

How to Reduce Harmonics in Power-System Design

In circuits and power-distribution systems, there are many ways to measure harmonics, e.g., using a clamp meter, and methods to reduce them, such as via K-rated transformers.

The IEEE standard 3002.8-2018, “Recommended Practice for Conducting Harmonic Analysis Studies of Industrial and Commercial Power Systems,” addresses the requirements for performing power-system harmonic analysis studies in industrial and commercial power systems due to increasing load nonlinearities and control devices.

What follows are ways to measure and reduce or eliminate the problems caused by harmonics.

Successfully Measuring Power-System Harmonics

Harmonic analysis is a discipline that’s quite different from any traditional methods used to solve problems in power systems. Finding solutions once a system is at the power system frequency will not do the job, though. The harmonic problem must be solved at multiple frequencies.

It’s critical to understand this distortion by measuring it on both the voltage and current levels for the power system. The power system will have a hardware interface; advanced software that can measure, analyze, and report the harmonic conditions of the power system; and lastly a PC.

Maximizing the efficiency and reliability of power networks can be achieved by increasing the power quality of the system. Harmonic content is a prime cause of low power quality. Agency standards help to ensure that manufacturers follow guidelines to measure and control harmonics.

To measure harmonics, engineers and technicians can use a clamp meter that indicates total harmonic distortion (THD) levels. The THD for voltage should not exceed 5% in most cases, while the THD for current will run much higher. Alternatively, testing the design with a power-quality analyzer can be performed to investigate the effects and magnitude of individual harmonics.

A power-analysis instrument is also a good option for

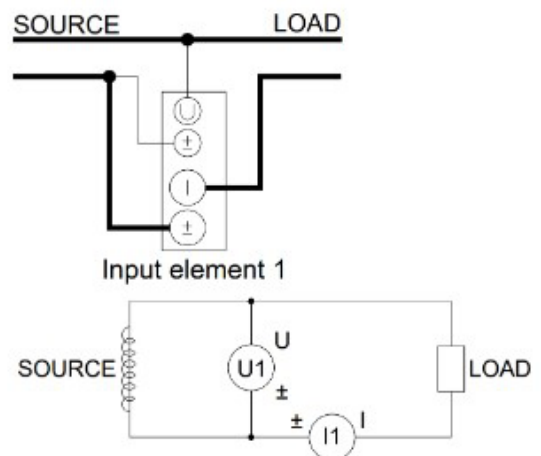
measuring and controlling harmonic disturbances (see the appropriate “Getting Started” guide, in Reference 5, for an instrument’s wiring instructions) (*see figure*). The essential task at hand is to analyze the specific source and generation mechanism of the system harmonics. It’s only then that designers will be able to propose an optimization method for phase-shifting control that will suppress the harmonics.

Reducing Harmonics

There are multiple ways to reduce and/or eliminate harmonics in system design:

Harmonic mitigating transformers

K-rated transformers, which comply with ANSI’s definition of K-factor, are designed to withstand any overheating problems that are created by harmonics. The use of a har-



Shown is an example of a wiring diagram for a single-phase load (1P2W) connected to a power analyzer. (Image courtesy of Reference 5)

monic mitigating transformer will help to mitigate problems by reducing or even canceling harmonics.

So, what's K-factor? The ANSI Standard C57.110-1986 defines it as a metric for evaluating the level of harmonic current that a circuit draws and determining the heating effect of that harmonic current.

In systems affected by harmonics, the K-factor can be measured with a power-quality analyzer. A K-factor of 1 will indicate a linear load. A higher K-factor will indicate an increase in heating from those harmonics. An example would be a circuit with a K-factor of 2, which will have twice the heating effect of a circuit with a K-factor of 1.

Manufacturers that submit their transformers to be evaluated by Underwriters Laboratories (UL) for harmonic loads can apply the UL label: "Suitable for Non-Sinusoidal Current Load with K-Factor not to exceed 4, 13, 20, 30, 40, or 50". However, loads with K-factors higher than 20 are rare.

