

VFD Specifications for Irrigation District Applications



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VFD (Variable Frequency Drive) Specifications for Irrigation District Applications

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Standards

The drives and all components shall be designed, manufactured, and tested in accordance with the latest applicable standards of IEC, UL, CUL, and NEMA.

- ICS 7-1993 Industrial Control and Systems Adjustable-Speed Drives.
- NEMA 250-1996 Enclosures for Electrical Equipment (1000 Volts Max.)
- MG1-1998 Motors and Generators
- ICS 7.1-1995 Safety Standards for Construction and Guide for Selection, Installation, and Operation of Adjustable Speed Drive Systems.

Warranty

Warranty shall be 2 years from the date of first successful start-up. The warranty shall include all parts, labor, travel time, and expenses.

Submittals

As part of the bid package, the following shall be submitted to the irrigation district in duplicate:

- Dimensioned outline drawing and environmental requirements.
- Schematic drawings detailing all options specified.
- Product data sheets
- Power and control connection diagram(s) including communication options and protocol.

- Drive (including all filters and accessories) losses at full load and at 50% load, and cooling requirements in BTU/hr.
- Recommended spare parts.
- Advantages and enhancements of specific products.
- List and description of all Modbus registers mapped within the VFD unit including standard control, communications, protection, diagnostics and other manufacturer-specific Modbus registers.

Prior to starting the manufacturing process two copies of the following shall be submitted to the District for approval:

- Control schematics and connection diagrams
- Complete instruction manuals and installation instructions
- Interconnection wiring schematics and diagrams
- List of spare parts provided.
- Configuration software if required.

Upon delivery of the VFD to the job site, the following shall be provided:

Two copies of Operation and Maintenance manuals must be provided with each VFD. They shall 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
- Data sheets on major components including power electronics devices.

Full complement of user instruction materials

Size of VFD

VFDs are typically classified by horsepower. However, they should be specified by amperage at a specific voltage.

The “Horsepower” size needed for a VFD is typically larger than the size of the motor being controlled by the VFD. This is for several reasons:

1. 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. This of course depends upon the

load that the pump exerts on the motor at a specific RPM. Pumps that are controlled by VFD controllers have neither constant amperage input nor constant torque; both depend on the RPM.

2. A VFD is typically rated by its output horsepower, which is the input horsepower to the motor. An electric motor, on the other hand, is rated by its output horsepower.
3. Many VFD controllers require “line filters” in front of them. These line filters drop the voltage on all 3 legs of a 3 phase system to the lowest voltage of any of the legs. Since it is rare that all 3 legs have the same voltage, this lower voltage will require more amperage to provide the power. This increased amperage in turn generates more heat in the VFD controller and in the motor, plus in the line filter itself. (note: line filters do not diminish the harmonics that are fed back into the source current).
4. VFDs are rated for a specific amperage and voltage at a specific temperature. If the temperature exceeds the threshold, the VFD efficiency drops very rapidly.

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 sufficient in this case for the 100 HP motor only if the temperature was carefully controlled and there were no incoming power quality problems.

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. There is a very wide difference between various manufacturers, when comparing “rated HP” to “maximum amperage at continuous operation”.

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.

The following are to be specified by the customer for each installation:

Amperage = _____ at
Voltage of _____ at a drive temperature
no greater than _____ Deg. F. and no lower than _____ Deg. F. at
an altitude of _____ feet above sea level
Supply voltage is: _____ V, _____ phase, _____ wires.
The 3 phase symmetrical fault current is _____ Amps with X/R = _____.
The total load on the _____ KVA transformer is _____ Amps.

