

SECTION 23 05 14

VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.01 DESCRIPTION

- A. Variable Frequency Drive (VFD) pulse width modulating type (PWM) inverter for use with NEMA B induction motors. The drive shall be designed for variable torque applications.
- B. The drive manufacturer shall supply the drive and all necessary controls as herein specified. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of twenty years and shall have an existing sales representative exclusively for HVAC products, with expertise in HVAC systems and controls and an independent service organization.
- C. All variable frequency drives for the project shall be from the same manufacturer. Coordinate with other sections of the specifications.

1.02 QUALITY ASSURANCE

- A. Referenced Standards:
 - 1. Institute of Electrical and Electronic Engineers (IEEE): Standard 519-1992, IEEE Guide for Harmonic Content and Control.
 - 2. Underwriters laboratories: UL 508C
 - 3. National Electrical Manufacturer's Association (NEMA): ICS 7.0, AC Adjustable Speed Drives
 - 4. IEC 16800 Parts 1 and 2
- B. Qualifications:
 - 1. VFD's and options shall be UL listed as a complete assembly. VFD's that require the customer to supply external fuses for the VFD to be UL listed are not acceptable. The base VFD shall be UL listed for 100 KAIC without the need for input fuses.
 - 2. CE Mark – The VFD shall conform to the European Union Electro-Magnetic Compatibility directive, a requirement for CE marking and product standard EN 61800-3 for the First Environment restricted level.

1.03 SUMMARY

- A. Submittals shall include the following information:
 - 1. Outline dimensions, conduit entry locations and weight.
 - 2. Customer connection and power wiring diagrams.
 - 3. Complete technical product description include a complete list of options provided
 - 4. Compliance to IEEE 519 – harmonic analysis for particular jobsite including total harmonic voltage distortion and total harmonic current distortion (TDD).
 - a. The VFD manufacturer shall provide calculations; specific to this installation, showing total harmonic voltage distortion is less than 5%. Input line filters shall be sized and provided as required by the VFD manufacturer to ensure compliance with IEEE standard 519. All VFD's shall include a minimum of 5% impedance reactors, no exceptions.

PART 2 PRODUCTS

2.01 ADJUSTABLE FREQUENCY DRIVES

- A. Manufacturers:
1. ABB ACH Series.
 2. Danfoss
 3. Reliance
 4. Graham
- B. The VFD manufacturer shall have available a comprehensive, HVAC Drive Computer Based Training including:
1. Detailed, interactive sections covering VFD unpacking, proper mechanical and electrical installation, and programming.
 2. Product shall allow the user to provide just-in-time training to new personnel or refresher training for maintenance and repair personnel on the user's site. The product shall be repeatable, precise and shall include record keeping capability. The product shall record answers to simulations and tests by student ID. The product must be professionally produced and have interactive sections, student tests, and include video clips of proper wiring and installation.
- C. The VFD package as specified herein shall be enclosed in a UL Listed Type 12 enclosure when installed in plenum, NEMA 1 when installed indoors and NEMA 3 for outdoor installation completely assembled and tested by the manufacturer in an ISO 9001 facility. The VFD tolerated voltage window shall allow the VFD to operate from a line of +30% nominal, and -35% nominal voltage as a minimum.
1. Environmental operating conditions: 0 to 40°C continuous. VFD's that can operate at 40° C intermittently (during a 24 hour period) are not acceptable and must be oversized. Altitude 0 to 3300 feet above sea level, less than 95% humidity, non-condensing.
 2. Units installed outdoors shall be rated for 130 degrees F.
- D. All VFD's shall have the following standard features:
1. All VFD's shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFD's.
 2. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate "bumpless transfer" of speed reference when switching between "Hand" and "Auto" modes. There shall be fault reset and "Help" buttons on the keypad. The Help button shall include "on-line" assistance for programming and troubleshooting.
 3. There shall be a built-in time clock in the VFD keypad. The clock shall have a battery backup with 10 years minimum life span. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault. If the battery fails, the VFD shall automatically revert to hours of operation since initial power up. The clock shall also be programmable to control start/stop functions, constant speeds, PID parameter sets and output relays. The VFD shall have a digital input that allows an override to the time clock (when in the off mode) for a programmable time frame. There shall be four (4) separate, independent timer functions that have both weekday and weekend settings.
 4. The VFD's shall utilize pre-programmed application macro's specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.
 5. The VFD shall have cooling fans that are designed for easy replacement. The fans shall be designed for replacement without requiring removing the VFD from the wall or removal of circuit boards. The VFD cooling fans shall operate only when required. To extend the fan and bearing operating life, operating temperature will be monitored and used to cycle the fans on and off as required.

6. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to setpoint without safety tripping or component damage (flying start).
7. The VFD shall have the ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.
8. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430-150 for 4-pole motors.
9. The VFD shall have an integral 5% impedance line reactor to reduce the harmonics to the power line and to add protection from AC line transients. The 5% impedance may be from dual (positive and negative DC bus) reactors, or 5% AC line reactors. VFD's with only one DC reactor shall add AC line reactors.
10. The input current rating of the VFD shall be no more than 3% greater than the output current rating. VFD's with higher input current ratings require the upstream wiring, protection devices and source transformers to be oversized per NEC 430-2.
11. The VFD shall include a coordinated AC transient protection system consisting of 4-120 joule rated MOV's (phase to phase and phase to ground), a capacitor clamp, and 5% impedance reactors.
12. 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 outputs shall include programmable time delays that will allow for drive acceleration from zero speed without signaling a false under load condition.
13. If the input reference (4-20mA or 2-10V) is lost, the VFD shall give the user the option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued, as selected by the user. The drive shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communication bus.
14. The VFD shall have programmable "Sleep" and "Wake up" functions to allow the drive to be started and stopped from the level of a process feedback signal.

E. All VFD's to have the following adjustments:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed.
2. Two (2) PID Setpoint controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed loop control. The VFD shall have 250 ma of 24 VDC 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. There shall be two parameter sets for the first PID that allow the sets to be switched via a digital input, serial communications or from the keypad for night setback, summer/winter set points, etc. There shall be an independent, second PID loop that can utilize the second analog input and modulate one of the analog outputs to maintain setpoint of an independent process (i.e. valves, dampers, etc.). All set points, process variables, etc. to be accessible from the serial communication network. The set points shall be set in Engineering units and not require a percentage of the transducer input.
3. Two (2) programmable analog inputs shall accept current or voltage signals.
4. Two (2) programmable analog outputs (0-20ma or 4-20 ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, and other data.
5. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices, typically programmed as follows:
6. There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications) the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a VFD digital input and allows VFD motor operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. The keypad shall

- display "start enable 1 (or 2) missing". The safety status shall also be transmitted over the serial communications bus. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC.
7. Three (3) programmable digital Form-C relay outputs. The relays shall include programmable on and off delay times and adjustable hysteresis. Default settings shall be for run, not faulted (fail safe), and run permissive. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 A at 250 VAC; Maximum voltage 300 VDC and 250 VAC; continuous current rating 2 amps RMS. Outputs shall be true form C type contacts; open collector outputs are not acceptable.
 8. Seven (7) programmable preset speeds.
 9. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.
 10. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and audible motor noise.
 11. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows the highest carrier frequency without derating the VFD or operating at high carrier frequency only at low speeds.
 12. The VFD shall include password protection against parameter changes.
- F. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). The keypad shall utilize the following assistants:
1. Start-up assistants.
 2. Parameter assistants
 3. Maintenance assistant
 4. Troubleshooting assistant
- G. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):
1. Output Frequency
 2. Motor Speed (RPM, %, or Engineering units)
 3. Motor Current
 4. Calculated Motor Torque
 5. Calculated Motor Power (kW)
 6. DC Bus Voltage
 7. Output Voltage
- H. The VFD shall include a fireman's override input. Upon receipt of a contact closure from the fireman's control station, the VFD shall operate at an adjustable preset speed. The mode shall override all other inputs (analog/digital, serial communication, and all keypad commands) and force the motor to run at the adjustable, preset speed. "Override Mode" shall be displayed on the keypad. Upon removal of the override signal, the VFD shall resume normal operation.
- I. Serial Communications
1. The VFD shall have an RS-485 port as standard. The standard protocols shall be Modbus, BACnet, Johnson Controls N2 bus, and Siemens Building Technologies FLN. Protocol shall be compatible with selected facility management system. Each individual drive shall have the protocol in the base VFD. The use of third party gateways and multiplexers is not acceptable. All protocols shall be "certified" by the governing authority. Use of non-certified protocols is not allowed. Protocol shall be coordinated with the energy management system that will be used for the project.

2. The BACnet connection shall be an RS485, MSTP interface operating at 9.6, 19.2, 38.4, or 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:
 - a. Data Sharing – Read Property – B.
 - b. Data Sharing – Write Property – B.
 - c. Device Management – Dynamic Device Binding (Who-Is; I-AM).
 - d. Device Management – Dynamic Object Binding (Who-Has; I-Have).
 - e. Device Management – Communication Control – B.
 - f. If additional hardware is required to obtain the BACnet interface, the VFD manufacturer shall supply one BACnet gateway per drive. Multiple VFDs sharing one gateway shall not be acceptable.

3. Serial communication capabilities shall include, but not be limited to; run-stop control, speed set adjustment, proportional/integral/derivative PID control adjustments, current limit, accel/decel time adjustments, and lock and unlock the keypad. The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature. The DDC shall also be capable of monitoring the VFD relay output status, digital input status, and all analog input and analog output values. All diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote VFD fault reset shall be possible. The following additional status indications and settings shall be transmitted over the serial communications bus – keypad “Hand” or “Auto” selected, bypass selected, the ability to change the PID setpoint, and the ability to force the unit to bypass (if bypass is specified). The DDC system shall also be able to monitor if the motor is running in the VFD mode or bypass mode (if bypass is specified) over serial communications. A minimum of 15 field parameters shall be capable of being monitored.

