Run Times
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Variable frequency drives (VFD's) are often promoted as money saving solutions for centrifugal pump applications. For some applications this is true. For other applications VFD's may be an unnecessary expense. In this issue we will cover some guidelines concerning when a variable frequency drive should be applied, and a few things that the buyer should be aware of when considering one.

Dale B. Andrews – Editor

Variable frequency drives are designed to deliver a constant torque, up to the motor's rated frequency (50hz or 60 Hz), and constant horsepower at above nameplate frequencies. A motor's rated torque, horsepower, and speed are related by equation (1) below. It can be seen that, in order to deliver constant torque, available power will decrease directly proportional to any change in speed. Power output is constant, at speeds above the nameplate rating, reducing available torque in direct proportion to the change in speed. In a centrifugal pump, the torque *requirement* is changed by the square of any speed change, and the power requirement changes by the cube of any speed change. The fact that a centrifugal pump's power requirement decreases more rapidly, with speed reduction, than the drive system's available power, makes centrifugal pumps particularly well suited for variable speed operation, over a broad operating range, below the motor's nameplate speed.

$$T = \frac{5250}{RPM} \times HP \quad (1)$$

Saving Money with a VFD

A variable frequency drive, used in lieu of a control valve to restrict pump output, often demonstrates a significant financial benefit. To reduce downstream flow, or pressure, part of the energy imparted to the fluid by the pump is given up in a control valve in the form of heat, noise, and vibration. A VFD offers a more efficient alternative to the control valve in a system where the pump head is primarily driven by friction resistance to flow.

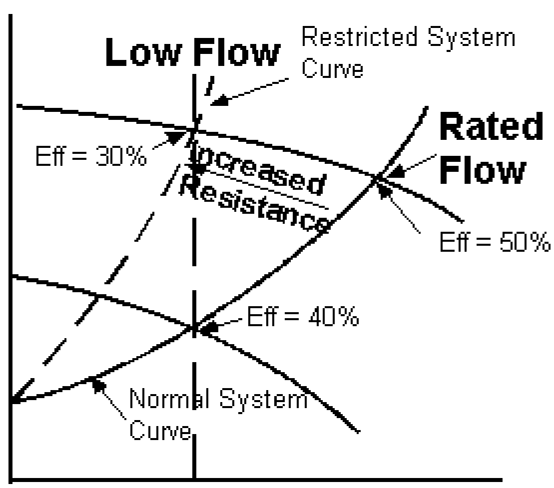

Fig 1

By way of example, Fig 1 depicts the flow characteristic of a 1780 RPM pump operating at a rated flow condition of 500 GPM 300' TDH with an efficiency of 50%. Based on a fluid sp.gr. of 1.0, the power requirement at the rated flow point is 75 HP. A control valve is used to reduce the flow to a 250 GPM low flow condition. As the pump moves back on its curve, TDH increases to 315', and the pump efficiency drops to 30% resulting in a 66 HP draw at the low flow condition.

Instead of using a control valve to limit flow, a VFD might be applied to control pump output by varying speed. As the pump speed is reduced, the pump output will follow the affinity rules shown in equation 2 below. In this example, lowering the speed by half to 875 RPM, would drop the pump flow to 250 GPM. The TDH required at half speed would be 25% of the TDH required at rated speed, or 63'. The pump would likely experience an efficiency loss with the large speed reduction. For this example we de-rated the efficiency to 40% at the reduced RPM low flow condition. The power required at this condition would be 10 HP. In this example, there is a 56 HP penalty for using the control valve instead of the VFD. If the pump operates 100% of the time, and is at the low flow condition 50% of the time, then the annual loss through the control valve is in excess of $13,000 per year based on a $0.08/Kw hr electric rate!

$$\frac{N2}{N1} = \frac{Q2}{Q1} = \sqrt{\frac{TDH2}{TDH1}} = \sqrt[3]{\frac{Bhp2}{Bhp1}} \qquad (2)$$

However, a variable frequency drive isn't always this cost effective. There are two key application assumptions in the above example. The first is that the pump is regulated to the low flow condition frequently, and the second assumption is that the system resistance is primarily frictional.

