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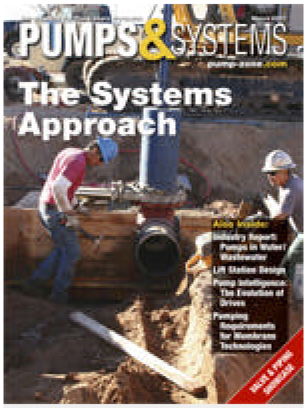

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What You Must Know About Variable-Speed Drives

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Over the past 50 years, advances in technology have provided the primary thrust behind the success and evolution of variable-speed drive systems. Here are some considerations for the proper selection and set up of different types of systems, and what lies ahead in the future.

Pump users have a repertoire of variable-speed systems to choose from that deliver high performance, efficiency, and reliability. However, industry prefers mechanical or electrical adjustable speed drives that ease users' concerns for drive application, maintenance, and the environment.

Compact in size and weight, the AC *variable-frequency drives* (VFDs) offer advances in power electronics coupled with induction motors. Utilizing the latest in power-switching transistors, microprocessors, hardware, and software functions, VFDs are the electrical adjustable speed drive most widely adopted by industry.

Permanent magnet drives (PMDs) are a mechanical adjustable speed drive technology that offers innovations in power transmission united with a simple machine design. Offering accurate process control, shaft misalignment tolerant, and a variety of equipment mounting configurations, this technology is a strong competitor with most variable-speed drive systems.

AC Drives

Though DC drives led the way early on for variable-speed motor control, AC drives made a big move to industry in the 1970s via variable-voltage/frequency control using silicon-controlled rectifiers and power switching devices.

Early AC drives operated in open loop but had limited performance. A major step forward was the development of field-oriented (flux vector) control for induction motors by Felix Blaschke at Siemens in 1971, which eventually pushed VFDs to meet or exceed DC drive performance in many applications. Sensorless-vector control (eliminating a shaft encoder) and other drive algorithm advances followed.

Early AC drives (circa 1980s) employed multiple transistors per phase due to their limited voltage and current ratings. This has changed to all-in-one packages, so that a 10-hp drive today has a structure smaller than one transistor pack of the vintage drive. New generations of transistors continue to be improved as manufacturers develop smaller and more efficient power devices. Insulated-gate bipolar transistors (IGBTs) are the present-day workhorse power devices.

Among major AC drive milestones was the arrival of industrial pulse-width modulated (PWM)-based drives and the introduction of Direct Torque Control (DTC) in 1995. DTC is regarded as advanced technology, able to control motor torque and speed directly without need for separate control of voltage and frequency. With DTC, 100 percent torque is available at zero speed and small torque increments can be controlled at low frequencies.

On the control side, analog was king at first, giving way to digital control initially based on integrated circuits. Microprocessor (MPU)-based digital drives came somewhat later and at first offered only open-loop (V/Hz) control. Continuing advances in MPUs allowed adding multiple control types in the same drive, with only software parameter changes needed to switch control mode.

Today, fast-switching PMW output is considered a prime VFD feature because of its minimal harmonic current production and dynamic motor torque control. Typical selectable features are speed or torque regulation, ability to accept various analog or digital preferences, speed or torque feedback, extra I/O points, as well as control of synchronous and induction motors.

Permanent Magnet Drives

Two types of magnetic slip couplings are available in industry, and they both function similarly. The heritage (earlier technology) product known as the eddy-current coupling is an electromechanical torque-transmitting device. Permanent Magnet Drives (PMDs), the latest technology product, were introduced in the mid-1990s and are mechanical torque-transmitting devices.

Both work on the principle of magnetic induction. Torque is generated as a function of slip between input and output members. The primary difference between these two types of devices is how the magnetic field is generated - one uses high strength permanent magnets and the other uses a field winding that is excited by direct current. The electrical power source is eliminated when using PMDs.

PMDs are best suited for controlling the speed of centrifugal equipment such as pumps, fans, or blowers. Early PMDs were horizontal design, performance rated up to 250-hp. They were primarily cooled by convection into the surrounding air, making their heat capacity a function of ambient air temperature and rotating speed. New materials and improvements in technology elevated the air-cooled performance rating to 500-hp with higher horsepower drives that utilize water-cooling.

A major high point for PMDs was the introduction of vertical mounting configurations. The addition of an enclosure supports the vertical motor and drive unit and limits overall height to prevent vibration problems. Pump hydraulic thrust loads can be accommodated with a vertical bearing housing.

On the control side, an actuator produces the movement needed to change the PMD position and vary the output shaft speed. A typical arrangement results from linear translating motion provided by a quarter-turn actuator working directly through linkage connected to the drive mechanism. A closed feedback control loop can be added to the system that receives an input signal from a controller or process source (e.g. speed, flow, pressure) and adjusts the PMD output speed to a prearranged corresponding value. Existing process control systems easily adapt for use with PMDs.

Today, improvements in performance of the technology, as well as machine design, equate to a completely robust, durable mechanical drive system. The technology has one of the fastest adoption rates for a new introduction in its targeted industries with nearly 5,000 installations currently operating and capability up to 6,000-hp.

PMD Technology

Since PMDs are a relatively new variable-speed drive system, an understanding of the basic technology is prudent. PMDs are non-energized, mechanical torque-transmitting devices. The technology uses powerful permanent magnets to transmit torque across an air-gap; therefore, the input and output members are mechanically independent.

