Cut Harmful Electrical Noise with Correct VFD Cabling Practices

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Introduction

Many existing variable frequency drive (VFD) installations use interlocked armor TECK or continuously welded and corrugated aluminum armor (CCA) cable to connect from the VFD to the motor. These cable types will release excessive electrical noise in many installations—and this electrical noise can wreak havoc with the sensitive electronic components, network cabling and other sensitive wiring found in most modern industrial facilities.

The solution is to use specially-designed VFD cable with a foil braid or copper tape shield and suitable ground wires. For larger cables it becomes important to use a symmetric ground design to balance the induced ground currents. Compared to TECK or CCA, this type of VFD cable provides superior performance in terms of common mode current (CMC) containmentand in other areas.

With VFD cable, CMC is effectively contained within the cable, with CMC returned back to the ground point of the VFD. With both TECK and CCA cable, CMC may be returned back to the VFD enclosure metal. Returning the current to the enclosure causes electrical noise to radiate from the enclosure into surrounding areas.

This radiated electrical noise, commonly referred to as electromagnetic interference/radio frequency interference (EMI/RFI), can often cause certain electronic components, cabling and wiring to malfunction. Other advantages of VFD cable as compared to both TECK and CCA cable will be detailed in this white paper.

The superior performance of VFD cable can result in reduced nuisance trips of alarms or safety circuits and enhanced signal integrity for critical process measurements. These and other advantages of VFD cable can be garnered for a relatively small price adder, particularly as compared to the cost of the entire VFD and motor installation.

In addition to demonstrating the advantages of using specially-designed VFD cable, this white paper will also show how to best install this cable between the VFD and the motor. But first, let's take a quick look at why VFDs are used and at the problems that can arise from VFD-motor connections.

VFDs provide many advantages over single-speed motor control, but care must be taken with connections between the VFD and the motor.

Why Use VFDs?

The full load efficiency of standard AC electric motors ranges from around 80% for the smallest motors to over 95% for motors greater than 100 hp, but the efficiency of all electric motors drops significantly as the load is reduced below 40%. As a result, good practice dictates that motors should be sized so that full load operation corresponds to at least 75% of the rated power of the motor.

In many installations, a VFD is the best way to assure that a motor is sized correctly and runs efficiently (Image 1). A typical VFD-motor installation will exhibit system efficiencies of up to 90% or more at full load. At reduced loads, the efficiency drops, but not as significantly as with single-speed motor installations. For example, VFDs coupled with motors equal to or greater than 10 hp may have 90% efficiency for all loads greater than 25% of full load.

This increased efficiency is the main economic reason for using VFDs, but VFDs do more than reduce energy cost as they also:

- Reduce power consumption by operating the motor at the speed required for the application, reducing energy dissipated by throttling or dampers.

- Reduce power draw during motor starting by gradually ramping the motor up to speed, often lowering electric utility demand charges.

- Accurately control the load to a specific speed.

- Cost less to maintain than mechanical speed controls such as valves and dampers.

- Reduce wear and tear on motors, sheaves, belts, couplings and other system components during startup and operation.

For the reasons given above, VFDs have a long history of proven use in industrial applications where it's necessary to control a motor at varying speeds. But, there are a number of potential issues that can arise if care isn't taken when selecting and installing cabling between a VFD and its associated motor.

Uncontained CMC Noise Can Wreak Havoc

There are a number of issues that need to be considered and addressed when selecting and installing wiring between a VFD and a motor including CMC, capacitive coupling (or cable charging) and reflected wave voltage.

By far the most important when comparing VFD to TECK or CCA cable is CMC. As previously mentioned, CMC is effectively contained within VFD cable in a correctly installed system, with CMC returned back to the ground point of the VFD.

With both TECK and CCA cable, CMC is returned back to the VFD enclosure surface, from which it finds a path to ground. This is electrically the same as using conduit and releases the most harmful noise currents at the most sensitive places.

Releasing CMC into the environment can cause the sensitive electronic components, cabling and wiring found in most modern industrial facilities to malfunction. Affected electronic components include but aren't limited to controllers, graphic displays, transmitters, network switches and any wireless device.

Most of the electronic components used in modern industrial plants contain one or more microprocessor chips and other special purpose integrated circuit chips. These chips will often malfunction when subjected to excessive EMI/RFI.

For example, a controller or a graphic display may lock-up, much like an office PC, and require a forced reboot. This is just an annoying condition with an office PC, but can result in much more serious consequences in a plant environment.

