

Harmonic solutions



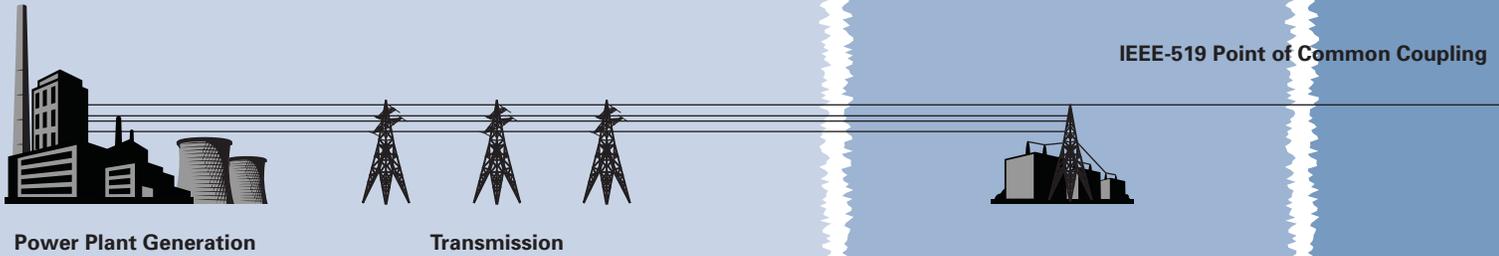
Clean power drive solution
to harmonic distortion

EATON

Powering Business Worldwide

Utility Grid

Utility Switch Yard



Increase efficiency, profitability and reliability

In today's business environment, expectations are only getting higher. Managers are increasingly concerned with operational efficiency. This includes minimizing costs, capital expenses and unplanned downtime. Rocketing prices have also caused us to take a closer look at our energy consumption, and make adjustments to help keep these costs and their corresponding expenses at a minimum.

Harmonics

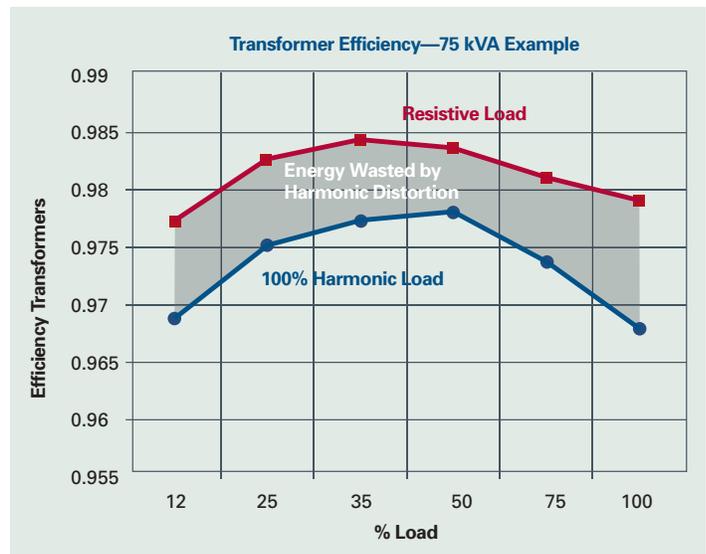
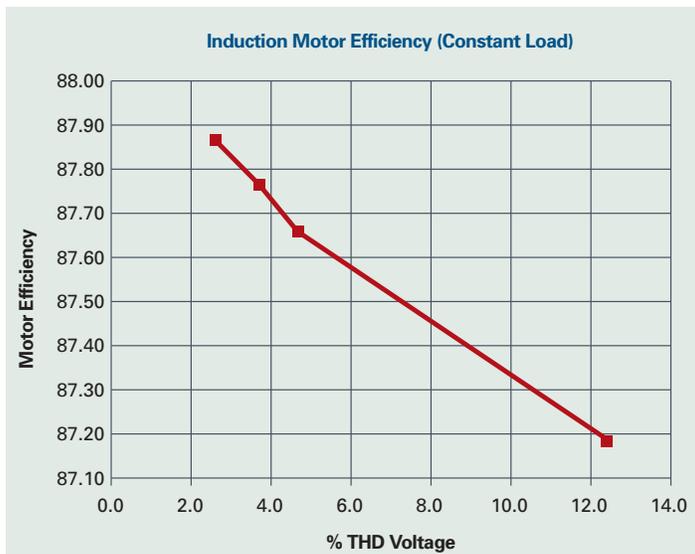
Harmonics are distorted electrical waveforms that introduce inefficiencies into your electrical system. They produce wasteful heat and can cause plant issues and fees from your local power company.

