How to Match the UPS and the Generator

A White Paper by Liebert

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For mission-critical applications, a standby power generator is as necessary as a UPS. Even if the UPS shuts down its load with no loss of data, the resultant downtime carries penalties in the form of lost productivity and lost sales. A standby generator is the only practical source of backup power during an extended outage.

The Problem

But UPSs and generators can be mismatched. Consider the following scenario:

> Utility power fails, and the UPS transfers to battery successfully to maintain the critical load. Less than a minute later, the standby generator starts up, supplying power not only to the UPS, but also to other essential systems such as lighting, air conditioning and ventilation, elevators, phones, and security networks. Everything seems to be working fine, but after fifteen or twenty minutes, the UPS shuts down the critical load. Meanwhile, the standby generator is still chugging away, supplying backup power for the lights, the air conditioning, the phones, and all the other systems on the standby circuit. Later, when utility power is restored, the UPS is restarted and operates perfectly.

What happened? The most common conclusion is that the UPS malfunctioned…never mind that the shut down was perfectly executed with no loss of data. The obvious solution is to get a new UPS. But, assuming everything worked as designed, a replacement UPS will likely yield the same result during the next extended outage.

If both the UPS and the standby generator worked perfectly, there is only one available conclusion—the power from the standby generator did not meet the input specifications designed into the UPS. Thus, the UPS was unable to transfer back from battery to generator power. When the battery was depleted, it shut down the load. Later, when utility power was restored, the UPS recognized acceptable input power and restarted.

Consistent voltage and frequency are directly proportional to the size and type of generator. Utility generators produce consistent power because they are huge. Any standby generator, by comparison, is quite small and, not unpredictably, produces inconsistent power. The voltage range may be acceptable, but the frequency range is very often wider than what an off-line or line-interactive UPS is designed to accept. It’s almost impossible to make an off-line or a line-interactive UPS work with a standby generator. Here’s why.

Off-Line UPS Technology

An off-line UPS passes utility power to the critical load with some surge suppression and some filtering—but no power conditioning. The only way it can protect the critical load from the frequency deviations that are common with standby generators is by transferring to battery.

Occasionally, the input frequency will meet the specifications of the off-line UPS, and it will transfer back from battery. These occurrences are infrequent and short-lived. The overwhelming probability is that the battery will support the critical load most of the time. So, when the battery is depleted, the off-line UPS shuts down the critical load.

Line-Interactive UPS Technology

Line-interactive UPSs have the same problem as off-line UPSs—they transfer to battery to protect the critical load from large frequency variations.

The power conditioning functions of a line-interactive UPS are greater than those of an off-line UPS, but they focus entirely on correcting voltage variations by means of a transformer and an automatic tap-switching feature. This has no effect on frequency variations, so the line-interactive UPS reacts to out-of-spec frequencies the same way as the off-line UPS—it transfers to battery. When the battery is depleted, the line-interactive UPS will shut down the critical load.

Why On-Line UPS Technology Works

On-line (or double conversion) UPS designs can work very well with generators because they accept input power with relatively wide variations in voltage and frequency.

An on-line UPS works because it actually re-develops the waveform. The AC input from either the utility or a standby generator is first converted to DC by the rectifier. The DC current is used to charge the battery. During an outage, DC current from the batteries is reformed by an inverter back to perfect sine wave AC for the critical load. Newer models also use PFC (power factor correction) front-end converters that provide an even wider input voltage range.

Because of this double-conversion (AC to DC, then DC to AC), variations in the input frequency are of little concern. The same frequency variations that would cause an off-line or a line-interactive UPS to transfer to battery have no effect on the on-line UPS.

The inverter also tracks the input frequency. If the frequency variations remain within a certain window, the inverter stays in synch with the input. Thus if a transfer to bypass is required due to overloads, load faults or a UPS fault, the inverter output is synchronized to the input voltage and a transfer can occur without interruption.
If the input frequency goes outside of specification, the majority of on-line UPS Systems will free-run. During free run, the oscillator in the UPS will assume control of the output frequency and maintain the frequency to the critical load within specification.

During free run, (the input voltage is within specification, but the input frequency is out of specification), the Liebert on-line UPStation S UPS system does not run on battery. The generator, not the battery, still powers the critical load. Free run does not deplete the battery, and the UPS will not shut down.

Sizing the Generator

A standby generator can be too small for any UPS to work properly. As connected loads turn on and off, they can cause voltage surges and sags of sufficient magnitude to cause even an on-line UPS to transfer to battery. This problem is easily avoided by selecting a generator with unused capacity equal to twice the kVA rating of the UPS as shown in the accompanying table.

Added Insurance

The generator circuit should also include two relatively inexpensive peripheral devices.
The generator itself should be equipped with a good electronic governor to reduce the magnitude of frequency deviations on its output.

The automatic transfer switch ahead of the generator should have either a neutral delay or an in-phase monitor. The transfer switch prevents the generator power from heading upstream. The neutral delay and the in-phase monitor are there to assure that the two power sources (generator and utility) are not out of sync when utility is restored as the transfer switch cuts away from the generator in favor of the utility. Out-of-sync power sources could result in a potentially destructive power spike to the UPS and unprotected connected equipment.

Summary

Liebert's recommendations for a matched UPS-generator support system for mission-critical applications are summarized in the accompanying diagram. The on-line UPS can accommodate most frequency variations while a properly sized generator will absorb most voltage variations. An electronic governor on the generator and a neutral delay or an in-phase monitor on the automatic transfer switch complete the requirements.

If...	Then...

There is one UPS.	The generator should be rated at three times the kVA rating of the UPS, e.g., a 9 kVA generator for a 3 kVA UPS.
There are two or more UPSs	The generator must be rated at three times the total kVA rating of the UPSs. A 2 kVA UPS and a 3 kVA UPS could share a standby generator rated at 15 kVA or higher.
The generator powers the UPS Plus additional essential loads, e.g., for emergency lighting or a security systems	The generator should carry a kVA rating equal to the sum of all the critical (UPS) loads and the essential loads, plus a reserver capacity of twice the kVA rating of the critical loads.

A Matched UPS/Generator System
Minimal generator size is the sum of the essential loads plus 3x the total critical load. Reserve capacity (2x the critical load) minimizes and stabilizes voltage variations caused by inrush currents.

The generator must be equipped with an electronic governor. Minimizes frequency variations.
The automatic transfer switch must be equipped with (a) a neutral delay or (b) an in-phase monitor. Either feature will prevent out-of-synch transfers from generator power back to utility power.

UPS must employ on-line (double-conversion) technology. An on-line UPS is more likely to accept the frequency variations common to power from standby generators. Do not use an off-line or line-interactive UPS.

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