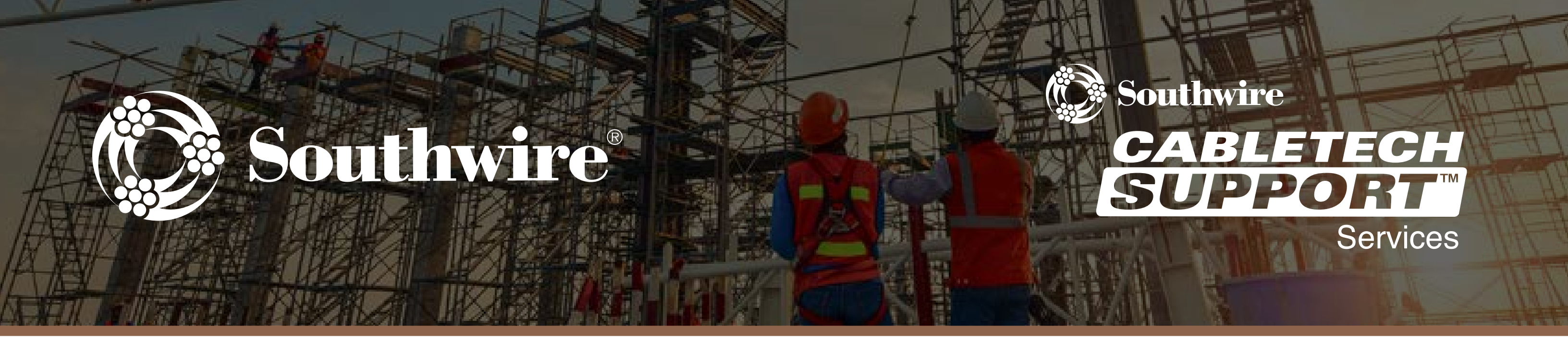


# ABOUT WIRE IN PIPE FOR DRIVE TO MOTOR CONNECTIONS

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## INTRODUCTION

It is a common question we receive: Why purchase a VFD cable when you can simply use wire in pipe (conduit)? After all, all VFD cable consists of three-phase conductors, a ground, and an overall shield. Why not just pull four single conductors into metal conduit and use that conduit as your shield? Is that not the same as using VFD cable? Well, no, it is not. Let's examine the distinctions from the inside out.

## INSULATION

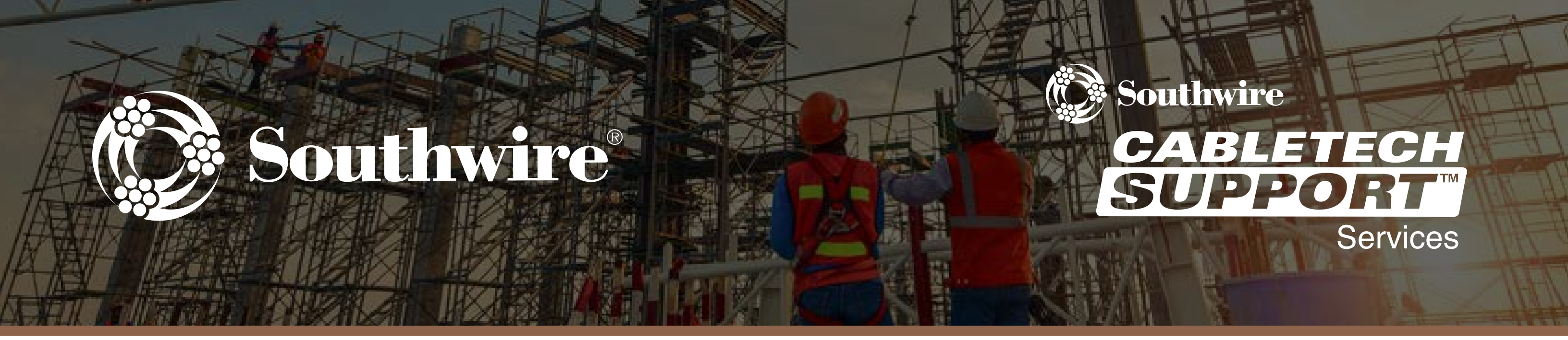
The output of a VFD is not a sine wave, it is a pulse-width modulated (PWM) waveform comprised of various frequency components. These PWM waveforms resemble a series of square waves with variable widths. These square waves possess extremely rapid rise and fall times (the time taken for the waveform to transition from 10% to 90% of its maximum value). In modern drives, this can occur in less than one hundred nanoseconds! These rapid changes create high-frequency components of over 30MHz. This is not something you would expect from a motor operating between say, 10 and 80Hz.

