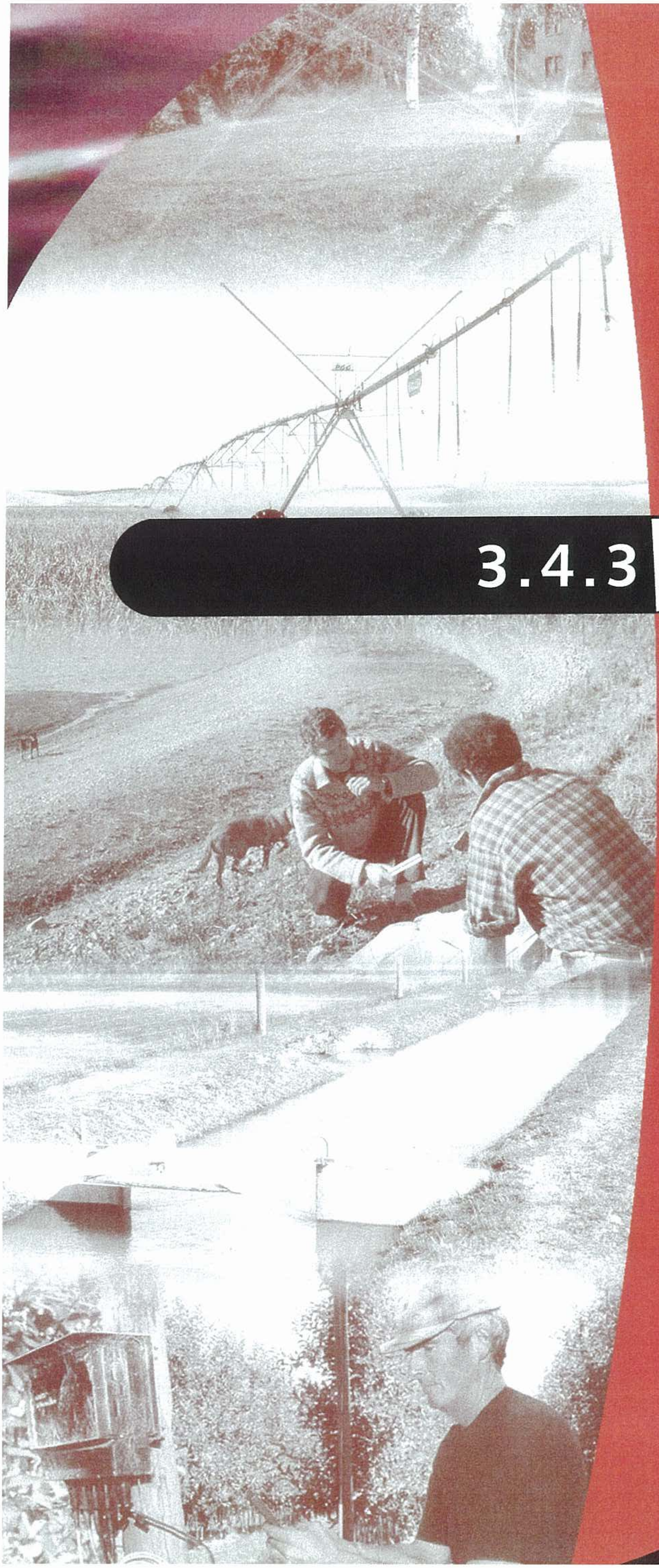
3.4.3 ELECTRICAL AND CONTROL



Use of variable frequency drives

Variable frequency drives (VFDs) are also known as AC motor drives, variable speed drives, variable frequency inverters or adjustable speed drives. Although 'drive' implies a combination of speed controller and motor, the irrigation industry is usually referring to the speed control unit alone when they talk about variable frequency drives.

VFDs change the frequency of the electricity supply from 50 Hz to frequencies ranging from zero to 50 Hz or more. Changing the electrical frequency to an electric motor changes its speed, which in turn changes the pressure and flow delivered by a pump and the energy that it uses.

