Department of Primary Industries

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Variable speed drives — an energy-saving option for irrigated horticulture

August 2016 Primefact 1398 First edition
DPI Agriculture Water and Irrigation Unit

A variable speed drive (VSD) is used to adjust a pump's flow or pressure to the field requirements (actual demand). Adopting VSDs in irrigation was historically for operational reasons such as providing constant pressure outputs, 'soft starts', or reducing pump wear. More recently, as energy prices continue to rise, the opportunity to save energy has emerged as a more important objective.

Irrigation pumping costs can be higher than they should be for three reasons:

1. More water than necessary is pumped and applied to a crop.
2. The pump has a low operating efficiency, and operating away from its best efficiency point (BEP).
3. The pumping pressure, or operating head produced, is greater than necessary.

This Primefact discusses using VSDs (variable speed drives) as a method to potentially reduce a pumping plant's required operating head to achieve reduced energy usage. Two case studies describing the reasons why and issues related to the adopted VSDs are also presented.

Advantages of VSDs

Where a single speed pump has been installed for a range of duties, it is usually sized to meet the greatest output demand. It will therefore be oversized and operating inefficiently for the remaining lower demands. During these periods of reduced demand, there is an opportunity to achieve an energy cost saving by using variable speed to reduce the power needed to drive the pump. VSDs allow the pump to be over designed to meet extreme requirements, without having continuous energy wasted during low demand.

Conventional methods for flow control in irrigation include throttling valves, impeller trimming or pump speed adjustments. These adjustment methods are reasonably permanent and unable to easily cater for the variable load requirements of pressurised irrigation. When irrigation situations demand flow adjustments from a pump, VSDs offer convenience and great potential for energy cost savings.

VSDs allow small variations in pump speed to be made rapidly and regularly. The most popular type of VSD for irrigation is the variable frequency drive (VFD) that controls electric motors by varying the frequency and voltage supplied, and which usually prove to be the most cost-effective. Other options do exist, including multi-pump VSD systems, which can cater for very small to large flow rates.

VSD systems are often a viable option for pumps that experience highly variable demand situations. For example, delivering water sequentially to irrigation units of variable size and elevation, subtle variations such as changes in river or bore height, and more frequent operations such as filter backflushing, can all require variable flow or pressure. Each of these situations has unique pressure and flow requirements.

Other benefits

- VFDs are also soft-start devices. These have ramp time adjustments for slow start and slow stop, eliminating the problems of water hammer and excess power draw on start-up; reducing or avoiding flow or pressure surges.
- Reductions in speed can also have major benefits in reducing pump wear, and in particular on bearings and seals.
- Improvements to system hydraulics ('hydraulic optimisation' such as installing low pressure filters or dripline) can lower the operating head, but unless the pump has the ability to respond to this lower head, energy savings will not be achievable. VFDs allow potential energy savings in an irrigation system to become realised savings.
- There are also agronomic benefits. In pressurised irrigation situations using single speed pumps where variable flows are required, managers in the past have tended to off-load water to shifts or patches that did not necessarily require an irrigation event. Managers do this in order to keep single speed pumps operating at their most efficient duty point. With a VFD, pumps can automatically adjust to suit the conditions, and therefore there is no need for managers to deliver unnecessary water to irrigation patches. This improves irrigation scheduling, avoiding rootzone waterlogging and water wastage, and increases the potential for high production while at the same time keeping energy costs to a minimum.

Taking advantage of positive suction head

Some communal irrigation supply districts (e.g. Coomealla and Curlwaa in the Sunraysia, and other districts around Leeton and Griffith in the Murrumbidgee Irrigation Area) have a level of positive suction head that is delivered to the farm outlet through a pressurised supply main. In situations when re-pumping is required to achieve a particular pressure and flow (duty point), a VFD is the best method to use the supply pressure available. The level of supply pressure is often variable between and within irrigation events, depending on demand from other users, making more permanent options such as impeller trimming or fixed changes to pump speed (RPM), unattractive alternatives. In a study conducted in Coomealla in 2011, it was found that if reasonable supply pressures are available at an outlet (100 kPa or greater), it was worth considering installing a VSD to take advantage of this supply pressure and reduce energy costs.

The study found:

1. With a fixed single speed pump, inlet supply pressure has no effect on pumping efficiency or power consumption.
2. With a variable speed driven pump, power consumption reduces with increased inlet supply pressure.
3. Although a fixed single speed pump requires less power when operating at low flow rates, power consumption is still considerably higher than that of a variable speed driven pump at the same flow rates.

Key requirements

Electrical

Usually there are no significant issues regarding power supply when VFDs are installed. A certified electrician must be used, but as the installation usually results in less power consumption, there should be no issues with your energy supplier. Drives manufactured to the international standard Ingress Protection Rating 54 (IP 54) are the minimum acceptable given the extreme conditions of some installations.

If retrofitting onto an existing motor, check the recommended minimum speed limitation. If the motor is run at low speed, overheating can occur. Harmonic filters can also be required to avoid efficiency reduction due to the motor overheating or misfiring.

