Operating Medium-Voltage Motors With Variable-Frequency Drives > Compressor applications are expanding

BY JAMES NANNEY

Pictured are surge capacitors and surge arrestors mounted in a terminal box.

The number of compressor power trains using electric motors with medium-voltage, variable-frequency drives (VFDs) has increased in recent years and all indications suggest this trend will continue.

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There are many reasons for using VFD's for large-motor applications. The question is, when a VFD configuration is chosen, what needs to be done to insure a high-reliability motor operating on the VFD?

Motor protection is a primary concern in medium-voltage motor design and must be coordinated with protection built into the VFD. Specifications should be modified, as some very common methodologies used for motor protection may interfere with the VFD's protection, create spurious trips in or even damage the VFD.

This coordination concern for medium-voltage motors contrasts with low-voltage motors (600 V or less). A low-voltage motor/drive will operate reliably with few considerations. A medium-voltage motor (above 600 V) will have protection built into the motor as accessories. As the motor size increases, and for critical applications, more sensors and protective accessories would be specified for the motor. The first consideration is the VFD application.

Of the two usual VFD compressor applications, the most common is "continuous" VFD operation, varying

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the speed of the motor for process control. Less common, but a growing application, is to use the VFD as a "soft starter" when the utility cannot support the motor starting inrush current.

In a VFD starting application, the VFD starts the motor then synchronizes the motor to the utility line power. This choice is recommended when the compressor can run at full speed and is not used for process control. Also known as "VFD starting," this arrangement will significantly reduce the VFD size and cost.

When multiple motor compressors require starting, a single VFD may be used to sequentially start the motors with the appropriate switchgear arrangement. Additionally the VFD provides more starting torque than an "across the line" starter. This is a good approach for reciprocating compressor applications and at a significant lower cost than individual VFDs for each motor.

Each of these applications presents specific concerns for proper motor protection. Using a motor specification based on "across the line starting" with traditional motor protection, applied to a VFD application with its intrinsic protection, at first glance would seem to offer the best approach for a critical application. For example, differential protection current transformers (CTs) are common on larger motors to measure the leakage current from the winding for an indication of the health of the winding. All VFDs have similar protection. The VFD will also monitor for current leakage to detect a potential short circuit as a way to protect the VFD.

Sometimes it is not the differential protection circuit of the VFD but rather the more sensitive VFD ground fault detection circuit that can create spurious VFDs trips when motor CTs are in the circuit.

If the VFD is used for starting applications once the VFD is bypassed, so is all the motor protection provided by the VFD. Placing CTs ahead of the VFD is one solution to provide the differential protection. The VFD supplier can provide guidance on past installation challenges using motor CTs.

For motors rated 10,000 hp (7.4 MW) and larger, it is common to install surge capacitors and surge arrestors to protect the motor winding. The same protection is provided by the VFD.

Surge arrestors may be used if coordinated with the VFD vendor. However, caution should be exercised as capacitors in the motor terminal box could cause damage to the VFD. Surge capacitors should never be located between the motor and a VFD. For VFD starting applications, any surge capacitors should be placed ahead or in the bypass circuit of the VFD to provide protection is again a good option.

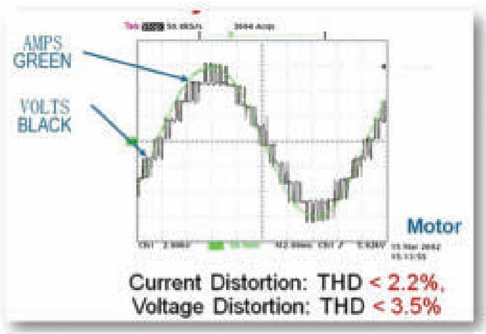
All medium-voltage motor manufacturers have a motor-overload protection system as part of their VFD. Motor protection relays (MPRs) used for across-the-line, medium-voltage motor applications are not designed to be connected to a VFD. Operating on the lower end of the speed range, the MPR operation may not be reliable and may cause spurious tripping.

A MPR is often located where motor bearing RTDs and motor winding RTDs temperatures are monitored. It is important to confirm the VFD has this capability for all the RTD's inputs specified for the motor or other means of monitoring is provided.

Accessories are added at the direction of the buyer, but the motor supplier bears some responsibility for insuring motor suitability for VFD application. This includes accommodating less efficient cooling of the motor while operating at slower speeds. Additionally, heating effects of the nonsinusoidal current from the VFD in the motor must be considered in the motor design.

The nonsinusoidal component of the output waveform is "harmonic current." Anything that is not a sine wave creates heat in the motor. The harmonic currents are motor converted into heat and the amount of harmonic currents varies by drive topology even within a manufacturer's product line.

All VFD suppliers provide data for harmonic current in the output waveform normally expressed in a percentage. This information must be



This readout shows the harmonic currents for a motor.

communicated to the motor supplier. The motor designer will determine if an increased in motor mass or additional cooling is required to offset the increase heating created by the harmonic current.

Speed turndown, type of compressor (centrifugal or reciprocating), and possibly the hazardous area maximum temperature all must be factored in the design to insure motor operating temperatures specifications are not exceeded while operating on a continuous VFD application.

VFD manufacturers must also supply the motor designer voltage spike information on the output waveform that is created by the specific VFD being used, in order to verify the motor insulation is suitable.

All VFDs induce currents in the bearings. Therefore protection of the bearings must be provided. This protection is usually accomplished by shaft grounding, insulated bearings or a combination of both.

