Water, energy and money
Improving efficiency in water networks

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Electricity, not surprisingly, represents 25 to 30 percent of operation and maintenance costs for water utilities. It is also the single largest controllable cost of providing water and wastewater services. In fact, energy costs are the largest operating costs in almost all water applications, accounting for up to 20 percent of total costs in thermal desalination, 50 percent in wastewater treatment and 60 percent in pumping stations.

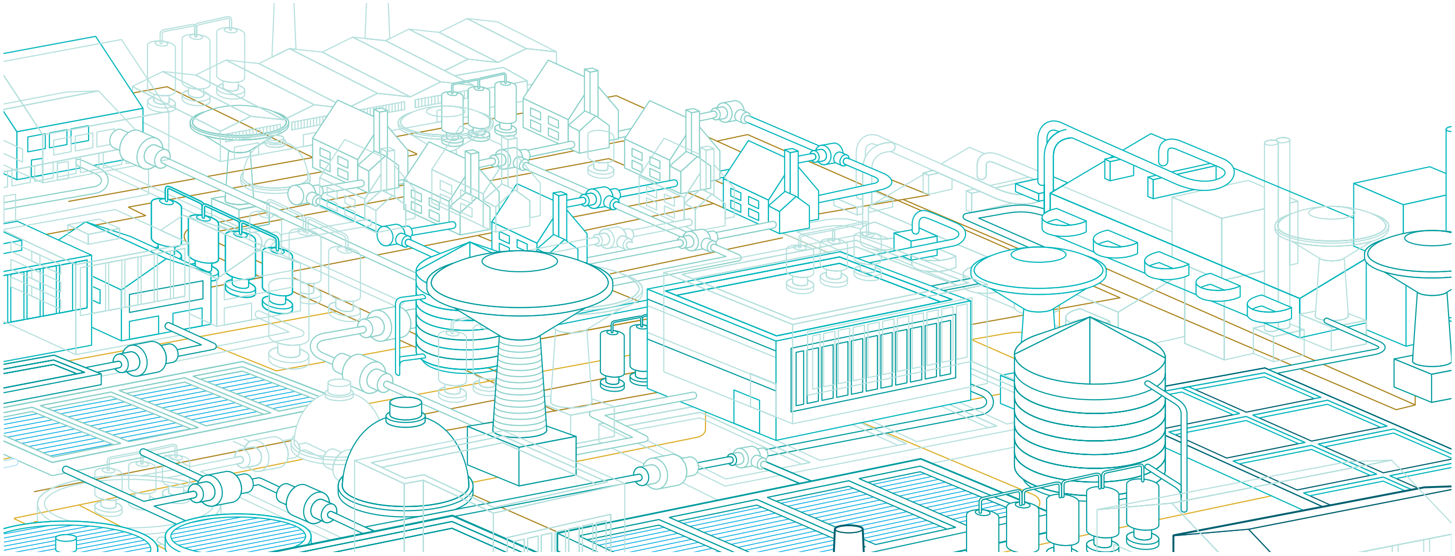
Meanwhile, tighter water quality standards and water scarcity are driving the need for more efficient pumping and processing technologies. Governments around the world are offering incentives, either direct or indirect, for water utilities to reduce their energy consumption.

Fortunately, energy efficiency is something that everyone can support. It comes with a ready-made business case that is all the more compelling given the energy intensity of water and wastewater services. Most efficiency investments in the water sector realize a rapid payback ranging from a few months to 5 years depending on the application.

In this paper we discuss efficiency-enhancing technologies in two of the most energy intensive water processes—pumping and aeration—and we examine the impact that monitoring and control systems can play in improving water system efficiency. Realizing energy savings, however, is best achieved by considering the broader picture. We have focuses on these areas simply because they represent the low-hanging fruit (pumping and aeration) and a less obvious path to greater energy efficiency (control optimization).

Efficiency in pumping and aeration

It's hard to overstate the role pumps and the motors that drive them play in water treatment. Energy makes up more than 90 percent of any given motor's total lifecycle cost, so the potential for savings through efficiency improvements in motors is substantial.



Estimated savings potential in efficiency projects (all water applications)

- Mechanical system optimization 10-40%
- Electrical system optimization 5-60%
- Control optimization 5-25%
- Energy reuse 5-20%

Pumps are one of the largest motor applications. It is estimated that 20 percent of the global electricity supply is used for pump system operations in various applications. Energy costs for pump systems in the 50 to 100 kW range, for example, can exceed twenty times the purchase price of the pump itself. However, there is also great potential for energy savings in such systems—between 20 and 30 percent using proven technologies. Another telling statistic is that some pump systems, 10 to 15 percent, operate below their best efficient point (BEP).

Perhaps the single most important technology for improving energy efficiency in pump systems lies with variable frequency drives (VFDs), which use power electronics to control flow and pressure by varying the speed of the pump rather than through mechanical means such as throttling valves or hydraulic couplings. These approaches are inherently inefficient because they involve restricting water flow while the pump continues to run at a constant speed. By definition, energy is being wasted.

How much? Here is where the laws of physics come into play to create a compelling business case. The power required to drive a pump motor is obviously related to the speed at which it is operating, but this relationship is not linear or “one to one.” In fact, power is proportional to the cube of pump speed so a pump running at half its maximum speed, for example, consumes as little as one eighth of the energy it would use running flat-out. This simple fact is the essence of the VFD’s impact on energy efficiency.

The use of VFDs in pump systems is well documented and has produced energy savings of 20 to 60 percent, depending on the particular application. However, the benefits of drives as applied in the water industry extend well beyond efficiency. They provide fast, precise control over pressure and flow—which eliminates pressure shocks and associated noise, erosion and leakage—and they reduce operating costs and extend the lifetime of other equipment.

