

## SECTION 16422 – VARIABLE FREQUENCY DRIVES

### PART 1 - GENERAL

#### 1.01 SUMMARY

- A. Section Includes: Types of motor controllers, including:
  - 1. Variable Frequency Drives

#### 1.02 DEFINITIONS

- A. CPT: Control power transformer.
- B. DDC: Direct digital control.
- C. EMI: Electromagnetic interference.
- D. OCPD: Overcurrent protective device.
- E. PID: Control action, proportional plus integral plus derivative.
- F. RFI: Radio-frequency interference.
- G. VFD: Variable-frequency Drive motor controller.

#### 1.03 SUBMITTALS

- A. Shop Drawings: For each VFD indicated.
  - 1. Include details of equipment assemblies. Indicate dimensions, weights, loads, and required clearances, method of field assembly, components, and location and size of each field connection.
  - 2. Include diagrams for power, signal, and control wiring.
  - 3. Provide manufacturer recommended spare parts list in with submittal.
  - 4. Installation and Maintenance manuals shall be shipped with the VFD and shall be in electronic format. Include website, detailed installation, start-up, and checkout procedures, adjustment and troubleshooting information, and related closeout documents. Provide OWNER with 3 copies each on separate, clearly labeled jump drives, one jump drive to be housed onsite.
  - 5. Submit evidence that the equipment will be provided with all specified controls, features, options and accessories.
  - 6. Submit certification that the equipment is designed and manufactured in conformance with all applicable codes and standards.
  - 7. Certified copies of test results shall be submitted for tests specified in this section, including but not all inclusive, manufacturer startup.
  - 8. Submit warranty information for equipment. Warranties to start from date of startup. Manufacturer startup certificate may extend warranty, if so provide new warranty update to OWNER.

#### 1.04 CLOSEOUT SUBMITTALS

- A. Operation and maintenance data: Provide the recommended maintenance schedule with the recommended spare parts. Provide the following.
  - 1. Three (3) electronic copies; searchable PDF. Individual jump drives shall be provided for each copy.

#### 1.05 QUALITY ASSURANCE

- A. Testing Agency Qualifications: Member Company of NETA or an NRTL.
- B. The drives and enclosure shall be assembled and built by the manufacturer. Drives assembled by the Contractor do not comply with this specification.
- C. Codes and Standards:
  - 1. UL Compliance: Comply with applicable requirements of UL 486A and B, and UL 508, pertaining to installation of motor controllers. Provide controllers and components which are UL listed and labeled.
  - 2. NEMA Compliance: Comply with applicable requirements of NEMA Standards ICS 2, "Industrial Control Devices, Controllers and Assemblies," and Pub No. 250, "Enclosures for Electrical Equipment (1,000 Volts Maximum)," pertaining to motor controllers and enclosures.

#### 1.06 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace VFDs that fail in materials or workmanship within specified warranty period.
  - 1. Warranty Period: Three years from date of equipment startup.

### PART 2 - PRODUCTS

#### 2.01 MANUFACTURERS

- A. Subject to compliance with specified requirements, manufacturer offering products shall be (no Or Equal):
  - 1. Allen-Bradley
  - 2. ABB
  - 3. Square D Group Schneider
  - 4. Siemens

#### 2.02 MOTOR CONTROLLERS

- B. General Requirements for VFDs:
  - 1. VFDs and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
  - 2. Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508A.
- C. Application: variable torque.

