

## PART 1 – GENERAL

### 1.1 SUMMARY

- A. This Section includes variable frequency drives (VFD) for HVAC systems motors. [VFDs shall be furnished and installed by controls system subcontractor specified in Section 23 09 00][Power wiring by the Division 26 contractor][and shall be provided as needed to AHU manufacturer for factory mounting and wiring].
- B. Related Sections:
  - 1. Division 23.
  - 2. Division 26.

### 1.2 SUBMITTALS

- A. General: Submit each item in this Article according to the Conditions of the Contract and Division 01 Specification Sections.
- B. Product data including certified performance data and capacities of selected models, weights, furnished specialties and accessories.
- C. Shop drawings showing layout and connections, wiring diagrams showing detailed wiring for power, signal, and controls systems interfaces, differentiating between manufacturer-installed wiring and field-installed wiring.
- D. Maintenance data for drives including operation and maintenance manuals specified in Division 01. Include startup instructions.

### 1.3 CODES AND STANDARDS

- A. Codes and Standards shall be the current version adopted by the Authority Having Jurisdiction.

### 1.4 QUALITY ASSURANCE

- A. Regulatory Requirements: Comply with provisions of the following:
  - 1. UL 508
  - 2. NEC
  - 3. CSA
  - 4. ETL
- B. The contractor shall coordinate VFDs for pumps and fans to be provided by one manufacturer. Only one brand may be provided for the entire project.

### 1.5 WARRANTY

- A. The VFD shall be warranted by the manufacturer for a period of [18] [24] [36] [48] [60] months from date of shipment. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized on-site service.

## PART 2 – PRODUCTS

### 2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Danfoss
  2. Yaskawa
  3. ABB
  4. Or Approved Equal

### 2.2 GENERAL

- A. Furnish complete variable frequency drives as specified herein for the fans and pumps designated on the drawing schedules or specified to be variable speed. All standard and optional features shall be included within the VFD enclosure, unless otherwise specified. VFD shall be housed in a metal [NEMA 1][NEMA 3R][NEMA 12] enclosure and shall be equipped with an integral fused disconnect switch.
- B. The VFD shall convert incoming fixed frequency three-phase AC power into a variable frequency and voltage for controlling the speed of three phase AC motors. The motor current from the VFD shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current suitable for centrifugal pump and fan control.
1. The VFD shall include a converter and an inverter section.
  2. The converter section shall convert fixed frequency and voltage AC utility power to DC voltage.
- C. The inverter section of the VFD shall invert the DC voltage into a quality output waveform, with variable voltage and frequency for a step-less motor speed control. The VFD shall maintain a constant V/Hz ratio through the specified range of operation. The output phase voltage shall maintain a balance of  $\pm 1\%$ .
- D. The VFD and options shall be tested to ANSI/UL Standard 508. The complete VFD, including all specified options, shall be listed by a nationally recognized testing agency such as UL, CUL, ETL, or CSA. Power line noise shall be limited to a voltage distortion factor and line notch depth as defined in IEEE Standard 519, "Guide for Harmonic Control and Reactive Compensation of Static Power Converters." The total voltage distortion shall not exceed 5% at the point of common coupling as described in IEEE Standard 519.
- E. The VFD shall not emit radiated RFI in excess of the limitations set forth in the FCC Rules and Regulations, Part 15 for a Class A coming device. The VFD shall carry an FCC compliance label. Pulse Width Modulation (PWM) type drives shall include RFI filters.
- F. An advanced sine wave approximation and voltage vector control shall be used to allow operation at rated motor shaft output at nominal speed with no de-rating. This voltage vector control shall minimize harmonics to the motor to increase motor efficiency and life.
- G. The VFD shall include a full-wave diode bridge rectifier and maintain a fundamental power factor near unity regardless of speed or load.

