VFD: INSTALLING CABLE THAT POWERS AND PROTECTS

TPC WIRE & CABLE CORP.

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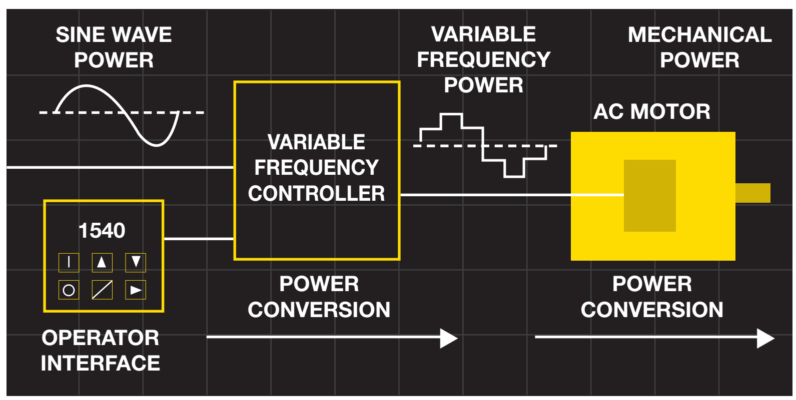
INTRODUCTION

The global VFD market is positioned for growth with some reports predicting a market value greater than $20 billion within the next 5 years. What's driving this growth? Advantages to using VFD such as improved efficiency, energy savings, process control, and reduced maintenance. Several VFD manufacturers offer end users a full family of controllers which, along with the motor, combine as the 2 primary components to VFD. However, there is one additional component that is often overlooked and yet it's key to achieving the above-outlined benefits: the cable. While certainly required to deliver power from the VFD to the motor, the cable's role in protecting VFD equipment from damage is of much greater significance, and yet it is less understood. To offer clarity, this paper provides you with a foundation of knowledge on VFD, addresses the challenges typically associated with VFD, and introduces the role cable plays in overcoming those challenges so that the desired benefits of VFD can be realized. The paper also contains points to consider when choosing a cable for your VFD system.

VFD DEFINED

Before going into cabling details, let's start with an understanding of VFD. VFDs, or Variable Frequency Drives, are electronic controls used to adjust the speed of AC motors. To facilitate controlling motor speed, the drive converts incoming AC power into a DC component, and then inverts the DC component to an AC output. The inversion from DC to AC utilizes IGBTs (Insulated Gate Bi-polar Transistors), which also regulate the voltage and frequency of power delivered to the motor.



Typically, the AC output of the VFD from the IGBTs is a PWM (Pulse-Width-Modulation) signal. The PWM output generates a series of pulses of varying width (or frequency). By varying the width of the pulses, the average power generated resembles a sine-wave output. It is important to note, discussed later in this paper, the switching speeds of the IGBTs typically operate in the 10-20 kilohertz range.

VFD ADVANTAGES

VFD systems are known to offer several benefits which tie to cost savings or process improvements. Some of these advantages include:

Energy savings by controlling motor speed
Most motor applications do not require a motor to run at a constant full speed. A VFD system can control motor speed to match the application requirement, thereby reducing energy usage.

Tighter process control
VFD controllers can run motors at precise speeds, and vary speeds per process requirements. Additionally, you can program a VFD control to gradually ramp motor speed up or down, stop at specific locations or positions, or apply a specific torque value to the motor application.

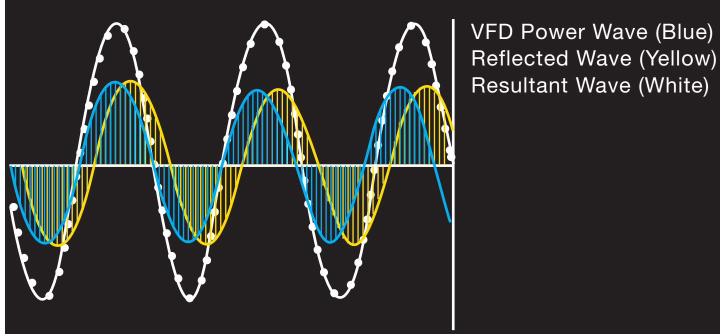
Longer equipment/motor life
As stated above, a VFD can gradually ramp speed to the motor, known as a “soft-start.” Soft-starts eliminate surge currents and excessive wear and tear on the motor. This extends motor life and reduces maintenance costs.

VFD CHALLENGES

The nature of a VFD controller, converting AC to DC, and inverting the DC back to an AC signal at high switching speeds creates a source of electrical noise. This “noise” can cause undesirable dynamics in the system leading to nuisance lock-outs, or premature failures.

Voltage spikes
Creating a PWM signal with high frequency switching speeds can lead to voltage spikes that easily exceed the source voltage. These high voltage spikes can superheat tiny airspaces inside the cable, which leads to raised internal temperatures and corona effects. Corona is potentially harmful to insulation systems and may cause degradation of the insulating material, leading to premature cable failure.

Reflected waves
Reflected waves are caused by an impedance mismatch between the motor and cable. An impedance mismatch results in reflected waves that can result in a doubling of peak voltages within the cable.



The Resultant Wave (White) is a combination of the VFD Power Wave (Blue) and the Reflected Wave (Yellow). The Resultant Wave amplitude is the sum of the Power Wave and the Reflected Wave amplitudes. When the VFD Power Wave and Reflected Wave peaks are in alignment, the Resultant Wave amplitude can be as much as 2X the “original” Power Wave.

