Pump ED 101

Lift Station Level Control – Almost Utopia

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Back in the old days, level control had little or nothing to do with saving energy. In fact, it was often a necessary evil. Today, that is no longer true - - the VFD offers the potential for power savings in lift station applications that range from a few hundred gallons per minute to those that have to move thousands of gallons each minute.

A Little History

In an ideal world, the flow of wastewater into a wet well would be constant. We could then size a pump (or pumps) that could run continuously and remove that entire inflow at the same rate as its entry. The result - - smaller pumps that run at BEP 24/7. We learned, early on, that this approach would be impractical unless we could gain total control over the habits of the populace. Although this has been attempted in other parts of the world, history has taught us that it seldom works. These revelations led to a less desirable but more practical alternative known as "pump down".

Pump down is extremely simple - - when the water in the wet well rises to some maximum level, a pump starts and pumps the well down to some predetermined lower level. The pump then shuts down and waits for the water to rise again. Usually a wet well is sized for some minimum pump run time in order to keep the number of pump starts within the guidelines of the manufacturer. Some may be oversized and employ multiple smaller pumps in an attempt to emulate that Utopian system we envisioned originally. Overall, pump down can be a very effective and relatively efficient process.

Historically one of the challenges of lift station design, especially high flow ones, has been keeping pump starts to an acceptable level. In some cases this can be attained by installing multiple pumps and alternating them with each successive pump down cycle. Another method is to stage multiple smaller pumps and attempt balance outflow with inflow (level control). Although both of these methods work well in many installations, there are times when the necessary wet well volume becomes unrealistic or the number of staged pumps required cannot be accommodated. An alternative approach would be to vary the pumping rate by changing pump speed. This would allow outflow to be closely matched to inflow and thus reduce, significantly, the number of pump starts.

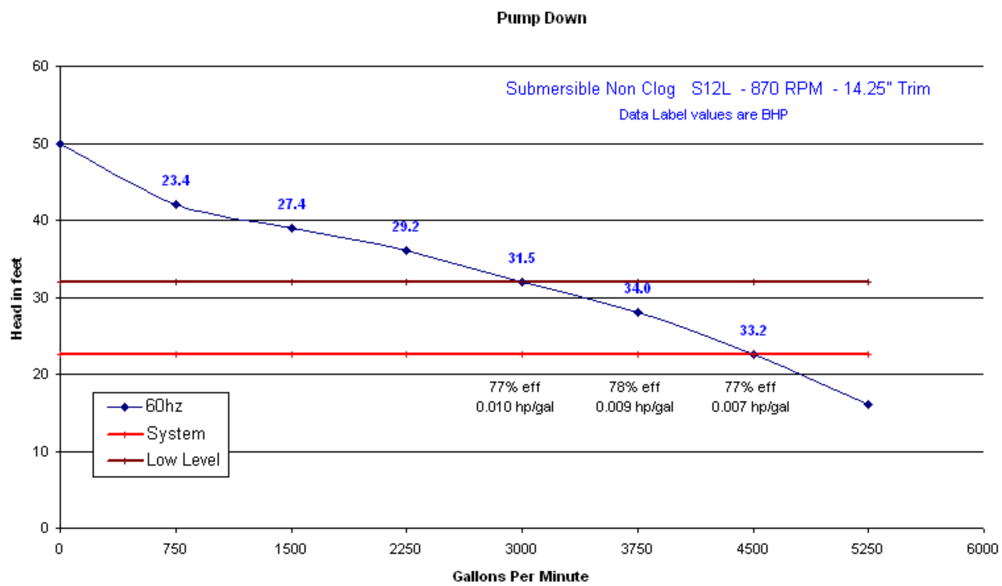
In the 1960's, well before the arrival of the VFD, a variable speed technique that employed a motor that was originally developed for constant torque applications became available. Figure 1 shows the rotor of the "wound rotor" induction motor. Rather than the imbedded bars, found in a standard rotor, it is wound with coils of insulated copper wire that terminate at a set of slip rings. Brushes, similar to those found in DC motors, allowed a resistance to be connected to the coils during motor operation. By varying the resistance of the rotor coils the slip speed of the rotor can be altered and that range varies from rated speed when the coils are shunted to approximately half speed at some maximum resistance.

The device that was used to vary the resistance seen by the rotor was known as a "liquid rheostat". Rube Goldberg died in 1970 but I think he must have spent his later years helping develop this machine. It consisted of large tank that contained an electrolyte (salt) solution and movable metal rods that were wired to the rotor brushes. When the rods were immersed deeper into the solution, resistance was lowered, due to increased surface area contact, and motor speed increased. When they were raised resistance increased and speed decreased. A bubbler system determined the wet well level and controlled a linear motor that raised and lowered the rods in an attempt to keep the level constant. The heat that was generated by the increased resistance was removed from the electrolyte solution by a circulating pump and heat exchanger. Rube would have been proud because it was a complex contraption and required considerable maintenance but, it met its goal – dynamic level control and decreased pump starts. The liquid rheostat was popular in the wastewater industry throughout the 70's and 80's and was still in use in the early 90's.

