

## Variable Frequency Control - Other Advantages

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So, reducing energy consumption in that constant pressure or circulation application is not a priority or maybe converting from pump down to level control leaves you wondering if it will really pay off? Not to worry - - there are several other advantages that may make VFD control worth investigating. Lets take a look at a few and I will let you determine if they, alone, might justify the cost.

### System Stress

The stresses seen by a pumping system can be lumped into three basic categories - [hydraulic, mechanical, and electrical](#). Some may affect a single component while others can involve the entire system. If left unchecked, these stresses can reduce the life of a pumping system. The soft start and stop feature that is provided by VFD control can significantly reduce or even eliminate many of their potentially damaging effects. When a VFD performs a soft start, it simply starts the pump at a lower frequency (speed) and then ramps up to full speed over a period of a few seconds. The soft stop is performed in the same manner but in reverse order.

[Hydraulic stress](#), which we typically refer to as waterhammer, is usually the result of an abrupt change in flow. In many cases these abrupt changes are due to the opening or closing of a valve or the starting or stopping of a pump. The shock waves that are generated during waterhammer can travel at the speed of sound and the additional pressure that they generate can be particularly damaging to a pipeline and other components within the system. Although it does not take into account pipe size and elasticity the equation,  $P = \alpha V / 2.31g$ , will give us some insight as to just how much additional pressure can be generated by waterhammer. In this equation,  $P$  is the additional pressure,  $\alpha$  is the shock wave velocity,  $V$  is the velocity of the water flowing in the pipe, and  $g$  is the universal gravitational constant @ 32 ft/sec<sup>2</sup>. At a pipeline velocity of 5 feet per second, the additional pressure generated by waterhammer is over 300 PSI. Increase that velocity to 10 fps and additional pressure increases to more than 600 PSI!

Now, the VFD cannot prevent the waterhammer that might occur during a power outage or when someone slams shut a downstream valve but, its soft start and stop

feature can significantly reduce or even eliminate the waterhammer due to normal pump starts and stops.

**Electrical stress** can affect both the motor and the power supply system. In the case of a motor that stress is in the form of heat. The typical induction motor consumes five to seven times its normal run current during across the line starting. This large increase in current produces additional heat in the stator windings and, over time, it will degrade the insulation. This degradation increases significantly when motors undergo frequent starts and especially when starts per period of time exceed those recommended by the manufacturer.

In addition to stress on the motor itself, the surrounding power supply system can also experience problems when large motors are started across the line. The reduction in available power, during starting, can lead to annoyances such as dimming of lights to less subtle problems such as temperature increases and tripped breakers in other circuits.

Almost any centrifugal pump can be started at a frequency that will reduce starting current to that, or less, than normal run current. It can then be ramped up to full operating speed over a period of seconds. This not only eliminates stress on the motor and surrounding system but also allows an increase in the number of starts per period of time.

**Mechanical stress** can affect both the motor and the pump. A typical 1750 RPM motor with no load will accelerate from rest to synchronous speed in less than one second. Add a centrifugal load and it will still perform that feat in less than two seconds. Depending upon its diameter and mass, the impeller and the fluid flowing through its vanes can create a significant inertial load during starting. One of the areas that sees the effect of this load are the shaft and impeller keyways. Also increased radial forces are generated which can place an additional load upon the bearings. If there is shaft coupling misalignment, you can expect additional stress in that area also.

The mechanical stress of acceleration also has an effect upon the motor itself. Newton's third law states that for every action there is an equal and opposite reaction. The interactions between the magnetic fields that cause the rotor to begin rotation also try to rotate the stator in the opposite direction. Since the stator is fixed to the motor housing and the housing is usually bolted to some other structure, this typically does not occur. What can happen, however, is a miniscule movement of the windings. Although extremely small these motions can

degrade the insulation over time. A soft start will greatly reduce all of these mechanical stresses.

### Power Factor Correction

The VFD is a little like Las Vegas in that "whatever happens in VFD land usually stays in VFD land". By that I mean that the VFD prevents the rest of the circuit from seeing the inductive load of a motor by isolating it behind its DC buss. VFD manufacturers will often quote a PF close to unity on the line side of the unit but, if they are not properly filtered, the harmonics that can be generated can reduce PF to as low as 0.7. Some VFD's have internal line side filtration while others require an external filter. Check with your VFD manufacturer to find out what type of filtration is required to maximize power factor.

