SECTION 16260

VARIABLE FREQUENCY DRIVES

# GENERAL

## DESCRIPTION

### This section describes materials, testing, and installation of variable frequency drives (VFDs) for pumping applications.

## RELATED WORK SPECIFIED ELSEWHERE

### Section 16010: General Electrical Requirements.

### Section 16012: Seismic Restraint for Electrical Equipment.

### Section 16150: Pump Motors.

### Section 16480: Low-Voltage Motor Control.

### Section 16938: Power System Study.

## SUBMITTALS

### All functions and features identified in this specification are to be provided regardless of if they are a standard of the manufacturer. Acceptance of any submittal where required items were not included does not alleviate the Contractor from the need to provide the items per plans and specifications

### Submit shop drawings in accordance with the General Conditions.

### Submit manufacturer's descriptive data including ratings, performance and operational features, dimensional data, conduit entry restrictions, and heat dissipation to ambient.

### Submit a schematic diagram for each drive showing field devices, wire numbers, terminal numbers, and interface with other panels.

### Submit harmonic analysis.

### Submit certified factory test report.

## MANUFACTURER'S SERVICES

### Provide equipment manufacturer's services at the jobsite for the minimum man-days listed below, travel time excluded:

#### Two man-days to check the installation, calibrate the drives, and advise during start-up and testing of the drives.

#### One man-day to instruct the DISTRICT's personnel in the operation and maintenance of the equipment.

## SERVICE ORGANIZATION QUALIFICATIONS

### The service organization office shall be located within 100 miles of the jobsite.

### The service organization must have been an authorized service organization of the equipment manufacturer for the past 12 months. Service engineers or technicians must be factory trained and certified.

### Maintain a spare parts inventory of 100% of the controller components.

## Ratings

### Motor horsepower ratings shown are minimum expected. This does not limit the equipment size. When motors furnished differ from the minimum ratings indicated, make the necessary adjustments to wiring, conduit, disconnect devices, VFD sizes, branch circuit protection, and other affected material or equipment to accommodate the motors actually installed, at no additional cost to the Owner.

## MAINTENANCE

### For services outside of the warranty, a maintenance contract shall be offered to the Owner which includes the following:

#### Provide for all maintenance, including new parts, repair of parts, and the installation of same, and make all adjustments required to keep the entire system in peak operating condition.

#### Maintain and restock the spares inventory.

## MEASUREMENT AND PAYMENT

### Payment for the work in this section shall be included as part of the lump-sum bid amount stated in the Proposal.

# MATERIALS

## GENERAL

### Variable frequency drives shall consist of variable frequency controllers, input circuit breaker, bypass starters, converter, input contactor, , output isolation contactor, input line reactors, and controls. Each drive shall operate as a simplex unit with no interaction with other drives. Horsepower rating of each drive shall be sufficient to drive the motor as shown in the drawings or the motors actually provided, whichever is larger, under the specified operating conditions.

### All components shall be integral to the VFD lineup, factory wired and testing as a complete system.

### Design equipment to operate under the following operating conditions:

#### Altitude to 3,300 feet above sea level.

#### Ambient 0°C to 40°C.

#### Noncondensing relative humidity to 95%.

#### A-C line frequency variation of ±3 hertz.

### VFD shall maintain a 0.95 minimum true power factor throughout the entire speed/frequency range.

### VFD shall be suitable for use with any standard NEMA-B squirrel-cage induction motor having a 1.15 service factor. Provide equipment for proper operation of motor and drive when required due to motor feeder length.

### Equipment shall comply with the requirements of ANSI, IEEE, and NEMA. The electrical equipment, design, and construction shall comply with the provisions of the NEC. The complete drive shall be UL listed.

### All drives shall be supplied by one manufacturer.

### Variable frequency drives shall be manufactured by Allen Bradley low harmonic PowerFlex Series. No equals allowed

## ENCLOSURES

### Mount variable frequency controller, bypass starters**,** output isolation contactors, and controls within a motor control center. Provide separate MCC section/area for each set of motor controls. The VFD manufacturer shall address the operation of the VFD in the installed condition at the specified ambient temperature.

