anomaly that occurs in less than 0.5 of a waveform cycle, or less than 8.33 msec. A transient can occur throughout the electrical distribution system and can consist of an increase in voltage (spike) or a decrease in voltage (waveform notching). Transients can be caused by the switching of utility capacitor banks, utility demand load switching, or from nearby lighting strikes.

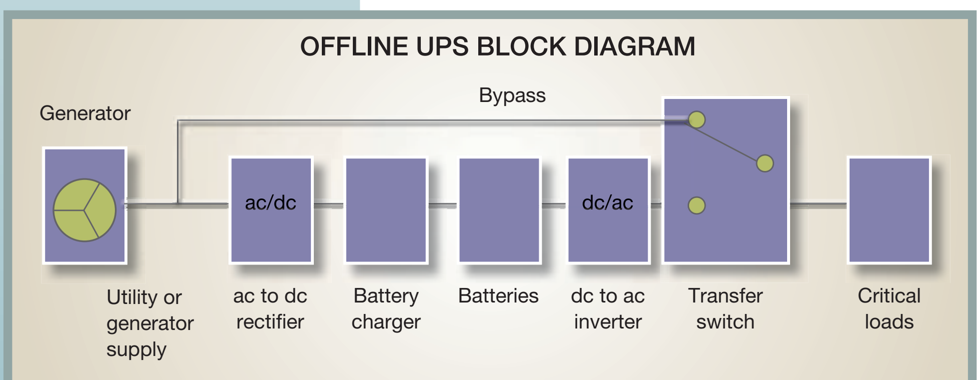

Figure 1: This illustration shows a block diagram of an offline UPS, or standby power supply. Under normal conditions, the power flows through the bypass switch—around the rectifier, battery charger, battery, and the inverter. When the UPS is bypassed, there is no electrical isolation between the power source and the critical load. Power system anomalies will pass directly to the critical systems. However, if the utility voltage drops below predetermined levels, the system will switch to UPS operation.
Courtesy: Lane Coburn & Assocs.

Blackout: A blackout is a complete loss of power. A blackout is also known as an outage. The Information Technology Industry (ITI) council, which was formerly called the Computer Business Manufacturers Assn. (CBEMA) considers a voltage drop below about 80 V to be a voltage sag or a blackout because most equipment will not operate below these levels for more than a very short period of time.

Sag or Brownout: A sag or brownout is a short-term reduction in voltage level for a period of time greater than 0.5 of a waveform cycle or 8.33 msec up to one minute. These types of power anomalies account for the majority of the power disturbances experienced in commercial buildings and critical environments.

Spike: A spike is an instantaneous and substantial increase in supply voltage that will typically last for 0.5 of a waveform cycle or 8.33 msec. Spikes are often caused by a direct lightning strike on a high-voltage power line or can occur when power returns from the utility after a blackout. The high voltages and currents caused by a spike can enter sensitive electronic equipment through power, phone, or data cables and can damage or destroy the equipment. In addition, critical data can be lost.

It is important to have a good understanding of these definitions when determining the appropriate form of power quality protection that is required to protect your critical systems and loads.

There are a several types of power protection devices on the market that are designed to protect equipment and data from damage caused by power outages or power quality anomalies. The most common type of system is the UPS. Most UPS technologies fall within three categories: offline, line interactive, and online double conversion.

OFFLINE UPS SYSTEMS

Offline UPS systems use a transfer switch for a system bypass. Typically, these systems also include a rectifier, which converts ac to dc; a battery charger; a battery; and an inverter, which converts dc to ac (see Figure 1). They are also referred to as standby power supplies (SPSs).

Offline UPS systems normally run in bypass mode, and therefore do not run current through the rectifier, battery, and inverter. When the system senses a power anomaly outside of strategically selected preset parameters, the transfer switch changes position and starts to draw power through the rectifier, battery, and inverter. Critical loads and critical systems typically have a direct connection to the utility or generator source of power. In this scenario, protection from power quality anomalies is available only when the serving voltage dips to a predetermined level and the transfer switch changes its position and draws current through the UPS system.

