



Line Side Harmonic Solutions

There are several line side harmonic mitigation solutions. There is no one size fits all as factors like the size and types of loads, IEEE-519 compliance targets, timelines, and project/ maintenance budgets help determine which solution or combination of solutions are appropriate. Some common types of mitigation solutions are:

- **Line Reactors** are simple inductors made up of coil wire wrapped around a magnetic core. Passing current creates a magnetic field, increasing the impedance (degree of resistance) of the line and reducing the harmonic content returning to the system. They also offer some protection to the VFD from surges and other transients.
- **Passive Harmonic Filters** are a combination of reactors and capacitors that are tuned to eliminate some frequencies while passing others through. They lower harmonic effects inside a facility and often meet IEEE-519 requirements. They have VFD protection characteristics, guaranteed stability, and little to no power consumption.
- **Active Harmonic Filters** monitor harmonic distortion levels and inject cancellation harmonic current into the line. They are more complex, using active components like transistors or amplifiers in addition to passive resistors and capacitors. They are used to handle multiple loads at one time. They can be located near the facility's power entrance to address a full system, or a section of the system. They will typically ensure IEEE-519 compliance, but do not always ensure that clean power is distributed throughout the facility and can be sensitive to the environment.
- **Multi-pulse & Active Front End (AFE) Drives** are types of VFDs that reduce the harmonics generated by using alternative technologies on the incoming side. Multi-pulse drives use phase shifting transformers and multiple diode bridges, while AFEs use an IGBT/diode-based converter. Since an AFE uses a power section on the incoming and outgoing portion of the drive, it can regenerate, or feed electricity back to the grid. Both types of drives can meet IEEE-519 standards, but are typically larger in size, require more maintenance, and are more complex than a standard 6-pulse VFD.

Load Side Harmonic Solutions

Load side protection means protecting the drive, motor, and cabling. VFD manufacturers often suggest minimizing the distance to the motor and using inverter duty motors and VFD cables. These solutions are not always practical. In many cases, the application will not allow for close motor installation. Inverter duty motors and VFD cables can also be more expensive than using standard solutions with protection. Some common types of motor protection are:

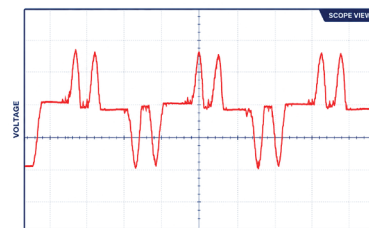
- **Shaft Grounding Rings and Brushes** are mechanical devices that mount to the motor shaft. They reduce common mode effects at the bearings by providing an alternate path to ground, but may increase total ground current. Larger sized units can be costly and higher ratings require expensive insulated bearings.
- **Common Mode Inductor or Chokes** are mounted around the motor cables and absorb common mode. Although they help with common mode, they do not have system damping resistance and may amplify current ring.
- **Load Reactors** are simple inductors like those used on the line side. They reduce dV/dt and audible noise and provide protection from voltage spikes. They also offer the VFD some short circuit protection.
- **dV/dt Filters** combine the current limiting ability of a reactor with a resistive capacitance circuit. They slow the rate of voltage increase and minimize the peak voltage that occur with long lead lengths so that they do not reach levels that can damage VFDs, cables, and motors.
- **Sinewave Filters & Isolation Transformers with Sinewave Filters** offer the most complete protection. A sinewave filter cleans the PWM to provide a near clean sinewave output. It eliminates differential mode problems and significantly reduces audible noise. An isolation transformer is often combined with the filter. In this case, the system is at its ultimate protection because the transformer removes most of the common mode voltage. This solution can be used on any application but is not always cost effective if a change in voltage is not needed.

MTE is the trusted leader in power quality.

Explore our most advanced solutions below, or browse the full lineup at mtecorp.com.

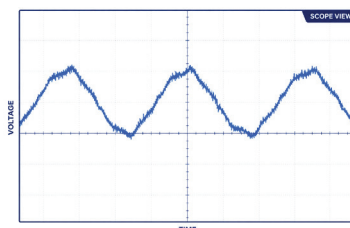


MTE's Line Side Solutions



No Protection

Up to 85%+ current harmonics. Risk of failure & utility fines.