### Verify that overall equipment dimensions are within the dimensions indicated in the drawings. If larger equipment is required, submit a proposed room layout showing arrangement of electrical equipment. Provide working clearances in accordance with the NEC. Any costs due to rearrangement of equipment shall be borne by the Contractor with no additional expense to the owner.

### Provide space for mounting variable frequency drives, bypass starters and controls for future pumps where indicated on the drawings.

### Provide additional pull sections as required for bottom entry of incoming and/or outgoing cables

## VARIABLE FREQUENCY CONTROLLERS

### Controller shall consist of a six-pulse minimum converter section and output inverter utilizing IGBT technology.

[Note to the Engineer: Check if the DISTRICT wants 18-pulse only for the particular application]

### Controller shall be pulse width modulated design.

### Controller shall be variable voltage/variable frequency (constant volts per hertz).

### The controller shall include the following features:

#### 460-volt a-c, +10%, -10% (at rated load), 3-phase, 3-wire, 60-Hz input power. or voltage and phase as required by driven equipment

#### 460-volta-c, 3-phase, 3-wire, ungrounded output power. or voltage and phase as required by driven equipment

#### Equipment fault current rating of 65,000 symmetrical amperes fault current.

#### Input power surge protector.

#### 20 to 60 Hz continuous operating range.

#### 115% overload rating for 100 seconds, 100% rated current continuous.

#### Output current limit, 50% to 110% adjustable. Limits motor inrush current during start-up.

#### Regulation ±3% of base speed.

#### Voltage Dip Ride-Through: Controller shall be capable of sustaining continued operation with a 40% dip in nominal line voltage. Output speed may decline only if current limit rating of the controller is exceeded.

#### Power Loss Ride-Through: Controller shall be capable of a minimum three-cycle power loss ride-through without fault activation.

#### Separately adjustable acceleration and deceleration rates.

#### Maximum and minimum speed adjustments.

#### 120-volt a-c control power for run/stop circuits.

#### Air, with thermal switch cutout

#### Comprehensive microprocessor-based digital diagnostic system which monitors its own control functions and displays faults and operating conditions in plain English without the use of codes. The digital keypad and display shall be a membrane keypad with integral 24-character minimum LCD display capable of controlling the VFD and setting drive parameters. Include self-test software program to verify proper keypad operations. A fault log shall record, store, display, and print, upon demand, the following for the 15 or more most recent events:

##### VFD mode (auto/manual).

##### Elapsed time (since previous fault) or fault time.

##### Type of fault.

#### The following digital indications shall be selectively displayed:

##### Speed called for by incoming process signal in percent of full speed.

##### Output current in amperes.

##### Output frequency in hertz.

##### Input voltage.

##### Output voltage.

##### Total 3-phase kilowatts.

##### Kilowatt-hour.

##### Elapsed time.

##### rpm.

##### D-C bus voltage.

#### Password security shall be available to protect drive parameters from unauthorized personnel.

#### A plain English user menu shall be provided in software in nonvolatile memory as a guide to parameter setting.

#### VFD parameters, fault log, and diagnostic log shall be changeable, up-loadable and downloadable via Ethernet.

### Minimum controller efficiency shall be 96% at 100% speed and 100% torque and 88% at 50% speed and 25% torque based on nominal 1,800-rpm motor with load horsepower to vary as cube of speed.

### The controller shall include protective circuitry that initiates an orderly shutdown of the inverter without component failure. The controller shall shut down and require manual reset for the following fault conditions:

#### Motor inverse time overload.

#### Instantaneous overcurrent.

#### Inverter fault.

#### Overfrequency.

#### D-C link overvoltage.

#### Ground fault.

### The controller shall ride through or shut down for the following fault conditions.

#### Incorrect phase sequence.

#### Loss of an input phase.

### The controller shall shut down for input undervoltage. The controller shall automatically restart upon a cleared fault condition.