- D. VFD Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.
1. Units suitable for operation of NEMA MG 1 motors.
  2. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.
  3. VFD shall be a 6 pulse system
  4. Insulated Gate Bipolar Transistors (IGBTs) shall be used in the inverter section. Bipolar Junction Transistors, GTOs or SCRs will not be acceptable
  5. Provide 5% line reactor and dV/dT output filter.
- E. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection. Unit shall be continuous use, heavy duty at full load rated amps. For units that will take a single-phase input and provide three phase, the unit shall be oversized per manufacturer standards.
- F. Output Rating: Three phase; 0 to 60 Hz, with voltage proportional to frequency throughout voltage range; maximum voltage equals input voltage.
- G. Unit Operating Requirements:
1. Input AC Voltage Tolerance: Plus 10 and minus 10 percent of VFD input voltage rating.
  2. Input AC Voltage Unbalance: Not exceeding 3 percent.
  3. Input Frequency Tolerance: Plus or minus 3 percent of VFD frequency rating.
  4. Minimum Efficiency: 97 percent at 60 Hz, full load.
  5. Minimum Displacement Primary-Side Power Factor: 98 percent under any load or speed condition.
  6. Minimum Short-Circuit Current (Withstand) Rating: 65 kA.
  7. Ambient Temperature Rating: Must be capable of operating between 32 deg F and 104 deg F.
  8. Humidity Rating: Less than 95 percent (noncondensing).
  9. Altitude Rating: Not exceeding 3300 feet.
  10. Vibration Withstand: Comply with NEMA ICS 61800-2.
  11. Overload Capability: 1.5 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
  12. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
  13. Speed Regulation: Plus or minus 5 percent.
  14. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.
  15. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.
  16. Total current harmonic distortion shall not exceed the values in Table 10.3 of IEEE – 519 at the point of connection.
  17. Noise: 80 dB or less.
- H. Inverter Logic Minimum Requirements: Microprocessor based, 32 bit, isolated from all power circuits.
- I. Isolated Control Interface: Allows VFDs to follow remote-control signal over a minimum 40:1 speed control range.
1. Signal: Electrical.

- J. Internal Adjustability Capabilities:
1. Minimum Speed: 5 to 100 percent of maximum rpm.
  2. Maximum Speed: 50 to 100 percent of maximum rpm.
  3. Acceleration: 0.1 to 999.9 seconds.
  4. Deceleration: 0.1 to 999.9 seconds.
  5. Current Limit: 30 to minimum of 150 percent of maximum rating.
- K. Self-Protection and Reliability Features:
1. Surge Suppression: Factory installed as an integral part of the VFD enclosure, complying with UL 1449 SPD, Type 1 or Type 2. Suppression shall be on the load side of the enclosure disconnect/breaker and fuses below.
  2. High speed short circuit protection: Provide high speed fast blow fuses on each input phase.
  3. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
  4. Under- and overvoltage trips.
  5. Inverter overcurrent trips.
  6. VFD and Motor-Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFDs and motor thermal characteristics, and for providing VFD overtemperature and motor-overload alarm and trip; settings selectable via the keypad.
  7. Ability to skip frequency bands that cause resonance or damage to the load; critical frequency rejection, with three selectable, adjustable deadbands.
  8. Instantaneous line-to-line and line-to-ground overcurrent trips.
  9. Loss-of-phase protection.
  10. Reverse-phase protection on load side.
  11. Short-circuit protection.
  12. Motor-overtemperature fault.
- L. Automatic Reset/Restart: Attempt minimum of three restarts after VFD fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
- M. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.
- N. Bidirectional Autospeed Search Type Feature: Capable of starting VFD into rotating loads spinning in either direction or returning motor to set speed in proper direction, without causing damage to the VFD, motor, or load.
- O. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
- P. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
- Q. Capable of disabling the ability to start the drive and adjust alarms and fault settings from the keypad.
- R. The entire drive electronics/circuit boards, bus bars and connections shall be conformal coated.

## 2.03 CONTROLS AND INDICATION

- A. Status Lights: Door-mounted LED indicators displaying the following conditions:
  - 1. Run.
  - 2. VFD fault.
  - 3. High Winding Temp
  - 4. Seal Leak (if applicable)
- B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English-language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.
  - 1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
  - 2. Security Access: Provide the ability to password protect the parameter settings.
- C. Historical Logging Information and Displays:
  - 1. Real-time clock with current time and date.
  - 2. Running log of total power versus time.
  - 3. Total run time.
  - 4. Fault log, maintaining last four faults, minimum, with time and date stamp for each.
- D. Indicating Devices: Digital display mounted in VFD door and connected to display VFD parameters including, but not limited to:
  - 1. Output frequency (Hz).
  - 2. Motor speed (rpm).
  - 3. Motor status (running, stop, fault).
  - 4. Motor current (amperes).
  - 5. Motor torque (percent).
  - 6. Fault or alarming status (code).
  - 7. PID feedback signal (percent).
  - 8. DC-link voltage (V dc).
  - 9. Set point frequency (Hz).
  - 10. Motor output voltage (V ac).
  - 11. Temperature (Deg F)
- E. Control Signal Interfaces:
  - 1. Electric Input Signal Interface:
    - a. A minimum of two programmable analog inputs: 4- to 20-mA dc.
      - 1) Speed Command
    - b. A minimum number of multifunction programmable digital inputs to allow the drive to operate as shown.
      - 1) Start
      - 2) Stop
      - 3) In Remote
      - 4) In Local
  - 2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the control system:
    - a. 0- to 10-V dc.
    - b. 4- to 20-mA dc.
    - c. Potentiometer using up/down digital inputs.

