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Pump Control with Variable Frequency Drives

A sensible approach to energy savings

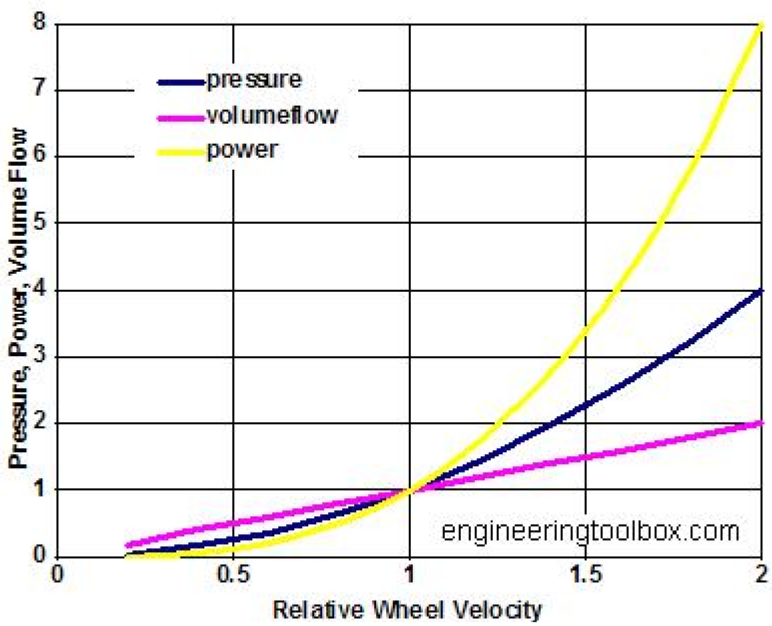
While the inefficiency of driving a car with the gas pedal to the floor and then controlling your speed using the brake is obvious to any driver, many facilities use that very same approach for pump control. Flow control with throttling or restrictive devices, as is often done, sacrifices energy efficiency and results in unnecessary costs. However, with an understanding of basic principles, an analysis of the specific application, information about available control solutions and evaluation of technologically advanced equipment, these facilities can make a quantum leap in improving the efficiency and economy of their pumping operations.

The basics

Energy efficiency starts with motor speed control. Sixty-five percent of *all* electrical energy used in the United States operates flow loads such as pumps, fans, blowers, and compressors. Constant speed induction motors power most of these. When output flow requirements fluctuate in such systems, an external means of adjustment is needed.

Commonly used methods for flow control include throttling or restrictive devices such as valves, outlet dampers, inlet vanes, and diffusers. Mechanical speed changers and recirculating systems are sometimes used too. However, all these devices waste energy, dissipate power by friction and diffuse heat.

Figure 1



Variable frequency drives permit users to consume the least amount of power to obtain desired pressure and flow

Fixed-speed pumps draw nearly full horsepower and consume nearly maximum energy full time, regardless of demand. Power requirements for throttled systems drop only slightly even when flow or volume is reduced significantly.

Variable speed devices such as belts, gears, magnetic clutches and hydraulic drives accomplish this function mechanically, but they are costly, bulky, waste power and require high maintenance.

DC adjustable speed drives can provide speed variation. However, DC motors are two to three times the cost of an equivalent-rated AC motor. DC motors are also larger, heavier, require more maintenance and are more difficult to operate in challenging environments.

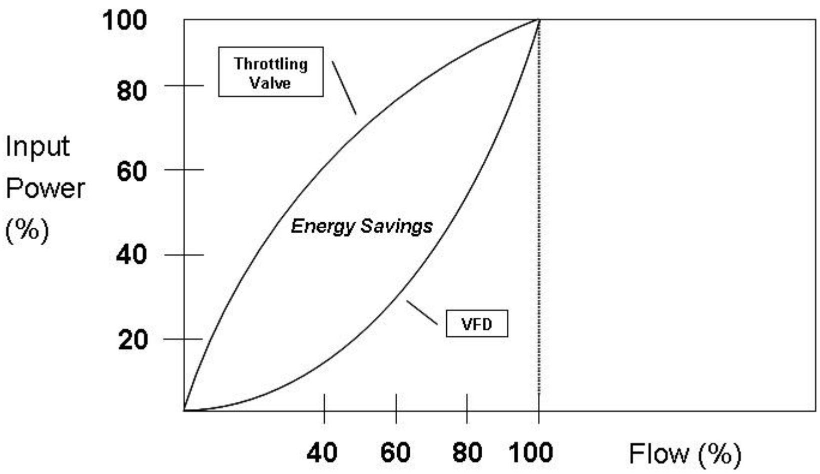
Variable frequency control of AC induction motors provides an economically sound and operationally effective solution for speed control and reduced power consumption. In addition, it can be made responsive to signals from flow sensors, programmable controllers, and other control systems. Microprocessor-based AC motor control affords users options that can provide short- and long-term productivity and profitability improvements.

Curves determine centrifugal pump efficiency

In-line valves are often used to regulate flow or pressure in liquid pumping systems. The valve can be a significant source of energy loss by causing a restriction in the flow path, thus increasing the pressure. An AC drive provides more efficient flow control by varying the pump motor speed. By comparing the energy requirements and costs when a throttling device, such as a valve, is used for flow control on a centrifugal pump with the power used when an variable frequency drive (ADF) is used to control the same flow, the potential savings become evident.

The first step is to determine the theoretical load requirements and potential energy savings for the specific application using three interrelated Affinity Laws.

Figure 2



- *Reduced speed reduces flow or volume proportionally.* Since flow varies linearly with speed, a 50 percent decrease in speed means a 50 percent decrease in flow.
- Pressure or head varies as the *square* of speed. At 50 percent speed, there is 50 percent flow, but only 25 percent pressure.
- Power requirements vary as the *cube* of speed. So at 50 percent speed, there is 50 percent flow, 25 percent pressure, but there is only 12.5 percent power.

