Pump ED 101

Variable, Fixed Speed Control - - Float Switch Activation

Joe Evans, Ph.D http://www.pumped101.com

Introduction

It has been said that there is more than one way to skin a cat. In fact, there would probably be many, many more if we just had more recipes. Think of the effect on world hunger - - but I digress. There is also more than one way to use a VFD in a waste water pumping application.

Although level control is the most efficient form of VFD control, VFS or variable, fixed speed control can increase application flexibility and the potential for power savings compared to that of standard pump down control. This is especially true in the case of smaller pump applications. One of the reasons is the current (2006) cost of small VFD's. For example, some manufacturers offer 5HP drives under $500 and 10HP units are priced under $750. Add to this the wide range of flows (up to 1500 GPM) produced by these smaller, solids pumps and this control method can become extremely attractive.

The Application

The reason that VFS works so well is that it is kind of a backwards approach to typical pump down. Instead of waiting for the basin to fill completely, VFS kicks in when it is partially full. It starts with a slower, usually more efficient, speed and then takes advantage of the centrifugal pump's natural ability to increase flow as available head increases. A typical application that can take advantage of VFS is one where in-flow may vary significantly, but is relatively continuous during certain periods of the day. Often, these applications will employ a smaller (2-3HP) lead pump (jockey) that is sized in proportion to the lower in-flow. Larger (5-10HP), redundant lag pumps provide the additional flow needed during peak periods. This configuration results in fewer large pump starts and may result in a small reduction in the total power consumed. With VFS control you can