Advantages of a VFD

- Significant savings in energy on systems with varying demands can be obtained.
- Pump speed automatically changes to meet the required demand.
- It allows use of a smaller pump on some installations.
- The built-in soft start eliminates the need for separate starters.
- It eliminates the need for additional control valves.
- There is no need for power factor correction with separate capacitors.
- The drive is not dedicated to a specific pump/motor combination.
- It is programmable for totally automatic operation.
- Operation is generally quiet.
- There is reduced danger of problems caused by operator error.
- There is generally no routine maintenance.
- It can provide automatic slow pressurisation of mainline at startup and automatic ramp down of system at shutdown.
- The system can be shutdown automatically on system failure.
- It can link into other control devices, eg flow meters.
- It provides feedback on system operation or reasons for failure or shutdown.

Disadvantages of a VFD

- Higher capital cost than other electric starter types.
- It does not reduce electricity company lines charges.
- It cannot be operated at very low frequencies with submersible pumps.
- There is a slight loss of efficiency in VFD unit.
- It doesn't protect against sudden power failure, which can cause water hammer.
- It can cause radio interference or distortion of electricity supply.

Applications

The aim of a VFD is to reduce friction losses in a system. It is not to improve pump efficiency. In fact, it will slightly decrease overall pump/motor efficiency.

VFDs are most cost-effective in situations where the required pressures and flows in an irrigation system change frequently, particularly where a system needs to operate at reduced flows for significant periods. They are also cost-effective where a system needs to provide a constant pressure under a wide range of flows, or a constant flow under a wide range of pressures. The savings that can be made depends on the amount of time the system is operated at reduced duties relative to the amount of time the system is operated at full load. Reducing the electrical frequency to a centrifugal pump from 50 Hz to 40 Hz will reduce the flow by 20%, the pressure by 36% and the electricity that it uses by 49%.

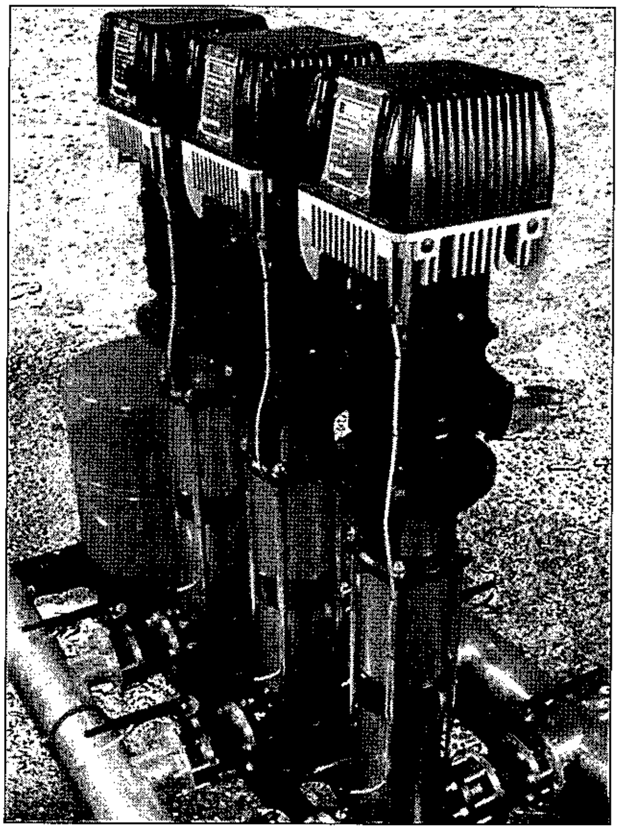
Problems and precautions

Provided appropriate safety systems are in place, problems should be minimal. Possible causes of problems are:

- lightning damage
- voltage surges
- dust and moisture
- excessive heat and cold
- vibration.

Where to get advice

Consult an irrigation design specialist and electrician to establish whether a VFD is applicable and cost effective.



June 2001

What is power factor correction?

