EMERGING TECHNOLOGIES

ENERGY↔WATER CONNECTION

Variable Frequency Drives – Planning your system

Many irrigation districts are installing Variable Frequency Drives (VFDs) to increase their level of service to their customers and/or to reduce their energy consumption.

However, not all VFDs are the same. The performance quality of a VFD will depend on the characteristics of the particular VFD, as well as how the VFD system is set up. Many times it is the seemingly small details that will have a large impact on performance in the long run. This brochure is intended to help irrigation districts properly evaluate what type of VFD they need and how to install it. Attending to the details outlined here will increase the efficiency and life of your VFD system.

Before You Buy

Retrofitting VFDs to existing motors

In general, existing motors in good condition can be retrofitted with VFDs. There are, however, some limitations. The motor windings must be in good condition. VFDs are more demanding of the motor because of the electrical distortions they cause. To determine if a motor is appropriate for a VFD retrofit, a Meggar test is used. A Meggar test measures the resistance between the motor windings and ground. This resistance is a measure of the condition of the motor winding insulation. If the resistance is over (about) 300,000 ohms and the installation criteria described above are followed, then the motor is probably OK for the VFD retrofit. If the resistance is less than 300,000 ohms then the motor should be "dipped and baked" to renew the winding insulation. One cautionary note – if the motor has been idle for a long time – several weeks or more – then the motor should be run long enough to bring it up to operating temperature and kept there for an hour or more before conducting the Meggar test. This is because dust and moisture can collect in the windings during idle periods. Running the motor drives off the moisture and "blows" loose dust from the windings. Moisture and dust in the windings will provide false low values when performing a Meggar test.

Automating with a VFD

For pipelines, an internal PID controller is often sufficient. Canals are special and generally require a separate PLC in an RTU to apply more sophisticated control algorithms. Modeling of a canal system is required to select the proper control algorithm constants.

The RTU must automate both the VFD and the other pumps that operate in parallel with the VFD.

The pump to automate with a VFD (in a location with multiple pumps supplying the same pipeline) is the smallest which will meet both of the following criteria:

- (Flow Rate of the VFD pump) + (Sum of the flow rates of all the smaller pumps) must be greater than or equal to the flow rate of the next bigger pump
- The flow rate of no single speed pump can exceed the combined flow of all pumps that are smaller than it – including the pump with the VFD at full speed.

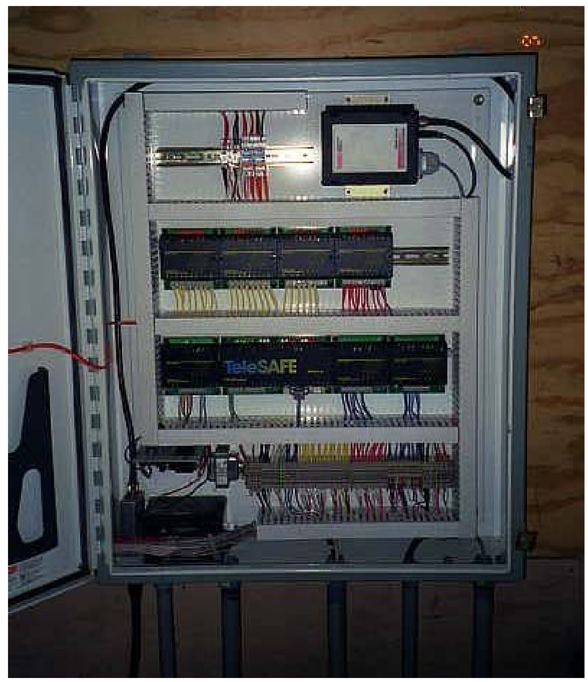
Choosing the Right Size of VFD

VFDs are typically classified by horsepower. However, the size of VFD necessary is probably larger than the size of the motor being controlled by the VFD. This is for two reasons. First, a motor can produce more than its rated horsepower. It is not unusual for a motor to produce up to 15% over the rated shaft horsepower by utilizing the motor's service factor. Second, the VFD is rated by its output horsepower, which is the input horsepower to the motor. The input horsepower is the motor's shaft horsepower divided by the motor efficiency.