get rid of the jockey pump and also make the lag pumps far more efficient. And, you can achieve this via the use of standard, on/off, float technology. In addition to increased efficiency the system can also take advantage of soft starts and stops, and greatly reduce the electrical, mechanical, and hydraulic stress's that can shorten pump life. Finally VFS will often allow a significant reduction in the size of the wet well and thus reduce first cost. In existing systems it can often reduce the pump down level by one half.

Most VFD's, even the lower cost ones, can provide both variable and fixed speed control. The former is achieved via a PI or PID algorithm that receives feedback from a 4-20ma level transmitter. The latter uses a series of on/off switches to set the drive output to some predetermined frequency. Most drives can accommodate a minimum of three different speeds and some will allow several more.

Simplex and Duplex Operation

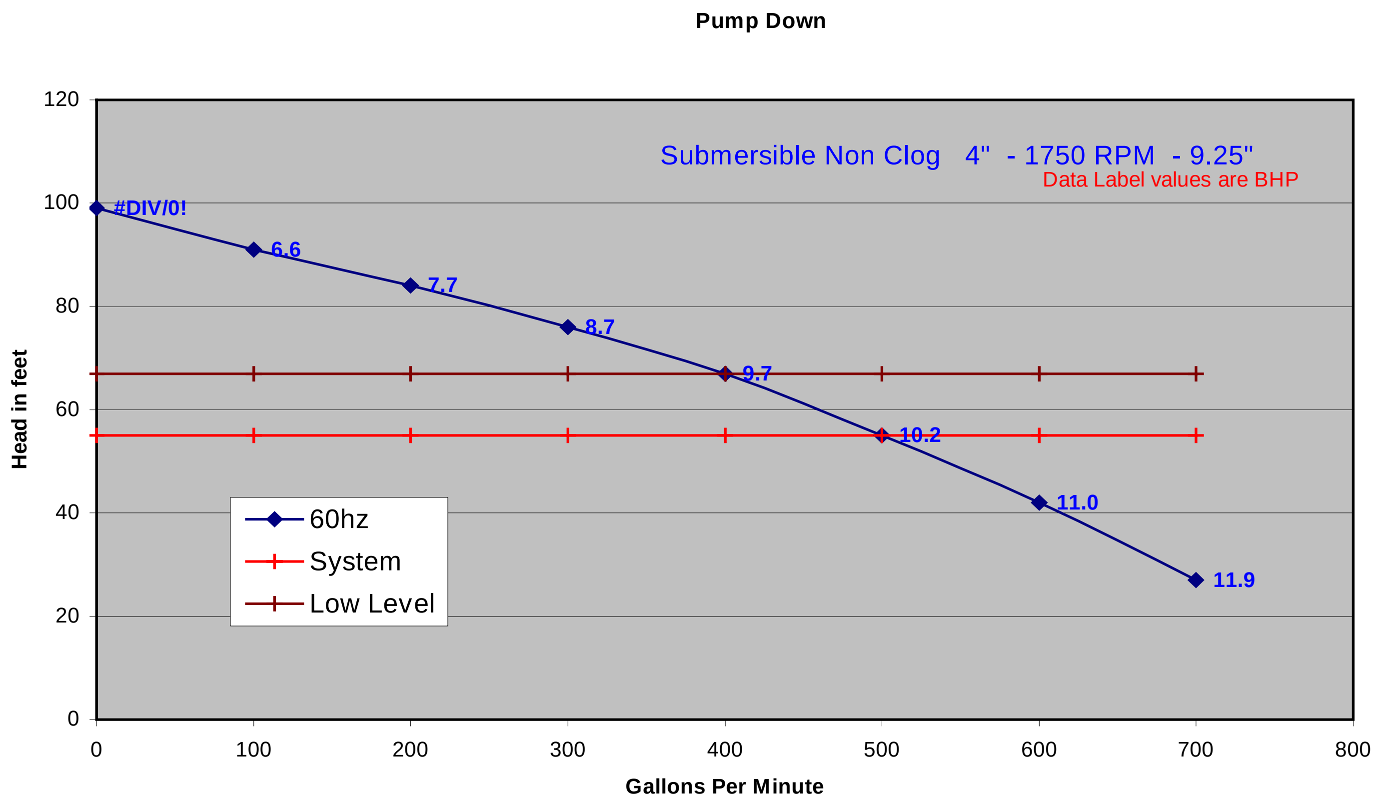
For example, a simplex system would typically employ four normally off, control switches - - pump off, on speed 1, on speed 2, and on speed 3. Switch 3 is positioned at the maximum allowable wet well level. Switch 2 is set a foot or so below switch 3 and switch 1 is several feet below switch 2. The off switch is positioned at the minimum allowable wet well level. When switch 1 is engaged the pump starts at it lowest speed and either maintains the level or pumps the wet well down and shuts off. If the level continues to rise, switch 2 is engaged and the pump increases its speed. If the level rises still more and switch 3 is engaged the pump will operate at full speed. As the level decreases, speed will again decrease as switches 3 and 2 move to the off position. This logic can be accomplished via wide angle floats in the case of switch 2 and 3 or, narrow angle floats plus some preset, minimum run time.