Harmonics flow into the electrical system as a result of nonlinear electronic switching devices, such as adjustable frequency drives (AFDs), computer power supplies and energy-efficient lighting.

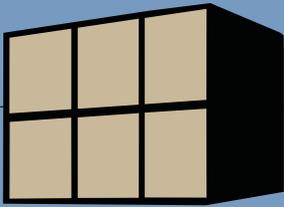
Similarly, companies with heavy motor, AFD and lighting loads need to be aware of the problems that harmonics can cause. These problems include:

- Increased electrical usage
- Increased wear and tear on motors/equipment
- Higher maintenance costs
- Power quality problems upstream and downstream
- Utility penalties for introducing problems to the power grid

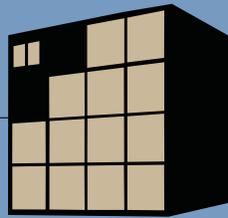
The charts shown below illustrate motor and transformer efficiency decreases due to system harmonics.



In the Facility



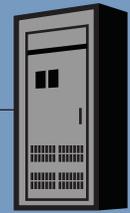
Medium Voltage Switchgear



Low Voltage Switchgear



Distribution Panel



Drives

Sources of harmonics

While AFDs reduce energy usage, they can also cause harmonics. Too much harmonic distortion can result in slow but steady damage to sensitive devices that rely on quality power. Other harmonic sources include lighting ballasts and UPS systems. These pieces of electronic conversion equipment introduce harmonic currents and voltage into the utility supply.

Who should be concerned?

With an increasing amount of sensitive electronic equipment, and numerous ways to measure efficiency, everyone from IT to accounting needs to know the harmful effects of harmonics. Even utilities are becoming aware and are imposing fines for harmonic distortion.

Management

There are many business implications to managing harmonic distortion. In today's competitive business environment, better awareness of electrical inefficiencies result in:

- Controlled capital expenses
- IEEE®-519 compliance
- Increased uptime and profits
- Added value to facilities
- Reduced energy expenses

Stakeholders and owners

Taking steps to curb harmonics can improve return on investment and boost the intrinsic value of the facility or the enterprise. Managing the electrical infrastructure will help to protect electrical assets and contribute to a "greener" environment by reducing utility CO₂ emissions.

Maintenance and facility engineers

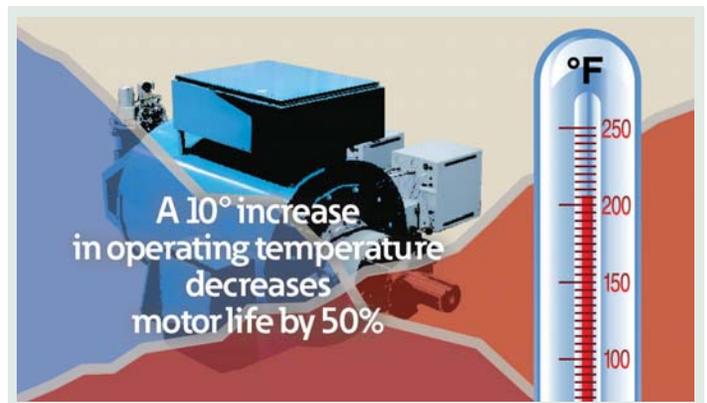
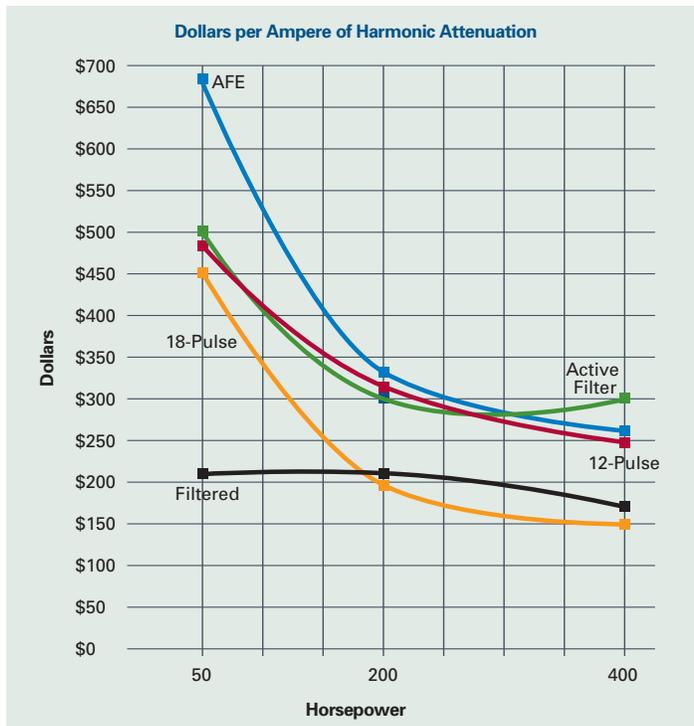
Taking a proactive approach to harmonic reduction helps to protect sensitive electronic equipment, reduce downtime due to motor and transformer heating, and eliminate the problems associated with sizing and applying backup generators on systems with high harmonics caused by drive loads.