4. The VFD shall allow the DDC to control the drive's digital and analog outputs via the serial interface. This control shall be independent of any VFD function. For example, the analog outputs may be used for modulating chilled water valves or cooling tower bypass valves. The drive's digital (relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the drive's digital and analog inputs shall be capable of being monitored by the DDC system.

5. The VFD shall include an independent PID loop for customer use. The independent PID loop may be used for cooling tower bypass value control, chilled water value control, etc. Both the VFD control PID loop and the independent PID loop shall continue functioning even if the serial communications connection is lost. The VFD shall keep the last good set-point command and last good DO & AO commands in memory in the event the serial communications connection is lost.

- J. EMI / RFI filters. All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level. Certified test lab test reports shall be provided with the submittal.

- K. All VFD's through 50 HP shall be protected from input and output power mis-wiring. The VFD shall sense this condition and display an alarm on the keypad.

- L. Bypass – All features to be furnished and mounted by the drive manufacturer. All features shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL 508 label. Bypass is not required for air handling units furnished with standby VFD.
 1. A complete factory wired and tested bypass system consisting of an output contactor and bypass contactor. Overload protection and shall be provided in both drive and bypass modes.
 2. Door interlocked pad lockable circuit breaker that will disconnect all input power from the drive and all internally mounted options.

3. Fused VFD only disconnect (service switch). Fast acting fuses exclusive to the VFD – fast acting fuses allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection, maintaining bypass capability. Bypass designs, which have no such fuses, or that incorporate fuses common to both the VFD and the bypass will not be accepted. Three contactor bypass schemes are not acceptable.
4. The drive / bypass shall provide single-phase motor protection in both the VFD and bypass modes.
5. The following operators shall be provided:
 - a. Bypass Hand-Off-Auto
 - b. Drive mode selector
 - c. Bypass mode selector
 - d. Bypass fault reset
6. The following indicating lights (LED type) shall be provided. A test mode or push to test feature shall be provided.
 - a. Power-on (Ready)
 - b. Run enable (safeties) open
 - c. Drive mode select damper opening
 - d. Bypass mode selected
 - e. Drive running
 - f. Bypass running
 - g. Drive fault
 - h. Bypass fault
 - i. Bypass H-O-A mode
 - j. Automatic transfer to bypass selected
 - k. Safety open
 - l. Damper opening
 - m. Damper end-switch made
7. 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 under load (broken belt))
 - f. Bypass H-O-A position
8. The digital inputs for the system shall accept 24V or 115 VAC (selectable). The bypass shall incorporate internally sourced power supply and not require an external control power source.
9. Customer Interlock Terminal Strip – provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in Hand, Auto, or Bypass modes (not functional in Fireman's Override 2). The remote start/stop contact shall operate in VFD and bypass modes.
10. Dedicated digital input that will transfer motor from VFD mode to bypass mode upon dry contact closure for fireman's override. Two modes of operation are required.
 - a. One mode forces the motor to bypass operation and overrides both the VFD and bypass H-O-A switches and forces the motor to operate across the line (test mode). The system will only respond to the digital inputs and motor protections.
 - b. The second fireman's override mode remains as above, but will also defeat the overload and single-phase protection for bypass and ignore all keypad and digital inputs to the system (run until destruction).

11. The VFD shall include a "run permissive circuit" that will provide a normally open contact whenever a run command is provided (local or remote start command in VFD or bypass mode). The VFD system (VFD or bypass) shall not operate the motor until it receives a dry contact closure from a damper or valve end-switch. When the VFD system safety interlock (fire detector, freezestat, high static pressure switch, etc) opens, the motor shall coast to a stop and the run permissive contact shall open, closing the damper or valve.
12. Class 20 or 30 (selectable) electronic motor overload protection shall be included.
13. There shall be an internal switch to select manual or automatic bypass.
14. There shall be an adjustable current sensing circuit for the bypass to provide loss of load indication (broken belt) when in the bypass mode.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Installation shall be the responsibility of the mechanical Developer Design/Builder. The Developer Design/Builder shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
- B. Power wiring shall be completed by the electrical Developer Design/Builder. The Developer Design/Builder shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
- C. Developer Design/Builder to coordinate with the energy management system interface.

3.02 START-UP

- A. Certified factory 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 County, and a copy kept on file at the manufacturer.

3.03 PRODUCT SUPPORT

- A. Factory trained application engineering and service personnel that are thoroughly familiar with the VFD products offered shall be locally available at both the specifying and installation locations. A 24/365 technical support line shall be available on a toll-free line.
- B. A computer based training CD or 8-hour professionally generated video (VCR format) shall be provided to the County at the time of project closeout. The training shall include installation, programming and operation of the VFD, bypass and serial communication.

3.04 WARRANTY

- A. Warranty shall be 2 years from the date of certified start-up, not to exceed 30 months from the date of shipment. The warranty shall include all parts, labor, travel time and expenses. There shall be 365/24 support available via a toll free phone number.

END OF SECTION