Variable speed pumping: myths and legends

Variable speed drives offer many advantages in the operation of centrifugal pumps but, in spite of this, many barriers remain to implementing the technology to its full potential. In this article from the USA, Mike Pemberton of ITT Goulds Pumps seeks to dispel the myths and legends surrounding variable frequency technology and its application, arguing that it has now developed to the point that these barriers are, for the most part, perceived rather than actual.

In common language, a myth is a fiction – something that is untrue. A legend is a story from the past about a subject that was, or is believed to have been, historical. So, myths and legends encompass beliefs that may or may not be true. And legends are often so embellished that it is hard to discern how much of the story is factually true.

When considering the application of a variable frequency drive (VFD) for centrifugal pump control, one often encounters myths and legends. How much is fiction and how much is fact? Today, it is increasingly important to sort through the misinformation in order to realize the significant benefits through application of this technology.

Traditionally, a fixed-speed pump and control valve have been used to regulate process flow. Even though VFD technology has grown rapidly in acceptance, the technology and benefits are often poorly understood. As such, there is uncertainty surrounding its use for pump control. There are any number of reasons for this confusion, including:

- Lack of knowledge about the difference in hydraulic performance between fixed and variable speed pump control
- Lack of knowledge concerning control and failure modes, especially for mission-critical applications
- Perception that a VFD is always more expensive than a control valve
- Concerns about the reliability of the electronics platform.

"Therefore, even the lover of myth is in a sense a philosopher; for myth is composed of wonders" – Aristotle

Many of these concerns stem from bad experiences before VFD technology matured. These legacy issues can be put into perspective by relating them to the evolution of PC technology. The cost of low-voltage VF drives continues to drop while reliability and functionality increase. As a result, VFD technology has become a highly reliable, cost-effective alternative to using fixed-speed pumping systems in low static head applications.

There are compound benefits through implementation. These include energy and maintenance savings, pump and process reliability improvements, better process control and less fugitive emissions. Also, on new projects, VFD application can reduce overall capital cost by eliminating valves and starters plus the associated wiring and pneumatic lines. In many cases, smaller pumps with lower horsepower motors can be used. In terms of piping, smaller diameters often suffice and by-pass lines can be eliminated.

Scope of opportunity

It is estimated that 20% of all electrical power is used to drive industrial pumps. Around 20% to 50% of the power consumed can be saved through variable speed operation. Opportunities to improve pump performance are often overlooked for the following reasons:

- Low awareness of motor energy-efficient technologies
- Financial and operational benefits are often not well understood
- The initial capital cost to employ motor-efficient technology may be higher (purchasing decisions are typically made on first-cost)
- Energy-saving projects are often ranked below other process-related capital expenditures.

How the VFD works

A VFD is an electrical system (i.e. inverter) used to control AC motor speed and torque. It provides a continuous range of process speeds compared to a discrete speed control device such as multiple-speed motors or gearboxes. Industry has standardized on the IGBT (insulated gate bi-polar transistor) based PWM (pulse width modulated) design.

A VFD controls motor speed by varying the frequency supplied to the motor. The drive also regulates the output voltage in proportion to the

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output frequency to provide a relatively constant ratio of voltage to frequency (V/Hz), as required by the characteristics of the AC motor to produce torque. In closed-loop control, a change in process demand is compensated by a change in power and frequency supplied to the motor, and thus a change in motor speed.

Latest VFD improvements

- Microprocessor controllers eliminate analogue, potentiometer-based speed adjustments with precise digital control capability.
- Advanced circuitry to detect motor rotor position by sampling power at the terminals, which keeps power waveforms clean and sinusoidal while minimizing power losses.
- Soft-start capabilities with higher starting torques at lower speeds.
- Built-in power factor correction and short-circuit protection.
- Digital bus communication to the DCS (distributed control system), PLC (programmable logic controller) or CMMS (computerized maintenance management system) for transmitting real-time information on equipment health.
- Radio frequency interference (RFI) filters to protect process equipment.

Application issues and benefits

It is widely recognized that the VFD can introduce harmonic distortion of voltage supplies caused by the non-sinusoidal currents drawn during the power conversion process inside the drive inverter.

