WORLD PUMPS August 2010

Energy efficiency

Energy savings – VFDs and more

In these energy-conscious times, pumping applications offer the potential for significant energy savings. Variable frequency drives are commonly applied for this purpose but are not the only solution available. Complementary solutions such as soft starters and energy management systems are also explored here by Jack Creamer and Grant Van Hemert of Schneider Electric.

We have all heard the buzz words: 'cap and trade'; 'sustainability'; 'green'. And we've also heard the rationale for these terms: global warming; the environmental and political vulnerability of our energy supply; dwindling resources. Some of these terms are obvious, while others are more controversial. No matter where your opinion lies, there are two truths. First, the sustainability and global warming movement has gained serious political momentum. Second, there are solutions available today that save money and free up restricted resources. One of the opportunities for increased energy savings lies in pumping applications.

Figure 1 shows that pumping, especially centrifugal pump applications, will produce the largest potential for energy savings, more than 50% of the overall total – including the better publicized approach using energy efficient motors. Figure 2 shows which industries and applications offer the most potential.

Initial versus life cycle costs

When it comes to installing new pump systems or making an upgrade to an existing pumping system to increase energy efficiency, most people are concerned about initial costs. However, many owners/operators of these systems don't realize that energy accounts for 40% of overall lifecycle costs, which, as indicated in Figure 3, is more than any other single element. Therefore, when considering a new installation or upgrading a system, overall energy savings should be evaluated as a primary factor in decision making. Energy savings calculators are available to help evaluate the actual energy savings based on application and duty cycle. An example is the ECO2 energy calculator from Schneider Electric (www.schneider-electric.us/solutions/energy-efficiency/drives-energy-efficiency/).

No silver bullet

Many articles on the subject of energy savings for pumping systems address the strategy of applying a variable frequency drive (VFD) to a pump to create energy savings. It is important to note that, while VFDs are an integral aspect, they are not the only piece to the energy savings puzzle. This article will discuss appropriate and effective applications for VFDs, power monitoring, starter selection and demand charge minimization, in addition to answering the question of

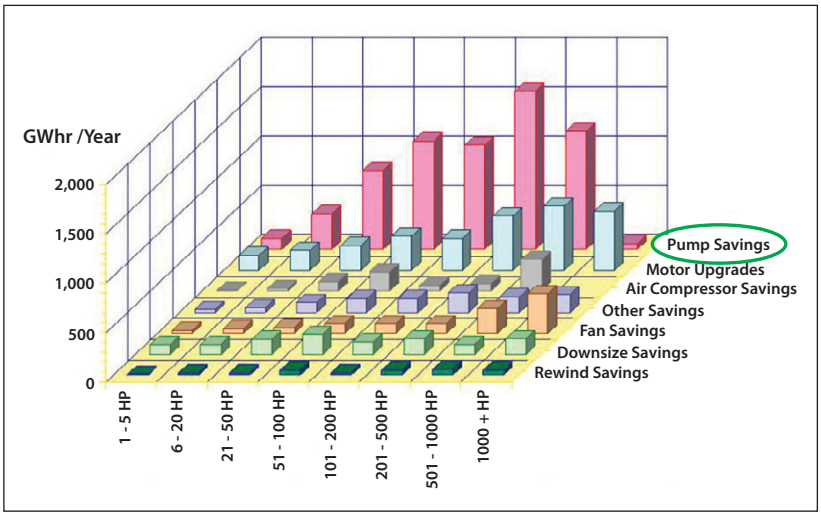

Figure 1. Potential energy savings for motor-driven loads. (Data sourced from: US Industrial Motor Systems Market Opportunities Assessment, *US Department of Energy.)*

