



## Uninterruptible Power Supply

In the electrical system environment, power disturbances will occur. These can be caused by faults on the distribution system, the operation of nearby equipment, lightning strikes, normal utility operations, or any number of other causes. The resulting disturbances such as electrical noise, voltage spikes, sags, swells, and complete outages can exceed the electrical tolerances designed for the electrical equipment in use.

In order to eliminate or reduce the loss of important data or control, it may be necessary to provide a level of power protection for your particular needs. An Uninterruptible Power Supply (UPS) can be that answer. These devices are designed to provide continuous power to a load, even with an interruption or loss of utility supply power. To determine the requirements for a UPS generally involves a balance of cost vs. need. This Power Note describes the aspects of selecting a UPS for small, stand-alone, single-phase computer applications.

The components of a basic UPS system contain a battery charger/rectifier, batteries, and an inverter. The battery charger is a rectifier that converts AC power to DC in order to charge the batteries. The batteries store power that is supplied to the load when there is a loss or decrease of a certain tolerance of utility supply power. The inverter converts the DC power from the battery to AC power used to supply the load.

### ***Three Types of UPS's***

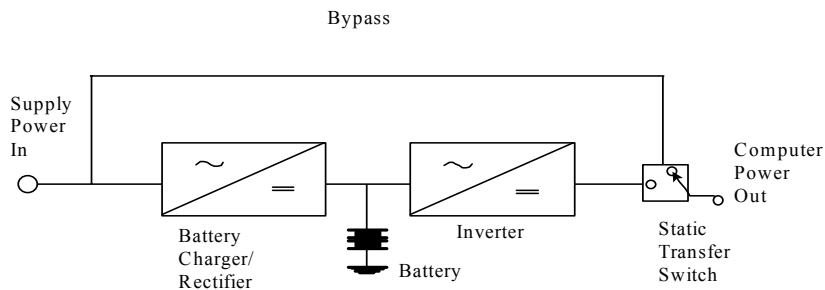
Not knowing the differences between UPSs creates confusion when trying to understand the types and technology you need. When deciding on the best UPS for you, it all depends on how much protection is necessary. Basically, there are three types of UPS's (Figures 1-3) - standby off-line UPS, standby ferroresonant UPS, and on-line UPS.

### ***Standby Off-Line UPS***

Under normal conditions an off-line UPS remains in a standby mode. The electric supply power is connected directly to the load and feeds a battery charger/rectifier to continually charge the battery. If the electric utility supply fails, the battery supplies power to an inverter, which is connected to the load by a static transfer switch that engages in a fraction of a cycle.

The off-line UPS is characterized by a switching delay of 1.5 to 4.0 milliseconds after supply voltage drops out of a specified tolerance band. The standby off-line UPS is typically suited for small loads (up to 1.5 kVA) that have a capacity in the power supply capable of riding through the transfer time.

## Standby Off-Line UPS



**Figure 1.** With the standby off-line UPS, the primary source of power comes from the utility. When the utility voltage drops out of the tolerance band, the transfer switch changes state and backup power comes from the battery via the inverter.

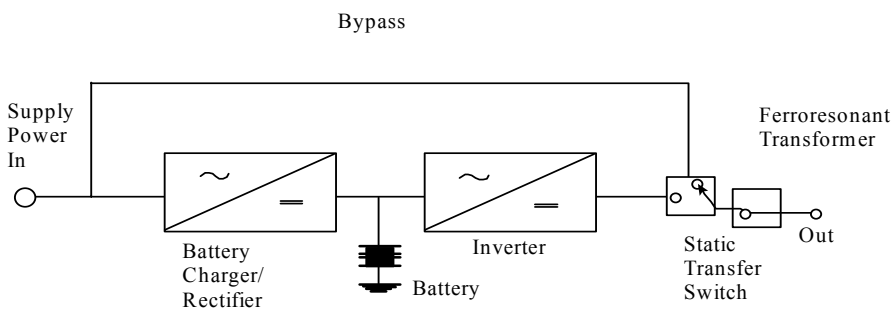
In operation, the system simply alerts the user that supply power failure has occurred and that the load now is on battery power. The available power from the battery will last approximately five to fifteen minutes. Some UPS's now have a smart charger to charge the batteries and to monitor for battery replacement.