- H. The VFD and options shall be tested to ANSI/UL Standard 508. The complete VFD, including all specified options, shall be listed by a nationally recognized testing agency such as UL, ETL, or CSA.
- I. The VFD shall have a dual 5% DC link reactor to minimize power line harmonics and protect the VFD from power line transients. VFDs with swinging chokes or saturating (non-linear) DC link reactors shall include an additional 3% impedance line reactor to provide acceptable harmonic performance at full load (where harmonic performance is most critical).
- J. The VFDs full load amp rating shall meet or exceed NEC Table 430-150. The VFD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and 220% of rated current for up to 1 second while starting.
- K. An automatic energy optimization selection feature shall be provided standard in the drive. This feature shall reduce voltages when lightly loaded and provide a 3% to 10% additional energy savings. If the load increases, the drive shall automatically return to normal operation.
- L. Input and output power circuit switching can be done without interlocks or damage to the VFD.
- M. Drive shall be capable of switching motors on output without damage to the drive. This capability shall not require interlocks with the VFD.
- N. The VFD shall be UL listed for a short circuit current rating of 100kA and labeled with this rating.

### 2.3 PROTECTIVE FEATURES

- A. The following protective features shall be included:
  - 1. A minimum of Class 20 I2t electronic motor overload protection for single motor applications and thermal-mechanical overloads for multiple motor applications.
  - 2. Provide a total of 3% input reactance in the form of line and DC bus reactor to protect against input transients, loss of AC line phase, short circuit, ground fault, overvoltage, under voltage, drive over temperature and motor over temperature.
  - 3. Protect VFD from input phase loss. The VFD should be able to protect itself from damage and indicate the phase loss condition. During an input phase loss condition, the VFD shall be able to be programmed to either trip off while displaying an alarm, issue a warning while running at reduced output capacity, or issue a warning while running at full commanded speed. This function is independent of which input power phase is lost.
  - 4. The VFD shall incorporate a motor preheat circuit to keep the motor warm and prevent condensation build up in the stator.
  - 5. Provide output devices as necessary to limit peak output voltage to less than 1,000 volts to ground, at the motor when connected to the VFD by less than 300 feet, and to reduce the VFD output rise time to less than 1,000 volts per microsecond. These output filtering devices shall be designed for constant duty with an inverter type adjustable speed drive output.
  - 6. Main input disconnect shall be provided that removes power from both the bypass and VFD.
  - 7. Main input motor rated fuses that protect the entire package.
  - 8. VFD only fast acting input fuses shall be provided. Packages that include only main input motor rated fusing or circuit breaker are not acceptable.

9. Drive shall catch a rotating motor operating forward or reverse up to full speed.

## 2.4 INTERFACE FEATURES

### A. Provide the following interface features:

1. All VFDs shall use one common type of user interface.
2. Provide complete programming software for use in a laptop PC so that changes to the VFD program can be made by directly connecting the laptop to the VFD.
3. Provide all hardware, software, and connecting cable (excluding DDC serial interface wiring and conduit from VFD to DDC controller) as necessary to digitally communicate and exchange information with the Distributed Digital Control (DDC) System. The exchanged information shall include: Motor speed, Electric load in KW, Volts, Amps, VFD fault, Hand/Off/Auto/Bypass mode and Network point address. The DDC system shall be able to start, stop, control motor speed and modify VFD settings including acceleration and deceleration times and skip frequency ranges through this communication system.
4. Local/Hand, Stop/Reset, and Remote/Auto selector switches shall be provided to start and stop the drive and determine the speed reference.
5. Provide a 24Vdc, 40mA max, output signal to indicate that the drive is in Remote/Auto mode.
6. Digital manual speed control. Potentiometers are not acceptable.
7. Lockable, alphanumeric backlit display keypad can be remotely mounted up to 10 feet away.
8. Displays shall be in English.
9. Display all faults in plain English. Codes are not acceptable.
10. Provide a red FAULT light and a green POWER-ON light.
11. Provide a quick setup menu with preset parameters.
12. The drive shall be fitted with a USB or RS 485 communications port and be supplied with software to display all monitoring, fault, alarm and status signals. The software shall allow parameter changes to be made to the drive settings as well as storage of each controller's operating and setup parameters.
13. Set point control interface (PID control) shall be standard in the unit.
14. Floating point control interface shall be provided to increase/decrease speed in response to switch closures.
15. An elapsed time meter and kWh meter shall be provided.
16. The following displays shall be accessible from the control panel in actual units: Reference Signal Percent, Output Frequency, Output Amps, Motor HP, Motor kW, kWhr, Output Voltage, No Load Warning, DC Bus Voltage, Drive Temperature and Motor Speed in engineering units per application (in percent speed, GPM, CFM,...).
17. The VFD shall sense the loss of load and signal a no load/broken belt warning or fault.
18. The VFD shall store in memory the last 8 faults and record all operational data.
19. Four programmable digital inputs shall be provided for interfacing with the systems control and safety interlock circuitry.
20. Two programmable relay outputs shall be provided for remote indication of drive status.
21. Two programmable analog inputs shall be provided and shall accept a direct-or-reverse acting signal. Analog reference inputs accepted shall include 0-10Vdc, 0-20mA, and 4-20mA.
22. One programmable analog output shall be provided for indication of drive status. Output shall be programmable for output speed, voltage, frequency, amps and input kW.