These high frequencies, along with the significant difference between the cable and motor surge impedances, generate reflected waves that traverse the cable. According to IEEE papers, these reflected waves can reach peak voltages of 1,560 volts in a 480-volt drive system. Cross-linked insulations (found in Type RHH/RHW and XHHW cables) can handle these voltage spikes, but thermoplastic insulations like Type THHN can break down when subjected to these voltages. In addition, THHN cables have the thinnest insulation wall thickness of any cable listed for typical motor connections. THHN also has the highest dielectric constant of any insulation used in these applications. As insulation wall thickness is inversely proportional to cable capacitance and the insulation's dielectric constant value is directly proportional to capacitance, THHN is the highest capacitance cable that exists for this application! This along with the high frequencies found in the waveforms can cause drive trips in lower horsepower systems.

Reputable VFD cable manufacturers avoid using THHN due to this concern. You might not intend to use THHN wire in your pipe - and that is good - but other issues still require your attention. Read on.

## GROUND CURRENTS

Conventional 60Hz power differs significantly from the power produced by a drive's inverter. As discussed earlier, drives emit high-frequency waveforms, and with increasing frequency comes greater power (also, with increasing amps comes greater power). This is why ground symmetry in larger drive to motor cables (say above #2 AWG) is crucial. Using four wires (three phases and one ground) in a pipe actually causes increased ground currents. That is because each phase induces a current and voltage on the ground, and because the ground is not equidistant from all phases, a net current and voltage are created. While this created signal is not high in power it is high frequency and can have large voltage and current peaks. Current peaks of over 100 amps are not unusual. Larger, high-quality VFD cables contain three phases and three grounds within the interstices of the phases. Why? Because this phase and ground arrangement results in favorable cancellation effects that minimize this current! It is widely understood that minimizing high frequency current flow on the ground improves overall system performance.




## CONDUIT IS NOT A SHIELD

In an ideal three-phase system, no current flows on the ground. This is not the case in a VFD system. Unlike traditional power, where the sum of the three-phase currents is zero, VFDs are known to push a net high-frequency current down the cable to the motor. This current cannot simply remain at the motor; it must return to the drive somehow per Kirchhoff's law. Real world testing and IEEE papers indicate that a common path for this current is through building steel. This is because at high frequencies, current flows on the surface of the conductor, not throughout its cross-sectional area (due to skin effect). An efficient low-impedance path for this current is often building steel due to its substantial surface area. However, having uncontrolled currents on uncontrolled paths throughout your facility is undesirable. Redirecting as much of this current as possible onto a controlled path—namely, the cable shield, which is also a large surface area path—is essential. But to achieve this, the cable shield must be properly terminated at both the drive and the motor. Without proper termination, there is no path for the current to return to the drive, and it will find other routes.

Conduit is made of metal and constitutes a large surface area element in your system. However, it is not designed or maintained as an electrical shield. Its purpose is solely mechanical protection, and it is maintained as such. Over time, joints can corrode, making your conduit less effective as a preferred path for this high-frequency current. Gradually, more of this current will flow through uncontrolled paths. When you eventually experience 100-Amp spikes on your ground right next to a PLC or alarm, serious issues can arise. Relying on a mechanical solution for an electrical problem is not advisable.

## CONDUIT IS TYPICALLY NOT JACKETED

Another consideration is that a VFD cable's shield is covered by an insulating jacket. This is important because we now understand that this high-frequency current is drawn to large steel surfaces. When you use VFD cable, you do not need to worry about the current jumping from the shield to building steel because the shield is isolated from the building's infrastructure. Once the current is on the shield, it has no path to jump off. The same cannot be said for conduit, which generally lacks a jacket and is often hung with components that serve as convenient paths for the common mode current to escape onto building infrastructure. When this occurs, control over the current's path is lost, and it can lead to a range of issues, such as triggering alarms, disrupting communications, causing PLC malfunctions, and more.

## CONCLUSION

Critical distinctions exist between using purpose-built VFD cables and traditional wire in pipe installations used in industrial systems. By considering factors such as insulation, ground currents, shield effectiveness, and jacketing, you hopefully now see the inherent advantages of VFD cables in managing challenges arising from high-frequency PWM waveforms. The adoption of VFD cables not only enhances operational stability but also safeguards sensitive equipment and systems from the adverse effects of uncontrolled currents.