For example, a motor with a 100 horsepower output rating and a motor efficiency of 93% that is being used at the limit of a 1.15 service factor would require a VFD with an output of 124 horsepower. This is 24% over the nominal motor horsepower rating. A 125 HP VFD would be marginal in this case, for the 100 HP motor.

For VFD retrofits to existing motors, the best way to determine the required size of a VFD is to measure the electrical current and voltage supplied to the existing motor under actual working conditions that include the condition of maximum load. For a centrifugal pump, maximum load is usually the maximum flow rate/minimum TDH condition. For an axial flow pump (propeller pump), maximum load is usually the zero flow/maximum head condition. Consult the pump's curve to determine the actual maximum loading condition.

Other factors also impact the horsepower rating of the VFD compared to the motor horsepower. Among these factors are altitude, air temperature, and the cleanliness of the motor, drive and appurtenances. Consult the VFD manufacturer to determine how VFDs are impacted by these conditions.



It is important to know how to specify the performance of what is inside the VFD panel. Patterson ID.

What to Expect from the Manufacturer

Technical Specifications

The Variable Frequency Drive (VFD) should be microprocessor-based inverter logic isolated from power circuits, with a Buffered Pulse Width Modulated (BPWM) output waveform using 4th generation Insulated Gate Bipolar Transistors (IGBT) technology. The VFD package should be completely assembled and tested by the manufacturer. The VFD should employ a full wave rectifier, DC link reactor, capacitors, and fourth generation IGBT as the output switching device. The drive efficiency must be 97% or better at full speed and full load. Displacement power factor must be between 100% and 95% lagging at all speeds and loads.

The VFD should have the following capabilities:

1. Automatic restart after an overcurrent, overvoltage, undervoltage, or loss of input signal protective trip. – The number of restart attempts, trial time, and time between reset attempts should be programmable.
2. An anti-back spin device to prevent the pump from starting while it is rotating in the reverse direction.
3. Control logic ride-through in the event of power outages up to 2 seconds in duration.
4. A 3-position Hand-Off-Auto (HOA) switch and speed potentiometer. – When in "Hand", the VFD will be manually started, and the speed will be controlled from the speed potentiometer. When in "OFF", the VFD will be stopped. When in "Auto", the VFD will start via an external signal from a PLC, and its speed will be controlled via PLC communications. For units with bypass capability, a 3-position Drive-Off-Bypass switch is required.
5. The rating of the drive should allow for 100% continuous operation, and operation with an overload current of 120% for one minute.
6. Input line fuses standard in the drive enclosure.
7. Optimized for a 2kHz carrier (switching) frequency. – The carrier frequency should be adjustable to a minimum of 8kHz. The carrier frequency should be adjusted to the minimum frequency that eliminates audible "hums" in the motor and drive.
8. At least 12 Pulse operation. – The number of pulses should be selectable.
9. Both volts per Hertz and "Sensorless Vector" operation. – The operating mode should be "Sensorless Vector" operation
10. Standard operating information on the VFD digital display:
    - Output Frequency
    - Motor Speed (RPM, % or Engineering units)
    - Motor Current
    - Output Voltage
    - Elapsed time meter
11. Speed command input made by the following:
    - Keypad
    - Local Manual Potentiometer
    - 4-20 madc input
12. I/O Communications for network communication with the PLC. – The PLC protocol will be Modbus.

Operation and Maintenance Manuals

Operation and Maintenance manuals must be provided with each VFD. They should include the following:

- Spare parts listing; source and current prices of replacement parts and supplies, including recommended spare parts to be pre-purchased by the district after the warranty ends
- Recommended maintenance and repair procedures and intervals. Include dimensioned as-built drawings
- Test and Calibration procedures
- Recommended cleaning methods
- Instructions for troubleshooting diagnostics
- Wiring diagrams
- Full compliment of user instruction materials

Warranty

Warranty should be 24 months from the date of first successful start-up, not to exceed 30 months from the date of shipment. The warranty must include all parts, labor, travel time, and expenses.