## 2.5 SERIAL COMMUNICATIONS

- A. VFDs shall include the following built-in communications protocols:
  - 1. Johnson Controls Metasys N2
- B. Option boards for the following communications protocols shall be available:
  - 1. LonWorks Free Topology (FTP) certified to LonMark standard 3.3
  - 2. BACnet MS/TP
- C. VFD shall have standard RS-232 or USB port for direct connection of Personal Computer (PC) to the VFD. The manufacturer shall provide no-charge PC software to allow complete setup and access of the VFD and logs of VFD operation through the port. It shall be possible to communicate to the VFD through this port without interrupting VFD communications to the DDC system.

## 2.6 ADJUSTMENT CAPABILITY

- A. The drive shall be provided with the following adjustment capability:
  - 1. VFD shall minimize the audible motor noise through the use of an adjustable carrier frequency. The carrier frequency shall be automatically adjusted to optimize motor and VFD operation while reducing motor noise. VFDs with fixed carrier frequency are not acceptable.
  - 2. Automatic variable-torque V/Hz patterns shall be provided with the ability to select a constant torque start pattern for each of them.
  - 3. A minimum of two preset speeds shall be provided.
  - 4. The number of restart attempts shall be selectable from 0–10 and the time between attempts shall be adjustable from 0–600 seconds.
  - 5. Four acceleration and four deceleration ramps shall be provided. The shape of these curves shall be adjustable.

## 2.7 FIRE ALARM INTERFACE

- A. Provide an override input so that opening dry contacts will absolutely stop the motor under any operating condition.
- B. Provide an override input so that closing dry contacts will cause the motor to operate at a speed predetermined by VFD programming.
- C. Provide a Summary Alarm dry contact, for connection to the Fire Alarm system, indicating that the VFD is not operable.

## 2.8 BYPASS SWITCH

- A. Provide a manual three-contactor bypass consisting of a door interlocked main fused disconnect, padlockable in the off position, a built-in motor starter and a four position DRIVE/OFF/LINE/TEST switch controlling three contactors.
  - 1. In the DRIVE position, the motor is operated at an adjustable speed from the drive.
  - 2. In the OFF position, the motor and drive are disconnected.
  - 3. In the LINE position, the motor is operated at full speed from the AC power line and power is disconnected from the drive, so that service can be performed.

4. In the TEST position, the motor is operated at full speed from the AC line power. This allows the drive to be given an operational test while continuing to run the motor at full speed in bypass.
- B. Contactors shall operate from a 24 Vdc power supply that shall function off of any two legs of the AC line and shall maintain power on the loss of any one of the AC lines.
- C. A Bypass pilot light shall indicate that the motor is operating from line power.
- D. Selectable Run Permissive logic shall operate in either VFD or bypass operation. When activated, any command to start the motor, in either Hand Bypass, Remote Bypass, Hand VFD or Remote VFD shall not start the motor, but instead close a relay contact that is used to initiate operation of another device, such as an outside air damper. A contact closure from this device shall confirm that it is appropriately actuated and the motor shall then start.
- E. Bypass package shall include an External Safety interlock that will disable motor operation in either bypass or VFD when open.
- F. Firemode bypass operation shall be standard. When activated via a contact closure, the motor shall transfer to bypass (line power) regardless of the mode selected. All calls to stop the motor shall be ignored. These include the opening of the start command, an external safety trip or the tripping of the motor overload. Firemode operation will take precedence over all other commands.
- G. The bypass must include a selectable time delay of 0 to 60 seconds before the initiation of bypass operation. When transferring from VFD to bypass modes, the time delay starts after the motor has decelerated to zero speed. This delay allows the BAS to prepare for bypass operation. Bypass packages that do not include a time delay, or do not include a selectable delay period, will not be acceptable.
- H. Automatic bypass shall be selectable. When active, the motor shall be transferred to line power on a VFD fault condition. The bypass time delay shall be activated prior to this transfer to line power to allow the VFD time to attempt to recover from the fault condition prior to running in bypass.