- d. Fixed frequencies using digital inputs.
  - 3. Output Signal Interface: A minimum of one programmable analog output signal(s) ( 4- to 20-mA dc), which can be configured for any of the following:
    - a. Output frequency (Hz).
    - b. Output current (load).
    - c. DC-link voltage (V dc).
    - d. Motor torque (percent).
    - e. Motor speed (rpm).
    - f. Set point frequency (Hz).
  - 4. Output Signal Interface: A minimum number of programmable digital output signal(s) required to meet the intent of the drive operation, which can be configured for the following:
    - a. Motor Running
    - b. VFD System Alarm
    - c. VFD in bypass (SPECIFY WHAT MOTORS HAVE BYPASS)
    - d. Three (3) Spares
- F. VFD shall be provided with control power transformers and DC power supplies as required to operate the controls and ancillary equipment. These power supplies shall be internally powered from the 480 VAC power feed and shall not require a separate external power feed.
- G. VFD shall be provided with the communications ports required for the control and monitoring communication shown on the drawings, not just programming interfaces.
- 1. The drive shall communicate to the PLC system directly without the need for gateways or protocol conversion modules.

#### 2.04 BYPASS SYSTEMS (ONLY as required by the application or specified by Owner)

- A. Bypass Operation: Transfers motor between power converter output and bypass circuit. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.
- B. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller.
  - 1. Bypass Contactor: Soft Starter or across the line starter based on application.
  - 2. Output Isolating Contactor: Non-load-break, NEMA-rated contactor.
  - 3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.
  - 4. Time delay on bypass while VFD is energized – settable from 0-5 minutes.
- C. Bypass Contactor Configuration: Full-voltage (across-the-line) type.
  - 1. NORMAL/BYPASS mechanically interlocked relays.
  - 2. ON/OFF/REMOTE selector switch.
  - 3. Contactor Coils: Pressure-encapsulated type.
    - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
    - b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.

4. Control Circuits: 24 VDC; obtained from integral power supply, with primary and secondary fuses, with supply of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.
  - a. Supply Spare Capacity: 100 VA.
5. Overload Relays: NEMA ICS 2.

## 2.05 ENCLOSURES

- A. VFD Enclosures: NEMA 250, to comply with environmental conditions at installed location.
  1. Type 12 (indoors, dry area). Add protection from circulating dust and dripping/spraying water.
  2. Type 12 (moist/wet environments). Add protection from falling dirt, rain, sleet, snow, and windblown dust. Add forced air ventilation for drive cooling. Enclosure shall be stainless steel.
  3. Type 12 (corrosive or H<sub>2</sub>S environments). Add protection from circulating dust and dripping/spraying water. Enclosure shall have enclosed cooling system. Enclosure shall be stainless steel.
- B. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFD as "Plenum Rated."
- C. Tilting: Equipment shall be rated to be tipped 100 degrees in all directions during installation. Price shall include cost associated with providing field service technicians for the removal and reinstallation of any components within the enclosure that maybe required to allow the enclosure to be tipped. Warranty shall not be affected by tipping requirements.
- D. Drives with NEMA 12 enclosures shall not be located back to back. Fans and vents may be located at the back of the enclosure.

## 2.06 ACCESSORIES

- A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; 30mm; factory installed in VFD enclosure cover unless otherwise indicated.
  1. Push Buttons: Unguarded.
  2. Pilot Lights: Push to test, LED.
  3. Selector Switches: Rotary type.
- B. NC and NO bypass contactor auxiliary contacts.
- C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.
  1. Time delay relays shall be 0 – 5 minutes.
- D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.
  1. Current Transformers (loads >5hp only): Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.
- E. Supplemental Digital Meters:
  1. Elapsed-time meter.