A duplex system offers three different control options. 1) The VFD can control the lead pump in the same manner as it did in the simplex example and the lag pump will operate across the line via an additional high level float. Alternation is not an option with this scheme. 2) If two pumps are sized to achieve the results of a single, larger pump and the capacity curve is relatively steep, the VFD can be sized to operate both pumps simultaneously. Both will run at the speed determined by the speed switches. Pump life is extended substantially (often beyond that of alternation) because they will usually run at about half of their individual capacities. 3) Finally two VFD's can be employed to control the lead and lag pumps individually and provide alternation on each successive cycle.

Examples

So, how much of a power reduction can we expect from VFS control. It will not be as much as true variable speed control but as long as the consumption is equal to or less than that of pump down we can gain several other benefits. Lets take a look at a couple of single pump installations and compare the power required for pump down and VFS control.

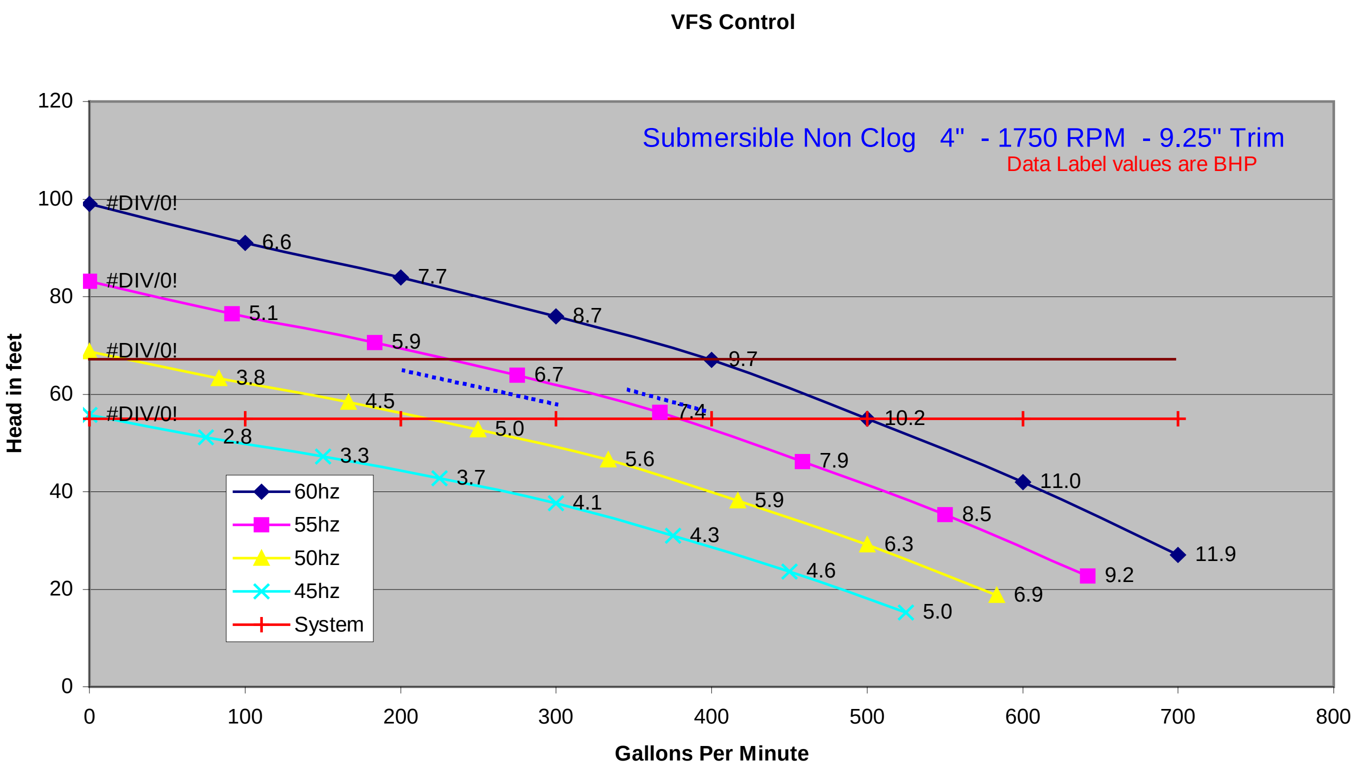
The example below illustrates the performance of a 4", 10 HP submersible nonclog operating in a pump down application. The red, horizontal line is the static or system head and the brown, horizontal line represents the additional elevation head (12') required to pump the wet well to its minimum level.



As the pump curve illustrates this application will draw approximately 10.2 HP at the beginning of the pump down cycle and about 9.7 HP as it approaches the end of the pumping cycle. Pump down can often be an inherently inefficient application because flow decreases much more rapidly than does HP as the wet well is pumped down. A good way to compare power consumption at various points, and between potential application techniques, is to convert total HP at any given point to HP per gallon of flow. If we do this we obtain a value of 0.0204 at 500 GPM and 0.0242 at

400 GPM. In other words the HP required to pump one gallon of wastewater increases by 18% as the level approaches the shut off point. That said, this particular pump is a very good selection for a pump down application because its relatively steep slope allows the pump down level to be reached at a flow point that is just 100 GPM below the starting point and has a similar hydraulic efficiency. But, since flow remains high throughout the cycle, the wet well volume must be sized appropriately if short cycling is to be prevented..