Water supply

VFDs make it possible to achieve the very low flow rates that some irrigation systems might require. However, it is important to be aware that water meter accuracy can sometimes be compromised at very low flows (e.g. 150 mm propeller meters are inaccurate below 9 L/s) and approval from water supply authorities for diverting such low flows might be required.

Cooling

VFD performance de-rates (a reduction in the maximum capacity a VFD can reliably handle) at approximately one per cent for each degree above 40 °C, hence the need to maintain a relatively cooler temperature. The need for cooling has been a particularly important consideration in the past. With the development of new VSD technology, in many cases simple ventilation and insulation is now proving adequate (see case studies). In some situations, the pumping unit is deliberately oversized to ensure less heat is generated. Some manufacturers now produce a ventilation attachment to electric motors to circulate air and provide the necessary cooling.

Hydraulic

To fully allow for the variable pressure requirements that can exist in an irrigation system, there should be at least two transducer set points. This is particularly the case for drip irrigation where a certain pressure requirement is needed to operate the irrigation system, and (usually) higher pressure is required when backflushing filters and operating the system simultaneously.

Gravel filters, for example, require approximately 27.5 m (275 kPa) pressure to backflush correctly. The pressure required for operation when irrigating could typically be 15–20 m, depending on the size of the system and existing elevation. In this situation, a head of 30 m can be used to select a single speed pump to meet the range of duties required. However, depending on water quality and the size of the filter bank, backflushing might only occur for 2–10 minutes of each hour. The pump might only be operating at this high duty point 5–20% of the operating time, and is, therefore, oversized for the remainder of the time and consuming additional energy.

One transducer set point located upstream of the filter bank, synchronised with timed backflushing, is required to increase the pump speed to meet backflushing requirements. This can also be made to occur when backflushing is conducted, using pressure differential as the trigger, which (depending on water quality) has the potential for further energy and water savings.

Another transducer set point is located at a representative point in the field to ensure enough pressure is produced to operate the system. Further transducer points can be an advantage in irrigation systems where large elevation or spatial variations occur, or different irrigation valves require significantly different pressures to operate correctly.

Some VSDs have options (termed ‘adaptive programming’ or ‘friction compensation’) that deliver even greater flexibility. For example, they might provide the most appropriate duty point when a system has a long mainline that could have high friction losses at high flows (and therefore require a higher duty) and virtually no friction loss with smaller flows.

With a VFD installed, existing regulating valves can often be opened up (or possibly removed) to use positive static heads, and then used as isolating valves only when necessary.

Pump efficiency

Pumps that are initially efficient can become inefficient through pump wear or changes to duty points due to changes to the irrigation system, such as converting from sprinkler to drip irrigation. Replacing worn pumps or impellers, trimming impellers and replacing mismatched pumps can improve efficiency. It is important to note that a VFD does not improve the pump efficiency. It simply reduces the input energy requirements by producing the flow and pressure combination that is required at that particular operating time.

When a VFD slows a pump down, the reduced flow rate can actually result in the pump operating less efficiently (see Primefact 1410 *Electric pumps — performance and efficiency* to calculate pump efficiency). While this is happening, however, the energy use is still reduced, resulting in an energy cost saving. Calculations can be made to determine which option results in the greatest energy savings. If the irrigation system requires significant flow rate variations or experiences frequently variable supply pressures, then using a VSD to slow down and speed up the pump regularly in response will usually result in the greatest energy savings.

Managing the installation

VFDs can be retro-fitted to existing systems or installed with new systems. Retro-fitted applications require additional earthworks if a hard-wired transducer set point is needed a large distance from the pump, unless telemetry systems are adopted.

A general concern with VFD installations is that the electrical contractor involved might not recognise or understand the unique hydraulics of a particular irrigation system. Specific issues for each situation involve identifying the appropriate location and setting of transducer set points. Managers should ensure that adequate communication occurs between the electrical contractor, the irrigation designer, and in some cases an irrigation agronomist. An irrigation agronomist can identify particular aspects of the enterprise (such as soil type variation, the need to apply cooling irrigations, fertigation, or the desire to adopt specific pulse or regulated deficit irrigation practices) that might result in further variations to pressure requirements.

No two irrigation systems are alike, and no two VSD requirements are the same. The unique hydraulics of the system must be correctly merged with the unique electrical requirements for every situation.

There are instances where VFD equipment has been installed without realising the intricacies of the irrigation system hydraulics and pump performance, resulting in a system that is energy inefficient. This can result from pumps that operate so far from their BEP with the VFD that the benefits from the head and flow reduction were outweighed by the pump operating at very low efficiency point on its performance curve. It is highly recommended that a professional pumping hydraulic design service is used to evaluate your irrigation system before VFD equipment is purchased and installed.

It is also important that VFDs are commissioned correctly and all safety cut-outs (high pressure, low pressure, loss of prime etc.) are set and tested. These are often overlooked, causing major issues over time. Managers should learn the basic operations of their VFD. This usually involves scrolling through a menu (as per a Mobile phone), to obtain information such as the current speed, current amps, pressure, etc. An understanding of this is useful if a pump faults. All VFDs also have a fault memory, so if a pump faults, there is always a history of when and why, which is helpful for diagnosing and resolving issues.

