SECTION 22 05 14
VARIABLE FREQUENCY DRIVES FOR PLUMBING

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this Section shall include, but is not limited to, the following:

1. Variable Frequency Drives (VFDs) for mechanical equipment where indicated.

B. All motors over 5 horsepower shall be provided with VFDs unless specifically indicated otherwise.

1.02 RELATED DOCUMENTS

A. Section 22 05 01 – Plumbing General Provisions

B. Section 22 05 13 – Electric Motors for Plumbing Equipment

C. Section 22 11 23 – Plumbing Pumps

D. Section 22 33 19 – Acoustics for Plumbing

E. Division 26 – Electrical Specifications

1.03 REFERENCE STANDARDS

A. International Electrotechnical Commission (IEC)

1. IEC 61800-1 – Adjustable Speed Electrical Power Drive Systems – Part 1: General Requirements – Rating Specifications for Low Voltage Adjustable Speed D.C. Power Drive Systems
2. IEC 61800-2 – Adjustable Speed Electrical Power Drive Systems – Part 2: General Requirements – Rating Specifications for Low Voltage Adjustable Speed A.C. Power Drive Systems

B. Institute of Electrical and Electronic Engineers (IEEE)

1. IEEE 519: Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

C. National Electrical Manufacturers Association (NEMA)

1. NEMA ICS 7.0 – Industrial Control and Systems Adjustable-Speed Drives
2. NEMA ICS 7.1 – Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable-Speed Drive Systems

D. National Fire Protection Association (NFPA)

1. NFPA 70 – National Electrical Code

E. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

1. ASHRAE Standard 135: A Data Communication Protocol for Building Automation and Control Networks

F. Underwriters Laboratories Inc. (UL)

1. UL 508C: Power Conversion Equipment

1.04 QUALITY ASSURANCE

A. Provide a 2-year unconditional parts and labor warrantee on all VFD components. The warranty shall include all parts, labor, travel time and expenses.

B. Qualifications: VFDs and components shall be UL Listed as a complete assembly. VFDs that require field-supplied external fuses for the VFD to be UL Listed are not acceptable.

C. Seismic Performance: VFD's shall withstand the effects of earthquake motions determined according to ASCE/SEI 7. The VFD shall remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit shall be fully operational after the seismic event. Provide description of equipment anchorage devices on which the certification is based.

1.05 SUBMITTALS

A. Product Data as specified, including outline dimensions, weights, power and control wiring schematics, enclosure type and details and equipment schedule.

B. Short-circuit (withstand) rating of enclosed unit.

C. Required working clearances and required area above and around the VFDs, including clearances between VFDs and adjacent surfaces and other obstructions.

D. IEEE – Standard 519 compliance calculation and harmonic analysis for this particular installation:

1. Total harmonic voltage distortion and total harmonic current distortion. Provide calculations, specific to this installation, showing total harmonic voltage distortion is less than 5 percent.
2. Input line filters shall be sized and provided as required by the manufacturer to ensure compliance with IEEE standard 519.
3. All VFDs utilizing 6-pulse rectification shall include a minimum of a 3 percent impedance reactor.

E. Manufacturer's Instructions for:

1. Testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
2. Setting of field adjustable overload relays.
3. Testing, adjusting and reprogramming microprocessor control modules.
4. Setting field-adjustable timers, controls and status and alarm points

F. Start-up Service Report and Guarantee.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Variable Frequency Drives: ABB, Graham/Danfoss, Yaskawa, Emerson

B. All VFDs shall be by one supplier for the project except where part of a proprietary pre-manufactured item or plant of equipment,

2.02 AC VARIABLE FREQUENCY DRIVE

A. Provide completely assembled VFD, factory-tested by the manufacturer. The VFD shall operate from a line overvoltage of 10 percent over nominal. The undervoltage trip level shall be 10 percent under the nominal voltage as a minimum.

B. The alternating current variable speed drive system shall include the microprocessor based variable frequency controller, the required signal logic and control. The electrical drive equipment specified including the variable frequency controller and its associated microprocessor control system shall be of the same manufacturer. Coordinate with driven equipment supplier to ensure compatibility between drive and AC Motors.