## 2.9 SERVICE CONDITIONS

- A. The drive shall be capable of operating in the following service conditions:
  1. Ambient temperature: 14–104°F (-10–40°C).
  2. Relative humidity: 0–95%, non-condensing.
  3. Elevation: Up to 3,300 feet without de-rating.
  4. AC line voltage variation:  $\pm 10\%$  of nominal with full output.
  5. Side clearance: None required for cooling of wall mount units

## 2.10 PERFORMANCE

- A. The carrier frequency of pulse width modulated VFDs shall be variable and automatically adjusted so motor noise resulting from VFD, measured at 3 feet from the motor, is less than 3 dB greater than the motor noise when operating across the line. When turned ON, the VFD shall be able to stop reverse motor rotation, apply a synchronized output to a rotating motor and then drive the motor to control set point.

B. Quality Assurance Provisions:

1. To ensure quality and minimize infantile failures at the jobsite, the complete VFD shall be tested by the manufacturer. The VFD shall operate a dynamometer at full load and the load and speed shall be cycled during the test.
2. All optional features shall be functionally tested at the factory for proper operation.

PART 3 – EXECUTION

3.1 EXAMINATION

- A. Installing contractor to verify that job site conditions for installation meet factory recommended and code-required conditions for VFD installation prior to start-up, including clearance spacing, temperature, contamination, dust, and moisture of the environment. Separate conduit installation of the motor wiring, power wiring, and control wiring, and installation per the manufacturer's recommendations shall be verified by the installing contractor.
- B. The VFD is to be covered and protected from installation dust and contamination until the environment is cleaned and ready for operation. The VFD shall not be operated while the unit is covered.

3.2 INSTALLATION

- A. The VFD shall be installed per manufacturer's recommendations.
- B. Installation and Field Wiring: Mounting and Control wiring shall be Division 23 09 00. VFD shall be mounted to rigid uni-strut type and/or building structures. Power wiring shall be by Division 26.
- C. Service During the Warranty Period:
  1. If necessary, the VFD shall be serviced by an agency located within 50 miles of the project site.
  2. Qualified technical support shall be available on site within 24 hours of request.

3.3 MANUFACTURER REPRESENTATIVE STARTUP

- A. The manufacturer shall provide start-up commissioning of the variable frequency drive and its optional circuits by a factory certified service technician who is experienced in start-up and repair services.
  1. When possible, the commissioning personnel shall be the same personnel that will provide the factory service and warranty repairs at the customer's site.
  2. Sales personnel and other agents who are not factory certified technicians for VFD field repair shall not be acceptable as commissioning agents.
- B. Start-up services shall include verification of proper installation and operation of the VFD, its options and its interface wiring to the DDC system as described in section 3.3.C below.
- C. Field Start Up and Testing:
  1. Verify all installation connections and controls.

2. Field adjust all VFD safety controls.
3. Field adjust VFD parameters as follows:
  - a. Acceleration time – According to inertia load.
  - b. Deceleration time – According to inertia load.
  - c. Minimum speed settings:
    - 1) Pumps: 30% of pump motor full load RPM
    - 2) Fans: 20% of fan motor full load RPM.
  - d. Program VFD so that, upon reapplication of power after a power failure, the VFD shall automatically reapply power and drive the motor to control set point.
  - e. Program VFD so no more than 6 automatic restart attempts will be made within one hour after shutdown due to input power problems.
4. Demonstrate operation of VFD including
  - a. Programming, control, and display of information by the DDC system.
  - b. Return to operation after a power failure.
  - c. Bypass switch-over.

### 3.4 TRAINING

- A. Provide two [4] hour training sessions during normal business hours.
  1. First session shall cover operation of VFDs. Second session shall cover system operation and trouble shooting. Give minimum one week notice prior to demonstration.
  2. Coordinate training times with the [insert applicable contact].
  3. Provide six sets of operating, troubleshooting, repair and maintenance manuals.

**END OF SECTION**