Technical Specifications

The Variable Frequency Drives (VFDs) must have:

- Microprocessor-based inverter logic isolated from power circuits,
- Buffered Pulse Width Modulated (BPWM) output waveform using 4th generation Insulated Gate Bipolar Transistors (IGBT) technology,
- A guaranteed ability to provide continuous output amperage of 15% greater than the maximum amperage required by the project for the motor at a specified input voltage.
- DC link choke for the DC bus reactor,
- Passive filter (line reactor and EMI/RFI filter) on the input side of the controller,
- Ability to accept a variation of input voltage of +10% - 15%.
- Ability to support a motor cable length of 100 feet (minimum) or any greater length specified for this application without voltage reflection or other problems.
- Temperature rating for 100% performance at 40 deg. Celsius.
- 3% input line reactor on the input (if not built-in)
- 6 pulses
- Testing by the manufacturer of the completely assembled package listed above.
- Drive efficiency (including all associated filters) of 96.5% or better at full speed and full load.
- Displacement power factor shall be between 1.0 - .95 lagging at all speeds and loads.
- The VFD shall have the ability to automatically 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 shall be programmable.
- The pump shall be fitted with an anti-back spin device to prevent the pump from starting while it is rotating in the reverse direction.
- The VFD shall have 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.
- The VFD shall have input line fuses standard in the drive enclosure.
- The VFD shall be optimized for a 2kHz carrier (switching) frequency. The carrier frequency shall be adjustable to a maximum of 8kHz. The carrier frequency shall be adjusted to the maximum frequency that eliminates audible “hums” in the motor and drive.
- The VFD shall provide volts per Hertz and “Sensorless Vector” operation. The operating mode shall be “Sensorless Vector” operation.

Operating Information Displays

The following operating information displays shall be standard on the VFD digital display.

- Motor Speed (RPM, % or Engineering units)
- Motor Current
- Output Voltage

The following are optional, but must be discussed with the customer:

- Elapsed time meter
- Output Frequency

Speed Command Input

The speed command input shall be made by the following:

- Keypad
- Local Manual Potentiometer
- 4-20 mADC input

Serial Communications

- The VFD shall have I/O Communications for network communication with the PLC.
- The protocol of the PLC will be Modbus, via RS-485 connection and be capable of being configured as a Modbus slave device with Modbus address of 1-254.
- RS-485 communication baud rate shall be 38.4 Kbaud or greater.

Required Accessories

All external interlocks and start/stop contacts shall remain fully functional whether the drive is in Hand, Auto or Bypass.

- All wires to be individually numbered or labeled at both ends.
- The disconnect handle shall be thru-the-door type, and be lockable in the “Off” position using a padlock
- Surge Protection on the incoming power lines shall be provided. The surge protectors must be placed outside the building and other panels, if there is a possibility that they will explode when activated.
- Stainless steel door nameplate
- Space heater for winter to prevent condensation
- Weatherproof and dust/insect-proof enclosure. A NEMA-1 is sufficient if inside a building; a NEMA-4 is required outside.
- Fluorescent light (external mounting)
- GFI receptacle (external mounting)

- A thermal sensor of the motor windings, interlocked with the VFD's control circuit. The motor specifications must be available so that the VFD connections will match properly with the specific thermal sensor.
- The following 3 types of wires must be run in independent conduits:
 1. Control circuit wiring (115 V or 24 V) for start/stop commands (note: 24 V is generally preferred).
 2. 4-20 mA or 0-5 VDC signals for speed control.
 3. Power wiring.
- In addition to the single-point grounding of the VFD, a grounding conductor must be brought back from the motor to the VFD's internal grounding terminal.

Required VFD panel cooling

The integrator must guarantee that the air conditioning will maintain the air on the electronics of the VFD drive below 40 deg. C (assuming that the drive is rated for 100% performance at 40 deg. C).

The actual BTUs that the air conditioning system must dissipate will depend upon the specific VFD drive and accessories, and on climatic conditions. The VFD specifications regarding minimum VFD plant (including all add-ons) efficiency, transistors, DC-link choke, etc. should help to minimize the heat buildup. Successful installation typically require anywhere from 125 – 250 BTU/HP.