What are the costs associated with harmonics?

Depending on your electrical power system, there are a lot of places where harmonics can cause inefficiencies.

In a manufacturing setting, unmanaged harmonics can increase motor temperatures by 10 degrees to maintain output. This side effect can reduce the life of a motor by 50%. Distribution transformers can lose a full +1% of efficiency when carrying 100% harmonic current, and motors lose 0.1% efficiency with each 1% of harmonic voltage distortion. These losses can cause a dramatic decrease in the lifespan of fan and pump motors due to extra heating in the motor stator.

In a hospital setting, a large HVAC system with a 500 horsepower fan and pump load, running at 5% voltage distortion instead of 1%, can cost \$15,000 per year at 10 cents per kwh. This is in addition to the costs of the reduced lifespan of the motors caused by the heating effects of the harmonic currents.



Select the clean power quality solution that meets your specific needs



Clean power solutions

More and more companies are using drives to take advantage of the energy savings, precision control and intelligent automation they provide. However, it is necessary to also manage the harmonics these drives create.

We wish the solution were as simple as one-size-fits-all. However, IEEE-519 standards are a system recommendation, not a product specification. The same drive in two different installations will have completely different harmonic profiles. Eaton will help you reduce the time and money needed to meet IEEE-519 recommendations.

Offering a full line of engineering and manufacturing solutions, Eaton is uniquely positioned to provide the right solution for the specific problem—from simple filters to sophisticated 18-pulse clean power drives. Eaton provides the optimal combination of products to solve harmonic distortion problems, reduce electrical usage, maximize equipment life and provide the greatest financial return.

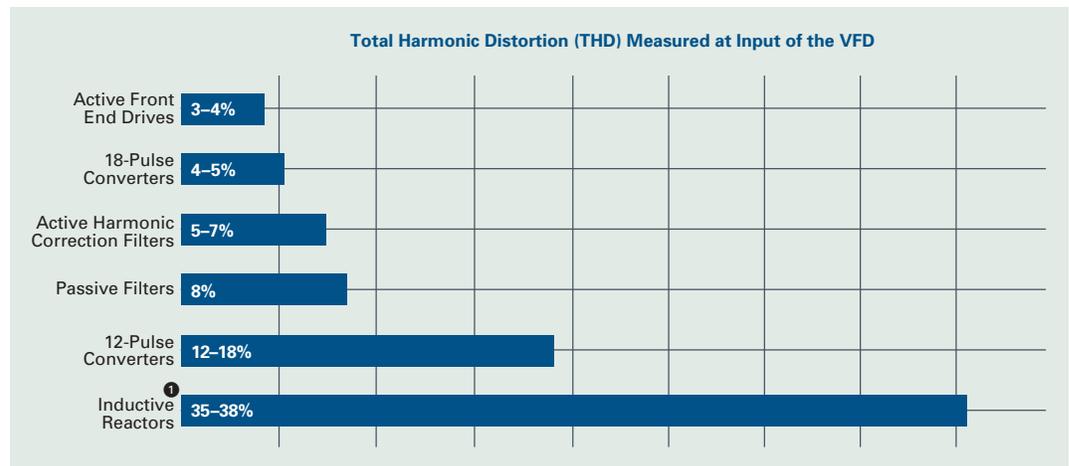


Harmonic Analysis Calculator

A free harmonic analysis tool can be downloaded from Eaton's website: www.eaton.com/drives (right-hand column under software downloads).

IEEE-519, a conservative guideline to long-term stability for your facility

The IEEE-519 is a conservative guideline written from the point of view of electrical utilities. This guideline establishes the level at which electrical energy is determined "clean." Eaton has product solutions to help lower your harmonics to the IEEE-519 level and beyond.



① 3% line or DC link choke.



Inductive reactors

By adding a line reactor or an isolation transformer to attenuate harmonics, you get a low-cost, technically simple solution. However, this solution tends to offer reduction in only higher-order harmonics and has little effect on the 5th and 7th harmonics. And, because of the associated voltage drop, there are limits to the amount of reactance that may be added.