It is common to insulate the bearing on the opposite drive end and provide shaft grounding at the shaft end. If shaft grounding is not an option, both bearings and the coupling between the motor and driven machine should be insulated to protect the motor bearings and driven machine.

In the case of VFD starting and bypass to line applications (VFD starting), the voltage surge and overload protection provided by the VFD during starting is lost once the VFD is bypassed and the motor is operating on utility power. In this scenario a motor protection relay (MPR) is required.

It is important to note the relay must

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A shaft ground brush assembly mounted on drive end of the motor.

be disabled or "locked out" at lower operating frequencies. The MPR protection should be established before the motor is synchronized to the line and the motor operates on line power. The MPR can cause spurious trips if this is not properly coordinated.

A synchronizing system is required for all VFD starting applications. It is separate from the VFD and the motor and should provide a "bumpless" transfer from VFD power to utility power. The synchronizing system matches the VFD output and frequency to that of the utility.

The motor will actually be receiving power from the line and VFD in a "closed transition" for a short period until the drive is turned off. This insures the motor transitions to the line bumplessly, thereby preventing damage to the compressor. At this same time of transfer, the MPR should be operating and all other required accessories — such as differential CTs, surge arrestors and surge capacitors — would be providing protection to the motor.

For a VFD starting application, bearing protection with insulated bearings or shaft grounding should be considered. The relative short time of the start does reduce the potential, but the risk of bearing damage remains. To prevent damage the same methods for protection for a continuous operating VFD would be applied to the motor.

Each VFD and motor manufacturer makes recommendations for motor protection. These recommendations should be coordinated. Coordination among suppliers is critical to the extent that using a single supplier for both the motor and VFD should be considered.

The retrofitting of an existing motor with a VFD is beneficial when efficiency of the compressor train and process control justifies the investment. The existing motor may need to be rewound to add extra electrical insulation to accommodate the VFD output.

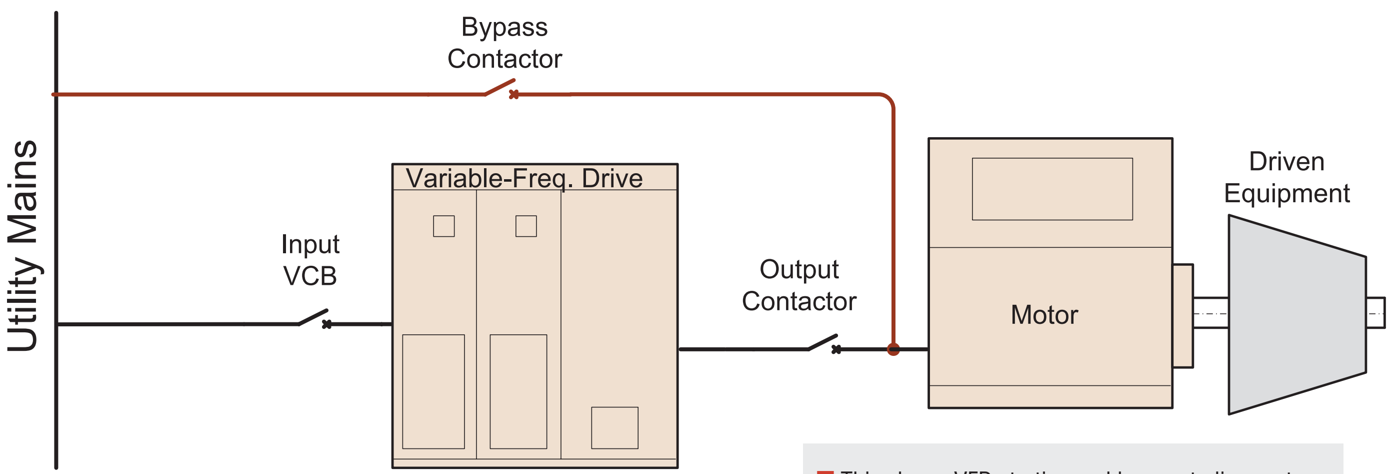
Consideration should be made for the increased heating by the VFD in the motor. The extra insulation and increased heating may also cause the motor to be slightly derated. When the motor is rewound, bearing protection can be added, and some accessories that might interfere with the VFD can be removed or disconnected.

In conclusion, it is paramount that equipment suppliers and end users communicate and cooperate in order to protect motors.

Equipment suppliers can substantially increase system reliability by informing end users about lessons learned in drive-motor/compressor applications. However, these communications are merely a start to the discussion about the proper specification of each component of the compressor train.

Key points are:

- VFDs provide good motor protection and will not interfere with vibration probes or resistance temperature detectors (RTDs).
- Always verify the VFD can support the RTD inputs or monitor with a data collection system.
- Do not connect surge capacitors to the output of the drive.
- Check with the VFD supplier on the suitability of differential CTs or surge arrestors in the motor.
- VFD suppliers provide the harmonic current content to the motor suppliers to ensure proper motor design.
- The normal protection must be isolated from the VFD during the starting phase of a VFD starting application.
- Using a bumpless synchronizing system for VFD starting applications is important to prevent motor and compressor damage.
- Because each VFD supplier has different protection schemes, a full review of all protection requirements is critical.
- Users should consider using a single supplier for a motor and drive combination. CT2



This shows VFD starting and bypass to line system.