### The controller shall have not less than five restart capabilities. If the drive reaches the limits of restart, the restart circuit shall lock out and shall provide a fault signal.

### Provide a common failure contact for remote indication of fault conditions previously listed.

### The power circuit design shall be such that the following fault conditions can occur without damage to the power circuit components:

#### Single-phase fault or 3-phase short circuit on VFD output terminals.

#### Failure to commutate inverter transistor due to severe overload or other conditions.

#### Disconnecting motor during VFD operation.

#### Loss of input power due to opening of VFD input disconnect device or utility power failure during VFD operation.

#### Loss of one phase of input power.

### The VFD drive shall provide an integral dual port Ethernet interface. This interface shall be used to allow remote access to the various parameters associated with the programming, monitoring, and control of the VFD. The protocol shall be modbus over Ethernet or approved equal.

### Provide a critical speed avoidance circuit for selection of a critical speed with a rejection band centered on that speed. The drive shall ignore any speed signals requiring drive operation within the rejection band.

### The VFD controller shall operate satisfactorily when connected to a bus subject to a total harmonic voltage distortion caused by other sources of up to 10% and commutation notches of up to 36,500 microsecond-volts.

### Accommodate the following external interface signals

#### Accept a remote start/stop dry contact closure signal which will allow control while in the remote mode.

#### Provide a remote status indication of “pump running” with a dry contact closure, rated for 5 amperes at 120-volt a-c.

#### Provide a remote status indication of local/remote switch (remote) position with a dry contact closure, rated for 5 amperes at 120-volt a-c.

#### Provide a percent of speed with 4- to 20-mA d-c output corresponding to 0% to 100% speed for remote indication of metering pump.

#### Accept a 4- to 20-mA input signal for speed control.

#### Provide a remote status indication of pump failed with an isolated dry contact closure, rated for 5 amperes at 120-volt a-c.

#### Accept a remote failure reset signal with a dry contact closure, rated for 5 amperes at 120-volt a-c to the metering pump controller.

## INPUT CIRCUIT BREAKER

### Circuit breaker shall be molded case or insulated case type, mechanically interlocked with the enclosure door to provide positive disconnect of incoming a-c power. The circuit breaker shall be rated for 65,000 AIC.

### Make provisions for padlocking external disconnect handles in the off position.

## BYPASS STARTER AND ISOLATION CONTACTOR

### Where included in the drawings, provide a full voltage non reversing starter for operating the motor from the 60-Hz a-c incoming line and a converter output contactor for isolation of the converter. Starter shall comply with Section 16480. Contactors shall comply with NEMA ICS2.

## CONTROLS

### Provide control logic and interlocks to interface the bypass starter with the variable frequency controller and the converter output contactor as shown in the schematic diagrams in the drawings.

### Provide control circuit transformers, indicating lights, selector switches, push buttons, elapsed time meter, analog dial-type speed indicator, [temperature monitors,] digital keypad and display as indicated in the schematic diagrams shown in the drawings. All control devices shall be 30mm in diameter and shall be heavy duty industrial, oil tight. Lights shall be LED push-to-test.

### Mount and wire the devices listed above on the controller cabinet door.

### Control circuit transformers, indicating lights, selector switches, push buttons, and elapsed time meters shall be as specified in Section 16480.

### Provide relays with the number of contacts shown on the schematic diagrams. Utilize additional contact blocks or relays to satisfy the number of contacts shown at no additional cost to the Owner. Plug-in relays shall have retaining clips.

## EMI/RFI INTERFACE SUPPRESSION

### The VFD shall fulfill all electromagnetic compatibility immunity requirements per the following standards utilizing input and output EMI/RFI filters. These filters shall suppress all objectionable interference to AM and FM radio signals in the immediate vicinity of the facility.

#### IEC 61800-2 and –3.

#### EN 50082-1 and –2.

#### EN 61000-6-1, -6-2, and –6-4.

#### EN 61800-3+A11.

### **Declaration of Conformity:** The Manufacturer’s Declarations of Conformity assuring the compliance of the proposed drives with the above standards shall be made available upon request.