Installing the VFD

The Contractor should Specify in the Bid

- The maximum overvoltage and undervoltage prior to trip
- Maximum overcurrent capacity prior to trip
- Maximum transient protection

Installation and Operation

To minimize the negative impacts of VFDs, several steps should be followed.

- Keep the cables connecting the VFD to the motor as short as practical.
    - Cable length can be as long as 100 feet. However, shorter cables mean less EMI and RFI and potentially less motor heat.
    - If a cable is over 40 feet long then "inductor duty" motors should be specified – particularly if the motor voltage is 460 Volt or higher.
- Provide shielding, like metallic conduit, for motor cables.
- Adjust the carrier frequency so that it is high enough to eliminate any objectionable hum. However, keep the carrier frequency on the low side. A carrier frequency between 4 kHz and 6 kHz will typically eliminate the hum and keep the motor temperature issues to a minimum.
- Measure the EMI and RFI generated by the installation. If the interference exceeds limits defined by IEEE 519-1992 then install filters.

Conditioning of Incoming Power

A self-contained control power transformer must be supplied to feed the GFI, controls, and light. The RTU must have an isolated, conditioned power supply and battery backup.

Harmonic filters must be provided for each leg of incoming power of the VFD.

If the VFD is to be installed on an ungrounded Delta system, then a 3 phase, Delta to Wye isolation transformer, electrostatically shielded, should be installed before the VFD with the WYE grounded with an individual grounding rod.

Lightening Protection

Recommendations of the NEMA Standard No. ICS7 should be followed.

Required Accessories

- *All external interlocks and start/stop contacts must remain fully functional whether the drive is in Hand, Auto or Bypass.*
- All wires must be individually numbered or labeled at both ends.
- The disconnect handle should be a thru-the-door type, and be lockable in the "Off" position using a padlock
- Surge Protection on the incoming power lines must be provided
- Stainless Steel Door Nameplate
- Space heater for winter to prevent condensation
- Weatherproof and dust/insect-proof enclosure
- Fluorescent light (external mounting)
- VFD panel cooling
    - Water cooling using process water and heat exchanger with an internal fan is acceptable only if water temperature is below 60°F the year-round. The water-cooling heat exchanger for the panel must be equipped with a large capacity water filter having automatic flushing.
    - Outside air cannot be introduced into the panel for cooling purposes.
    - Refrigeration cooling is almost always required.
    - Calculations are required to demonstrate that cooling is adequate during "historically hottest days"
- GFI receptacle (external mounting)
- Shading of the panel from direct sunlight

A new air conditioned enclosure for a VFD application at South San Joaquin ID.

Abbreviations

BPWM – Buffered Pulse Width Modulated
EEPROM – Electrically Erasable Programmable Read Only Memory
HOA – Hand-Off-Auto (switch)
IGBT – Insulated Gate Bipolar Transistors
IHP – Input horsepower, the electric horsepower delivered to the motor. The motor's shaft horsepower is the input horsepower times the motor efficiency.
madc – milliamps direct current
MCC – Motor Control Center
OIT – Operator Interface Terminal
PCC – Point of Common Coupling
PID – Proportional/Integral/Differential "equation" used to get "process value" to converge on setpoint in the minimum number of tries
PLC – Programmable Logic Controller
PWM – Pulse Width Modulated
RTU – Remote Terminal Unit
TDH – Total Dynamic Head of a Pump
THD – Total Harmonic Distortion
VFD – Variable Frequency Drive

For Further Information

- **Additional Links**
  - http://www.itrc.org/reports/VFDand SCADA.html
  - http://www.itrc.org/reports/vfdspecs. html
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