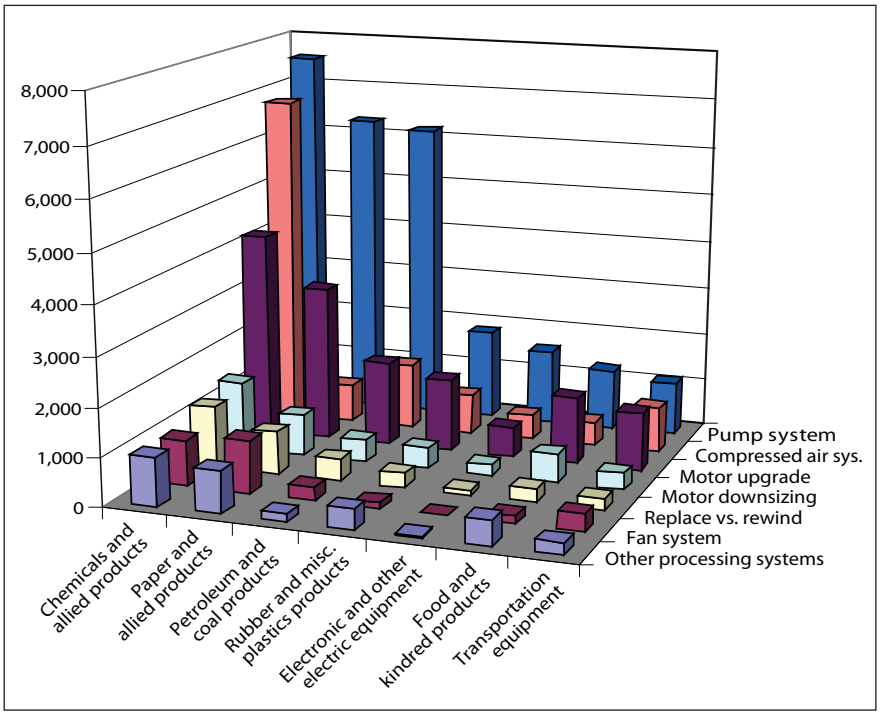

Figure 2. Energy savings potential according to industry sector and application. (Used with permission: Hydraulic Institute, Optimizing Pumping Systems: A Guide for Improved Energy Efficiency, Reliability and Profitability, *available at eStore.Pumps.org)*

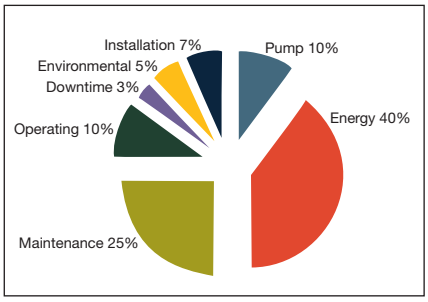

Figure 3. Example life cycle costs for a pumping system. (Used with permission: Hydraulic Institute, Optimizing Pumping Systems: A Guide for Improved Energy Efficiency, Reliability and Profitability, *available at eStore.Pumps.org)*

how to determine whether an application is actually saving energy.

Contrary to the focus of many articles of this nature, drives are not the silver bullet for energy savings. For example, in a properly sized pump running at constant pressure and flow at all times, a drive is likely not needed. In this application, a traditional motor starter, or soft start (for inrush and mechanical benefits), is probably all that is required. But, when looking at the overall centrifugal pump market, two dynamics come into play:

- Most applications are not constant pressure and flow. The pressure and/or flow vary either by process demand or simply by time of day.
- During design, dynamics can come into play that lead an engineer to oversize a pump. Whether it is for anticipated increase in demand or simply a safety factor to make sure all goes well, the result is that most pumps are not optimally sized.

As most applications fall into the above two categories, let's look at how they are solved:

- If the pump operates under variable pressure and/or flow, then a VFD can provide more enhanced energy savings then mechanical means.
- Many applications will have a non-optimized pump, and variable loading. For this, the VFD can solve both challenges simultaneously.
- If the pump is a constant-speed pump that is not optimized, then reducing the pump speed can match the performance to actual site conditions. This reduction in speed will also save energy due to the affinity laws.

Affinity laws and the benefits of VFDs

The secret to success with VFDs is an understanding of the affinity laws (Figure 4). Given a set of operating conditions, these relationship laws tell you what will occur if the system deviates from these conditions. One of the interesting aspects of these laws is that the relationship between power usage and speed is cubic. Thus, if you decrease a pump to 50% of full speed, you will decrease power consumption by about 88%. This surpasses the energy savings seen from mechanical means such as inlet valve throttling.

Once the ramifications and application of the affinity laws in pumping are fully understood, a pump operator can begin to take advantage of the full benefits of VFDs as outlined in the box (see p. 26).

Energy efficiency beyond the VFD

Despite the many benefits of VFDs for energy savings, the key to energy efficient pumping is actually power monitoring. After all, it is impossible to quantify something that is not being measured.