## HARMONIC SUPPRESSION EQUIPMENT

### VFDs shall meet requirements outlined in the latest edition of IEEE 519 for each individual and total harmonic voltage and current distortion and as indicated in these specifications. Individual or simultaneous operation of the VFDs shall not add more than [3%] to the total harmonic distortion at the main switchboard bus [while operating from the utility source or more than [8%] while operating from standby generator] as defined by IEEE 519. Total harmonic current demand distortion for each VFD operating at full load and speed shall not exceed 5% as calculated and measured at the VFD input terminals. Provide additional harmonic filters, if required, to meet these requirements.

### Submit a harmonic analysis showing compliance with the above requirement including all voltages and current harmonics up to the 49th.

### Base harmonic analysis on a short circuit current available at the main switchboard of [30,000 amps]

### If a passive harmonic filter is selected, provide filter as part of the VFD assembly. Provide protection monitor/harmonic power factor meter.

### Provide filters on the output of the VFD to allow the use of standard low-voltage building wires to motors fed from VFDs. Check cable lengths and apply to the selection of the appropriate filters. Otherwise, VFD cables shall be used.

## FACTORY TESTING

### Subject the VFDs to a complete functionality test. Simulate remote inputs and outputs and verify correct operation. Submit certified factory test report.

### Set adjustable set points of the drives at motor manufacturer’s recommended values. Coordinate with motor manufacturer and obtain recommended set point values in writing. Document information in O&M manual.

## SPARE PARTS

### Provide [six] spare fuses of each type and ampere rating installed. Provide two of each type of converter power semiconductor, two of each type of inverter power semiconductor, one keypad assembly, five of each type of panel lamps, and one of each type of control printed circuit board and gate firing boards. Pack spare parts in a wooden box; label with manufacturer's name and representative's name, address, and telephone number; and attach list of material contained within.

### Provide one spare control keypad for each pair of VFDs.

# EXECUTION

## INSTALLATION

### Secure drives rigidly to floors or mounting pads and walls with anchor bolts or concrete anchors. Anchor bolts or concrete anchors shall be 316 stainless steel. Installation shall be in accordance with manufacturer's recommendations and Section 16012.

### Provide the services of a qualified factory-trained manufacturer’s representative to assist in installation of the equipment specified under this section. The manufacturer’s representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, connections, and adjustments.

## FIELD TESTS

### Adjust control set points and verify proper operation. Coordinate minimum speed with performance requirements of driven equipment.

### Test the operation of each interlock to verify that the interlock performs its function.

### Test the operation of each control feature to verify operation of the controls.

### Perform dynamic tuning tests with the facility controls.

### Measure total harmonic distortion with one, two, three, and four drives operating at 100% speed for compliance with harmonic design requirements. Utilize a recording-type harmonic analyzer displaying individual and total harmonic currents and voltages up to the 49th harmonic. Test shall be performed by a NETA-certified independent testing company.

### Provide the services of a qualified factory-trained manufacturer’s representative to assist in testing and start-up of the equipment specified under this section, in accordance with manufacturer’s published start-up services. Additionally, perform the following minimum work under the technical direction of the manufacturer’s service representative if not included in their published start-up services:

### Perform insulation tests on each phase and verify low-resistance ground connection on ground bus. Exclude such tests harmful to electronic components.

### Torque all bolted connections made in the field and verify all factory-bolted connections.

### Verify that factory-set adjustable set points of VFD are in accordance with the motor manufacturer’s recommendations.

### A qualified factory-trained manufacturer’s representative shall certify in writing that the equipment has been installed, adjusted, and tested in accordance with the manufacturer’s recommendations. Drive and motor nameplate information, settings, and operating parameters shall be documented. Equipment shall be inspected prior to the generation of any reports.

### Submit final harmonic compliance certification signed by a California registered engineer to verify that installed VFDs meet or exceed IEEE 519 standard voltage and current requirements i.e., voltage and current THD are below IEEE 519 limits.

END OF SECTION