Power factor

The power used by electrical resistive loads such as bar heaters or incandescent lights depends on the voltage across the load and the current passing through the load. In mathematical terms:

$$\text{Power (kW)} = \frac{\text{Voltage (V)} \times \text{Current (A)}}{1000}$$

In other loads such as electric motors, more current is drawn by the load than that indicated by the above equation. Put another way, the power used by the motor (kW) is less than that calculated by multiplying voltage by current (kVA). The ratio of the power consumed in kW and that calculated by multiplying voltage by current (kVA) is called the power factor.

$$\text{Power factor} = \frac{\text{Motor power (kW)} \times 1000}{\text{Voltage (V)} \times \text{Current (A)} \times 1000}$$

The extra current is known as magnetising current and is needed to maintain the magnetic fields to make the motor run. In motors with low power factor, the magnetising power is quite large and adds significantly to the total power needed to be supplied by the power supply company.

Power factors of irrigation pump motors range from about 0.6 for small motors under light loads to about 0.9 for large motors under full load. Typical values are 0.8-0.85.

What effect does power factor have?

The power factor has no effect on the operation of motors or on other loads connected to it. Irrigation pumps should still be able to run at the nameplate output power provided the distribution system supplies the correct voltage. Because most electricity meters measure kWh, not kVA, there is no additional cost at the meter for operating motors with low power factors.

However, the extra current creates an additional load on the electricity network, which must be supplied by the generator and results in energy losses within the power lines, transformers and other equipment on the network. So, while there is little direct incentive for irrigation pump owners to improve power factors from an energy point of view, there is a significant incentive for energy supply companies to have their customers do so. Some electricity network companies now charge capacity based on kVA, not kW. So, if the power factor of your motor is 0.8, you will be paying an extra 25% in capacity charges compared to the situation if you have a power factor of 1.0.

How can it be improved?

By adding power factor correction capacitors (kVAr) to the electrical circuits of motors, it is possible to improve power factor to whatever level is required. Typically, it is cost-effective to correct to about 0.92-0.95.

Benefits can be achieved in the following ways:

- Lower capacity charges where a kVA, rather than a kW tariff applies.
- Rebates where a power factor correction rebate is available.
- Smaller cables can be sometimes used.
- Improved performance through lower voltage drops.

Should you add power factor correction?

Many electricity network companies stipulate that power factor must be corrected to a specified level, usually 0.95 or better. The existing power factor for a pump motor is usually available from the pump supplier or the electrical installer. They will be able to advise you on how much correction is required. Alternatively, you can use the table and follow the example calculation below to make an estimate.

Existing	Required Power Factor				
Power Factor	1.0	**0.95**	0.90	0.85	0.80
0.70	1.020	0.691	0.536	0.400	0.272
0.75	0.882	0.553	0.398	0.262	0.132
0.80	0.750	**0.421**	0.266	0.130	-
0.85	0.620	0.291	0.135	-	-
0.90	0.484	0.155	-	-	-
0.95	0.328	-	-	-	-

Example :

- a 150 kW submersible pump with 0.80 power factor, to be corrected to 0.95
- capacity charge is $69/kW per year
- power factor correction cost assume $50/kVAr installed
- power factor correction rebate is $23.46/kVAr/year
- from Table 1, the required kVAr to improve power factor from 0.80 to 0.95 is 0.421*150 = 63 kVAr

Existing load	150 kW	187.5 kVA	0.80 Pf
Power factor correction installed	63 kVAr		
Resulting load	150 kW	158 kVA	0.95 Pf
Reduction in demand	29.5 kVA		
Capacity charge saving	Nil, as capacity charge is per kW, not per kVA		
Power factor correction rebate	$1478/year	(63*$23.46)	
Cost of power factor correction	$3150		
Payback period	2-3 years		

- Where a capacity charge is made in kVA, savings will be made by reducing kVA, rather than given as a rebate.