After losing power from the utility or generators, the voltage-sensing transfer switch changes position and the battery-powered inverter turns on to continue supplying power to the critical loads in the electrical distribution system. Batteries are charged, as necessary, when power is available from the serving utility or standby generator (see Figure 1).

The time required for the inverter to come online is typically called the switchover time and varies with each unit and manufacturer. While some computer manufacturers indicate that their power supplies can handle a switching time of 50 to 100 msec, actual switching-time tolerances vary. The ITI/CBEMA curve indicates that switching-mode power supplies should be able to handle a complete supply-voltage outage for up to 20 msec (see Figure 2). Most offline UPS systems claim a transfer-to-battery time of about 4 msec or 0.25 of a cycle, which is well within the ITI/CBEMA curve.

Standby power systems offer the least amount of protection to critical loads, and are the least expensive of all of the types of UPSs. Even within this class of device, the system quality and effectiveness vary significantly. These systems are also very efficient because most of the time they are in bypass mode and there are no losses through the rectifier, inverter, or tap transformer.

Because critical loads connected to the supply are basically connected directly from the power source (either utility or standby generator), offline UPS systems provide relatively poor protection from line noise, frequency variations, line spikes, and sags or brownouts.

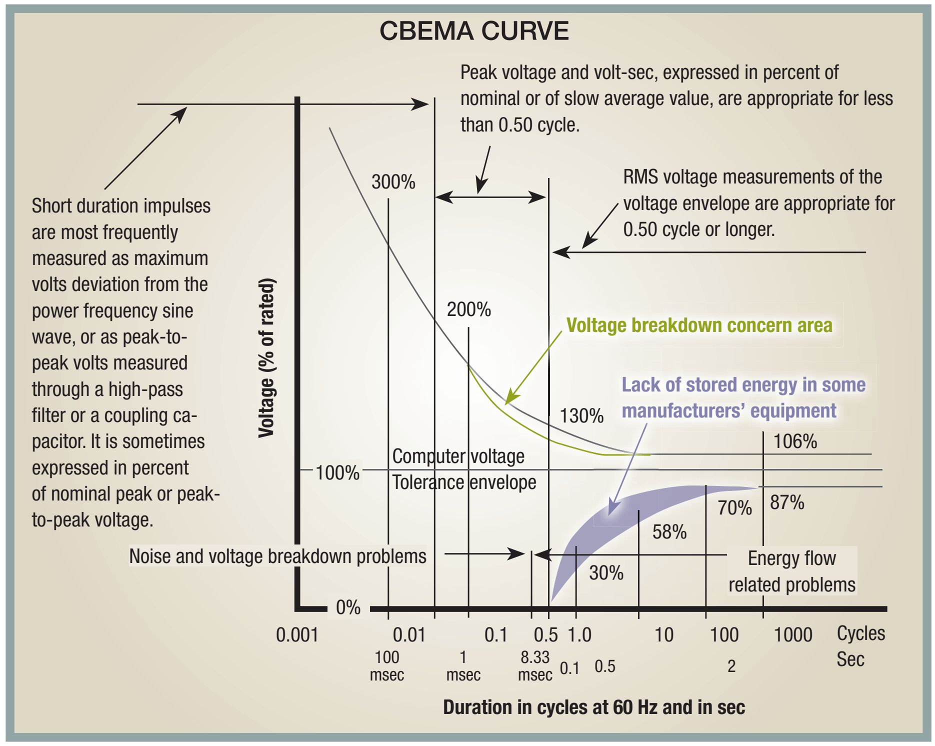

Figure 2: The CBEMA curve shows that 8 msec of zero voltage is acceptable for sensitive IT and electronic equipment. This curve was established in 1978 as a susceptibility curve for power supply engineers and manufacturers. The curve was updated in 2000 to reflect a tolerance of a complete outage of power for 20 msec. Courtesy: Computer Business Manufacturers Assn.