MTE Filters

Reduces harmonic distortion up to 5%. Meets IEEE-519 standard.

Active Harmonic Mitigation

SyntriX AHF®

- Responds to changing loads in real time
- Corrects harmonic distortion from multiple loads
- Ideal for dynamic electrical systems
- Provides intelligent monitoring and control

SyntriX AHF provides active harmonic correction for multiple or rapidly changing loads.

Passive Harmonic Mitigation

Matrix® Family

- Reduces harmonic distortion
- Adapts across varying load levels
- Helps meet IEEE 519 requirements
- Improves system reliability and efficiency

Matrix® AP

Adaptive passive harmonic mitigation for standard applications.

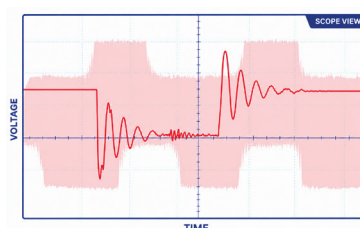
Matrix® AP+

The same proven Matrix AP performance, designed for high-THVD applications—primarily in oil and gas.



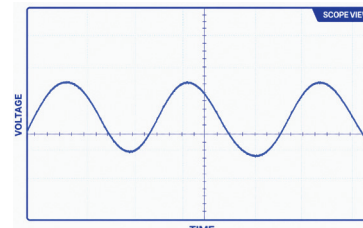
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MTE's Load Side Solutions



No Protection

Background: PWM pulses coming from VFD. Foreground: closeup of pulse showing ringing which can aggravate reflective wave.



MTE Filters

For long cable runs. Triple defense - Peak voltage, reflective wave, differential and common modes.

Complete common mode and differential mode motor protection

Nexus® Family

- Protects cables, motor windings and bearings
- Reduces motor noise and heating
- Helps extend motor life
- Provides comprehensive VFD-to-motor protection

microNexus™

Compact design for smaller drives with the ability to mount the VFD directly to the filter.

SineWave Nexus®

Full-size solution for standard and higher-power motor applications.

Advanced differential mode motor protection

Guardian® Family

- Cleans the VFD output waveform
- Reduces voltage peaks and motor heating
- Protects motor insulation
- Supports reliable operation over long motor leads

SineWave Guardian®

Designed for conventional motor applications.

High Frequency SineWave Guardian®

Optimized for high-frequency motors, particularly in demanding oil and gas applications.

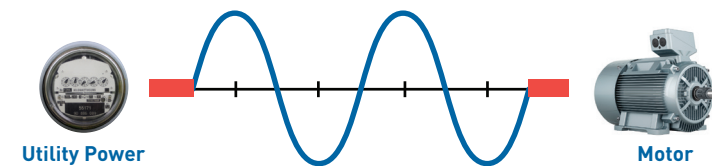


Variable Frequency Drive Effects on Power Quality

A simplified approach to what you need to know.

“Across the Line” Motor Application... Why VFDs Are Needed

When a motor runs directly from the power source, it is said to be running “across the line.” In this approach, there are uniform, sinusoidal current and voltage waveforms and relatively few power quality concerns.



Unfortunately, this method is inefficient because the motor is continuously running at its top speed, regardless of the load requirement. The application uses the energy it needs, and the rest of the energy is wasted.

VFDs Add Efficiency...

But Create Power Quality Issues

Adding a VFD to electrically control motor speed raises efficiency by limiting energy consumption and reducing equipment wear. However, VFDs inadvertently create power quality issues in the form of harmonics, which are changes or distortions in the waveforms. There are different types of harmonic distortions on the line and load side of a VFD.



On the line side, harmonics are created because the incoming side of a standard six-pulse VFD does not draw current linearly. Instead, it pulls in six distinct pulses that each use some of the current and send the unused portion back to the source as current harmonics. Since current and voltage are proportional, current harmonics ultimately affect voltage, which impacts connected equipment. This is not only a problem for equipment in the same facility as the offender, but for any consumer who shares a connection to the facility.