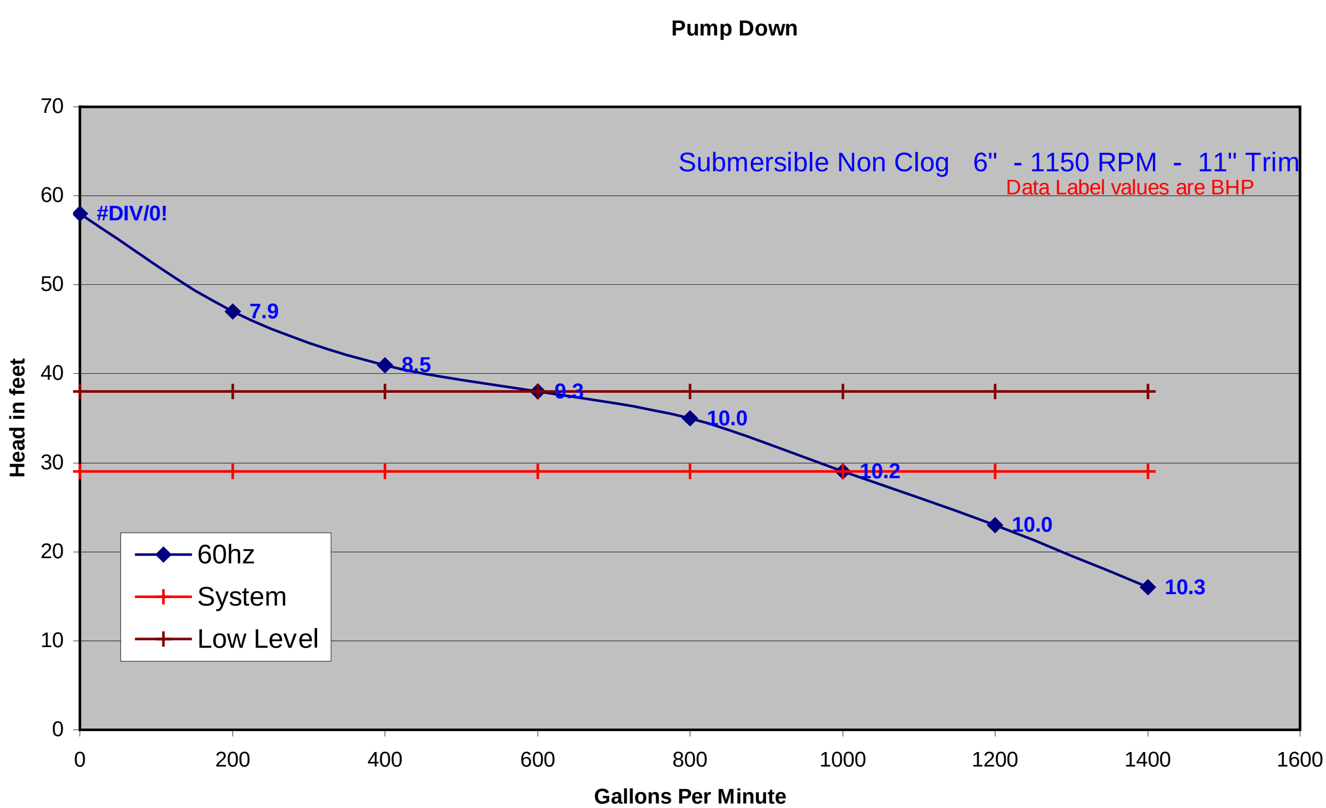
The figure below shows this same pump operating in a variable speed environment. The multi colored curves show pump performance from 45 to 60hz in 5 hertz increments.



Suppose, for a moment, that we set this application up for level control. We could us a control range of approximately 47 – 60hz to maintain the wet well level within a foot or so of the static or system head. But you have to be careful "how slowly" you allow the pump to operate. If you calculate the HP/gal for each of the major flow points you will find that, as flow decreases to about 200 GPM, HP/gal rises to a level that is greater than any of the higher flow points. And, it increases significantly as flow drops below 200 GPM. If the "pumping time" spent in this area is small compared to that of higher flows, we might safely set our minimum flow to about 150 GPM. If, however, we find that say - - 15 – 20% of the pumping cycle is spent there, we would probably limit our lower flow to 250 GPM. These guidelines are all about saving energy and, if maximum energy savings is not the major goal, a wider speed range may be used.

The same guidelines hold true for an application that employs variable, fixed speed control. The blue, dotted lines at approximately 53 and 57 hertz show the operating range of Switches 1 and 2. Switch 1 could be positioned to start the pump around the mid point elevation of the wet well. The initial capacity of 250 GPM will increase to about 300 GPM as the level rises and approaches Switch 2. When switch 2 is activated, capacity will increase to about 350 GPM and eventually reach 400 GPM as the level approaches maximum. At the maximum level, switch 3 is activated and the full speed flow of 500 GPM is attained. The positions of floats 1 & 2 and their corresponding fixed speeds can be adjusted for optimum performance once we have a little operational history. Since "full speed", minimum run time is no longer a concern, the off switch can also be set at a higher level and decrease to overall pump down elevation. The rate of change in speed, or acceleration, is parameter driven and can be set during start up. In this example 1hz/sec will provide good response and eliminate surging.

