



A dozen attachments.

Powered by FirstSource

Products Articles

[Advanced Search](#) | [Search Tips](#)

REGISTER FOR THE E-NEWSLETTER NOW. It's Free!

[LexisNexis](#)



Pure Power

Power Quality and Generators – Part 2: The Effects of Harmonics

Editor's Note: This is the second in an ongoing series that will cover basic engineering and code issues for standby generators. In a subsequent column, the author will continue with a more in-depth look at the various types of generator ratings.

CSE and More

[Home](#)

[Reader Service](#)

[Electrical/Power Quality](#)

[Fire, Life Safety and Security](#)

[HVAC and Building Automation](#)

[Lighting](#)

[Plumbing](#)

[Management Practices](#)

[CSE Articles \(1997-present\)](#)

[CSE Articles \(1985-1996\)](#)

[CSE NewsWatch](#)

[Pure Power](#)

[Specifier's Guide](#)

[Continuing Education](#)

[Deep Links](#)

[Industry Organizations](#)

[Engineering Firms](#)

[Calendar of Events](#)

[About CSE](#)

[Contact CSE](#)

[Advertise with CSE](#)

[CSE Reprints](#)

[Get a Print Subscription](#)

[Register](#)

Sign up today for special features, including free e-letters and much more. [Register](#)

By Keith Lane, P.E., RCDD/NTS Specialist, LC, LEED AP
 Vice President - Engineering
 SASCO
 Seattle

A standby generator and an uninterruptible power supply (UPS) are two main critical components of a reliable electrical distribution system. A well-designed system with both a standby generator and UPS will ensure good power quality and maximum uptime. A UPS generally sits between the power supply (utility or generator) and critical loads to prevent undesirable features of the power supply—outages, sags, surges or harmonics—from adversely affecting the device performance.

Different loads affect the sizing and the performance of generators in a variety of ways. Loads that require high initial inrush and/or loads that are high in harmonic content will require a larger generator. As discussed in my last [column](#), devices that use silicon-controlled rectifiers (SCRs) to chop up AC waveform will provide a nonlinear waveform. This nonlinear waveform, known as harmonics, will cause voltage distortion across the reactor of the generator and can cause unacceptable transient performance. This will adversely affect the performance of the entire system.

Linear and nonlinear waves

UPS rectifiers usually do not draw a sine wave current from the power source. The greater the current waveform is different from the sine wave, the more total harmonic distortion (THD) the waveform contains. Harmonic distortion can cause excessive heating at the generator and can cause excessive voltage distortion across the entire system.

An engineer must be familiar with the various methods UPS and generator manufacturers rely on to make their UPS systems “friendlier” to generator systems. These methods include the use of:

- UPS with 12-pulse rectifiers in lieu of 6-pulse rectifiers.
- UPS with passive filters.
- UPS with step loading or walk-in features.
- Permanent magnet generators (PMGs) with digital excitation controls.
- UPS with reduce maximum input current.

A 6-pulse rectifier will typically have about 30% THD, rich in 5 th and 7 th harmonics. A 12-pulse rectifier will have less than one-half of the THD that we see in a 6-pulse rectifier and is rich in 11 th and 13 th harmonics.

UPS manufacturers can provide passive filter to reduce the total harmonic distortion that the generator sees. At low loading on the UPS, the static filter can provide an excessive capacitive component that will be sent back to the generator. Unlike a utility source, a generator cannot absorb the voltage rise caused by the capacitance in the system. Theoretically, the generator's voltage regulator can lose control and raise the output voltage to the UPS. The UPS rectifier may turn off when it sees the rise in voltage. This disconnecting of the UPS rectifier will remove the additional capacitance in the system, which will allow the generator's voltage regulator to operate properly. This cycle can continue and the UPS will be unable to pick up the load under generator power.

This problem can be eliminated by evaluating the system and providing a smaller filter, sized to

First Source

[Project Leads](#)
[RS Means Cost Calculator](#)
[RS Means Bookstore](#)
[First Source News](#)
[Building Codes](#)
[ProFile Directory of Architecture Firms](#)

Construction E-Wire Newsletter

[Get listed on First Source](#)

[Order First Source](#)

[About First Source](#)

[Link to First Source](#)

[Contact First Source](#)

[Contact RS Means Help](#)

[Click here to make us your home page](#)

[Click here to bookmark this page](#)

provide no excitation at the lowest possible load. In addition, the filter can be completely removed under generator power with control circuitry. Strategically providing reactive load in the system and connecting them to the generator prior to the UPS will allow these loads to absorb the capacitive component. Essentially redirecting the capacity component away from the generator.

A 100% step loading of the UPS system to the generator in the case of a loss of utility power will cause sudden fluctuations in both frequency and voltage of a standby generator. Many manufacturers will offer a "walk-in" function. During a utility power outage, the load served through the inverter output from the utility source via the rectifiers will immediately switch to the UPS batteries. Once the generator is up to speed (voltage and frequency) the total load on the UPS systems batteries can be slowly applied to the generator over time. This can be typically programmed to occur over a 30-second period. This walk-in feature will greatly reduce the frequency and voltage fluctuation on the generator output.