Typical reactance is either AC or DC, with both delivering similar harmonic mitigation, but AC reactors provide additional protection to the drive rectifier bridge. Reactors are typically rated between 1.5% and 5%, with 3% being the industry standard due to the diminishing returns and voltage drop issues that higher levels can deliver. Reactors rated 3% typically deliver approximately 35–38% current distortion, with 5%-rated reactors or equivalent DC link chokes dropping this only nominally.

12-pulse converters

A 12-pulse converter incorporates two separate AFD input semiconductor bridges, which are fed from 30-degree phase-shifted power sources with identical impedance. The 12-pulse arrangement allows the harmonics from the first converter to cancel the harmonics of the second, especially at the 5th and 7th harmonics.

The 12-pulse converter is lower in cost than the 18-pulse unit and produces a substantial reduction (up to approximately 85%) in voltage and current harmonics compared to 6-pulse

AFDs. It also provides increased input protection for the AFD and its semiconductors from line transients. Conversely, impedance matching of phase-shifted sources is critical to performance, and transformers often require separate mounting or larger enclosures. Additionally, this converter may not reduce distribution harmonic levels to below IEEE-519 1992 guidelines. Twelve-pulse converters have been largely superseded by 18-pulse converters due to the significant harmonic attenuation benefits provided by the newer 18-pulse technology for a marginal price difference.

Passive filters

This method of harmonic reduction blocks harmonics from being transferred to the electrical distribution system through the use of an inductive and capacitive (L-C) filter. A primary inductor with relatively high impedance blocks higher-order harmonics, and a shunt-connected tuned reactor is connected with a capacitor to mitigate the 5th and 7th harmonics. These filters have a relatively low cost compared to 12- or 18-pulse converters, though there are a few concerns with their use. They can be challenging to size as they can act as a magnet for existing harmonics that are on the system. When the drive is off, the capacitor can cause power factor and voltage rise problems, and in the event of capacitor failure, standard units offer no indication of this failure. These filters can be sensitive to future system changes, and careful application is required by the design engineer.

Active harmonic correction filters

Active harmonic correction units are high-performance inverters that measure system harmonics through current transformers and inject harmonics of equal amplitude and opposite phase into the system. These systems are very expensive and are rarely applied for low-diversity, high-horsepower applications. They can be well-suited to systems where low horsepower loads are numerous and diverse, as a single active filter can be applied to mitigate the harmonic distortion effects of many drives. They also can make an excellent retrofit for existing systems because they are a shunt-connected device. When lightly loaded, most devices can correct power factor using the capacitance built into them. Drawbacks to this technology include high cost per amp and lower energy efficiency.

Active front end drives

The active front end is a bi-directional power converter for the front end of a common DC bus drive lineup. Although it does not affect other harmonics and cannot be retrofitted into existing drives, it does reduce total harmonics at any load to 2–3% THD. This power converter is immune to voltage imbalance, is available in 10–2000 hp, and can be used on multiple drives with a single front end. It provides voltage sag ride-through capabilities, a unity power factor and a regenerative power flow.

The active front end drive is a newer technology designed for regenerative loads, such as test stands and centrifuges. It requires an inductive-capacitive-inductive filter to filter the high frequency IGBT switching from the line. Because of the added technology introduced by the additional IGBTs, the cost of an active front end drive can be prohibitive in many applications. Also, the capacitive filter and the IGBTs are not as robust as the simple, but reliable, magnetics and diode technology of the 18-pulse drives.

18-pulse converters

The Eaton 18-pulse clean power converter will consistently meet IEEE-519 standards by reducing current distortion to 5% or less. The 18-pulse drive offers 50% better harmonic ratings (10% for 12-pulse vs. 5% for 18-pulse) at only a slightly higher cost. The efficiencies of this new drive have helped to take harmonic reduction to a new level for manufacturing facilities across the globe. It meets IEEE standards in every case, attenuates all harmonics up to the 35th, stops harmonics at the source, is insensitive to future system changes, and increases the life of the drive through incredibly stable DC bus voltage (18 small inputs instead of six large ones). The 18-pulse converter is the most cost-effective solution at 50 hp or higher.