C. All equipment shall comply with the applicable requirements of the latest standards of ANSI, IEEE, and NEMA. The electrical equipment, as well as the design, construction, and installation thereof, shall comply with all the applicable provisions of the National Electrical Code and be ETL-SEMKO or UL approved.

D. The VFD shall be mounted in a minimum NEMA 1 enclosure for drives inside the building and in air handling plenum spaces, and NEMA **[3R] [4X]** enclosure for drives outside the building unless specifically indicated otherwise. The control circuitry shall be isolated from the power circuitry.

E. The manufacturer shall submit calculated line distortion percentages in accordance with IEEE Standard 519, based upon the total connected horsepower and source kilovolt-amperes of the utility and emergency power distribution system. Request electrical data for calculation from the Division 26 contractor.

F. The speed controller shall respond to a speed adjusting potentiometer from the VFD sequence panel when in the manual mode or shall respond to a milliamp or voltage electrical signal when operating in the automatic mode.

G. The cabinet shall require front access only. The unit shall be suitable for operation in ambient air at 0 degrees C to 40 degrees C and up to 95 percent RH at rated load and switching frequency.

H. The variable frequency controller shall convert 230 or 480 volt (plus or minus 10 percent) 3-phase, 60 hertz (plus or minus 3 percent) utility supplied or standby generator supplied power to variable frequency, variable voltage three-phase AC power for induction motor speed control. The controller shall be selected to have sufficient capacity to provide stepless speed control of the specified horsepower motors throughout a continuous speed range under a variable torque load not exceeding the motor full-load rating.

I. All VFDs rated **[25] [50] [75]** horsepower and higher shall utilize minimum 12-pulse rectification.

2.03 VARIABLE FREQUENCY CONTROLLER

A. BACnet Interface:

1. Provide a BACnet interface device for each VFD. The interface shall provide control of the VFD by the BACnet BAS system through the **[MS/TP] [IP]** connection.
2. Each BACnet interface shall have PICS submitted to BACnet International in compliance with the BACnet standard.

B. The controller shall be of the pulse width modulated (PWM) type and shall have three sections including a minimum 3 percent line impedance reactor as follows:

1. AC-DC section (a 3-phase, full wave, half diode bridge or transistor bridge)
2. Capacitor section
3. 3-phase output module

C. The controller shall be capable of performing the following functions:

1. Adjustable linear timed acceleration and deceleration
2. Plus or minus 0.5 hertz frequency stability
3. 10:1 controlled speed range
4. Manual/automatic operation
5. Other functions as described

D. Include the following protective devices and/or features:

1. Regulator with self-contained test module or panel.

2. Contactor shall carry specified current (OLT) on continual basis without damage (normal condition), designed to break specified locked rotor ampere current repeatedly without damage (abnormal operation). Entire VFD assembly shall be rated for minimum **[100,000] [200,000]** amperes interrupting capacity root mean square symmetrical (AIC RMS).
3. AC overload protection to continuously monitor peak current and shut down the DC module gate signals if the instantaneous electrical trip motor current exceeds 180 percent of the controller full load current rating.
4. Monitor lamps or LED read-out on VFD front panel to provide immediate indication of controller functions.
5. Current limit.
6. Adjustable volts/hertz.
7. Adjustable offset voltage increases starting and accelerating torque capability.
8. All output phase modules shall turn off instantly when a high DC bus occurs or when the current exceeds 150 percent of rated current.

E. The following controller adjustments shall be contained on one regulator card of microprocessor control board:

1. Minimum hertz/maximum hertz
2. Acceleration rate (adjustable 0 to 125 seconds)
3. Deceleration rate (adjustable 0 to 125 seconds)
4. Volts/hertz
5. Offset voltage

F. Provide a test panel or module to permit on-line monitoring and troubleshooting of the drive. Monitor the following regulator signals:

1. Internal power supplies
2. Ramp generator output
3. DC bus voltage

2.04 SAFETY CONTROLS AND PROTECTIVE COMPONENTS

A. The VFD shall be capable of starting into a rotating load (forward or reverse) and accelerate or decelerate to setpoint without safety tripping or component damage (flying start). The VFD shall also be capable of DC injection braking at start to stop a reverse spinning motor prior to ramp.