A transmitter may send out a false reading, causing a spurious alarm or trip. This can often cause all or part of a plant to go off-line. Network switches can send out erroneous data, leading to incorrect information, or at the very least transmission delays as error-correcting mechanisms spot the problem and force retransmission.

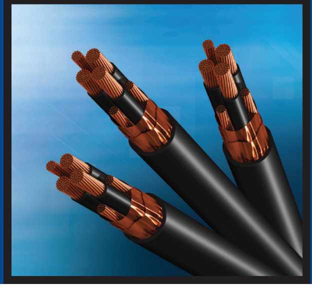
More and more plants are employing wireless devices of all types including handheld operator interfaces and wireless sensor and transmitter systems. These wireless devices can be particularly sensitive to EMI/RFI radiated into plant areas, causing false signals and poor overall wireless network performance.

The signals contained within cabling and wiring can be very sensitive to EMI/RFI, particularly when these signals are either digital or voltage-based analog. More and more industrial plants are installing digital networks within their facilities such as Ethernet and various specialized process and discrete digital automation networks. As with any digital network, excess EMI/RFI can degrade performance.

Most plants utilize voltage-based analog signals for sensing temperature, weight and other parameters. These signals can be acutely sensitive to EMI/RFI, causing false readings.

For example, a thermocouple typically sends a millivolt-level signal to a controller's analog input through thermocouple cable. If EMI/RFI is excessive, the signal level can spike, causing the controller to falsely read a high temperature. This can often cause a trip, interrupting plant operations and possibly causing a safety-related incident.

In systems greater than 50 hp, another issue with CMC and other electrical noise is excess current introduced into the motor bearings. Motor bearing life can be shortened by this electrical discharge through the bearings, causing etching in the races and premature motor failure.



Although noise generated by improperly contained CMC is the most compelling reason to use VFD cable instead of TECK or CCA cable, there are other factors that favor its use.

VFD Cable Specifics

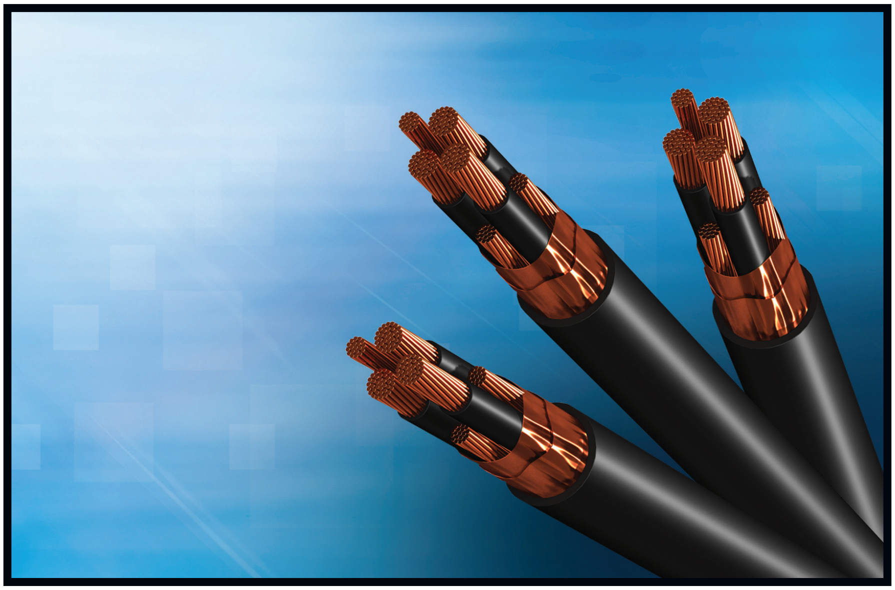
VFD cable features grounding systems which are specifically designed for the application. These systems utilize much more copper in the grounds to reduce induced and coupled ground currents. For higher power applications VFD cables utilize symmetric grounds to reduce induced currents. TECK has neither the grounds size, nor symmetry required to reduce ground currents and potential difference. The lack of symmetric grounds in TECK cable results in the introduction of excessive current noise into the grounding system, particularly with high horsepower VFD-motor installations.

So TECK cable not only generates more current noise due to the lack of symmetric grounds, but also radiates more of this noise into the environment due to intermediate termination of shields at the VFD enclosure instead of the VFD itself.

TECK cable is constructed with shields in a spiral path. This spiraling creates an inductor, which cannot carry the high frequency components of common mode current, forcing those components to travel through other paths outside of the cable, creating excess EMI/RFI.

High performance VFD cables use either a braided shield—or a double copper tape with contra-helically application to maximize surface area for high frequency conduction and to minimize the inductive effects of a single tape.