Because of the fast switching frequency of the IGBT drive and impedance mismatching between the motor and transmission lines, a reflective wave occurs, which results in spikes that are sometimes two to three times the rated bus voltage. These occur on every pulse of the output and travel unevenly through the coils of the motor. The following are considerations in addressing this issue:

- Induction motors used with inverters to supply adjustable frequency power should include inverter grade insulation.
- Inverters produce steep fronted voltage spikes that can damage the stator winding insulation.
- Part 31 of the National Electrical Manufacturer's Association (NEMA) MG-1 standard requires the insulation of inverter duty motors to be capable of handling 1600 V spikes for supply voltages up to 600 V. .
- Most standard induction motors meet this requirement, but always consult with the motor supplier if there is a question on suitability for inverter duty.
- Use inverter duty motor power cables with a continuous corrugated armour sheath; i.e., one that provides low impedance to high frequency.
- When the distance between the drive and the motor exceeds the recommended lead length, added protection is required, i.e., add a line reactor at the drive and RFI filter at the motor.

It is important to specify the technical performance of the VFD and make sure that proper electrical practices are followed during installation. It is equally important to realize these technical issues are well understood and can be successfully mitigated. Often, the concerns over these potential side effects have slowed acceptance of the technology. While this concern is valid, the technical issues can be addressed. The economic benefits are too compelling to delay implementation.

Energy savings potential

Energy savings are possible with VFD control due to the affinity laws that govern the operation of centrifugal pumps (Figure 1). Compared with throttling valves and bypass systems, speed reduction provides significant energy savings at partial load. The reduction of speed provides:

- Flow (Q) reduction according to a *linear* function
- Head (H) reduction according to a *quadratic* function
- Power (P) reduction according to a *cubic* function.

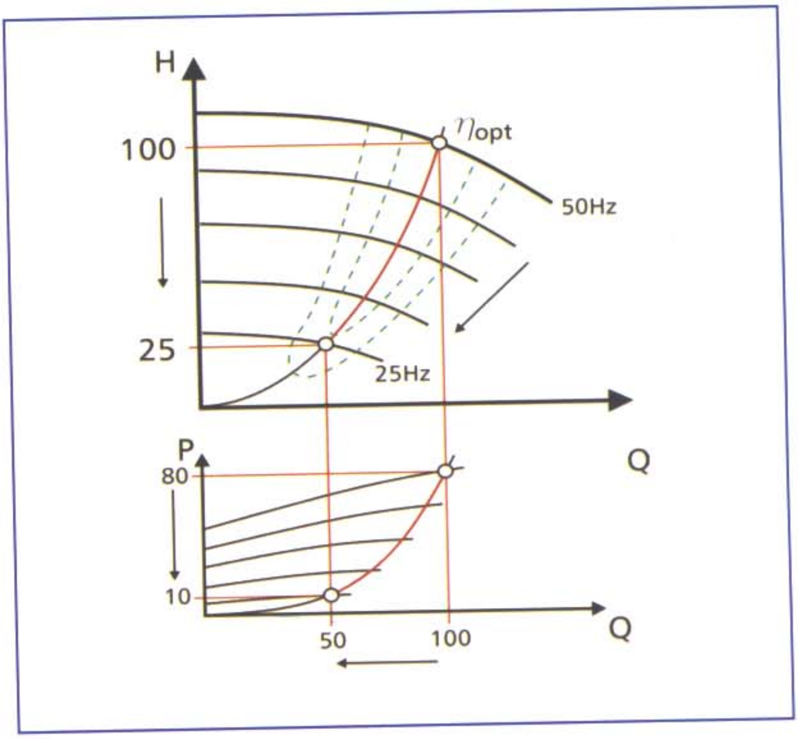

Figure 1. Affinity laws in action.

Medium versus low voltage motors

It is common practice in industrial plants to switch from low-voltage to medium-voltage motors above 200 horsepower (HP). The primary reason for switching to medium voltage is to reduce the amperage required to start and continuously operate fixed-speed motors. For example, the full load amps for a medium-voltage 200 HP, totally enclosed fan cooled (TEFC) motor at 1180 rpm is four or more times less than an equivalent low-voltage motor.