Frequency of control

If the pump operates at the reduced flow rate because it is oversized for the system, the best way to save money might be to eliminate the control valve by replacing, or re-rating, the oversized pump with one of the correct size. If the low flow condition occurs for short durations and relatively infrequently, then the control valve might be the most economical choice. In the above example, the penalty for restricting flow with the control valve is $3.34 per hour. If the low flow condition only occurs one hour during each 8 hour shift, then the cost savings would drop to $3300 annually, making it more difficult to justify the conversion to a variable frequency drive control.

System Characteristics

Many pump applications require a pump to supply fluid to a pressure vessel. Under this condition, it is possible that only a small portion of the total head developed by the pump is being utilized to overcome system friction. Borrowing from the example above, Fig 2 shows the same pump, developing 300 ft TDH to supply 500 GPM into a pressure vessel. In this example, system friction losses are negligible. To reduce the pump output to 250 GPM with a VFD, the pump head needs to be reduced by about 13'. This requires a speed reduction of about 40 RPM from the rated condition. As the speed reduces, the pump moves back on its curve, and the efficiency drops to about 31%, lowering the HP requirement to 61…only a 5 HP benefit over the control valve condition. In this case it is unlikely that there would be a financial justification for applying a VFD in lieu of a control valve based on efficiency gains alone.

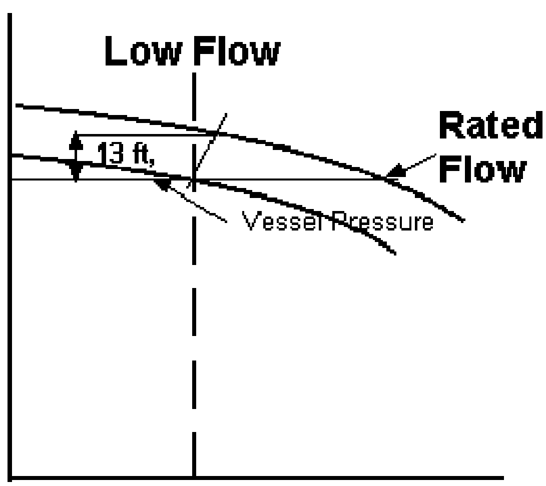

Fig. 2

- Motors operated by VFD's run hotter than motors operated across the line. Heat deteriorates motor insulation over time. When supplying motors for variable frequency operation, manufacturers typically use more expensive motors with a higher insulation class than motors used in a similar non-drive application.

- The motor manufacturer should be consulted for operational limitations. Most variable frequency drives restrict the minimum continuous speed to some percentage of the nameplate speed. Below this minimum speed, temperature rise may damage the motor. Every 10^{o}C rise above the rated temperature in a motor reduces the insulation life by half.

- The motor manufacturer should be consulted before applying a VFD to an existing motor. In addition to higher temperatures, non-VFD motors may have component natural frequencies that will conflict with the drive output frequencies, resulting in noise, vibration, and premature failure.

- Explosion proof motors must be rated as certified for VFD operation before they can be used with a VFD. Qualified motors will state on the nameplate that they are certified as explosion proof for VFD operation, as well as any operational limitations.

- Variable frequency drives should be placed near the motor. A large distance between the drive unit and the motor may result in increased motor voltages and temperatures that stress the conductor insulation. Special inverter duty motors are available that are made to withstand these higher voltages. When installing long cables, special filters may be required to reduce these effects.

- Another problem that has come to light in recent years is stray electrical currents induced into the motor shaft by the variable frequency drive output signal. These stray currents cause electrostatic discharges across the bearings, resulting in bearing damage. To avoid this problem, brushes or slip rings are applied to provide a different path to ground for these currents.

- Some centrifugal pumps have integral shaft driven circulation devices to support bearing or mechanical seals. The pump manufacturer should be consulted regarding the minimum speed at which these devices will operate properly.

This newsletter touches just a few of the issues that should be considered when applying a variable frequency drive. All of these potential problems are avoidable by working closely with the manufacturer in the selection and application of the drive and motor. Variable frequency drives provide very economical and reliable control when selected properly and applied to the right applications.