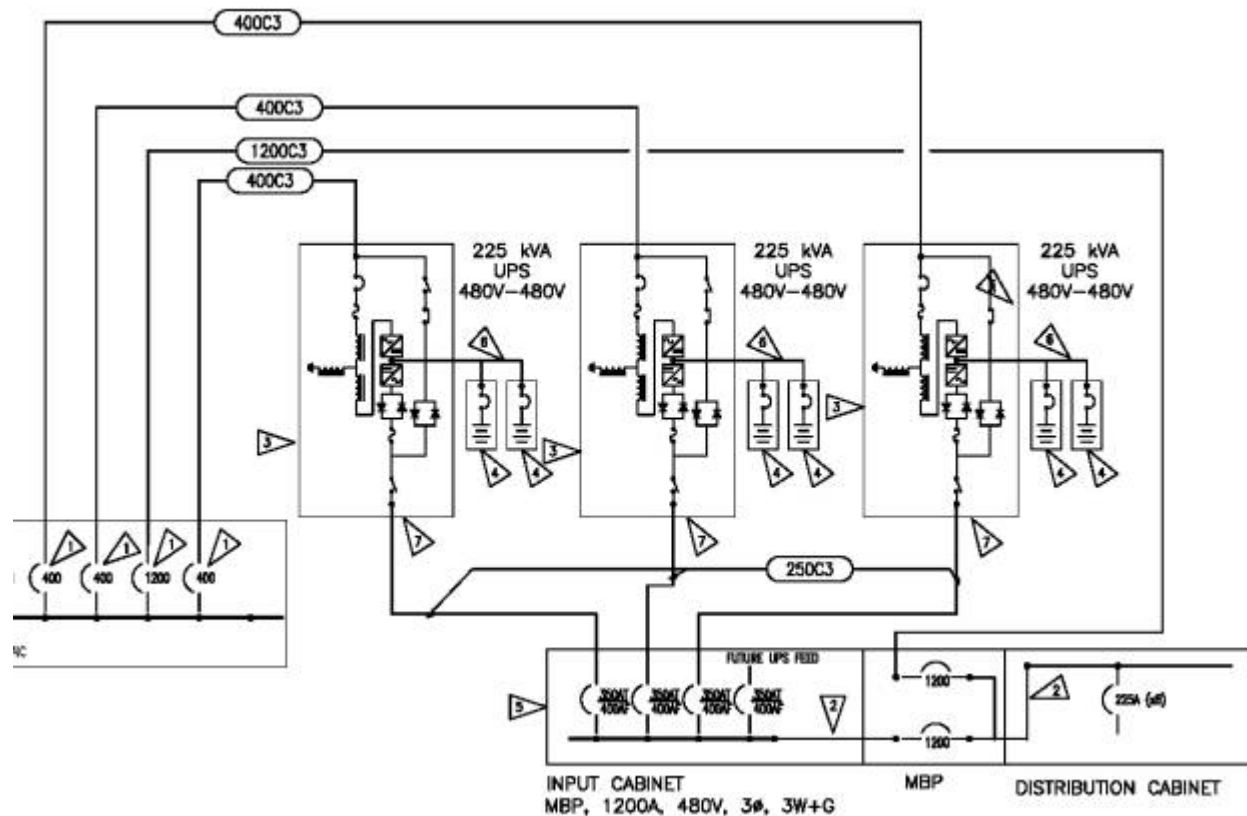
UPS harmonics can cause voltage waveform distortion at the generator. But permanent magnet generators that derive their own excitation can help to mitigate this problem. In addition, digital voltage regulators and digital excitation controls can further provide immunity to the harmonic effect of non-linear loads.

Many types of UPS allow the operator to set the maximum input current. After restoration of AC power, the rectifier/battery charger shall power the inverter and simultaneously charge the batteries. The maximum possible input current to the UPS must be considered when sizing the generator. If an operator reduces the maximum input current, the total load on the generator is reduced, but the time to recharge the batteries is increased.

In addition, a UPS with SCRs can be damaged if it is transferred rapidly with an out-of-phase source. When power fails, there is inherently an outage of several seconds before the generator starts and produces appropriate voltage and frequency levels and the automatic transfer switch transfers over to the standby source. Once the normal source returns, the typical contact open time for a mechanical automatic transfer switch can be up to 10 cycles. To protect the UPS, an intentional time delay of 1-3 seconds is recommended when transferring between out of phase standby (generator) and normal source (utility).

Ensuring proper frequency levels

When designing critical systems, an engineer needs to ensure proper levels of frequency variation when under standby power. A generator is much more susceptible to voltage and frequency fluctuations with large load changes than a utility. A UPS can be susceptible to slew rates (rate of change of frequency) of 1-2 Hz/sec. Some UPS systems will be designed with a solid-state bypass switch to allow for a very quick transfer to input power and bypass the UPS inverter. In order to achieve this static transfer, the UPS must remain synced with the input power. UPS loads cannot tolerate slew rates exceeding 1-2 Hz/sec and will not be able to sync with the input power. Failure to sync will require the static bypass function to be disconnected. Frequency disturbances from the generator can be controlled by limiting heavy block loading and providing stepping of loads.



The riser diagram illustrates three paralleled UPS modules with both internal static switch and external breaker operated maintenance bypass.

Many critical installations will utilize a dual bus UPS system downstream of a standby generator to provide a redundant UPS source. Proper syncing between UPS modules in a dual bus topology is essential to maintain uptime. In a topology utilizing static transfer switches between UPS modules and step down transformers, out of phase transferring can cause residual magnetization in a transformers core at the moment of transfer. A static transfer switch can switch between sources in a quarter of a cycle or about 4 ms. The characteristics of a transformer can require twice the normal magnetic flux at starting condition if the transformer is connected when the AC voltage is at the zero crossing. In an ideal transformer, the current would also rise to about twice its normal level. Most transformers will saturate at this level of flux and will require significantly more current to generate this magnetic flux. Residual magnetization from an out of phase transfer as noted above can exasperate the inrush problem and cause an even more server inrush current. This significant inrush current can cause a voltage distortion or could cause a UPS to shutdown when in battery operation.

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