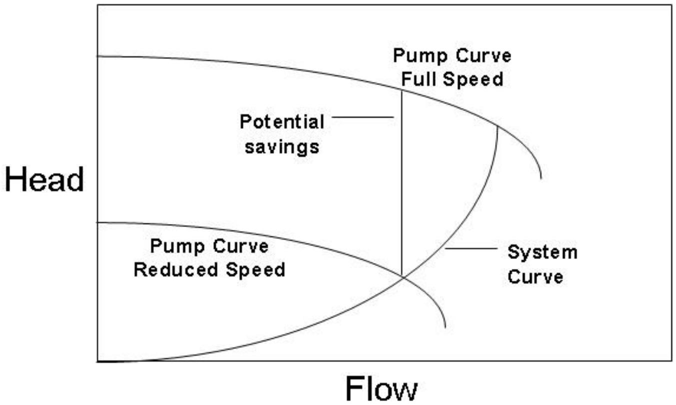
The second step is to define the pump system curve. Typical characteristics of a pump system are:

- Static head of lift, which is the height the fluid must be lifted from the source to the outlet.
- Friction head, which is power loss caused by the flow of the fluid through the pipe, valves, bends and any other device in the piping. This loss is non-linear and dependent on flow.

Adding the two heads together creates the system curve. This describes what flow will occur given a specific pressure. Knowing the system curve, the pump manufacturer can select an impeller size to meet the flow requirements specified.

The point where the pump curve and the system curve cross determines the operating point of the system. This system will have only one operating point. Thus, if variable flow is required, something needs to be added.

Figure 3



Flow control

Not all options are created equal. The typical technique for flow control is the use of a throttling valve. Partially closing the valve adds another restriction, raising the system losses and the system curve. The flow rate will now be determined by the point where the new system curve crosses the pump curve. The amount of energy the system consumes to do this is proportional to the head pressure and the flow rate. By using an variable frequency drive to control the flow, there is no additional restriction added to the piping. Therefore, the system curve remains the same. Varying the speed with an variable frequency drive has the same affect as installing a different-size impeller on the pump--a new pump curve results.

While there are several methods of flow control, each has different levels of energy efficiency.

- Diverting valve – flow is diverted from the output of the valve back to the valve input; the energy usage is the same, independent of how much output flow is created.

- Hydrostatic drive – a variable speed device like the variable frequency drive, but its internal operating losses are higher.

- Mechanical drive – a variable belt and sheave device; additional friction and windage losses are created.

- Eddy current drive or clutch – uses magnetic coupling to transfer torque at different speeds; the slip losses in the clutch keep it from being a superior performer.

- Variable frequency drive – what makes the variable frequency drive superior is its low internal power losses over the speed range.

Using an variable frequency drive in a pumping system provides additional savings because many elements required in a valve-controlled system are eliminated or reduced without affecting the function.

In a valve-controlled system, there are losses in the valve and in the additional piping required to bring the valve to a location where it can be adjusted. With the variable frequency drive, there is no valve, hence no valve losses. With no pipe bends required for the valve, the piping losses are reduced also. With the elimination of the pipe and valve losses, often a smaller pump can be used. This enables users to achieve the same results – flow rates and pressure – with a lower horsepower pump. Significant system cost savings are realized, providing additional economic justification for using an variable frequency drive.

Further, microprocessor-based variable frequency drives can perform functions previously handled by programmable controllers, improving process flexibility and further eliminating components and cost.

Choices

Variable frequency drives are available from fractional to 1000 hp with a wide range of Input voltages and options. Since they are designed to operate with standard motors, they can be applied to an existing system easily. However, when choosing an variable frequency drive for a particular system, it is essential to evaluate the product in terms of:

- Features and functions
- Ease of installation
- Ease of operation and maintenance
- Availability of options
- Expansion or upgrade capability to meet present and future needs
- Comprehensiveness of the vendor's application and service offering

Among the features pump users should investigate are:

- Pump functionality – features that are specifically designed for pumping applications, and minimize startup time and provide a smooth interface for operators

- Application support – application engineering support is an essential resource for users before, during, and after the installation.

- Input AC line reactors – most variable frequency drives require some amount of input impedance. An externally mounted AC line reactor normally satisfies this requirement. It also protects the inverter from line surges and provides a degree of harmonic noise suppression.

- Output filters – when an application requires a long cable length between the variable frequency drive and the motor, some type of output filtering is required. This is due to the *reflected wave phenomenon* that results in damaging high peak voltages at the motor terminals. To protect the motor, users need to verify that several different types of output filtering devices are available. These include output reactors, RLC filters, sine wave filters, and filters that reduce or eliminate the high voltages.

- Other options – options such as communication interfaces, RFI filters, etc. that may be required to meet the specific needs of the application.

Your selection should depend on flexibility, options, service, and support which are critical to the business and operational success of your control system. The importance of choosing a supplier with the appropriate technical capabilities and expertise in applying variable frequency drives solutions cannot be overemphasized.

Conclusion

The business and operational benefits of implementing the most effective pump control solution are evident. With thorough understanding of simple principles, examination of the specific application needs, and evaluation of options, engineers can gain substantial costs saving and performance advantages.

As energy costs continue to rise, it will become more imperative to find ways to cut energy consumption. Variable frequency drives in pumping applications is a key facet to this effort. Furthermore, with the ongoing development and enhancement of technologically advanced variable frequency drives, users will have system-critical equipment with the ability to make a larger contribution to operational performance. As an integral part of enterprise-wide systems, variable frequency drives afford users pump control options that save dollars and make sense.

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