There are 3 means of cooling the VFDs:

1. 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. It is unacceptable for irrigation district applications.
2. Installing the VFD inside an air-conditioned building. This may not cool the inside of the VFD enclosure sufficiently. If the building is air-conditioned, the intake to the AC shall be at the top of the building, and the cold air shall enter near the floor. The VFD panel must be properly designed with a fan, to allow sufficient cold air to pass through the panel enclosure.
3. Installing a dedicated air conditioner for the VFD panel. (Outdoor installation requires a VFD housed in a NEMA –4 or better enclosure.) An attached air conditioning forced air unit must cool the entire inside of the enclosure by circulating the captive air over coils, without introducing any outside air. *All outdoor installations must have a shade roof over the panels to eliminate extra heating caused by direct sunlight.*

VFD drives shall not be installed inside of Motor Control Centers (MCC's) because of difficulties with cooling and installation/repair.

Other VFD Application Notes

Automation

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 the unsteady hydraulics of the canal system is required to select the proper algorithm and control algorithm constants. All canal gates/pumps in series must be modeled simultaneously to accurately determine the required 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 that 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.

Pump Details

It is important to know the pump (Flow vs. Head) characteristics for the complete range of operation. One can extrapolate a curve of a constant speed pump into curves of various speeds – but the complete curve must be known on existing pump (or any new pump). A motor should not operate at less than about 50% speed – unless special motor cooling is provided. This is because the motor inefficiencies are greater at low speeds (resulting in the output of heat), yet the cooling fan on the motor is operating at a lower speed.

Conditioning of Incoming Power

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

A VFD must not be installed on an ungrounded Delta system. If that is the case, the electric utility should be asked to switch the transformer from a Delta to a Wye isolation transformer. If the utility will not do this, then an extra transformer must be installed. In this case, 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.

The contractor shall specify in the bid

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

- Maximum transient protection

Lightning Protection

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

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 satisfactory 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.

Abbreviations

EEPROM – Electrically Erasable Programmable Read Only Memory

A computer memory “chip” that can be erased and rewritten with new software.

HOA – Hand-Off-Auto (switch)

Switch located at an RTU or other facility that selects if the device is to be turned off, operated in an automatic mode or operated in a manual mode.

IGBT – Insulated Gate Bipolar Transistors

Transistors capable of high power applications used to switch the electric pulse (see PWM) on and off to construct alternating current of variable frequency

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

Often used as the “signal” for sensors and control of devices with “analog” characteristics

MCC – Motor Control Center

The relays, circuit breakers, and switches directly attached to a motor that locally control the operation of a motor

OIT – Operator Interface Terminal

An interface (usually with a display and buttons) that allow an operator to interface with a control system – usually located on or very near the device being controlled

PCC – Point of Common Coupling

Where the “private” side of an electric service is connected to the utility. Usually taken to mean the high voltage side of the last utility owned step down transformer serving an electric customer or local group of electric customers.

PID – Proportional/Integral/Differential “equation”

Control algorithm used to get “process value” to converge on setpoint in the minimum number of tries by calculating a correction that is proportional to the present error, considers the accumulation of past errors (integral) and considers how fast the error is decreasing.

PLC – Programmable Logic Controller

An industrial computer used to automatically control electronic or mechanical devices

PWM – Pulse Width Modulated

Method used to create the magnitude of voltage or current by using a voltage or current of a fixed magnitude applied for a variable amount of time. The effective voltage or current is determined by the width of the constant magnitude pulse.

RTU – Remote Terminal Unit

Virtually the same as a PLC – often used to describe the PLC and all appurtenant equipment such as control relays, communications devices and power supplies required to make a PLC work.

TDH – Total Dynamic Head of a Pump

The increase in head between the suction and discharge of a pump, including pressure and elevation.

THD – Total Harmonic Distortion

The ratio of the sum of the powers of all harmonic frequencies above the fundamental frequency to the power of the fundamental frequency. THD is usually expressed in dB. THD is a measure of the “noise” carried on a harmonic “wave” like a.c. current or voltage.

VFD – Variable Frequency Drive

A device used to change and/or control the frequency of alternating electric current

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