VARIABLE SPEED DRIVES – SAVING ELECTRICITY AND MORE IN MODERN IRRIGATION

What can they do for us in the irrigation industry?

By John Starke, Irri-Gator Products (Pty) Ltd.

When using Variable Speed Drives (VSD) there are many benefits and cost saving possibilities, writes John Starke. Not only does this modern electrical device allow the possibility of unlocking electrical savings, VSD also for the first time enable the farmer to take control of the pump. It now becomes possible to manage the operations of the pumping unit, such as ramping periods, controlling the flow or pressure according to various variables. The pump/s can also be started and controlled remotely, via GSM (cell phone modem technology) and RF (radio frequency) devices with ease.

BRIEFLY, VARIABLE SPEED DRIVES (VSD) DELIVER THE FOLLOWING BENEFITS TO OUR INDUSTRY:

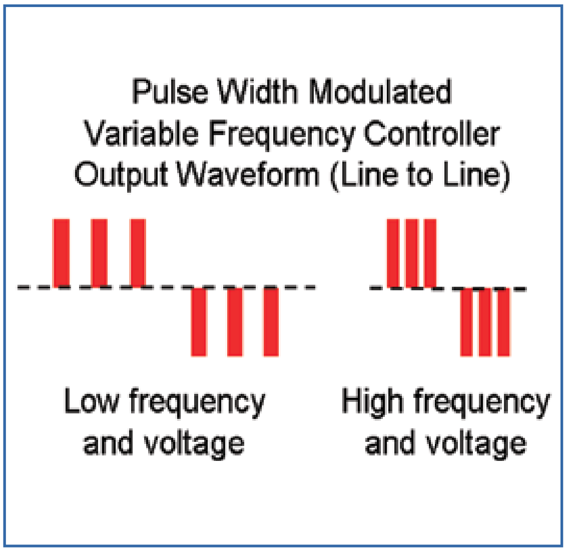
- Electricity savings
- Control of start up and shutdown procedures
- Reduces motor burn outs
- Prevents shaft breaks
- Reduces wear on pumps and motors
- Keeps pumps working at best efficiency points on curve
- Minimises water hammer in pipelines due to controlled acceleration/deceleration
- Reduces voltage draw down on power lines at start up
- Eliminates need for pump control valves in many instances
- Controls pump to deliver accurate flows or constant pressures

WHAT IS A VARIABLE SPEED DRIVE?

"Frequency Inverter" is perhaps a better term to use when looking for a definition for this device which is used for controlling electric motors. Whilst researching a definition, I realised that I could not phrase it better than the one below in Wikipedia:

"Variable frequency drive controllers are solid state electronic power conversion devices. The usual design first converts AC input power to DC intermediate power using a rectifier or converter bridge. The rectifier is usually a three-phase, full-wave-diode Bridge. The DC intermediate power is then converted to quasi-sinusoidal AC power using an inverter switching circuit. The inverter circuit is probably the most important section of the VFD, changing DC energy into three channels of AC energy that can be used by an AC motor. These units provide improved power factor, less harmonic distortion, and low sensitivity to the incoming phase sequencing than older phase controlled converter VFD's. Since incoming power is converted to DC, many units will accept single-phase as well as three-phase input power (acting as a phase converter as well as a speed controller); however the unit must be derated when using single phase input as only part of the rectifier bridge is carrying the connected load."

This is a fair mouthful, however what is important to note is that it is a **solid state device** for controlling electric motors and therefore has no contactors which can burn out. **Power factor correction** is built into most drives of the conventional range, in some situations single phase incoming power can be used with certain limitations. **Essentially, in the VSD AC power is internally converted to DC** and using a system called Pulse Width Modulation (PWM) **the frequency of the electrical wave (usually supplied at 50 Hz)** is changed (reduced by no more than 50% or increased by not more than 20%) which gives us different speeds on the motor.



The VSD, therefore, has as its main function the ability to vary the speed of the motor it is coupled to. Furthermore it has inbuilt electrical protection devices such as phase failure, phase recognition, over/under voltage protection, amperage protection. It is capable of recognising the direction of rotation of the motor which is important in automatic restarts.

When using a VSD coupled to an electric motor which is in turn coupled to a centrifugal pump the Laws of Affinity come into play.

THESE LAWS DEFINE THAT, IF THE IMPELLER SIZE OF THE PUMP IS KEPT CONSTANT AND THE SPEED IS VARIED:

1. **Flow rate** is proportional to the shaft speed;
2. **Pressure Head** is proportional to the square of the shaft speed;
3. **Power required** is proportional to the cube of the shaft speed.

A. $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$

B. $\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$

C. $\frac{BHP_1}{BHP_2} = \left(\frac{N_1}{N_2}\right)^3$

The benefits with regards to pumping water is that we can now use the same pump and impeller for varying flows and heads, and still keep it as close as possible to the best efficiency point on the pump's curve. Best of all we will only use the electricity required for the work done with no unnecessary energy losses due to throttling valves etc.

CENTRIFUGAL PUMPS

A few basics which tend to be forgotten:

- Always start and stop against a closed valve
- Run a pump according to its best efficiency point (BEP) on the curve
- Choose the driver motor size (kW) according to non-overload for the impeller size
- Always fit a non return valve on the delivery side of the pump after the main valve in such a manner that the load of the thrust which is applied upon it from the water returning following an uncontrolled shutdown is dissipated as soon as possible into thrust blocks. Never allow the thrust be taken up by the pipe work or volute casing.