Power monitoring is not new. However, the equipment has traditionally been applied to motor control centres (MCC) and switchgear. Very little has been done

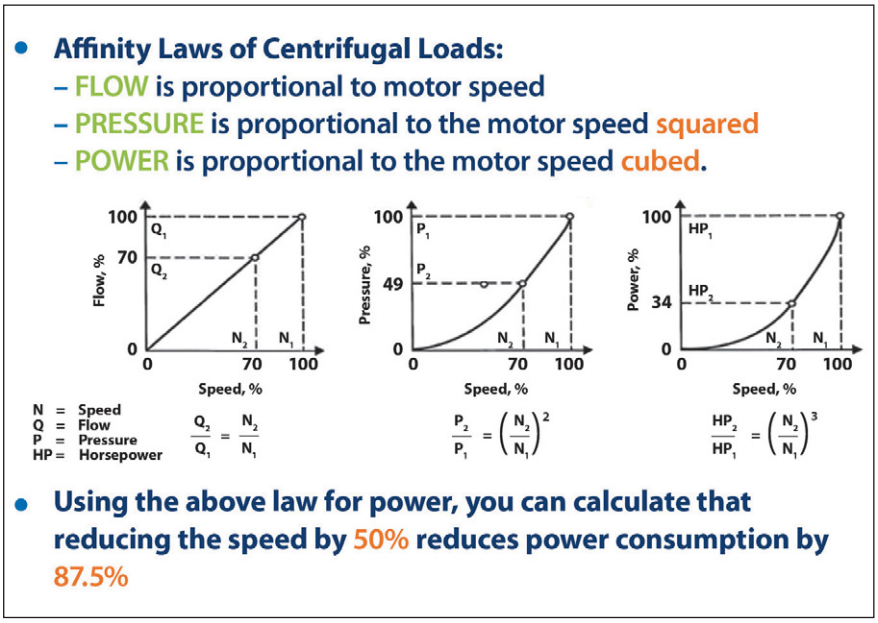

Figure 4. The affinity laws for centrifugal loads.

in the way of power monitoring for custom control panels, especially in the lower horsepower ranges. So, how do we address this?

Let's assume that we have a low horsepower, custom control panel pump station that is connected via a utility meter to the utility. Let's also assume that traditional power monitoring equipment is too expensive. Thus, power consumption is only examined at this meter. If power consumption goes up, it is hard to determine how many pumps, or which pumps, are experiencing the increase.

New devices, such as Schneider Electric's TeSys T motor management system, can be placed into the location as a constant-speed starter's overload. These devices will provide overload protection while also offering the ability to monitor power. While lacking the data analysis capability of a full-featured power monitoring system, they keep project costs low both in direct component cost, and by minimizing enclosure size.

Can power monitoring provide energy savings without the need for an energy-efficient device such as a VFD? Certainly. Studies in quantum physics and human psychology have both shown that observing a criterion yields an impact on the result. Schneider Electric has found that power monitoring alone can save 4–5% on energy.

Some monitoring examples

For the first example, let's assume that a treatment plant operator is monitoring the power and becomes aware that the sludge transfer system (Figure 6) is consuming power at night, even though the pumps are not used. This power usage might be from the electronics in the VFDs, MCCs or a custom control panel. Thus, the operator may start powering off this equipment when the day shift is over. Without power monitoring, this power loss situation might have been out of sight, and thus out of mind.

In another example, a plant manager might realize that water tower filling operations result in unnecessary demand charges. For instance, some utilities drop their demand charges at 5:00 pm (Figure 7). This is also the time that people travel home. Let's assume that a water utility starts to pump up the water towers at 4:30 pm to ensure adequate evening water supply. However, starting these pumps at 4:30 pm can incur a charge. By monitoring power, and tank level, the operator might be able to delay the filling operation until 5:10 pm. Thus, no impact to service, and still savings.

Remember those sludge transfer pumps mentioned in the first example. At night, power is often cheaper. The operator might want to transfer sludge at night to take advantage of the lower rate. This would also ease the burden of duty on the first shift.

These are several examples of how power monitoring can impact power usage without changing the equipment used in the power distribution system.

Process SCADA

Many power monitoring systems installed today have full networking capability. This data is run to separate software, independent of the supervisory control and data acquisition (SCADA) system. This software might run on a separate computer, meaning that a concerted effort has to be made to correlate the two systems. This extra work will likely mean that the task won't be performed that often. The only way to assure this is done with minimal effort is to bring the power data into the process SCADA. Not only should this be trended with the rest of the pump data such as flow and pressure, but it must also be displayed graphically. That way this parameter is always being looked at. The operator will then get a 'feel' for the normal power usage and be able to see when things are not correct.

The benefits of using VFDs in pumping applications

- On centrifugal loads such as pumps, VFDs save energy because of the affinity laws (see Figure 4).
- They provide precise speed control for an AC motor.
- VFDs can generate full torque and low motor speed.
- They protect a motor and wiring from overload currents.
- They also have inherent power factor correction, increasing efficiency.
- VFDs limit inrush current to provide soft start and soft stop.