Common mode currents
Common-mode currents are also a concern in a VFD system. These currents find the passage of least resistance to ground within a VFD system. If common-mode currents are not addressed, they will find the lowest impedance path to ground, which is typically through motor bearings. This leads to pitting of the bearings and shortened motor life.

MITIGATING VFD CHALLENGES WITH VFD CABLE

A key factor to successfully implementing a VFD system includes choosing and installing cable specifically intended for VFD motor drives. Doing so ensures the cable will handle the amp load and minimize voltage drop, reduce the effects of electrical noise generated from the high switching speeds of the VFD, provide a shield to minimize radiated noise, and provide a solid ground for the motor to reduce shock hazards.

Cable Design

The noise characteristics discussed above (voltage spikes, reflected waves, corona) can lead to premature cable failure if the cable in use is not designed for VFD applications.

VFD cables are most common in two configurations:

- 4 conductors – 3 power, 1 full size ground
- 6 conductors – 3 power, 3 symmetrical ground wires

Motor size will dictate the preferred cable configuration. For larger sized motors, cables using 3 symmetrical grounds are preferred to minimize induced voltages into the ground circuit. For smaller motors, 4-conductor cable designs are sufficient.

Insulation systems designed for VFD applications are subjected to harsh electrical noise including voltage spikes, doubling of voltage due to reflected waves, and the corona effect. A properly designed VFD cable will include an insulation system that will resist break-down and degradation due to electrical noise issues stated above. The choice of insulation materials and wall thickness' is a key to maximizing cable performance.

An overall shield is required to reduce the effects of radiated noise travelling within the cable, and to provide a low-impedance path to ground. Shielding radiated electrical noise minimizes potential interference to other nearby equipment. A low impedance path to ground is important with respect to addressing common mode currents. The objective of the shield is to provide a low impedance path to drive common mode currents through the cable shield instead of through motor bearings. Shielding in the form of a copper braid, aluminum foil wrap, or copper tape is common in a majority of VFD cable designs.

Cable Sizing

The size of the power conductors are chosen based on the amp load of the motor. End users must choose a conductor size that will safely handle the load current. Article 430 in the NEC handbook addresses motor full-load currents, and defines the requirements placed on cable ampacity based on full-load currents. For adjustable speed drive systems, required cable ampacity is typically 1.25 times the motor full-load current.

Shield Termination

A question often asked is "should I terminate the cable shield at both the motor and drive ends, or just at one end?" There are pros and cons to both methods, and many VFD manufacturers recommend terminating the shield at both ends. The best advice is to follow the instructions provided in the manufacturers VFD manual. Be sure your termination is both electrically and mechanically solid to avoid creating a high impedance connection.

ADDITIONAL CABLE CONSIDERATIONS

When selecting a cable, be sure to understand the environment, installation requirements, and application dynamics. Will the cable be exposed to extreme temperatures, caustic chemicals, abrasion/ impact, or dynamic flexing?

Environment

If the cable will have exposure to extreme temperatures, chemicals, or mechanical abuse (abrasion, impact, crushing), it is important to understand the construction and materials used, especially the jacket material. For exposure to chemicals or temperature extremes, make sure the jacketing will perform reliably to the temperature extremes, or the chemicals in the vicinity of the cable. For mechanical abuse, a jacket material that will protect the inner cable from abrasion, cut-through, impact or crushing is required.

Installation

Many VFD cable installations are simple straight runs from the VFD control to the motor. However, some installations require multiple tight bends. For larger-sized VFD cables, these tight bends can make it difficult to install cable without damaging the jacket or cable itself. For these difficult installations, look for cables that are flexible and easy to bend. Cables constructed with braid shields offer very good flexibility, especially when larger conductor sizes are in play.

It is also good practice to limit your cable runs in order to minimize charging currents. Excessive charging currents can lead to a reduction in available torque to the motor and cause nuisance trips in the drive.

Application Dynamics

If the application includes dynamic flexing (such as in a cable-track), look for a cable that is built for flexing applications. Course, stranded conductors and copper tape-shielded cable may not offer the performance required. You will experience longer cable life when installing a cable with high strand conductor counts and braid shields.

FINAL THOUGHTS

VFD applications are known for their harsh, electrically noisy environments and the potential for creating noise-related faults and failures. When installing a VFD system, it is in your best interest to take all precautions to minimize the effects of electrical noise. Follow the manufacturer's installation and wiring instructions, choose a cable designed specifically for VFD applications, and minimize cable run lengths. Following these basic guidelines will improve your VFD system's performance and reliability.

It's not unheard of for end-users to continue using a non-VFD designed cable when switching to a newly installed VFD system. Although it may appear that the VFD system is running free of noise-related issues, there are concrete signs that point to potential problems. Frequent nuisance faults, premature motor failure, and premature cable failure may all indicate a problem within the VFD system. If you are not using a cable designed for VFD applications and you are experiencing such indicators, it's a step in the right direction to explore making the switch to a VFD cable.

Founded in 1979, TPC is a leading supplier of high-performance wire, cable, connectors, assemblies, and accessories used in harsh industrial environments. TPC products are designed to withstand abuse from impact, abrasion, flexing, chemicals, and extreme temperatures. The company's dependable products outlast ordinary cable in the most difficult applications to reduce downtime and overall cost. TPC serves a variety of industries including the steel, automotive, utility, transportation, food & beverage, oil & gas, and wood, pulp & paper markets. ***For more information, visit www.tpcwire.com.***

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