Harmonic filters

Harmonic filters may be designed into a system to reduce harmonics. Designers may consider installing harmonic filters to reduce the harmonic distortion levels and shift resonance frequencies to less harmful regions.

Harmonic filtering that employs passive filters is one of the easiest and most practical methods for harmonic distortion reduction, along with parallel resonance mitigation.

The *table* shows commonly used filters, along with their impedance magnitude versus frequency characteristics.

Methods for Mitigating VFD Harmonics

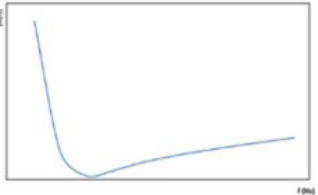
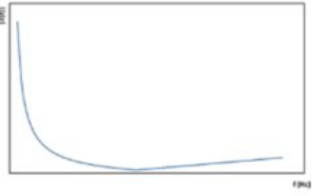
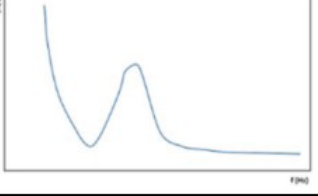
Nonlinear devices are increasingly being used in industry, which will ultimately lead to expensive production interruptions as well as electrical facility malfunctions.

THD and harmonic levels must be measured at the point of common coupling (PCC). When troubleshooting this kind of system, the PCC is the point at which the nonlinear loads typically become problematic and will be connected to the rest of the distribution system.

A variable-frequency drive (VFD), or adjustable-frequency drives, adjustable-speed drives, variable-speed drives, AC drives, micro drives, and inverter drives are kinds of AC motor drives (in a system incorporating a motor) that can control the torque and speed by varying the input frequency of the electricity.

VFDs are usually employed in applications that can range from small appliances to large compressors. Systems with VFDs may have a higher efficiency than hydraulic systems (for example, systems with damper controls and pumps used in many fans).

VFDs are susceptible to electrical harmonic distortion problems. Harmonics can be any current form at an integral multiple of the fundamental frequency. For example, it's usually 50 Hz for three-phase AC power in China. Harmonics may cause problems in electrical systems, so it's very important to understand how those harmonics are generated and the circumstances for which the harmonics may be harmful to a system.

Type	Structure	Impedance vs. frequency
Single-tuned filter		
High-pass filter (second order)		
Undamped high-pass filter (third order)		

[TABLE] These filters are commonly used to mitigate harmonics. (Image courtesy of Reference 3)

Many different methods can be applied to reduce, or even, eliminate the harmonic content created by a VFD. One simple method is to add an inductor to the input of the VFD. This inexpensive solution will help reduce harmonic content from higher than 60% down to the 40% range.

Designers can also use harmonic mitigating transformers to reduce power-system harmonics. Transformers configured with Delta-Wye wiring can aid in lowering harmonic effects, too.

What are Triplen Harmonics?

Triplen harmonics (or triplens) are defined as odd multiples of third-order harmonics (3rd, 9th, 15th, etc.). Only single-phase loads will generate triplen harmonics.

Triplen harmonics may lead to problems such as overloading in neutral conductors, transformer overheating, as well as telephone interference. Three-

phase electronic loads that are connected phase-to-phase—for example, 208-V power supplies or 480-V variable-speed motor drives—will not generate any triplen harmonics. However, these three-phase electronic loads are able to generate high levels of other higher-level harmonics.

Single-phase electronic loads connected in a phase-to-neutral configuration, as in 120-V office circuitry and 277-V lighting circuitry, will generate third harmonic distortion along with decreasing levels of higher odd harmonics.

Summary

This article offers tips and methodologies on measuring and reducing, or even eliminating, harmonics in power systems. The use of K-rated transformers will help to mitigate system harmonics, and harmonic filters can be used to lower or virtually eliminate distortion.

Ultimately, measuring the system harmonics will enable designers to determine the right level of harmonics that can be tolerated in a power-system design to meet the overall final target of system performance.

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