TECHNICAL NOTE

Variable-Speed Drives in Multipump Applications

UNICO®

Multi-Pump Applications

Overview

Variable-speed drives are commonly known by several names—VFDs, ASDs, and inverters, to name just a few. They are a great way to improve the performance and efficiency of your pumping and irrigation systems by matching pump output to system demand. By changing the speed of the pump, rather than using bypass or throttling valves, significant energy savings can be realized. There are other benefits as well. A properly controlled drive/pump combination can prevent the water hammer, cavitation, and surges normally associated with starting and stopping pumps, filling empty lines, changing wheel lines, and the like. Additionally, special single-phase drives allow the use of three-phase motors as large as 125 hp where only single-phase power is available. These drives convert incoming single-phase power into perfectly balanced three-phase while providing variable-speed, constant-pressure control with soft start and stop. Some drives are also capable of coordinating the starting and stopping events of additional, fixed-speed pumps to provide wide demand coverage.

Multipump Systems

In multipump systems, variable-speed drives work in concert with fixed-speed drives to ensure that output meets demand. For example, suppose a system has four pumps to cover a given flow range. Pump one is a variable-speed pump and takes care of the first one-fourth of the flow range, matching its output to system demand. Pumps two, three, and four are fixed-speed pumps. When pump one can no longer keep up with demand, pump two starts. Together, the two pumps cover from one-fourth to one-half of maximum flow. When demand increases beyond the halfway point, pump three starts to extend the range to three-fourths. When demand exceeds three-fourths, pump four starts to cover the remaining quarter of the flow range. As demand is decreased, just the opposite takes place and the pumps stop in reverse order. It is helpful to think of the variable-speed pump as supplying any fractional portion of a whole pump necessary to meet demand, alone or in combination with the fixed-speed pumps.

Control the Key

When properly controlled, this approach works very well and provides smooth, reliable operation. If not properly controlled, however, the fixed-speed pumps can rapid cycle extensively as they hunt back and forth whenever demand is close to the crossover points between them. There are two basic but very different approaches to achieving multipump control with variable-speed drives: frequency-based control and pressure-based control. The following example will help illustrate the important differences between the two methods.

Let's assume that we want to maintain 60 psi in our system and that demand will vary between zero flow and 1,000 gpm. Let's also assume we have selected two 500 gpm pumps to cover the range. Pump one is a variable-speed pump and will cover up to 500 gpm. When flow exceeds 500 gpm and pump one is unable to maintain the requested pressure of 60 psi, we want to start pump two, which is a fixed-speed pump. Pump two will contribute 500 gpm while pump one automatically varies its output to maintain 60 psi system pressure. When demand decreases and both pumps are no longer needed, pump two will be shut down and pump one will continue to regulate its output to maintain requested pressure. For all of this to take place automatically, some method of decision making is required as to when to employ the second pump.

Frequency-Based Control

The first approach is to base all start and stop decisions for the fixed-speed pump on the output frequency of the drive. For example, we could start pump two when the output frequency reaches 58 Hz and stop it when it gets back down to 43 Hz. While the frequencies that trigger the starting and stopping are adjustable, pump two is turned on and off without regard to system pressure. Pump two might be started when pump one could maintain adequate pressure on its own. When both pumps are running and demand decreases to the point where one pump would be just right, the variable-speed pump might be allowed to run at a no-flow condition for extended periods of time. To guard against this, the point at which pump two is turned off must be set so that pump one is still contributing some flow when pump two stops. This, however, sets up the possibility of hunting between the pumps when flow rates are near the crossover point—pump one speeds up, which starts pump two, slowing down pump one, which stops pump two, causing pump one to speed up, starting pump two, and so on. The negative effects of rapid cycling pumps are well known. Along with these come abrupt pressure changes and poor system control. Drive output frequency, therefore, is simply not a reliable indicator of whether or not an additional pump should be started or stopped.

Pressure-Based Control

The preferred approach bases control decisions on system pressure. The drive's on-board microprocessor constantly monitors system pressure using a proportional feedback signal from a pressure transducer. This scheme ensures constant-pressure control. When pump one gets to full speed, fixed-speed pump two will not be allowed to start as long as system pressure remains within a user-adjustable range called "allowable error." Once pressure falls below the range, pump two will start as long as other user-specified conditions are met.

Depending upon the nature of the system, it may be desirable to impose several such additional conditions. For example, if the system is prone to very large, rapid demand increases within the range of pump one, we might require that feedback pressure stay below the low limit for a few seconds before considering starting pump two. This will allow pump one time to respond to the new condition without starting pump two unnecessarily. If pressure is still low after the delay expires, it is fairly certain that pump two is required and it will start.

Once the controller makes the decision to start pump two, we may want to ramp pump one down slightly first so that the system is not over pressurized. Since the control program is looking at system pressure, we should be able to select a specific pressure to trigger the starting of pump two. Thus, the starting sequence for pump two would be: (1) system pressure falls below the allowable error range and stays there for the duration of the pump two on timer; (2) pump one begins to ramp down in preparation for the starting of pump two; (3) feedback pressure falls to the level we have chosen for pump two to start at, and (4) pump two is started.

The stopping sequence is basically the reverse of the starting sequence. As system demand is reduced, pump one will eventually ramp down to zero speed. It is important to note that pump one is not shut off but rather is running at zero speed. When demand is further reduced and fixed-speed pump two backs up on its capacity curve, pressure will begin to rise. When pressure exceeds the allowable error and stays there for the duration of the pump two off timer, pump two is shut down and pump one will speed up to maintain requested system pressure. If the pumps want to "walk" back and forth, the user can widen the allowable error deadband, increase the duration of the timers, or use a combination of these adjustments to eliminate the problem.

Additional Advantages

Using pressure feedback as the basis for logic decisions allows the drive to provide other important functions not usually found in speed-based schemes. A low-pressure alarm can shut down all pumps if low system pressure suggests a large line break or loss of prime. A high-pressure cutoff can provide rapid shutdown of fixed-speed pumps if pressure rises to an abnormally high level. Other useful features include alternation of fixed-speed pumps, friction loss compensation, on-board time clocks, minimum speed selection, and fixed-speed pump restart timers to limit the number of starts per hour to manufacturers' requirements. If your system drains so that there are empty lines that require filling when the pumps are started, initial speed limits with timers can be set to assure smooth line filling without cavitation.

Conclusion

There is more than one way to incorporate a VFD into a multipump application, but it is very important that control decisions be based upon the most important thing being controlled—pressure.

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Unico is a leading global innovator of motion-control solutions for industry. Founded in 1967, the company develops, manufactures, and services variable-speed drives, application-engineered drive products, integrated drive systems, and ancillary products that improve operations by increasing productivity, safety, and equipment life while lowering energy and maintenance costs.

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