June 2001

Automatic control of irrigation systems

Automatic control means operating or controlling irrigation systems without being present or providing manual input, while maintaining safe running conditions. It usually involves automatic starting and stopping, or changes in duty while the system is running.

Advantages

- It maximises pumping time by keeping the system operating as much as possible.
- It can allow automatic starting or stopping from remote locations.
- It can provide automatic restarting after loss of power.
- It can allow the convenience of short-term or long-term changes in duty to be accommodated without manual intervention, eg when shifting irrigators.
- It can protect the system from unwanted operating conditions – high pressures, water hammer etc.

Disadvantages

- Special care and design is needed where water hammer problems could occur or automatic priming of pumps is needed.
- It can be costly on complex systems.
- It could increase the potential for damage to the system if not properly designed and installed.

Pressure or flow control valves (diaphragm valves, chamber valves, electronic butterfly valves, etc)

These are usually set to maintain a constant pressure downstream of the valve regardless of the flow rate. They are not normally used on irrigation systems that contain only one irrigator and one pump unless automatic restarting is required. They are particularly useful on systems that are operating two or more irrigators and where one irrigator needs to be shut off for shifting, with the other continuing to operate.

They are also useful on multiple irrigator systems where irrigators have automatic shutoff valves and one irrigator reaches the end of a run and shuts off before the others.

Most can be fitted with special features such as two-stage opening or flow control. Stage one restricts the flow during mainline filling to prevent excessive pumping rates and water hammer. Stage two should operate the valve in a fully open state. Switching from stage one to stage two is regulated on a time basis or using a differential pressure sensor. Flow control valves control the filling rate of the mainline, and once the mainline is full, open fully.

Automatic valves always add extra friction loss to the system, which adds a small energy cost. The extra pressure loss, although usually small, must be allowed for in the pump duty.

Valves should be selected and set so that they operate in a fully open position as much as possible, and have as low as possible pressure loss. If the system is operating continuously with the valve in a regulating state, energy is being wasted, and changes to the system or a different method of control would be recommended.

On systems with more than one pump feeding into a connected system, pressure or flow control valves are usually only installed on one of the pumps, to prevent hunting.

In addition to the normal protection equipment, systems using pressure or flow control valves **must** be fitted with pressure switches or flow switches on the upstream side of the valve. This is to ensure that the pump will shut off if the valve closes to the extent that flow stops or is lower than the minimum allowable flow for the pump.

Surge valves

Pressure control valves or flow control valves are very useful in preventing water hammer problems during automatic starting of systems or adjusting pressure and flow when operating conditions in the field change. However, they do not provide much protection against sudden stopping of pumps, which is often when many water hammer problems occur.

Surge valves are designed specifically for control of pressure surges caused by water hammer and are sometimes used to complement pressure or flow control valves. They contain a sensor that detects pressure surges or water hammer and open quickly to discharge water to reduce the effect of the surge.

Motor speed controllers

Controllers such as variable frequency drives adjust the speed of the pump motor to provide a wide range of duties. They allow ramping up in speed for slow filling of pipelines and ramping down for slow stopping, to prevent water hammer problems. The changes in speed are controlled by the electronic settings. Automatic pressure or flow control is carried out using timers or pressure or flow sensors. See Sheet 1, Section 3.4.3.

Precautions

If an irrigation system has problems with unwanted shutdowns, it may not benefit from automatic starting. The problems with the irrigation system should be sorted out first.

Safety shutdown controls should always override restart controls, so that full protection is maintained. The system should be set so restart attempts are minimised if other problems are likely.

Systems that can presently be restarted without manual control of valves are probably suitable for automatic restarting without the need for additional valves.

Elevation differences between pumps and irrigators determine the type of water hammer control needed. Systems pumping uphill should remain full if non-return valves are operating properly without leaking, and will probably only need a single automatic valve. Systems pumping downhill are likely to empty during shutdown, and will require more sophisticated valve control.

Systems with very high pressures, complex combinations of pumps and very long pipelines will require detailed analysis and should be designed by a qualified engineer.

June 2001