VFD cable is suitable for installation in either conduit or cable tray, while TECK and CCA cable aren't designed to be installed in conduit. For plants that prefer to run cable in conduit, this can be a compelling reason to use VFD cable. VFD cable is also much more flexible than TECK or CCA cable, making installation within cable tray easier.



This cable is specially designed to connect a VFD to a motor and provides superior performance over standard motor wiring and cable.

Reflected wave voltage may produce potentially destructive voltage stress on the motor insulation. Cabling that is specially designed for VFD-to-motor connections will not eliminate reflected wave voltages, but their lower capacitance conductors will effectively increase the allowable cable distance before experiencing significant buildup of reflected waves. In some cases, the difference in allowable cable length can be as much as 3 times farther with VFD cables.

Any cable with more than three conductors, not including ground, increases cable charging losses due to conductor capacitive interaction. TECK cable is often installed with more than 3 conductors. Also, TECK cable can potentially interact with other cables due to the gaps in the interlocked armor

VFD Cabling Specification and Installation

To prevent excess current that may damage drives during events such as line disturbances or certain types of ground faults, drives should have a minimum amount of upstream impedance. In many installations, this impedance comes from the supply transformer and the supply cables. In certain cases, an additional transformer or reactor is recommended to minimize impedance.

When the cable impedance closely matches the motor impedance, the voltage pulse from the VFD to the motor is evenly distributed. However, when the motor impedance is much larger than the cable impedance, the pulse reflects at the motor terminals, causing standing waves. So, a best practice is to select cabling from the VFD to the motor such that the cable and motor impedances are as closely matched as possible.

Drive cable shields should always be terminated at the motor and at the drive, any intermediate termination of the ground or shield is not recommended. The shield acts as a conductor for CMC, so proper termination is essential.

Failure to terminate the shields and grounds properly can result in harmful electrical noise flowing in the ground grid, or radiated to the surrounding environment. Intermediate grounding of the shield can cause the unintended release of shield currents and resulting electrical noise.

VFD cable is designed to be terminated at the motor and at the drive, minimizing the release of electrical noise into the surrounding environment. TECK and CCA cable is designed to be terminated at the drive enclosure, which causes electrical noise to radiate from the enclosure into surrounding areas

Ungrounded VFD metal parts can accumulate electrical charge thru leakage current, sometimes resulting in voltages greater than the recognized safe touch potential of 50 V. Thus, all drive metallic parts, both internal and chassis, should be bonded together, with a ground wire connected to the drive potential earth (PE) terminal.

The VFD PE terminal should be wired to a cabinet PE bus bar, thus providing electrical ground continuity. An appropriate sized single ground conductor leaving the cabinet must then be bonded to the true earth zero voltage ground. This ensures safe touch voltage potentials exist under ground-fault conditions.

Grounding provides a path for undesirable currents to be safely managed, but the voltages as a result of harmonics can still be quite significant. These problems can be compounded if care is not taken in the selection of the wiring and cabling used to connect a VFD to its associated motor.

Care should be taken when selecting a cable gland to ingress any enclosure. The role of the shielding and grounds in creating an effective CMC containment system can be compromised or rendered ineffective by improper gland selection—so, it's important to select a gland with a suitable rating for ingress protection and with the proper environmental classification.

Like any other conductor, a conductive gland should carry an applicable agency listing such as UL, CSA, or IEC. For non-conductive cable glands, the correct degree of ingress protection must be considered for each application.

When drives are mounted in enclosures which contain sensitive items such as analog signals, PLCs and I/O modules—non-conductive glands are recommended. Shields and jackets should be left intact until the cable enters the drive proper to ensure maximum protection from current and noise release. Use of a conductive gland provides a release point for shield currents and related noise, with current levels often high enough to be measured in amps.

In addition to releasing ground and shield currents prematurely, the use of a conductive gland also implies that within the enclosure the cable would be unshielded, creating a great potential for radiated noise in a very sensitive environment. Some manufacturers offer shielding kits, for use inside the enclosure, but again these kits are difficult to fit effectively and will introduce additional contacts points for noise release.

Some credible gland manufacturers offer isolation bushings, with grounding lugs for shield contact. These can be effective in preventing the release of shield noise into the enclosure metal and can be effective if the cable contains insulated ground conductors.

Summary

Selecting and installing the right cable for VFD-motor connections mitigates or eliminates many of the issues that can arise from the inherent characteristics of VFD installations. A relatively small investment in properly designing, selecting and installing the right VFD-motor cabling increases reliability, improves safety and reduces maintenance.

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