

Top 10 Tips: Specifying VFDs

Variable frequency drives — or VFDs — can reduce energy consumption, improve realtime control, and lengthen motor life. Selecting the right one for your application requires asking the correct questions. Here are some expert tips to consider.

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Determine if a VFD is right for your application

The primary function of a variable frequency drive is to vary the speed of a three-phase AC induction motor. VFDs also provide nonemergency start and stop control, acceleration and deceleration, and overload protection. In addition, VFDs can reduce the amount of motor startup inrush current by accelerating the motor gradually. For these reasons, VFDs are suitable for conveyors, fans, and pumps that benefit from reduced and controlled motor operating speed.

A VFD converts incoming AC power to DC, which is inverted back into three-phase output power. Based on speed setpoints, the VFD directly varies the voltage and frequency of the inverted output power to control motor speed. There is one caveat: Converting AC power to a DC bus — and then back to a simulated AC sine wave — can use up to 4% of the power that would be directly supplied to a motor if a VFD were not used. For this reason, VFDs may not be cost-effective for motors run at full speed in normal operation. That said, if a motor must output variable speed part of the time, and full speed only sometimes, a bypass contactor used with a VFD can maximize efficiency.

Consider your reasons for choosing a VFD

Typical reasons for considering VFDs include energy savings, controlled starting current, adjustable operating speed and torque, controlled stopping, and reverse operation. VFDs cut energy consumption, especially with centrifugal fan and pump loads. Halving fan speed with a VFD lowers the required horsepower by a factor of eight, as fan power is proportional to the cube of fan speed. Depending on motor size, the energy savings could pay for the cost of the VFD in less than two years.

Starting an AC motor across the line requires starting current that can be more than eight times the full load amps (FLA) of the motor. Depending on motor size, this could place a significant drain on the power distribution system, and the resulting voltage dip could affect sensitive equipment. Using a VFD can eliminate the voltage sag associated with motor starting, and cut motor starting current to reduce utility demand charges.



Figure 1: In addition to varying speeds, conveyor applications typically require frequent starting and stopping. Here, VFDs substantially reduce starting current to extend motor life.

Controlling starting current can also extend motor life because across-the-line inrush current shortens life expectancy of AC motors. Shortened life cycles are particularly prominent in applications that require frequent starting and stopping. VFDs substantially reduce starting current, which extends motor life, and minimizes the necessity of motor rewinds.

The ability to vary operating speed allows optimization of controlled processes. Many VFDs allow remote speed adjustment using a potentiometer, keypad, programmable logic controller (PLC), or a process loop controller. VFDs can also limit applied torque to protect machinery and the final product from damage.

Controlled stopping minimizes product breakage or loss, as well as equipment wear and tear. Because the output phases can be switched electronically, VFDs also eliminate the need for a reversing starter.



Figure 2: Using VFDs to operate fans and pumps can significantly reduce energy consumption, because they can tailor fan speed to the application. Fan horsepower is proportional to the cube of fan speed, so depending on motor size, energy savings can compensate for the initial VFD purchase price in less than two years.

Select the proper size for the load

When specifying VFD size and power ratings, consider the operating profile of the load it will drive. Will the loading be constant or variable? Will there be frequent starts and stops, or will operation be continuous?

Consider both torque and peak current. Obtain the highest peak current under the worst operating conditions. Check the motor FLA, which is located on the motor's nameplate. Note that if a motor has been rewound, its FLA may be higher than what's indicated on the nameplate.

Don't size the VFD according to horsepower ratings. Instead, size the VFD to the motor at its maximum current requirements at peak torque demand. The VFD must satisfy the maximum demands placed on the motor.

Consider the possibility that VFD oversizing may be necessary. Some applications experience temporary overload conditions because of impact loading or starting requirements. Motor performance is based on the amount of current the VFD can produce. For example, a fully-loaded conveyor may require extra breakaway torque, and consequently increased power from the VFD.

Many VFDs are designed to operate at 150% overload for 60 seconds. An application that requires an overload greater than 150%, or for longer than 60 seconds, requires an oversized VFD.

Altitude also influences VFD sizing, because VFDs are air-cooled. Air thins at high altitudes, which decreases its cooling properties. Most VFDs are designed to operate at 100% capacity up to an altitude of 1,000 meters; beyond that, the drive must be derated or oversized.

Be aware of braking requirements

With moderate inertia loads, overvoltage during deceleration typically won't occur. For applications with high-inertia loads, the VFD automatically extends deceleration time. However, if a heavy load must be quickly decelerated, a dynamic braking resistor should be used.

When motors decelerate, they act as generators, and dynamic braking allows the VFD to produce additional braking or stopping torque. VFDs can typically produce between 15 and 20% braking torque without external components. When necessary, adding an external braking resistor increases the VFD's braking control torque — to quicken the deceleration of large inertia loads and frequent start-stop cycles.

Determine I/O requirements

Most VFDs can integrate into control systems and processes. Motor speed can be manually set by adjusting a potentiometer or via the keypad incorporated in some VFDs. In addition, virtually every VFD has some I/O, and higher-end VFDs have multiple I/Os and full-feature communications ports; these can be connected to controls to automate motor speed commands.

Most VFDs include several discrete inputs and outputs, and at least one analog input and one analog output. Discrete inputs interface the VFD with control devices such as pushbuttons, selector switches, and PLC discrete output modules. These signals are typically used for functions such as start/stop, forward/reverse, external fault, preset speed selection, fault reset, and PID enable/disable.