- F. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, Type 12 enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings. Provide cabinet desiccant driers.
- G. Filters: VFD manufacturer shall provide sufficient supply and exhaust fan sizing to allow the owner to install furnace-type filters over the air supply openings. The installation of such filters shall not reduce VFD performance nor void any manufacturer warranty.
- H. Enclosure fans shall start with the initiation of a VFD run signal and have an adjustable 0 – 10 minute off delay timer.

## 2.07 CONTROL WIRING INSTALLATION

- A. Bundle, train, and support wiring in enclosures.

## 2.08 IDENTIFICATION

- A. Identify VFDs, components, and control wiring per labeling specification 16075.
  - 1. Label each enclosure-mounted control and pilot device.
  - 2. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

## 2.09 SPARE PARTS

- A. Provide the following in addition to the manufacturer recommended parts:
  - 1. One (1) box of fuses for each type and size used. A minimum of three (3) fuses per size.
  - 2. Two (2) timers of each type used.
  - 3. Six (6) relays of each type used.
  - 4. Two (2) sets of overloads.
  - 5. Materials for two (2) sets of filter replacements

## PART 3 - EXECUTION

### 3.01 START UP AND COMMISSIONING

- A. An experienced, competent, and authorized representative of the manufacturer or supplier of each item of equipment shall be available to visit Site of Work a minimum of 2 times per VFD. The equipment supplier's representative shall revisit Site as often as necessary until all trouble is corrected and the equipment installation and operation is satisfactory to OWNER.
  - 1. The supplier shall provide a field start-up and calibration service on-Site. The supplier is to perform the calibration at Site at a mutually set time with ENGINEER. ENGINEER is to witness the calibration. The designated OWNER representative(s) is to be notified for all tests and calibrations. The supplier's personnel shall have a stable 4-20 mA source, and a plus or minus 0.5 percent accurate 3-1/2-digit, digital milliamp meter to be used in the calibration procedure. The supplier's personnel must also have an electronic vibration sensor that reads in displacement and velocity to dynamically balance the motor and its driven device over the entire operating speed range. The pump and motor coupled and running under load shall be dynamically balanced after installation. The amplitude of vibration shall be measured on the bearing housings of the motor in all directions with a portable electronic measuring device such as Balance Technology Inc., Model 801, Vittec, Inc., Model 655, Metrix Instrument Co.,

Model 5282, or equal. The plane and rpm of maximum vibration shall be determined at each bearing and recorded. The frequency of maximum velocity vibration amplitude shall also be determined and recorded for each bearing. The maximum allowable vibration velocity for an acceptable installation shall be 0.3 inch per second. The vibration testing shall be witnessed by ENGINEER. The recorded results shall be submitted to ENGINEER including a sketch showing the plane of maximum vibration.

2. The system will be calibration checked at 100 percent, 75 percent, 50 percent, and minimum speed points. The minimum and maximum speeds will be set. The deceleration and acceleration rates will be set. The delay to restart will be set.
- B. Manufacturer's representative shall provide all necessary tools and testing equipment required including noise level and vibration sensing equipment.
- C. Each equipment supplier's representative shall furnish to OWNER a written report providing a manufacturer's certification that the equipment:
1. Has been properly installed;
  2. Is balanced and in accurate alignment;
  3. Is free from any undue stress imposed by connecting piping or anchor bolts;
  4. Has been operated under full load condition and that it operated satisfactorily to OWNER;
  5. That OWNER's operators have been instructed in the proper maintenance and operation of the equipment; and
  6. Furnish OWNER a copy of all test data recorded during the installation check and startup, including noise level, current and vibration readings.
- D. Furnish training at the site on the operation and maintenance of the two different drive setups (VFD only, VFD with Bypass) per specification 01650.

### 3.02 OPERATION AND MAINTENANCE TRAINING

- A. Provide services of manufacturer's service representative to instruct OWNER's personnel in operation and maintenance of equipment. Training shall include start-up and shutdown, servicing and preventative maintenance schedule and procedures, and troubleshooting procedures plus procedures for obtaining repair parts and technical assistance. Refer to specification 01650 for further clarification.
1. Manufacturer's representative shall provide two, eight-hour days with each day scheduled one week or more apart (scheduling of days shall be determined by Owner).
    - a. Each day will include up to 12 trainees.
  2. Review operating and maintenance data contained in the operating and maintenance manuals.
    - a. Maintenance schedule shall be provided as hard copy at training. The maintenance schedule shall be discussed and demonstrated.

END OF SECTION