VFD Level Control

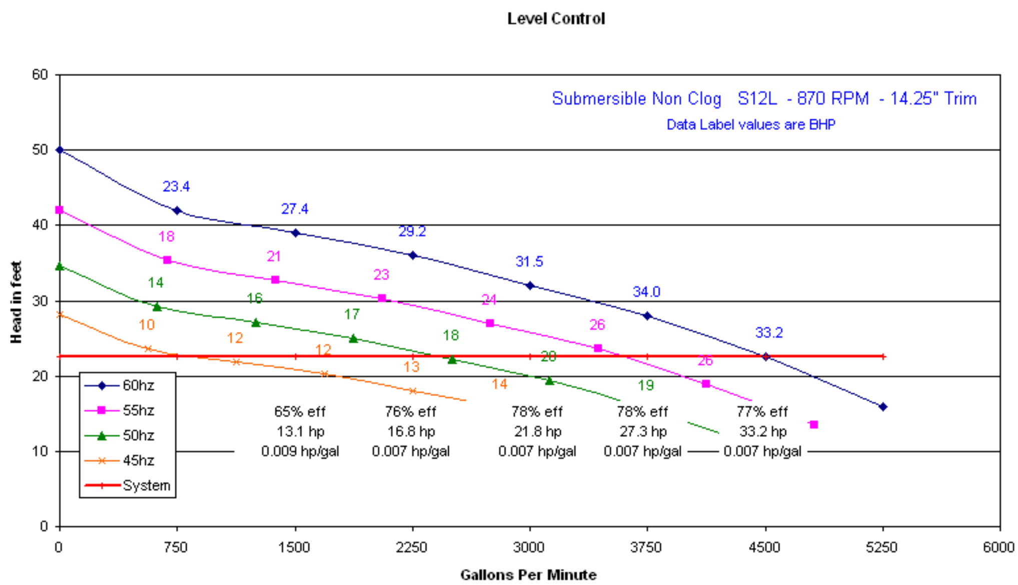
The liquid rheostat was all about controlling level for the purpose of reducing motor starts. Even though the required HP was reduced at lower speeds, the heat generated by the higher resistance tended to cancel any potential energy savings. Also, in order to keep from stopping the pump, it would often be forced to run at lower than optimal speeds which resulted in low hydraulic efficiency. Today, we can achieve level control without these drawbacks and save energy to boot. Lets compare a pump down and level control application that uses the same pump.

Figure 2 shows the performance of a 12" non clog, with an manufacturer approved flow range of 800 – 5500 GPM, in a pump down application. The red horizontal line at 22.5 feet is the static head seen by the pump when the wet well is full and the brown line at 32 feet is the maximum head at the end of the pump down cycle. The cycle begins at 4500 GPM and ends at 3000 GPM and, hydraulic efficiency is maintained at a healthy 77 to 78% across the entire range of the pump down cycle.



On first glance this appears to be a pretty efficient operation. All pumping occurs at or very near BEP and hp drops as we approach the end of the cycle. But, if we divide the hp required at each major flow point by the flow in gpm at that point we will gain an entirely different perspective. What we learn is that the power required per gallon pumped increases continuously as the wet well is evacuated. In our example it is 0.007 hp/gpm at the beginning of the cycle and 0.01 hp/gpm at the end - - an increase of almost 43%! Now there is nothing wrong with this - - it is normal for a typical pump down application. But it does indicate that there may be an opportunity to decrease power consumption.

Figure 3 shows the same pump operating under variable speed control. The colored curves are the pump HQ curves from 45 to 60hz in 5hz increments and the red horizontal line is the desired wet well level at a static head of 22.5 feet. The intersections of the HQ curves and wet well level line are the flow rates at that



particular frequency. As I have mentioned in my previous variable speed columns, the typical VFD has a resolution of 0.01 hz and an accuracy of about 0.1 hz, so be aware that there are actually quite a few more operating points than shown here.

The hp required at full flow is the same as before but, the data shown below each of the other major flow points are a result of reduced operating head and a leftward migration of hydraulic efficiency due to a reduction in speed. The pump can operate at flows as low as 2250 GPM (49hz) and not exceed its full flow power requirement of 0.007 hp/gal. Even at 1500 GPM (47hz), power increases to just 0.009 hp/gal or the 3750 GPM point in the pump down application. As flow decreases to 750 GPM (45hz, 40%eff, 10.7hp) the power required per gallon increases to 0.014 hp/gal.

So, how much power savings could we expect if this pump is used in level control versus pump down? It depends on the pumping range you decide upon. If you can keep flow above 2250 GPM pumping efficiency, per gallon, will remain at its highest level and power savings can be substantial. Although not entirely accurate, if you compute the average hp/gal using several points across the pump down cycle the result is about 0.0088 hp/gal. At a constant 0.007 hp/gal, level control will consume about 21% less power per gallon pumped.

One of the advantages of VFD operation is that we do not have to achieve "perfect" level control and can therefore avoid those higher power areas. If inflow drops below some acceptable minimum the drive can stop the pump, allow the level to increase slightly, and then restart the pump a short time later. The restart begins at a lower frequency (say 30hz) and then ramps up to the desired pumping frequency. By employing this "soft start" technique, starting current will never exceed the rated full load current of the motor and the number of starts per unit of time can be increased substantially.

Not all applications will benefit from level control. Lift stations with just a few starts per day are typically better suited for pump down. Potential level control installations include subdivisions and other municipal applications with continuous, predictable flows during certain periods of the day. Industrial processes and municipal wastewater treatment are also good candidates.

Although this column has focused on potential energy savings, there are other advantages that can justify level control. Soft start and stop can prolong both pump and motor life and first costs can often be reduced due to a smaller wet well requirement. There is also an inexpensive, variation on level control that can be applied to smaller pumps. Known as variable fixed speed (VFS) control it utilizes float switches to vary pumping speed based on inflow. We will take a look at this particular application in a future column.

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