DOE/GO-102001-1165
NREL/BK-710-29267
May 2001

5.7.2 Variable-Frequency Drives

Variable-frequency drives, a type of variable-speed drive, are controllers that vary the speed of induction motors. VFDs save substantial energy when applied to variable-torque loads, thus reducing electricity bills for most facilities. These energy savings are possible with variable-torque loads, such as fans and pumps, because torque varies as the square of speed, and horsepower varies as the cube of speed. For example, if fan speed is reduced by 20%, motor horsepower (and energy consumption) is reduced by 50%.

VFDs generate variable voltage and frequency output in the proper volts/hertz ratio for an induction motor from the fixed utility-supplied power. VFDs can be retrofitted into existing motor systems and can operate both standard and high-efficiency motors ranging in size from 1/3 hp to several thousand hp. Unlike mechanical or hydraulic motor controllers, they can be located remotely and do not require mechanical coupling between the motor and the load. This simplifies the installation and alignment of motor systems.

Opportunities

Variable-flow applications, where throttling or bypass devices are used to modulate flow, are good candidates for VFDs. These include centrifugal fans, pumps (centrifugal, impeller, or turbine), agitators, and axial compressors. The best applications for VFDs are large motors that can operate for many hours each year at reduced speeds. Some opportunities common in facilities include the following:

- **Variable-air-volume HVAC fans:** Airflow in older VAV systems is usually controlled by opening and closing dampers or inlet vanes. Because the systems often operate at low airflow, considerable energy savings are possible by converting to VFDs. VFDs vary motor speed in order to match fan output to varying HVAC loads, making dampers or inlet vanes superfluous.
- **Cooling tower fans:** Cooling towers may be good candidates for VFDs, because motors are large, fans often operate for long periods of time, and loads can vary both seasonally and diurnally.
- **Circulating water pumps for chillers and boilers:** Pumping systems can be made variable by sequencing fixed-speed pumps and a single variable-speed pump. This will save the cost of installing VFDs on each pump.
- **Special industrial applications**: The economics of using VFDs for applications such as grinding and materials handling, where precise speed control is required, depend on the size and run-time of the motors involved.

Technical Information

Three major VFD designs are commonly used: pulse-width modulation (PWM), current source inverter (CSI), and variable voltage inverter (VVI). A fourth type, the flux vector PWM drive, is gaining popularity but is considered too expensive and sophisticated for most applications. Knowing the characteristics of the load is critical in evaluating the advantages and disadvantages of each technology.

- **Pulse-width modulation** is the dominant VFD design in the 1/2 hp to 500 hp range because of its reliability, affordability, and availability. PWM outputs emulate sinusoidal power waves by varying the width of voltage pulses in each half cycle. Advantages of PWMs are low harmonic motor heating, excellent input displacement power factor, high efficiencies at 92–96%, and ability to control multiple motor systems with a single drive.
- **Current source inverter** designs are quite reliable because of their inherent current-limiting characteristics and simple circuitry. CSIs have regenerative power capabilities, meaning that CSI drives can reverse the power flow back from the motor through the drive. However, CSIs "reflect" large amounts of power harmonics back to the source, have poor input power factors, and produce jerky motor operations (cogging) at very low speeds. CSIs are typically used for large (over 300 hp) induction and synchronous motors.
- **Voltage source inverter** designs are similar to CSI designs, but VSIs generate variable-frequency outputs to motors by regulating *voltage* rather than current. Harmonics, power factor, and cogging at low frequencies can be problems.

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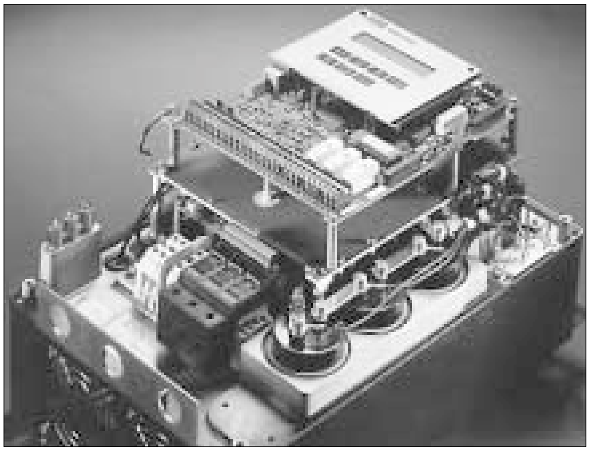

This variable-frequency drive significantly improves overall energy efficiency. Source: Alpha Electrical Service

VFDs should be properly installed to avoid damage to their electronics. This includes proper grounding, mounting, connection, voltage, and cooling. Improper installation and start-up accounts for 50% of VFD failures. **Precautions** for specifying, installing and operating VFDs are numerous.

- **Use the VFD start-up sheet** to guide the initialization check before energizing the VFD for the first time. If a VFD is started when the load is already spinning, the VFD will try to pull the motor down to a low, soft-start frequency. This can result in high current and a trip unless special VFDs are used.
- **Always install wall-mounted units** against a smooth, flat, vertical surface, or install a piece of plywood or sheet metal to create the required cooling channels. Installing VFDs intended for wall mounting as freestanding units will interfere with the "chimney effect" cooling of the heat sink.
- **Check and monitor motors operating at low speeds** because they can suffer from reduced cooling. For maximum motor protection on motors to be run at low speeds, install thermal sensors that interlock with the VFD control circuit. Standard motor protection responds only to over-current conditions.
- **Ensure that the power voltage** supplied to VFDs is stable within plus-or-minus 10% to prevent tripping faults.
- **Separate speed control wiring**, which is often 4 mA to 20 mA or 0 VDC to 5 VDC, from other wiring to avoid erratic behavior. Parallel runs of 115 V and 24 V control wiring may cause problems.
- **Prevent damage from corrosive environments**, humidity above 95%, ambient air temperatures exceeding 104°F (40°C), and conditions where condensation occurs, as much as possible.
- **If power switching is anticipated, include this capability in the specification.** Switching from grid power to emergency power while the VFD is running is not possible with most types of VFDs.
- **Interlock the run-permissive circuit to the disconnect** if electrical disconnects are located between the VFD and motor .
- **Use "inverter duty" motors** on new installations that will have VFDs.

> If a motor always operates at its rated load, a VFD will *increase* energy use, as a result of electrical losses in the VFD.

References

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