Discrete outputs can be transistor, relay, or frequency pulse types. Typically, transistor outputs drive interfaces to PLCs, motion controllers, pilot lights, and auxiliary relays.

Relay outputs usually drive AC devices and other equipment with its own ground point, as the relay contacts isolate the external equipment ground. The frequency output is typically used to send a speed reference signal to a PLC's analog input, or to another VFD running in follower mode.

Typically, general-purpose outputs of most VFDs are transistors. Sometimes one or more relay outputs are included for isolation of higher-current devices. Frequency pulse outputs are usually reserved for higher-end VFDs.

Analog inputs are used to interface the VFD with external 0 to 10 VDC or 4 to 20 mA signals. These signals can represent a speed setpoint and/or closed loop control feedback. An analog output can be used as a feedforward to provide setpoints for other VFDs so other equipment will follow the master VFD's speed; otherwise, it can transmit speed, torque, or current measurement signals back to a PLC or controller.

Select the proper control mode

VFD control mode choice greatly depends on the application. The three VFD control modes are volts-per-Hertz (V/Hz), sensorless vector (sometimes called open-loop vector), and closed-loop.

V/Hz-type VFDs use the ratio between voltage and frequency to develop the operating flux to supply operating torque to the motor. Sensorless-vector VFDs have accurate torque control over a wide speed range without having to use encoder feedback. Closed-loop VFDs use encoder feedback to obtain motor speed and slip information.

Control mode comparison			
	V/Hz	Sensorless vector	Closed loop
Operating complexity	Low	Moderate	High
Performance	Good	Good	High
Starting torque (typical)	150 to 175%	200%	200%
Speed regulation (typical)	±2%	±1%	±0.2%

V/Hz control is adequate for many applications such as fans and pumps. However, for applications that require greater degrees of speed regulation, sensorless vector or closed-loop control types may be necessary. Applications such as paper mills, web printing presses, or material converting require the added speed regulation that closed-loop control provides.

Understand your control profile requirements

Selecting the proper VFD control profiles is critical and depends greatly on the application. Control profiles to consider include acceleration, deceleration, ramp linearity, torque control, braking, and PID. Most of these parameters are available on nearly every VFD type on the market, but PID may not be offered on very basic models.



Figure 3: Web printing presses, paper mills, and material converting applications require the precise speed regulation of closed-loop control available in higher-end VFDs. Elsewhere, volts-per-Hertz (V/Hz) and sensorless (or open-loop vector) modes are used.

These parameters are programmable and can be selected using the operator keypad, or by digital communications. Understanding these parameters (and how they affect integration of the VFD into the process) is imperative; to this end, VFD user manuals typically provide the information required to select and program the right control profiles.

Know your communication options

Many VFDs have one or more built-in digital communication interfaces. Even the most economical models typically include a serial interface such as Modbus RS-232/RS-485. Ethernet and fieldbus communication are options offered with many VFDs.

A digital communication interface can be used to connect the VFD to other devices that can function as a master device such as a PLC or PC-based controller. The master device can control the VFD with this interface instead of using the discrete and analog I/O. The master can also use this interface to monitor the status of various VFD parameters such as speed, current, and fault status.

An RS-232 connection is somewhat limited as the maximum RS-232 network cable length is 50 feet. Also, the RS-232 interface is one-to-one, allowing connection of only one VFD to one controller. An RS-485 network cable can span up to 4,000 feet and allows connection of multiple devices. Extra adapters may be required to make this type of connection.

An Ethernet Interface provides a high-performance link between the control system and multiple VFDs. Some VFD Ethernet interfaces are even available with a web server that allows users to configure and control the VFD from any web browser. Ethernet protocols such as Modbus TCP/IP and EtherNet/IP take the guesswork out of VFD control over Ethernet and make setup easy for non-IT users.

Don't overlook installation and operating requirements

VFDs generate a significant amount of heat. This heat can cause the internal temperature of an enclosure to exceed the VFD's thermal rating. Enclosure ventilation or cooling may be necessary to keep enclosure temperature within specified limits. Ambient temperature measurements and calculations should also be made to determine the maximum expected temperature.

Operating precautions must also be considered. One should avoid running a standard induction motor at low speed for an extended period of time, as this can cause the motor temperature to exceed its rating due to limited airflow produced by the motor's fan.

When a standard motor operates at low speed, output load must be decreased. If 100% output torque is desired at low speed, it may be necessary to use an inverter-duty rated motor.

Don't use a contactor or disconnect switch for run/stop control of the VFD and motor; as this reduces VFD life. Cycling the input-power switching device while the VFD is operating should be done only in emergency situations.

Beware of harmonics

Any non-linear load, which includes anything with rectifiers, generates harmonics — including VFDs. If excessive, harmonics can overheat and damage equipment, transformers, and even power distribution wiring.

Two types of filters can mitigate the harmonics associated with VFDs. Passive harmonic filters include AC line reactors and chokes. Reactors and chokes reduce VFD-related harmonics and line notching, and are recommended for all installations. They also protect the VFD from transient overvoltages, typically caused by utility capacitor switching. Active harmonic filters sample the harmonic current waveform, invert it, and feed the inverted waveform back to the line to counteract harmonics. Some active filters also have dynamic braking circuits that allow motor deceleration to place regenerative current back on the AC supply line.

Output line, or load, reactors protect motor and cable insulation from VFD short circuits and insulated gate bipolar transistor (IGBT) reflective wave damage. They also allow the motor to run cooler by smoothing the current waveform. Output line reactors are recommended for operating non-inverter duty motors and applications in which VFD-to-motor wiring exceeds 75 feet.

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