With a VSD fitted to the motor of the pump, the drive can be programmed to start from zero RPM to the maximum required speed over a specified period of time which will allow the column of water to start moving slowly. The reverse is also true when stopping the pump. The pump can start automatically after power failures and can easily be started using remote control via GSM or Rf.

APPLICATIONS USING A VSD IN THE PUMPING OF IRRIGATION WATER

A. Single pump with multi head duty points.

This is possibly the most common application for a VSD in pumping applications. In a situation where a pump has a fairly constant flow, but a varying head due to the topography of the land we are able to change the pressure of the pump by changing the rotational speed of the pump. In doing this it is possible to unlock considerable energy savings!

This system can be used in most of the different irrigation systems from micro/drip to sprinklers and centre pivots. In fixed block systems such as micro irrigation, the irrigated area can be divided into different height zones and each zone can have a different pressure requirement at the pump station. For instance, if there are 5 zones requiring from 3, 4, 5, 6 and 7 bar respectively to fulfil the highest duty point, the VSD will then ramp the pump speed up or down at the requirement of the valves as they operate in their respective zones. This can be either manual or automatic. With a centre pivot for instance, if the land is sloping, it too can be cut into sectors which require different pump pressures. These points on the circle of the pivot can be activated by means of limit switches which are activated and deactivated as the pivot traverses its arc. The signals can be relayed either by wires or by using wireless signals sent to the VSD to activate the different set points.

The point of the exercise is to strive to create only the energy required at the different duties by the system to work optimally and not to have to waste energy due to using throttling devices. These devices can be pressure reducing valves; flow control valves; orifice plates and similar. It is seldom possible to be exact and practical, so most of the time we cannot discard these devices entirely but rather use them for the "fine tuning".

The VSD operates on PID (a proportional–integral–derivative controller is a generic control loop feedback mechanism) using a 4 – 20 milliamp pressure transducer fitted in the discharge line of the pump. This pressure transducer will give feedback on the actual line pressure and the VSD will compare this to the pressure setting on the drive as set by the potentiometer (set point).

B. Pumping with multi flow

In a scenario such as where we have a pump with a fairly large capacity and operating a number of irrigation blocks or number of sprinkler lines, we are able to allow the flow to vary and maintain a constant operating pressure. In other words, when cutting back on flow, the pump will reduce in speed and the flow will reduce, but still keep as close as possible to the best efficiency point on the curve. As the system calls for a larger volume of water the pump will supply more but keep a constant pressure.

If there are two pumps in parallel, it is possible to use two VSD's and allow them to cascade. This means when pump 1 exceeds its flow and the pressure condition can no longer be met as it is pumping too far to the right on the pump curve, the 2nd VSD can be called in and then the 2 pumps will balance out in flow and supply what is required at the determined pressure. As the flow increases or decreases, the pumps will ramp accordingly until the flow decreases and the 2nd pump is no longer needed and it will fall out and only pump number 1 will operate.

A similar way of dealing with varying flows at constant heads can be solved using one VSD and conventional Star Delta starters on the other motor/s. There are positives and negatives in each of these scenarios which require investigation on a case by case scenario.

C. Serial Pumping

Two or more pumps in tandem can also be controlled with VSD's. Using either a VSD at each pump (ultimate flexibility) or one VSD coupled with Star Delta starters on the subsequent motor/s.

As the 1st pump ramps to its maximum hertz and maintains it for a determined time the 2^{nd} drive can be pulled in and then the two operate together. These can be programmed so that either both float together or one operates at maximum and the other fills in the difference required. Here too a Star Delta combination can be used. The Star Delta can be fitted to the 2^{nd} pump and when the VSD is at its maximum it can bring in the Star Delta and then ramp down to meet the exact requirement of the system. Again there are positives and negatives in each of these scenarios which require investigation on a case by case scenario.

D. Pumping from a Borehole

With many boreholes the dynamic water level and correctly tested flow rate is not known. This results in many pumps working well to the right of the curve (or too far left). A VSD is able to control the pumping from a borehole by pressure or flow control. This will extend the life of many pump units as they will operate closer to their best efficiency points on the curve. If the borehole is pumped at the correct volume according to the 48 hour constant flow tests it will last longer than when poorly managed by over pumping.

SUMMARY

In summary, when using a VSD there are many benefits and cost saving possibilities for pumping applications in the irrigation sector.

It is important to look at a Variable Speed Drive application for a motor in conjunction with the curve of the pump. The hydraulics of the system need to be understood and best is to plot the curve onto a simulation program which can show how the varying speed influences the characteristics of the pump. This coupled with the change in kilowatts power consumed at the different duty points will allow the customer to make an informed decision.

Irri-Gator Products, the importer and supplier of INVT CHF range of Variable Speed Drives, design and build panels according to the pumping system's requirement. These panels are easy to install and manage; are backed up by Irri-Gators team of professionals. A range of devices such as the Gator short distance radio and Cellulink II GSM controller can be fitted to add extra flexibility to the final product which will help the irrigator reduce electricity costs and manage a more flexible modern pumping system.