If the electrical equipment being protected cannot withstand any outage, such as the one experienced when an off-line UPS transfers from utility power to battery, the user should consider purchasing an on-line UPS. In some instances the one-half to one cycle ride-through provided by a ferroresonant transformer may be adequate. Of the three types of UPS systems described in this document the off-line UPS is the most efficient and the least expensive. They can be purchased in any electronic or discount retail store. They may not provide for any filtering in the normal mode of operation.

### Standby Ferroresonant UPS

A ferroresonant transformer UPS is similar to an off-line UPS. However, the transformer can store energy from one to several cycles depending on the loading. Figure 2 shows how a ferroresonant transformer is added to the output of the UPS system shown in Figure 1.

## Standby Ferroresonant UPS



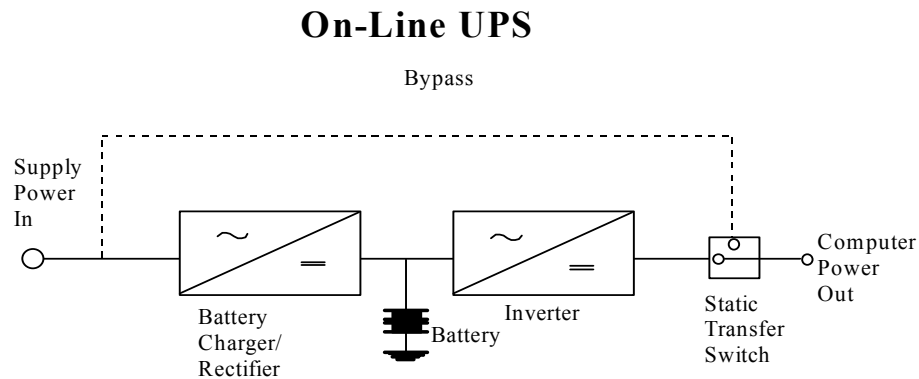
**Figure 2.** The schematic for, and operation of, the standby ferroresonant UPS is the same as that of the standby off-line UPS except for the addition of the ferroresonant transformer at the output which provides a limited ride-through capability.

This option is usually incorporated into the UPS by its manufacturer, but could be added by the user.

With this design, the time that it takes to switch to the inverter, is covered with the ride-through capability provided by the energy stored in the ferroresonant transformer. Therefore, the sensitive load is unaware that any switching has taken place. The transformer also provides output voltage regulations and protects the UPS from overload and short circuit conditions. Another advantage is that it extends battery life by switching over to battery power less often. This lowers maintenance costs, since batteries can be expensive to replace.

### **On-Line UPS**

An on-line, or double conversion UPS, is the ultimate in UPS protection because the utility supply power does not flow directly to the load like the off-line UPS. Instead, the power flows continuously through a charger/rectifier that feeds both a storage battery and an inverter. The inverter generates AC power to the load being protected. In the event of a power failure, the inverter is fed by the battery. Since the power flows through the rectifier and inverter before reaching the load, most power disturbances are eliminated through constant filtering. Therefore, an on-line UPS is a good idea for any system which is sensitive to transients, noise, and/or cannot tolerate any power interruption.



**Figure 3.** The double conversion on-line UPS has all its power flow continuously through the input rectifier and DC voltage link. Hence, most disturbances on the input are isolated from the output. The bypass for this system may be used to take the UPS out of service.

### **Other Types of Non-UPS Mitigation Equipment**

The first three columns of Table 1 show the capabilities of the three basic types of UPS's. In addition, three other commonly used devices to mitigate the type of power disturbance as described in the left column are shown.

## Mitigation Equipment Capabilities

Type of Disturbance	Standby Off-line UPS	Ferro-resonant UPS	On-Line UPS	Spike Arrester	Voltage Regulator	Isolation Transformer
Electrical Noise	-	✓	✓	-	Minimal	Minimal
Impulses/Spikes	-	✓	✓	✓	Minimal	Minimal
Momentary Interruptions	✓	✓	✓	-	Minimal	-
Flickers	-	✓	✓	-	Maybe	-
Voltage Dips/Sags	Most	✓	✓	-	✓	-
Swells	✓	✓	✓	-	✓	-
Under Voltage Brownouts	Minimal	✓	✓	-	✓	-
Over Voltage High Line	✓	✓	✓	-	✓	-
Outage/Blackout	✓	✓	✓	-	-	-
Frequency/Variation	Some Types	Some Types	✓	-	-	-

**Table 1. A comparison of the capabilities of various types of power disturbance mitigation equipment.**

The three types of non-UPS mitigation equipment included in Table 1 can be described as follows:

- A spike arrester clips voltage peaks off spikes and transients in the voltage wave form.
- A voltage regulator maintains a constant voltage output under varying input voltage conditions.
- An isolation transformer electrically separates the electrical equipment from the power source, in effect filtering out common mode electrical noise.