LINE INTERACTIVE UPS SYSTEMS

A line interactive UPS provides better power quality protection than the offline UPS system. This UPS type is similar in functional topology to the offline UPS. Typically, line interactive technology also includes buck-and-boost transformer capability. The addition of a tap-changing transformer adds voltage regulation to the UPS system. As the input voltage changes from the incoming power source (generator or utility) the tap-changing transformer can modify the output voltage to the desired voltage level.

Line interactive UPSs use a voltage-sensing transfer switch to draw power from the batteries when incoming power is outside of the buck-and-boost input voltage range. The tap transformer feature compensates for power surges and sags that are 20% to 30% of the normal incoming voltage level without requiring the use of the batteries to regulate the voltage. This significantly reduces the number of times the batteries need to be used. A significant reduction in battery duty-cycle—from going to battery only if the voltage parameters are outside of the transformer's capabilities—means that the batteries in the UPS will last longer than in the offline type of UPS system.

The critical equipment is also supplied by a more reliable system because the battery backup is typically subjected to fewer discharges and failures. A line-interactive UPS typically has a few minutes of backup time when fully loaded, which is enough to ride through approximately 85% to 90% of the

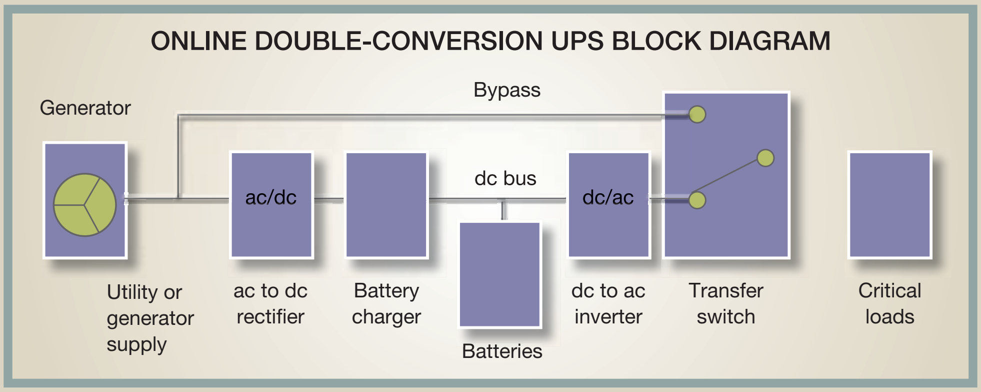

Figure 3: This illustration shows a block diagram of an online double-conversion UPS located downstream from a standby generator. Under normal conditions, the power flows through the rectifier, the dc bus, and the inverter, providing complete isolation between the power source and critical loads. Typically, a maintenance bypass is provided. Courtesy: Lane Coburn & Assocs.

power anomalies. In the event of a longer outage, software is available to provide an orderly shutdown of the critical loads. In addition, UPS software can monitor and log power supply status, display voltage and current draw, and provide alarms for certain error conditions.

A line interactive UPS system provides good protection against high voltage spikes and switching transients. Without complete electrical isolation, as seen with double conversion online UPS systems, common-mode noise passes through to the critical loads. Transformers are good at protecting from normal-mode noise only. These systems offer adequate protection as long as the power sags are not happening on a continuous basis. During a situation when sags are occurring on a regular basis outside of the capacity of the tap transformer, the battery system is being used frequently and may not be able to recharge the batteries for use in a power outage situation.

ONLINE DOUBLE-CONVERSION UPS SYSTEMS

Online double-conversion UPS systems provide the highest level of power quality protection for the most critical loads (see Figure 3). Online double conversion UPS systems are typically used in data centers and other critical applications where uptime is essential for system operation and financial viability.

These systems use a power circuit and an inverter that changes the incoming ac power into dc power through a rectifier and reconverts the power back to regulated ac through an inverter. This collective double conversion continuously provides power to the load to provide both conditioned power and protection from power outages. The batteries on the dc bus are float-charged during normal operation.