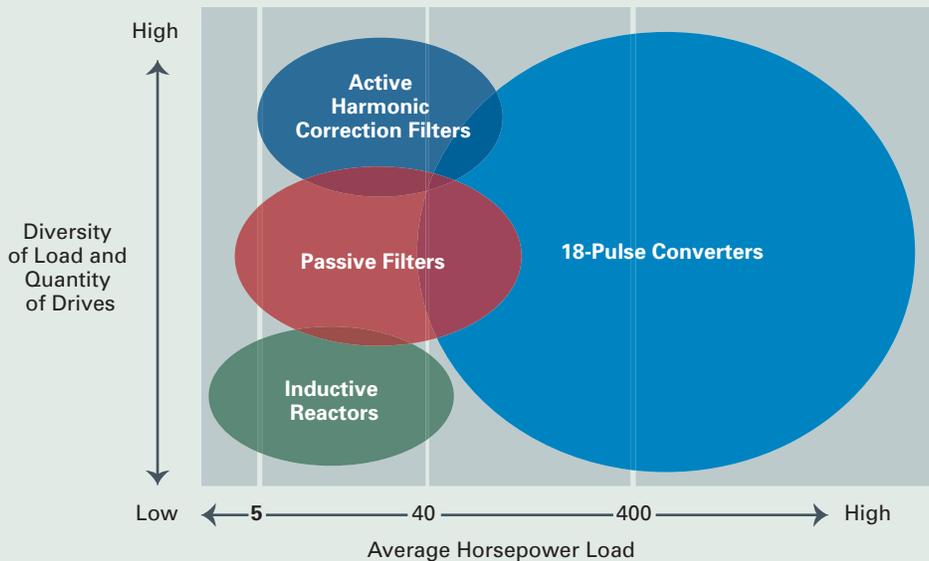
The broadest product selection for your applications

CPX9000—the optimal 18-pulse clean power drive

For critical loads, you need a comprehensive, single-source solution. The Eaton 18-pulse converter gives complete protection to the sensitive equipment and power that you rely on daily. No need to worry about the harmful effects of power quality—less application, installation and maintenance time requirements make the 18-pulse converter the right solution for most situations.



Mitigation Technique Application Range



For any motor over 50 hp, the 18-pulse converter offers maximum efficiency. At smaller loads, an inductor or passive filter is usually sufficient to provide the needed harmonic mitigation. Some high-diversity low-power applications can cost-effectively benefit from an active harmonic correction filter due to the small individual load requirements.



Selection guide

Technology	Inductive Reactors	12-Pulse Converters	Passive Filters	Active Harmonic Correction Filters	Active Front End Drives	18-Pulse Converters
How it works	Mitigates higher-order harmonics by providing high input impedance that limits high-frequency currents	Two parallel 6-pulse converters fed by parallel isolation transformer paths, phase shifted 30°, which mitigates 5th and 7th order harmonics. Input impedance mitigates higher-order harmonics as well	Provides high input impedance for higher-order harmonics and a shunt-tuned reactor and capacitor to mitigate 5th and 7th harmonics	Actively measures and injects equal and opposite harmonics into the system, canceling most harmonic currents below the 49th harmonic	IGBT-based front end pulls relatively linear power from the line and uses an L-C-L filter to mitigate the IGBT switching noise	Three parallel 6-pulse converters fed by a single-phase shifting autotransformer, phase shifted 20° to cancel all harmonics below the 17th. Input impedance mitigates higher-order harmonics as well
Typical THD	33–38%	12–18%	6–8%	5–10%	3–5%	3–6%
Advantages	<ul style="list-style-type: none"> • Low-cost, simple application 	<ul style="list-style-type: none"> • Simple to apply • Extremely robust 	<ul style="list-style-type: none"> • Simple retrofit • Low cost for performance • Insensitive to voltage imbalance 	<ul style="list-style-type: none"> • Simple retrofit • Good for high-diversity systems 	<ul style="list-style-type: none"> • Slightly higher efficiency • Immune to voltage imbalance • Regeneration capability 	<ul style="list-style-type: none"> • Simple to apply • Extremely robust
Disadvantages	<ul style="list-style-type: none"> • Low effectiveness • Voltage drop concerns 	<ul style="list-style-type: none"> • Not as effective as other methods • Relative high cost compared to passive filters 	<ul style="list-style-type: none"> • Challenges with generator design • Power factor issues • Less robust than 18-pulse 	<ul style="list-style-type: none"> • High cost per ampere • Relatively low efficiency • System compatibility issues 	<ul style="list-style-type: none"> • High cost, not as robust as 18-pulse 	<ul style="list-style-type: none"> • Not available as a retrofit • High cost on small hp

A commitment to clean power

As drive usage continues to grow and technology continues to get more complicated, power quality issues are a growing concern for utilities and electrical consumers. Look to Eaton to provide a variety of solutions for your exact situation—ensuring efficient, profitable and reliable electrical energy.



Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

© 2013 Eaton
All Rights Reserved
Printed in USA
Publication No. BR04007002E / Z13790
June 2013

Eaton is a registered trademark.
All other trademarks are property
of their respective owners.