Figure 5. Typical variable speed drive.

Figure 6. Energy conservation techniques will produce savings even on intermittent operation applications such as sludge pumping.

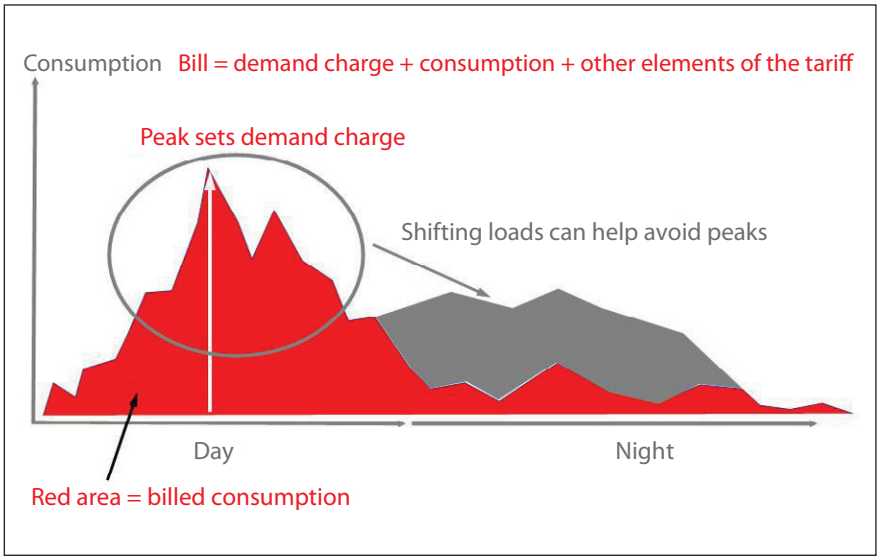

Figure 7. Effects of peak demand and load shifting.

Constant-speed motors

Constant-speed motors will usually use either a soft start or a contactor-based starter for control.

The biggest energy savings from a soft start is that it will eliminate the inrush, and minimize the demand charge severity as well as mechanical stress. However, once the pump has reached full speed, keeping a soft start engaged wastes energy. This is because the internal components continue to consume energy and generate heat. To eliminate this situation, use a combination of isolation and shorting contactors. When engaged, the shorting contactor shorts electrical energy across the soft start to the motor. This effectively bypasses the soft start. As a result, the heat loss through the soft start is minimized. Once the shorting contactor is engaged, an isolation contactor can be used to open the three-phase input to the soft start. This will completely isolate the soft start and eliminate any remaining energy loss.

Full voltage starting is accomplished with the use of a traditional starter. A starter comprises a contactor and an overload. A contactor is nothing more than a high-powered set of contacts that are opened and closed by the magnetic field from an electromagnet. However, people often overlook that this coil consumes energy.

Energy Consumption By Product

Style	Product	Watts
IEC	Contactor + MCP	5.18
NEMA	Starter + Circuit Breaker	34.86
BOTH	Self Protected Motor Starter	2.54

SPMS versus IEC based solution -> 50.97% savings

SPMS versus NEMA based solution -> 92.71% savings

Figure 8. Energy consumption for different motor starter systems. An SPMS provides big savings compared to traditional IEC and NEMA solutions.

Also, most starters use a melting alloy overload. This alloy is heated by the motor current passing through the alloy. If the current is high enough, the alloy melts. This then removes power to the electromagnet, and the contacts open. However, even during normal running, a certain amount of heat is generated through the melting alloy. This heat comes at the expensive of a certain amount of current. This amount of energy is usually very small and thus some might just want to ignore it. However, this current is metered and thus the energy loss is paid for. When it comes to energy usage, it doesn't make sense to be pound-wise and penny-foolish.

Some of the newer starters have lower energy usage then the traditional NEMA (National Electrical Manufacturers Association) starters (see Figure 8). One starter, the self-protected motor starter (SPMS), not only uses less energy but can also be restarted after a fault without replacing the contacts. This saves energy and increases the reliability of the pump system. For a wastewater system, being able to put a starter back into service, without a rebuild, can help eliminate a sewage overflow and its associated fines.

Summing up

Several factors have made energy conservation a much more critical criterion. Current technologies can provide as much as 30% savings in energy usage. The affinity laws allow for large energy savings in variable speed applications. But power monitoring, starter selection and demand charge minimization can also save money and energy. Finally, simple steps like integrating power monitoring into process systems can keep the importance of energy savings in the operators' minds. Energy savings is a process, and not one step. By implementing the correct steps, resources can be saved. ■

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