Double-conversion UPS systems provide protection and complete electrical isolation from power problems including power surges, high voltage spikes, switching transients, power sags, electrical line noise, frequency variation, brownouts, and blackouts. There are some systems of this type on the market that have efficiencies as high as 97%. The major disadvantages of double-conversion UPS systems are increased cost, increased power consumption due to losses in the rectifier and inverter, and increased heat generation.

Because double-conversion UPS systems rectify the input power supply, this type of UPS can accommodate significant swings in supply frequency and continue to operate without going to battery operation. As previously mentioned, large swings in standby generator output frequency can cause other technologies to cycle into battery operation, which reduces battery system longevity.

A fully online double-conversion UPS system can produce harmonic currents that affect the upstream electrical distribution system. The process of drawing power from the upstream power source through the rectifier creates the harmonic distortion. This distortion causes both current and voltage harmonics, increases the total RMS current, and reduces the power factor of the electrical distribution system. However, harmonic filters and power conditioners can reduce this distortion, minimizing its effects on the upstream electrical distribution system.

DELTA CONVERSION UPS MODULES

Recently, more energy-efficient UPSs have appeared on the market using delta conversion technology. Delta conversion technology converts only the power difference between the UPS input and output, hence the name "delta conversion." With this type of UPS, the inverter continually supplies voltage to the load. Only the difference in voltage between the input and output goes through the double-conversion process. Because the inverter is always supplying the load voltage, the system is not considered to be line interactive. Additionally, because only a portion of the load (the delta) goes through the inverter, some do not consider this technology to be a true online double-conversion system.

Delta-conversion UPSs have certain advantages over the traditional double-conversion UPS. They include power factor that approximates unity, and 200% overload capability in normal operation.

The power balance point is a node that includes three wires, which are:

1. Input power from the delta transformer
2. Output power to the load
3. A connection to the main inverter, which imports or exports power to the node to maintain the node's power balance.

The power balance point of the delta-conversion UPS follows Kirchhoff's current law: "Currents at a node are algebraically summed to zero."

As stated earlier, there are some advantages of the delta conversion technology. The following are some of the advantages in greater detail:

- They are more energy-efficient because only the "delta" of the load is rectified based on the Kirchhoff current load
- They operate at approximately unity power factor because kW = kVA in this type of system
- Low input harmonic current, which is typically less than 5%, and high power factor make this type of UPS generator-friendly.

Generators must often be oversized to deal with harmonic distortion that comes back from the UPS input.

This technology does not change the frequency of the input waveform. The frequency of the waveform coming into the UPS from the serving utility or the standby generator will be the frequency of the waveform leaving the UPS to the critical load. Additionally, because the frequency waveform is not modified, two different load buses from two different power sources cannot be synchronized.

SELECTING A UPS TECHNOLOGY

When determining which type of UPS technology or manufacturer to use for a critical system, it is important to look for additional criteria, which include—but are not limited to—the following:

Output waveform: The output waveform should be as close to the ac sinusoidal waveform as possible. Cheaper UPS equipment tends to produce an output waveform that can deviate significantly from a sine wave—and can even look more like square waves. This can significantly affect switch-mode power supplies because they draw their current at the peak of the ac waveform.

Inverter technology: Look for inverters that use insulated-gate bipolar transistors (IGBTs). These devices are used to switch large amounts of current with a small amount of control signal. Some UPS systems use silicon-controlled rectifiers (SCRs) or bipolar transistors. IGBTs have many advantages including fast switching time, high current capacity, increased surge tolerance, and energy efficiency.

Manual bypass: It is critical for a UPS system to have a manual maintenance bypass. Without a manual maintenance bypass, the UPS system acts as a single point of failure. This bypass is improved if it uses a static transfer switch. Typically, static transfer switches use SCRs and allow transfer to bypass within 4 msec. This transfer is fast enough to keep critical equipment from shutting down during transfer. In these conditions, routine maintenance can be performed without affecting the critical loads.