The drive consists of two primary component assemblies - a magnet rotor that revolves freely within a conductor rotor. When the conductor rotor rotates relative to the magnet rotor, the magnetic flux from the magnet poles permeates the air-gap and creates eddy currents in the conductor. The eddy currents create poles that interact with the magnet poles, whereby the magnetic flux develops a tangential force tending to turn the magnet rotor in the same direction as the rotating conductor. The net results are a torque available at the output shaft for driving a load and speed changes obtained by varying the width of the air-gap between the rotors.

The PMD may be mounted inside an enclosure, similar to an eddy-current coupling, with two shaft extensions that are flexibly coupled to the driver and load. One significant advantage of horizontal, shaft-mount PMDs are that they install the same as a conventional coupling, using hubs secured directly to the motor and load shafts.

Hence, the PMD serves as both adjustable speed drive and coupling, providing shaft alignment capability without relying on the flexing of a coupling element. Lastly, PMDs can be installed indoors or outdoors without special consideration.

As with electrical drives, PMDs perform a variety of process control tasks well, including the following:

- Variable-torque control to drive a pump, fan, or blower.
- Energy savings due to the Affinity Laws.
- Soft start of the system to reduce in-rush current and fatigue stress.
- Fast and precise response to changes in the control of the system.

Considerations: VFDs

The VFD is the predominant type of variable-speed drive system on the market (see Figures 1 and 2). Its use has expanded rapidly due to two factors - steadily improving performance along with a continual drop in price. Evolving semiconductor technology has resulted in performance improvements, such as improved electrical characteristics, easier programming of desired control response, and smaller size and weight of the unit.

Figure 1. Typical wall-mount VFDs.

Points to watch out for during VFD selection and set-up are:

Figure 2. A large VFD system.

- If the VFD will operate more than one motor, then total peak currents of all motors under worst operating conditions must be calculated.
- If the load is spinning when the VFD is started (fan applications), then the load will be out of sync with the VFD. The VFD will attempt to pull the motor down to the lower frequency, which may require high current levels and cause over-current faults.
- If the power supply source is switched while the VFD is running, then some drives will ride through a brief power outage while others may not.
- If starting or stopping times are critical, or if the load needs high starting torque, then over-sizing of the VFD may be required.
- If power factor correction capacitors are being switched or exist on the intended motor loads, then this usually generates power disturbances in the distribution system, affecting VFDs. Isolation transformers or line reactors may be required.
- When using medium voltage systems, a climate-controlled room may be required.

Considerations: PMDs

The PMD is quickly gaining market acceptance due to three factors - a simple mechanical solution, ever-expanding performance ratings, and retrofits that typically replace a conventional coupling without driver modification (see Figures 3 and 4).

Figure 3. Typical shaft-mount PMD.

Evolving material technology has resulted in performance improvements, such as improved mechanical characteristics, ability to handle higher power levels, and higher system efficiency.

Points to watch out for during PMD selection and set-up are:

- If using a vertical configuration where the system is susceptible to resonance vibration, then the system reed-critical frequency should be reviewed to verify adequate stiffness to support the equipment and avoid natural frequencies.
- If using a horizontal configuration with long, small diameter shafts, then the weight, length and center of gravity should be reviewed to assure critical frequencies are outside the operating range.

- For an assembled drive unit, electromagnetic interference (EMI) is not a factor and is less than that typically found in an electric motor. However, for disassembled units, individual magnets and exposed magnet rotors require strict safety precautions and handling procedures.

Figure 4. Vertical PMD installation.

- If using a motor equipped with sleeve journal bearings and no thrust bearing, then a modification is required to limit the total axial end float. Optional bearing frames are available.
- During maximum slip heat conditions, temperatures can easily reach 250-deg F. Therefore, protective guards must provide sufficient airflow for adequate heat dissipation.

The Next Decade

All variable-speed drive systems will evolve to meet future challenges. Lower-cost, higher-reliability drive systems will become available that, in turn, yield lower installation and maintenance costs. The next decade promises strong advancement for VFDs and PMDs, including speed actuators with a scalable, field-level machine/process control unit with PLC or process capability, and performance monitoring programs compatible with customer operating systems and plant wide networks.

Industry experts see tighter integration with control systems for VFDs. Real integration fully involves the drive in the programming and configuration environment of the control system. We are beginning to witness the adoption of distributed drive systems, mainly from a greater integration of motion control and PLC functionality into VFDs. As energy costs and grid standards increase, an active drive front-end (including harmonic limitation) is slowly gaining acceptance.

PMDs will encompass ever-higher performance (30,000-hp) rated units. Advances in the overall technology, composite/specialty materials, and design innovations will result in enhanced process control, low-speed efficiency and improved product cooling while reducing the drive's physical size and weight. Development of low cost, lightweight products to better serve applications under 50-hp, including fractional horsepower, is underway.

Summary

Many of today's industrial applications benefit from optimizing and controlling the equipment process operating speed, and this benefit can easily be provided for any process system by using modern VFDs or PMDs. Owners love the payoff from "green" energy-efficient upgrades.

When drive systems deliver similar energy savings, it is important to look at the total cost of ownership associated with these systems during selection. The simplicity of these drives remains a strong selling point because the technology benefits the user by providing an easy retrofit, lower installed cost, reduced start-up time, proven equipment compatibility, reliability, and reduced exposure to electrical hazards.

Whether your motivation rests with electrical or mechanical variable-speed drive systems, you can be assured that these exceptional products will persevere and evolve with time.

References

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