On the load side, the VFD does not feed the motor a true sinusoidal voltage waveform, but rather a series of electrical pulses in a pattern that replicates an AC sinewave. This is called pulse width modulation (PWM) and although it is effective at precisely controlling motor speed, it creates harmonics that can damage motors, cables, and bearings. The problems are magnified if the physical distance between the VFD and motor is long.



IEEE-519 STANDARD

The Institute of Electrical and Electronics Engineers (IEEE) provides some guidance about harmonic distortion. The IEEE-519 standard is a recommended practice for acceptable levels of harmonic distortion at a facility's "point of common coupling," or the electrical connecting point between the facility and the public power system. From a user viewpoint, it is a guideline for setting limits on how much harmonic distortion a facility's total system can pass back to the grid. The goal is to limit the harmonics from individual customers so they do not cause unacceptable distortion for the neighboring population. In exchange, the utility promises to act to maintain prescribed levels of voltage distortion going to a facility.

LINE SIDE HARMONICS PROBLEMS



The two main line side harmonic concerns are the problems caused in the facility where they are being generated and the degree of harmonic infection passed to neighboring facilities. The degree of impact for either area depends on the number, size, and frequency of use of all linear and non-linear loads (including VFDs).

Within the facility

- Within a facility, the ultimate expense of line side harmonics are the costs of frequent downtime or errors, premature equipment replacement, and utility expenses. Some of the specific problems a facility may experience include:
- Inadvertent "nuisance" tripping of breakers, fuses, and relays are caused by harmonic current peaks that are higher than standard waveforms.
 - Logic faults in digital devices, malfunctions of automatic control systems, and inaccuracy of instrument measurement are possible because harmonics can alter the parameters these devices are designed to run on.
 - Current harmonics create inefficiencies that cause overheating in the supply transformer and cables feeding the VFD.
 - High harmonics require oversizing, where equipment is sized larger to accommodate harmonics. This adds additional cost and may make it difficult, or impossible, to expand facilities.
 - Higher utility bills caused by increased total power consumption. Additional current harmonics represent reactive power (power not actually used to complete work). Since utilities typically bill for total power (active + reactive power), they are both still included in a facility's utility bill.

Neighboring facilities

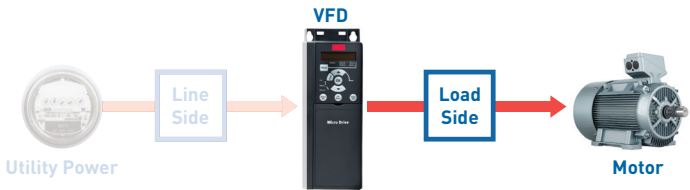
Since line side harmonics are being pushed from the VFD back to the source power, most of the problems seen in the offender's connected equipment can eventually be seen by neighboring facilities connected to the same utility distribution system. To avoid this overabundance of dirty power, many utilities require compliance to the IEEE-519 standard. Utilities also investigate individual facility harmonics when connected customers complain or if the utility experiences voltage distortion over its system. Offending facilities can be fined and have their power limited or cut off if they are not able to improve their harmonic output.