### Single to Three Phase Conversion

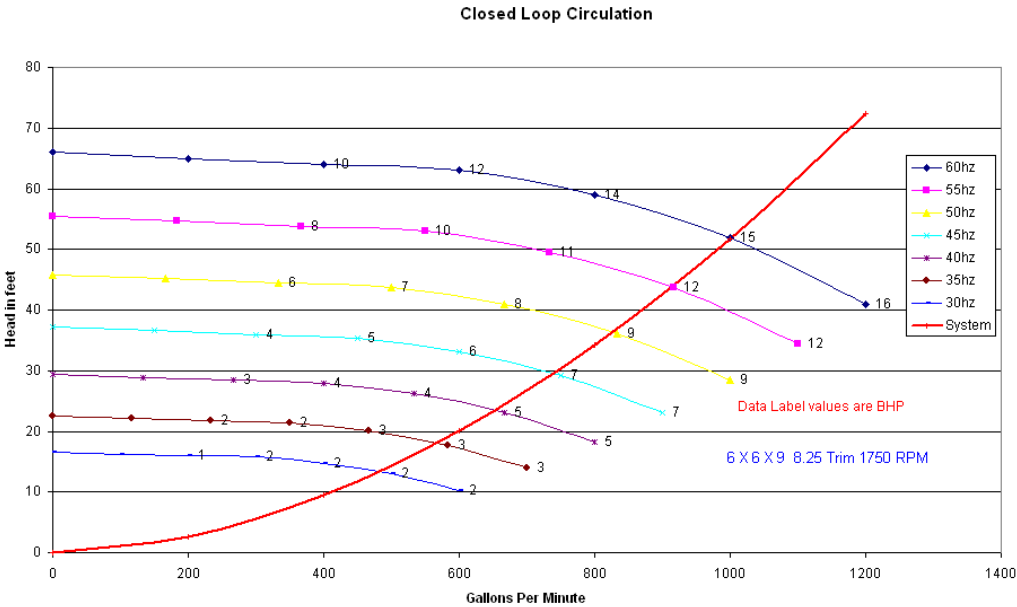
The VFD offers us an alternative to other forms of power conversion in areas where three phase power is unavailable. Since it converts incoming AC power to DC, the VFD really doesn't care if its source is single or three phase. Regardless of the input power, its output will always be three phase and, you get soft start and stop for free. Drive sizing, however, is a factor since it must be capable of rectifying the higher current, single phase source. As a rule of thumb, most manufacturers recommend doubling the normal three phase capacity of a drive that will be operating on single phase input.

### Open Delta Phase Balancing

There are times when utilities will use two transformers, instead of three, to produce three phase power. This open delta connection is often seen in more remote areas where a relatively small amount of three phase power is needed and lower installation cost is a factor. One of the problems with this lower cost approach is that there is a high potential for phase and voltage imbalance. This will cause current imbalance in a three phase motor which can significantly shorten its life. Since the VFD converts the incoming AC to DC and then generates its own three phase output, voltage will always be balanced. My little community near Mt. Hood in Oregon uses VFD's on both of our well pumps for this very purpose. In addition we can also take advantage of soft starts and stops.

# Application Changes

There are times when we can actually design a pumping system that will operate at its design point from the day it is commissioned until it has to be replaced due to old age. But, more often than not, the requirements can change considerably. Take, for example, a constant pressure system installed in a new subdivision. Many of these will operate well below design flow until the project is completely built out and this could take years. Commercial and industrial projects are not immune to this scenario either. Many designs include pumping systems that are sized to accommodate flows that may not occur for several years. Figure 1 shows how a VFD can be used to match pumps, designed for future growth, to current conditions.



Here we see a simple, closed loop circulation application with a build out design of 1000 GPM @ 52'. The system curve represents the friction that arises in 450' loop of 6" steel pipe. Suppose, that initially, only 650 GPM is required. You could regulate flow with a valve and the HP required would decrease from 15 HP to about 13 HP. Or, you could use a VFD to reduce both flow and head and further reduce the HP required to about 5 HP. At this point the drive would be operating at 40 hz (1166 RPM). If required flow increases to 825 GPM, you could reset the drive to operate at 50 hz and obtain a power savings of about 5.25 HP over that required by valve regulation. In addition to more efficient operation you also can take advantage of soft start and stop.

This same scheme can be employed in reverse to accommodate application shrinkage. If demand declines a VFD can slow the pump and reduce the power required without replacing the entire system.

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