Variable frequency drives (VFDs) replaced motor generator sets and DC drives because of improved process performance and reduced maintenance costs.

Variable frequency drives: energy savings for pumping applications

In the early days of VFD technology, the typical application was in process control for manufacturing synthetic fiber, steel bars and aluminum foil. When the energy crisis occurred in the early 1970s, saving energy became a critical goal and the use of VFDs quickly spread into large pump applications and eventually into HVAC fan systems.

VFD vs. throttling devices

Mechanical throttling devices are used to limit flow. Although this is an effective means of control, it wastes mechanical and electrical energy in many flow applications. Fig. 1 represents a pumping system using a mechanical throttling valve and the same system using a VFD. If a throttling device is employed to control flow, energy usage is shown as the upper curve in Fig. 2, while the lower curve demonstrates energy usage when using a VFD. Because a VFD alters the frequency of an AC motor, speed, flow, and energy consumption are reduced in the system. The energy saved is represented by the green shaded area.

Variable frequency drives theory

The affinity laws can determine the system performance for centrifugal devices, including theoretical load requirements and potential energy savings. Represented in Fig. 3 are the three affinity laws:

- Flow or volume varies linearly with speed. If speed decreases by 50%, the pressure decreases by 25% (Fig. 3, graph B).
- Power or energy consumption varies as a cube of the speed. If speed decreases by 50%, power consumption decreases to 12.5% (Fig. 3, graph C). The potential of energy saving is available as the flow requirement is reduced.

Pumping system characteristics

Determining the system curve, which describes what flow will occur given a specific pressure, is critical to selecting the appropriate pump for a system. To determine an accurate system curve, two elements must be known:

- Static head or lift: The height that the
Fluid must be lifted from the source to the outlet.

- **Friction head**: The power required to overcome the losses caused by the flow of fluid in the piping, valves, bends, and any other devices in the piping. These losses are completely flow-dependent and are nonlinear.

In Fig. 4, the static head, friction head, and resulting system curve are shown for a typical pumping system. In this example, the maximum flow rate required is 606 l per minute of flow. The system will have a single operating point unless a device is added, and rarely does a pumping application require the pump to produce maximum flow.

### Throttling device application in a pump system

A throttling device is often used as a mechanical method to reduce the flow rate in a pumping system. Applying a throttling device to the system changes the pump curve (see Fig. 6). This reduces the flow of the system, but the pump curve is not altered and continues to operate at full speed. This creates mechanical stresses – excessive pressure and temperature – on the pump system, which can cause premature seal or bearing failures. More importantly, this also consumes a tremendous amount of energy. The energy consumed is represented by the blue shaded area in Fig. 6.

### Variable frequency drives application in a pump system

Applying a VFD to the pump allows control of the pump’s speed electrically while using only the energy needed to produce a given flow. This is similar to applying a new pump with a smaller impeller. Fig. 7 demonstrates the new pump curve and the energy consumed by this method. The pressure is also reduced, which helps reduce the mechanical stresses generated by throttling devices. Overlaying the two previous graphs, the difference is obvious in Fig. 8. The blue shaded area is the energy saved by using a VFD instead of a throttling device.

### Further cost savings

The use of VFDs can bring further total system cost reductions due to the elimination of components required for valve control only. In a valve flow control system, there are losses in the valve and additional piping required to bring the valve to a height where it can be adjusted. In the previous example, the piping loss is 10 hp, and the valve loss is 15 hp. Because of these losses and the internal pump loss, an equivalent of a 90 hp pump and a 100 hp motor is required to obtain a head equivalent to 50 hp. With the use of the VFD there are no valve or pipe losses due to bends or additional piping, thus reducing the piping losses to 8 hp. A smaller pump can be used with lower losses with this reduction. For the equivalent of 50 hp of head, only a 68 hp pump and a 75 hp motor are required. This results in a substantial system cost and installation savings, further justifying the use of the VFD.

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