Drives have now evolved to the point where specialized devices designed specifically for water applications are widely available. Such VFDs include built-in logic to support functions such as anti-ragging in which the pump is run through a series of forward and backward operations to clean the impellers without any manual intervention (and the time and cost that implies). Drives can also operate pumps in a “sleep and boost” mode to maintain pressure while minimizing energy use by monitoring flow rates and only engaging the motor when the flow drops to a predetermined minimum. VFDs can even perform flow calculations and provide this data back to the control center.

In terms of efficiency, VFDs deliver similar benefits to another energy-intensive process in water treatment, aeration. In fact, as much as two thirds of the energy used in waste water treatment goes to aeration, or specifically the compressors that force air into the water being treated. Microorganisms that decompose biodegradable organics in wastewater rely on a steady supply of oxygen to do their work. In conventional activated sludge processes, this amounts to an average of 0.8 to 1.5 cubic feet of air per gallon of wastewater.

Importantly, aeration is a 24/7 process, so the compressors are running on a near constant basis. A number of external variables impact aeration effectiveness (e.g., changes in volume or biological load in the waste stream, local climate, plant layout and the instrumentation and process control system). Still, EPA estimates that energy savings of 25 to 50 percent are readily achievable in aeration, and VFDs can play a key role in realizing those gains by eliminating on/off control of the blowers or the need to reduce flow with a mechanical device.

The importance of control systems

VFDs, however, are only part of the efficiency story in the water industry. The efficiency of pump system operations depends not only on particular pieces of equipment but on how the system is operated as a whole. Control systems today offer numerous opportunities for energy savings by optimizing pump schedules across the network. The algorithms that support this kind of optimization incorporate various elements such as efficiency curves for individual pumps, water consumption data and even local electricity rates to arrive at a schedule that meets the organization's objectives.

Those might include, obviously, pumping when power is cheapest, but how low can a given reservoir get, for example, before pumping must resume? Today's advanced process control systems can answer such questions. They can also interface with VFDs to add pump speed to the schedule in addition to simple startup/shutdown parameters.

Advanced water system models can require substantial time and computing power to calculate optimized schedules, but some control systems also provide operators with the ability to simplify the process and thus generate pump schedules more quickly. Operators can also make adjustments to model inputs on the fly.

One important area where control systems play a major role in improving overall efficiency is in leak detection. It's important to realize that water losses are also energy losses. Every lost gallon represents wasted energy that was used to treat and pump that water. In fact, AWWA estimates that there are around 237,600 breaks per year in US water systems leading to approximately $2.8 billion in lost revenue annually. However only around 10 percent of water losses occur in large

Examples of efficiency improvement projects

Metering stations / storm water runoff
- Optimization / rehabilitation of mechanical pumps
- Optimization / rehabilitation of drives
- Checking and upgrade of metering system

Preliminary treatment
- Optimization / rehabilitation of spiral mechanical pumps
- Optimization / rehabilitation of drives
- Proper control of pumps (control of sump height)
- Control of sand filter

Biological process area
- Optimization / rehabilitation sludge recirculation
- Optimization / rehabilitation sequence of disc aerators
- Reduction of sludge age (less O2 needed)
- Advanced control
- Optimization of aerators

Sludge thickening, stabilization and conditioning
- Optimization / rehabilitation of centrifuges
- Optimization of paddle mixers

Downstream optimization
- Application of power generation with digester gas
- Conversion of digester gas to high value fuel (methane)
- Application of high performance digester
- Application of waste water energy reuse (heat pump system)

pipe bursts—most are much harder to detect.

Leak management, then, falls into two broad categories: active leak management in which pressure levels are manipulated to minimize existing leakage flows and prevent the occurrence of new leaks, and passive leak management in which the focus is on finding leaks in their early stages and supporting a maintenance regime to address them. Modern process controls for water systems support both of these.

By constantly monitoring pressure and flow values across the pipeline network, control systems apply pattern recognition algorithms to identify anomalous events that could indicate leakage flows. Other data streams such as maintenance history, customer information and weather can be overlaid to narrow down the geographic area. As time goes on, the system builds on its "knowledge" of the system, constantly improving its ability to identify leaks.

Importantly, this kind of analysis does not require extensive system modeling, but using a hydraulic network model, water utilities can assess the probability of a leak in a given pipeline segment and prioritize maintenance activities accordingly. This leads to a maintenance approach that is more condition-based and predictive in nature.

Most US states have regulations on allowable water loss—most are in the 10 to 15 percent range—but the question remains as to where that lost water is going. Applying available leak detection technologies can help to distinguish between theft, fire use and simple accounting issues, for example.

Guidelines for efficiency projects

As the list below indicates, we have only touched on a few of the many potential opportunities for improving energy efficiency within the water sector. Any given project, however, should be evaluated within a larger view of water utility operations. A simple four-stage process is recommended:

- Identification of the given energy-saving project
- Assessment of the equipment involved, with specific attention to whether it is required to run the process, whether it can be run for fewer hours and whether the process can achieve the same results at a lower flow capacity
- Master plan development considering the technical feasibility and level of confidence in results, business impact vs. development requirements, timescale to implement, and estimated ROI
- Implementation of the project, assuming it makes the cut under the assessment and master plan stages

Projects that make the short list at water utilities typically yield a 5 to 10 percent improvement in energy efficiency.

Variable frequency drives offer one example of how proven technologies can be applied to increase energy efficiency in the water industry, but they also illustrate the fact that often improvements in efficiency come with associated benefits in other areas as well. Clearly, there is tremendous potential for technologies like VFDs and specialized control systems to improve energy efficiency, and in the process also produce substantial returns for the business.

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