It should be noted that most personal computers employ switched-mode power supplies, which are very tolerant as far as voltage fluctuations and wave shapes are concerned. Tests have also indicated that the capacitors in such power supplies provide a ride-through capability of about four cycles. Therefore, the need for voltage regulators and ferroresonant transformers should be objectively evaluated. In addition to providing filtering, a Ferro's voltage regulation function can extend battery life considerably.

While UPS systems mitigate power quality problems, they do not solve grounding problems that may cause errors in transmission and reception of communication signals. When a UPS is packaged with an isolation transformer on the load side of the static transfer switch, neutral-to-ground bond can be re-established at the transformer secondary, reducing the neutral-to-ground impedance considerably.

## Factors to Consider when Selecting a UPS

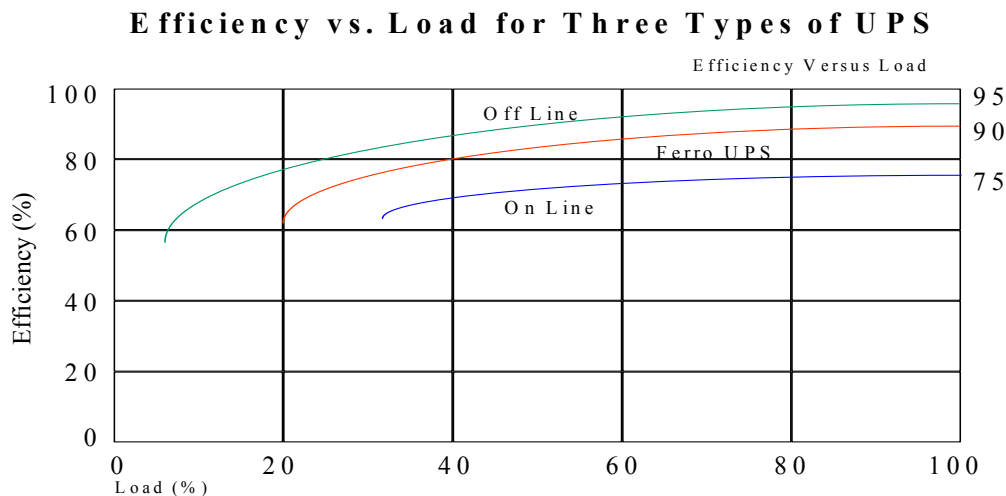
### Output Power

It is necessary to consider the size of the load that is to be connected to the UPS. The load may consist of a specific type of computer, workstation, mini-mainframe, hard disk drive, or test equipment. Once the equipment requiring a continuous power source is identified, the necessary rating of the UPS system can be determined by adding the volt-ampere (VA) rating on the nameplate of the equipment to be served by the UPS.

The maximum power rating of a standby, off-line unit is approximately 1.5 kVA, while the on-line UPS systems power ratings typically start at 500 VA. Sometimes power ratings are given in watts. The conversion formula from watt to volt-ampere is typically:

$$\text{volt-ampere} = \text{watt} \div (0.7\text{PF})$$

Sizing should always be based on volt-amps plus 50-100%. One might consider purchasing a UPS which is rated somewhat larger to accommodate future growth and peak currents of switching power supplies. However, UPS systems typically work most efficiently near their rated capacity. Figure 4 shows the efficiencies of the three types of UPS's of a percentage of the load.



**Figure 4. Efficiency vs. Load for a typical 1.5 kVA UPS**

The efficiency of a standby ferroresonant type follows the efficiency curve of the off-line UPS but somewhat lower. The efficiency for an on-line UPS will be lower yet because of the AC/DC/AC conversion. Typically, the best efficiency expected for an on-line UPS will be about 75% for small stand-alone, single-phase UPSs for computer applications rated at 5 kVA and below.

### Batteries/Space/Heat/Noise

It should be mentioned that battery life is a major consideration for UPSs. Battery manufacturers' state a five-to seven-year life for the lead-acid batteries used in the UPS. However, the actual battery life is determined by how often the battery is called upon to take over when there is an outage, surge, sag or swell. Each time the battery takes over, its useful life diminishes.