VFD pump control often results in operation at 50–75% of full speed to deliver the same flow rate. Subsequently, the horsepower and associated current draw is significantly reduced. For example, a low-voltage 200 HP TEFC motor at 60% of full speed requires about 30% of full load power. Therefore, the amp draw required for variable speed pumping at partial load is typically only one or two times greater than is required for a medium voltage motor at full speed.

In addition, the VFD has a soft-starter built in to prevent over-current and over-torque conditions on start-up. The inherent soft-start capability avoids pressure spikes (water hammer) and reduces pipe fracture. Repeated pressure spikes can reduce the lifetime of the pumping system.

Reliability savings potential

Variable speed operation contributes to reliability improvements by allowing the pump to operate at slower speeds, near the best efficiency point (BEP) with a 25% trimmed impeller. Operation more than ±10% from the pump's BEP significantly lowers component reliability (Figure 2).

Although often overlooked, the excess energy in fixed-speed systems is being dissipated into the infrastructure and can lower equipment life. This energy may transmute into vibration that can damage the pumping system including the pipes, instruments and valves.

Intelligent pumps

In recent years, automation suppliers have introduced smart instruments and valves. Pump suppliers now offer a 'smart' pump, i.e. a standard VFD with embedded pump intelligence. This advent represents the next logical step in the evolution of intelligent field devices. With the growing use of digital field buses to communicate between smart devices and process control systems, equipment health information can be sent to asset management software in real time. An intelligent pump can be seamlessly integrated into the process control system architecture.

The perception may exist that a VFD with pump intelligence is highly customized and complicated to implement and use. Yet, the opposite is true. An intelligent pump is a standard VFD with embedded algorithms to monitor the pump's health and to provide protection from process upsets. The operating manual is written in easy-to-understand language with the pump operator in mind. The intelligence is only enabled if you choose to do so. Similar to a cell phone, there are many useful functions that are only employed if and when needed.

Conclusion

In spite of the operating and economic benefits, there are many hurdles to implementing VFD technology. Among these constraints is the lack of awareness among plant engineering, operating and maintenance staffs of this approach for pump control. The myths and legends surrounding VFD technology and its application further exacerbate the situation.

There is one overriding issue to understand. Motor and valve performance can make or break your bottom line. For the most part, the enormous cost of inefficient pump operation and valve throttling goes unnoticed. It is time to sort through the myths and legends surrounding variable speed pumping in order to reveal its wonders and transforming power. ■

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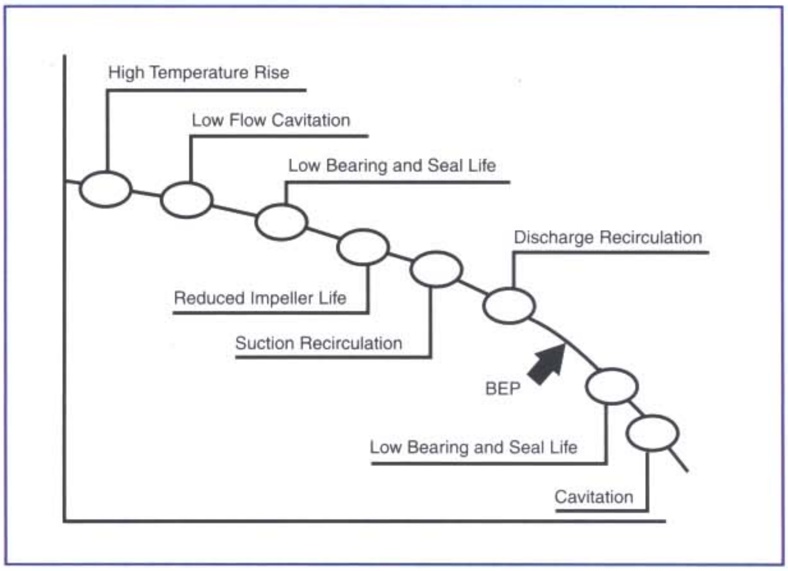

Figure 2. Reliability issues versus BEP.