Onboard monitoring: Onboard monitoring equipment and software are critical. The ability to determine the percent loading, the remaining battery life, and input power quality is essential to ensure proper system maintenance.

Low harmonics: Low input harmonic characteristics are important for any UPS system. The lower the input harmonic current, the more generator-friendly the UPS system will be.

Proper design and specification of UPS system components is essential and will ensure the desired level of power quality and system uptime.

UPS BATTERY SYSTEMS

UPS battery systems and their associated system requirements must be considered when selecting the appropriate type of UPS system. The battery system is an essential part of the UPS, but in many cases can be the weak link to the reliability of a critical application. The two main types of battery system used in most UPS systems are the flooded battery—sometimes referred to as a vented or wet cell battery—and the valve-regulated lead acid (VRLA) battery.

Flooded cell batteries require significantly more ventilation and monitoring requirements than VRLA batteries, but typically provide for considerably longer battery life. Typically, large UPS systems use wet cell battery systems, while smaller UPS systems use VRLA battery systems. Wet cell systems are superior at applications requiring large currents for short periods of time.

Flooded batteries are sometimes called "vented" because they allow gases to escape during the recharging process. These batteries lose fluids during recharging and require fluid replenishment, and consequently require more regular maintenance than VRLA batteries.

VRLA batteries are sealed, although they do have pressure-relief valves. This type of battery does not require as much maintenance as wet-cell batteries. If these batteries are overcharged or exposed to high temperatures, they will release gases in to the air.

Most wet cell or flooded cell batteries have a 20-year lifecycle. VRLA batteries are available in five-, 10-, or 20-year life expectancies. The stated life for a battery system depends on the load it serves, the number of discharges, the depth of the discharges, and the temperature of the environment where it is installed.

Temperature is a key factor in the actual life of a battery system. VRLA battery systems typically operate at extreme temperatures. However, they are rated at 77 F. The ideal operating temperature for most VRLA battery systems is between 68 and 77 F. Systems that function in higher temperatures will have a reduced battery life. This type of battery system typically has a 50% reduction in life for every 50 F in excess of 77 F. Systems that operate in cooler temperatures will have a reduction in total backup time. It is imperative to maintain temperatures in battery rooms to ensure the reliability and longevity of battery systems.

VRLA battery systems that are deeply discharged—to 70% to 80% of the total depth of discharge—can cause problems.

Battery systems that are only partially discharged will reduce the recharge voltage at the float voltage and will in turn reduce the battery voltage.

It is important to limit the recharge current in VRLA batteries to minimize the potential of damaging the battery system. At 77 F, a VRLA battery can tolerate a 25% current limitation of the amp-hour rating of the battery. For a 500 amp-hour battery, the recharge current should be 125 A above the load being served. Below 77 F, the battery system can tolerate 30% of the current of the amp-hour rating of the battery system. At 90 F, the battery system can tolerate 20% of the current of the amp-hour rating of the battery system. A rate of 20% to 25% of the charge-current limit is recommended.

VRLA batteries create more internal heat than flooded batteries because of the recombination of oxygen at the negative plate. Additionally, the reduced electrolyte level in VRLA batteries reduces the amount of heat that is conducted away from the battery plates.

While the flooded cell batteries can provide longer battery life, these systems can take up considerably more space and require significantly more ventilation and monitoring requirements than VRLA batteries. Typically, wet cell batteries continuously release hydrogen gas into the air and are required to be installed in their own dedicated, well-ventilated battery rooms. This is not the case with VRLA battery systems; these systems recombine the hydrogen inside the battery to create water. Hydrogen is released only when overheating or overcharging occurs. In addition, VRLA battery systems normally do not require additional ventilation systems. Typically, normal ventilation for human occupancies exceeds the ventilation requirements for these systems. With wet cell or vented systems, two air exchanges per hr are required, and the systems typically require an independent ventilation system. Ⓟ

ABOUT THE AUTHOR

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