B. The VFD shall be equipped with an automatic extended control power loss ride-through circuit, which shall utilize the inertia of the load to keep the drive powered.

C. The overload rating of the drive shall be 110 percent of its normal duty current rating for a minimum of 1 minute. The minimum full-load ampere rating shall meet or exceed the values in the NEC/UL table 430-150 for 4-pole motors.

D. All VFDs utilizing 6-pole rectification shall have an integral 3 percent impedance line reactors to reduce the harmonics to the power line and to add protection from AC line transients.

E. The VFD shall be capable of sensing a loss of load (broken belt / broken coupling) and signal the loss of load condition. The drive shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. Relay output shall include programmable time delays that allow for drive acceleration from zero speed without signaling a false underload condition.

F. Provide surge reduction filter for electrical circuit lengths in excess of 200 feet.

G. The following shall be provided:

1. Motor thermal overload relays at the output for motor protection.
2. Enclosure door interlocked disconnect switch.
3. All coils for relays and contactor shall be suppressed.
4. Automatic Restart: Controller shall automatically attempt to restart five (5) times after a fault. After five (5) restarts, a manual start of the drive equipment is required.
5. The following contacts shall be wired to terminal boards of users control and indication:

    a. Motor running speed
    b. Drive faults
    c. Remote stop-starting

6. **[A complete factory-wired and -tested bypass system consisting of an output contactor and bypass contactor. Overload protection and single phase protection shall be provided in both drive and bypass modes. Include door-mounted manual by-pass switch with bypass contactor and indicator light. Electronic bypasses are not acceptable.]**

H. Drive faults shall consist of the following:

1. Motor thermal overload.
2. AC input voltage dips to 60 percent or less of its nominal value.
3. Drive output current exceeds 110 percent of controller full load rating.
4. A fault condition in any of the 3 output power module phases.

2.05 ADJUSTMENTS AND CONTROLS

A. All VFDs shall have the following operator adjustable components:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed.
2. PID setpoint controller shall be standard in the drive, allowing a pressure or flow signal to be connected to the VFD, using the microprocessor in the VFD for the closed loop control. The VFD shall have 250 milliamp of 24 volts DC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID setpoint shall be adjustable from the VFD keypad, analog inputs, or over the communications bus.
3. Two (2) programmable analog inputs shall accept a current or voltage signal.
4. Two (2) programmable analog outputs.
5. Three (3) programmable digital outputs (minimum one (1) Form-C and two (2) Form-A types). The relays shall include programmable on and off delay times. Default settings shall be for run and not faulted (fail safe).
6. Five (5) programmable preset speeds.
7. Two (2) independently adjustable acceleration and deceleration ramps.

B. All VFDs shall have the same interface, including backlit LCD digital display and keypad, regardless of horsepower rating.

1. The keypad shall be used for local control, for setting all parameters, and for stepping through the displays and menus. The keypad shall be removable from the cabinet, capable of remote mounting, and shall have its own non-volatile memory. The keypad shall allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.
2. The keypad shall include Hand-Off-Auto selections. When in “Hand”, the VFD shall be started and the speed will be controlled from the up/down arrows. When in “Off”, the VFD shall be stopped. When in “Auto”, the VFD shall start via an external contact closure and the VFD speed shall be controlled via an external speed reference. Manual pilot devices are not acceptable.
3. The keypad Display shall indicate drive frequency, output voltage or output current. In addition the keypad display shall Provide an indication of the activation of the drive protection features and/or status in plain English without the use of code abbreviations as follows:

a. Overcurrent
b. Overvoltage
c. Current Limit
d. Decel Voltage Limit
e. Ground Fault
f. Overtemperature
g. I^2T Protection
h. Improper Input Voltage Selected

i. Minimum/Maximum Speed Improperly Adjusted

C. Serial Communications:

1. The VFD shall have an RS-485 port as standard. The standard protocol shall be BACnet **[MS/TP] [IP].** Optional protocols that must be available are: Modbus, LonWorks, and Johnson Controls N2 bus.
2. Serial communication capabilities shall include, but not be limited to, run-stop control; speed set adjustment, proportional/integral/derivative PID control adjustments, current limit, and accel/decel time adjustments. A minimum of 15 field parameters shall be capable of being monitored. The DDC system shall be able to monitor if the motor is running in the VFD mode or bypass mode (if bypass is specified) over serial communications. The drive shall have the capability of allowing the DDC to monitor feedback as a minimum, with 5 additional:

    a. Process variable feedback
    b. Output speed/frequency
    c. Current (in amps)
    d. Percent torque
    e. Power (kW)
    f. Kilowatt hours (resettable)
    g. Operating hours (resettable)
    h. Relay outputs
    i. Diagnostic warning and fault information
    j. Remote VFD fault reset shall be possible