INDUSTRY	APPLICATION	COMMON ISSUE	MTE SOLUTION
 HVAC	• Chillers • Cooling towers • Rooftop units • Pumps & fans	Harmonic distortion impacts system efficiency and transformer loading. VFD-driven motors can suffer insulation stress and bearing damage which can lead to unexpected HVAC downtime.	• SyntriX AHF® • Matrix® AP
 FOOD & BEVERAGE	• Conveyor systems • Mixers & blenders • Packaging lines • Refrigeration systems	Unplanned downtime disrupts production. Electrical noise, harmonics, and motor stress reduce reliability in continuous operations.	• microNexus™ • Sinewave Nexus® • SyntriX AHF®
 DATA CENTERS	• CRAC / CRAH units • Chillers • Cooling pumps • CDU systems	Mission-critical cooling cannot fail. Harmonics reduce efficiency while VFD-induced issues threaten uptime and generator performance.	• SyntriX AHF® • Matrix® AP
 WAREHOUSE/LOGISTICS	• Conveyors • Sortation systems • Automated storage • Material handling	Multiple VFDs can create harmonics that drive premature motor wear which may lead to costly delays and downtime.	• microNexus™ • Sinewave Nexus® • SyntriX AHF®
 WATER/WASTEWATER	• Lift station pumps • Aeration systems • Clarifiers & mixers • Treatment pumps	Long lead lengths and remote locations increase motor failures. Harmonics and reflected wave issues reduce equipment life.	• SyntriX AHF® • Matrix® AP • microNexus™ • Sinewave Nexus®
 OIL AND GAS	• Pump jacks • Compressors • Pipeline pumps • Processing equipment	Harsh environments and remote sites make downtime expensive. Long motor leads and harmonics impact reliability and generator systems.	• SineWave Guardian® HF • Matrix® AP+ • Matrix® AP

NEMA MG-1, Parts 30 & 31

Parts 30 & 31 to "NEMA MG-1 defines your motor limits, yet most facilities don't know they're already pushing past them. Standard motors are rated at 1,000V peak. Inverter duty motors push to 1,600V. Sounds like plenty of headroom — until you add a VFD. The load-side distortions and voltage spikes a drive introduces can exceed those limits daily, wearing down insulation, pitting bearings, and shortening motor life without a single warning sign. By the time you notice the problem, the damage is already done."

LOAD SIDE HARMONICS PROBLEMS



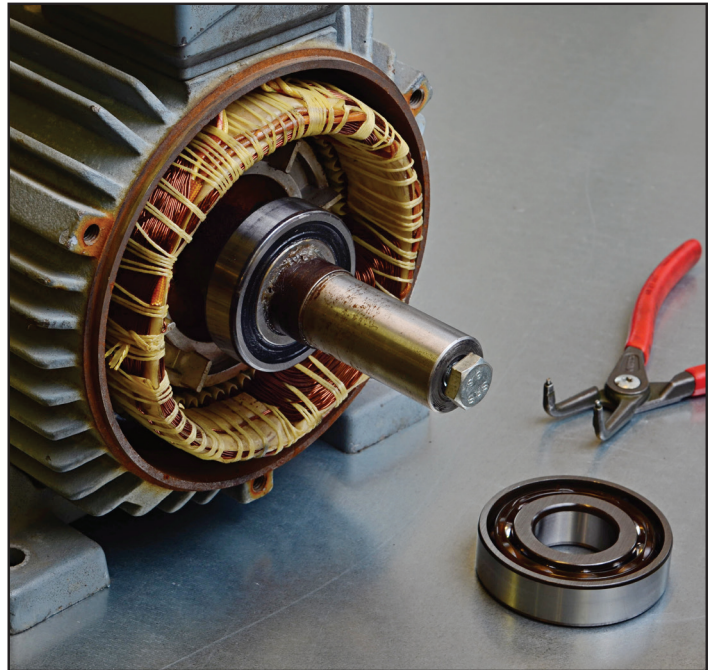
Load side harmonic issues are related to differential mode or common mode. In addition to individual problems related to each mode, excess heat generation and audible noise are shared concerns.

DIFFERENTIAL MODE

The voltage between phase conductors (line-to-line) — this is the actual power signal driving the motor. VFD switching can create voltage spikes and reflected waves at the motor terminals, stressing the winding insulation and creating heat. The issue gets worse as the length of cable between VFD and motor increases.

IN SHORT:

Differential mode is voltage **between** phases; common mode is voltage to **ground**.



COMMON MODE EXPLAINED

The voltage from all three phases to ground (line-to-ground). Normal utility power is balanced and produces no common mode voltage. However, VFD output pulses don't cancel out, resulting in leftover high-frequency voltage relative to ground. This couples through parasitic capacitance in the motor and cables, inducing shaft voltage that discharges through the bearings — causing pitting, arcing (EDM damage), and premature bearing failure. Common mode may also cause ground faults and EMC issues.