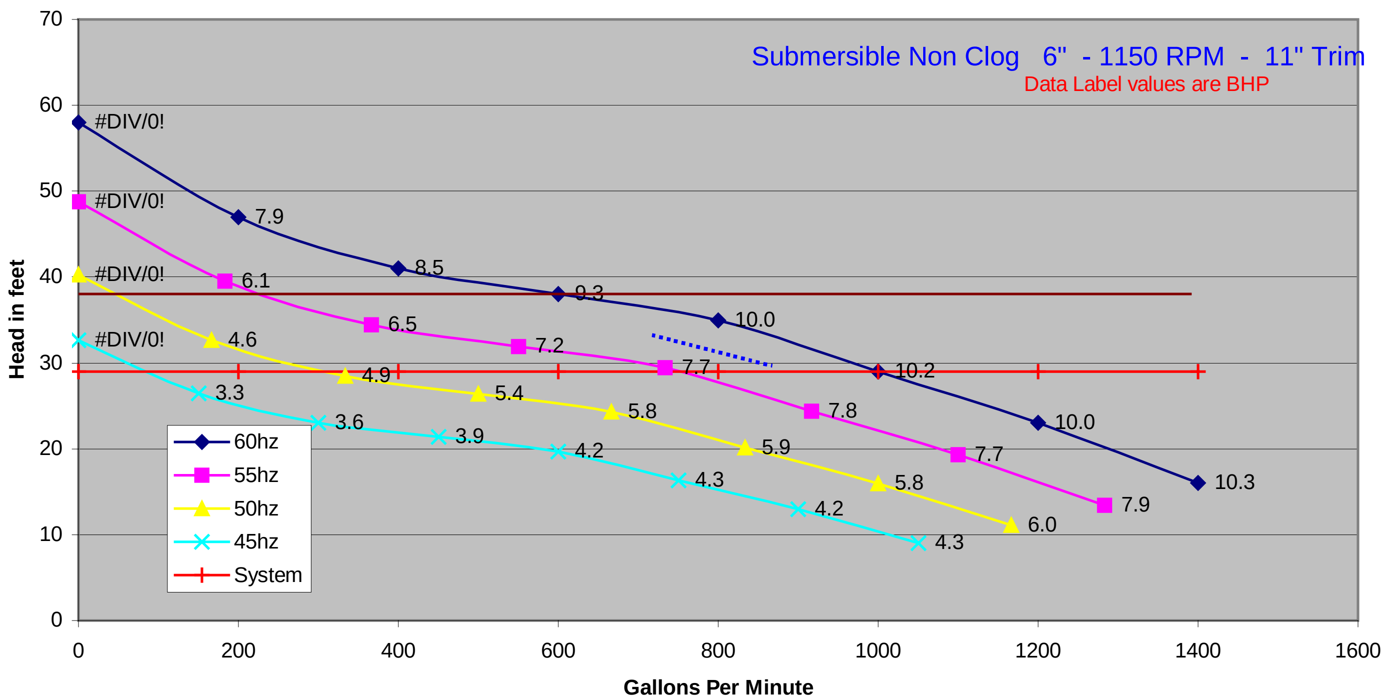
Lets take a look at a pump with very different characteristics operating in the same environment. The chart below shows a 6", 10 HP submersible nonclog operating in a pump down application. The red system curve shows a static head of 29 feet and the brown curve at 38 feet is the combination of static and pump down



elevation. At the beginning of the pumping cycle, the power required is 10.2 HP and at the end it is 9.3 HP. This corresponds to a HP/gallon of 0.010 at 1000 GPM and 0.0155 at 600 GPM or an increase of about 55% from the beginning to the end of the cycle. This substantially larger increase, compared to our previous example, is due to the increased flow range (400 GPM) required to reach the minimum pump down level.

Although this pump is still an good choice for this application, it will probably benefit, to an even greater extent, from conversion to VFS control. The chart below shows the same pump operating in a variable frequency environment.

VFS Control



Actually, this pump is an excellent candidate for level control because flow can decrease to 300 GPM before HP/gal rises to the level seen in the pump down application. And, the flows at 400 GPM and above have values similar to that of max flow. That said, it can also benefit from VFS control.

Because the head / capacity curve has a gentle slope from 300 GPM to full flow, we can use a very narrow frequency range (55-60hz) to control flow and minimize energy consumption. For example, if speed 1 is 55hz, switch 1 could be positioned to start the pump at about 5' and switch 2 could be set to activate at 8' with a speed of about 57hz. This arrangement will provide a flow progression of 400 to 900 GPM. And, chances are that speed 3 will seldom, if ever, be needed. Again, float levels and fixed speeds can be adjusted for optimum performance once we gain a little history.

So now you have an option. If level control will not work in a particular application or if you just like float switch logic, VFS may be an alternative. It is not limited to the small pumps in our examples - - I used them simply because of the low cost of small VFD's. And, I cannot overemphasize the value of soft starts and stops. If you start a pump at 30hz and then ramp up to the desired speed over a period of a few seconds, the inrush current is reduced below that of full load current. The result is longer insulation life. Also, the mechanical stress caused by Newton's third law is also greatly diminished. And, this stress affects not only the pump components but the motor stator as well. Finally soft starts and stops can virtually eliminate water hammer.

You do, however, need to pay attention to a couple of conditions. One is minimum pump flow. Since VFS typically operates over a limited speed range, make sure that the minimum speed does not produce a flow that is lower than that recommended by the manufacturer's pump curve. This is usually not an issue when the speed range is 15hz or greater but it can be when the range is limited to 5 or 10hz. The second condition is flow velocity. In any solids application the flow must be great enough to create the velocity necessary to keep solids suspended.

Joe Evans
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