3. The VFD shall allow the DDC to control the drive's digital and analog outputs via the serial interface. The serial communications interface shall allow for DO (relay) control and AO (analog) control. This control shall be independent of any VFD function. The outputs can be used for modulating chilled water valves via the analog output, actuate a damper etc. In addition, all drive digital and analog inputs shall be capable of being monitored by the DDC system.

4. Fused VFD only disconnect (service switch). Fast acting semi-conductor fuses exclusive to the VFD to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection, maintaining bypass capability. Bypass designs, which do not have fuses, or that, incorporate fuses common to both the VFD and the bypass will not be accepted. Three contactor bypass schemes are not acceptable.
5. VFD shall have a service switch for total unit isolation.
6. The following operators shall be provided:

    a. Bypass Hand-Off-Auto
    b. Drive mode selector
    c. Bypass mode selector
    d. Bypass fault reset

7. The following indicating lights (LED type) shall be provided. A test mode or push to test feature shall be provided.

    a. Power-on
    b. External fault

c. Drive mode selected
d. Bypass mode selected
e. Drive running
f. Bypass running
g. Drive fault
h. Bypass fault
i. Bypass H-O-A mode
j. transfer to bypass selected

8. The following relay (Form C) outputs from the bypass shall be provided:

   a. System started
   b. System running
   c. Bypass override enabled
   d. Drive fault
   e. Bypass fault- motor overload or underload due to broken belt
   f. Bypass H-O-A position

9. The digital inputs for the system shall accept 24-volt or 115-volt AC (selectable). The bypass shall incorporate internally sourced 24-volt power supply and not require an external control power source.
10. Customer Interlock Terminal Strip: Provide a separate terminal strip for connection of additional inputs and external start commands.
11. All external safety interlocks shall remain fully functional whether the system is in Hand, Auto, or Bypass mode. The remote start/stop contact shall operate in VFD and Bypass modes.
12. The VFD shall include a “run permissive circuit” that will provide a normally open contact any time a run command is provided (local or remote start command in VFD or Bypass mode).
13. Class 20 electronic motor overload protection shall be included.
14. There shall be an internal switch to select manual or automatic bypass.
15. There shall be an adjustable current sensing circuit for the bypass to provide loss of load indication when in the Bypass mode.

PART 3 – EXECUTION

3.01 INSTALLATION

A. The Contractor shall install the drive and power wiring shall be completed in accordance with the recommendations of the manufacturer as outlined in the installation manual.

B. For VFDs mounted on walls, install with top of units at a uniform height and with disconnect operating handles not higher than 60 inches above finished floor unless otherwise indicated. Bolt units to wall or mount on lightweight structural-steel channels bolted to the wall.

C. For freestanding VFDs, provide structural-steel frames and align units similar to wall-mounted types.

D. Start-up Service: Provide certified factory-authorized start-up service for purposes of installation inspection, initial drive equipment setting, energization and adjustment. Start-up shall be provided for each drive by a factory authorized service center. A certified start-up form shall be filled out for each drive with a copy provided to the Owner.

E. Program all microprocessor controllers for required operational sequences, status indications, alarms, event recording and display features. Clear the events memory after final acceptance testing and prior to Substantial Completion.

F. Set field-adjustable switches, auxiliary relays, time-delay relays, timers and overload relay pick-up and trip ranges.

G. Coordinate with equipment supplier to ensure compatibility between VFD and the motor supplied with the equipment.

H. Division 26 shall mount and wire the drives in locations as shown on the Drawings.

I. Maintain code required electrical clearance around all VFD cabinets.

END OF SECTION 22 05 14