Case study — Andy Murdoch, drip irrigation, Coomealla NSW

Why VSD was installed

Andy Murdoch has a vineyard of 18 hectares irrigated in four sections. Each section is of a different size and required constant manual pump adjustment when switching between sections. This meant the irrigation system could not be automated and required manual adjustment between changeovers. A VSD allowed this adjustment to occur automatically between the different sections of the vineyard.

The Coomealla Irrigation Area near Dareton in south-western NSW supplies irrigators with moderate to high supply pressures through 75 km of communal pipelines. A further advantage of VSD for this grower was that it provided a way to take advantage of the pressure available through the delivery system, resulting in further energy savings. See Taking advantage of positive suction head section.

Attendance at a NSW DPI workshop identified that there was no other way of taking advantage of the moderate to high supply pressures provided in Coomealla. Some basic cost calculations found that installing a VSD provided a very quick return on investment.

VSD model installed

An Allen Bradley Powerflex 753 with two transducer settings, 275 kPa for backflushing, and 170–200 kPa for drip system operation was installed. Gravel filters backflush for 90 seconds every 90 minutes.

Cooling

The entire 5 x 9 x 3 m pump shed is lined with foil board (Figure 1), with two ‘whirly birds’ installed in the roof. The shed was lined to ensure temperatures do not exceed 30 °C.

Figure 1. Wall mounted VSD unit with surrounding foil board.

Problems

Some adjustment on downstream pressure setting was needed initially. Little information was available for this adjustment, except an 80-page internet download from the supplier. After working through this, the issue was resolved.

Suggestions

Select the VSD that is the best fit for the existing system as a whole. All systems are unique and the most suitable arrangement needs to be adopted.

Energy savings

In the first year following installation, average daily energy usage dropped 39% even though 27% more water was used and pumped to meet crop water requirements compared with the previous season. A power saving of approximately $4,000 was realised. The VSD cost $12,000 .

Case study — Rob Ridgewell, drip irrigation, Darling River NSW

Why VSD was installed

Rob Ridgewell converted from a low-level sprinkler system and a shared pump arrangement to a stand-alone drip system in 2003. Before converting, Rob tolerated an inflexible shared system when irrigating with low-level sprinklers, but felt he could not convert to drip without having the greater flexibility that a VSD provides. The additional cost for a VSD in relation to the whole scheme was relatively minor.

VDS model installed

A Telemecanique Altivar 58, with one pressure point located after the filter to maintain input head was installed.

Cooling

Natural air ventilation is created with a 2 m elevated mesh floor (figures 2 and 3). This was considered suitable at the time and has since proven correct. Elevation provides excellent air circulation. There are also two electric exhaust fans in the cabin (Figure 2).

Figure 2. VSD on mesh floor, and electric exhaust fans at top of cabin.

Figure 3. Pump shed housing VSD with elevated floor.

Problems

No major problems were experience with the VSD. Lightning strike damage to the board has been the only issue.

Vermin such as mice and rats have been known to cause damage in their desire to find heat through the night. Sealed VSD units (to IP 54 standard) largely overcome this concern.

Suggestions

Ask electricians about their experience with VFDs, and visit other projects if possible. In 2003, one option was to install two pumps (two 22 kW pumps), with one having a VSD. This was too complicated and eventually a single 37 kW pump with VSD was chosen.

Advantages

Having many small plantings of various varieties and ages, the VSD provided a considerable advantage to this farm. Each patch has a different flow requiring adjustment, however, with a VSD, if someone else manages an irrigation, they can turn it on and the system will look after itself.

The VSD is able to take full advantage of varying river heights in relation to the pump as it can adjust to the varying head levels.

Energy savings

Significant energy cost savings were realised by maintaining the pump capacity to meet the load required.

Key messages when considering a VSD

- Recognise that no two irrigation systems are alike.
- Contractors need to recognise that all situations are unique, and communication is needed between electrical contractors and irrigation designers.
- VSDs are not needed in all situations. Determine how variable the pressure requirements are in a situation to determine a VSDs benefits. If duty requirements do not vary, resizing the pump or trimming the impeller might be more viable options.

More information

Irrigation system and pump selection. AgGuide Water Series. NSW Department of Primary Industries

Primefact 1410. *Electric pumps — performance and efficiency*

Acknowledgments

Jeremy Giddings Irrigation Industry Development Officer (Horticulture)

Graham Hall, GH Electrical, Mildura Vic

Graeme Zanoni, Mildura Irrigation, Mildura Vic

Robert Welke, Tallemenco Pty Ltd, Adelaide (Pumping & Hydraulics Consultant)

Peter Smith, former Irrigation Development Officer, NSW DPI, Tamworth

Bill Yiasoumi, Training Manager, Irrigation Australia Limited

Case Study irrigators: Andy Murdoch and Rob Ridgewell

Published by the NSW Department of Primary Industries.

V15/304

PUB 15/180

Jobtrack 14135