New battery life technologies are being incorporated into today's UPS's. For example, Powerware, formerly Exide Electronics has developed the Cell Saver™ technology that uses a two-pronged approach toward improving battery life. By providing a wide AC input voltage range (85 to 144V at full load) and energy storage capacitors, an on-line UPS supplies a constant sinewave output via an inverter and does not switch to its battery during short-duration power line disturbances. Under these conditions, the output is a 120V (+/-2%), 60 Hz sinewave. The same basic circuit technology is employed for UPSs covering from 600VA to 3.0 kVA. For more information regarding this technology, please refer to Powerware's website at [www.powerware.com](http://www.powerware.com).

The batteries are the weakest component of UPS's. When battery failure occurs, UPS's are commonly sent back to the factory for service. However, it may be more economical to purchase a new UPS rather than to repair the old one. To solve this problem, user friendly, hot-swappable battery replacement systems are available. These are modular replaceable battery packs that can be quickly and safely swapped out without powering down the connected load (hot-swapped) by the user. No tools or disassembling of the unit is required. This saves the time and expense of returning the UPS to the factory for battery service.

The type of UPS selected will also have an impact on physical size due to floor space availability and weight. The UPS and the addition of optional batteries decreases available floor space and increases the concentrated weight. The ferroresonant type UPS that contains a ferroresonant transformer is generally heavier than other types of systems.

As an example, a ferroresonant UPS with a power rating of 2.0 kVA weighs 420 lbs., while a non-ferroresonant UPS with about the same power rating weighs 230 lbs. UPS systems using silicon controlled rectifiers (SCR) contain more circuitry but no large transformer, and therefore weigh less than the ferroresonant UPS. Even better, the UPS units with power MOSFET and GTO thyristor technology contain fewer components, and therefore weigh the least.

The heat rejection or heat loss of a UPS is normally given by the manufacturer. For a single small unit of 1 kVA or less, the heat load to an office or room may be negligible. However, for multiple units or larger UPS systems, it is necessary to account for the additional heat load on the room, office, or laboratory air conditioning system. A ferroresonant UPS typically has a lower heat rejection rating. For example, the heat rejection of a 5 kVA ferroresonant UPS and a on-line 5 kVA UPS system is 1.9 KBtu/hr and 2.9 KBtu/hr., respectively.

Audible noise in a continuous UPS is a major concern when the supply is placed in a work area. Most systems have a noise level between 50-60 dBA at 6 feet.

### ***Diagnostic/Communications***

Some UPS's have a microprocessor on board to monitor the state of the supply power, the internal parameters of the UPS, the output power and load current. These types of systems often can be connected to the computer installation to warn the user, for example, of any potential power line problems and the charge level of the battery. These systems will automatically close files and do an orderly shut down should the battery reserve become low during a power failure. This system typically requires an RS-232 interface from the UPS to the computer and appropriate software to link the UPS to operations for your specific computer system.

UPS Type	Standby Off-Line Standby Ferroresonant Double Conversion On-Line
Output Voltage Waveform	Sinusoidal Square
Output Voltage	120 V Typical
Output Rating	Voltage-amperes (must exceed load by 50% minimum)
Peak Output Current	(Must meet peak currents of critical load)
Utility Cut-off Voltage	<95 V Typical
Utility Restart Voltage	>100 V Typical
Transfer Time	<4 ms (Typical)
Battery Backup Backup	Minutes
Computer Communications Interface	None RS-232 Other
Voltage Regulation Capability	Regulate from -40% to +20%
Hot Swappable Battery	Replaceable modular battery pack that can be changed out without powering down the connected load

Table 2. Summary of critical features to consider when purchasing a UPS.

### **UPS Selection Criteria**

After determining the specific UPS features required for the application and developing a list of qualifying UPS systems, selection principally becomes an issue of engineering quality, layout and economics.

The supply voltage has a sinusoidal waveform. The inverters of some standby off-line UPS do not produce a sine wave when the supply power fails; it is sometimes cheaper to put out a square wave or a rectangular voltage waveform. A more sophisticated control system is required to produce sinusoid voltage.

Although many personal computers operate well on square wave voltages, a sinusoidal voltage output from a UPS will assure that the computer installation experiences consistent waveform conditions during a loss of power. This should minimize future difficulties as the installation changes. The inverter consists of a number of very fast-acting switches. To produce a sinusoidal voltage waveform, a switching scheme must be used that results in a series of voltage pulses that closely approximate a sine wave. One method of switching is called pulse width modulation (PWM), which sequences the duration of the on-time from switches to produce an excellent synthesis of a sine wave.

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