

SECTION 16483B
ADJUSTABLE FREQUENCY DRIVE – HVAC (HVX)

PART 1 GENERAL

1.01 SCOPE

- A. This specification describes the electrical, mechanical, environmental, agency and reliability requirements for three-phases, Adjustable Frequency Drives (AFD) as specified herein and as shown on the contract drawings.

1.02 RELATED SECTIONS

1.03 REFERENCES

- A. The adjustable frequency drives and all components shall be designed, manufactured and tested in accordance with the latest applicable standards.
 - 1. Institute of Electrical and Electronic Engineers (IEEE)
 - a. IEEE 519-1992: Guide for harmonic content and control
 - 2. Underwriters Laboratories (UL508C: Power Conversion Equipment)
 - a. UL
 - b. CUL
 - 3. National Electrical Manufacturer's Association (NEMA)
 - a. ICS 7.0: Industrial Controls & Systems for AFD.
 - 4. IEC 61800-2 and –3. EN 50082-1 and –2
 - a. Fulfill all EMC immunity requirements
- B. In case of conflict between the requirements of this section and those of the listed documents, the requirements of this section shall prevail.

1.04 SUBMITTALS FOR REVIEW/APPROVAL

- A. The following information shall be submitted to the Engineer.
 - 1. Dimensioned outline drawing.
 - 2. Control Schematic diagram.
 - 3. Power and control connection diagram(s)
- B. Submit four (4) copies of the above information.

1.05 SUBMITTALS FOR INFORMATION

- A. When requested by the Engineer the following product information shall be submitted:
 - 1. Product bulletins
 - 2. Technical product data sheets
 - 3. Harmonic analysis result

1.06 SUBMITTAL FOR CLOSE-OUT

- A. The following information shall be submitted for record purposes prior to final payment.
 - 1. Final as-built drawings and information for items listed in Section 1.04.1.
 - 2. Installation information.

1.07 QUALIFICATIONS

- A. The supplier of the assembly shall be the manufacturer of the electromechanical power components used within the assembly, such as bypass contactors, power distribution circuit breakers, when specified. These parts, when specified, shall have a commonality with other manufacturer's products.
- B. For the equipment specified herein, the manufacturer shall be ISO 9001 certified. All equipment shall have been tested and listed by UL as complying with the requirements of UL508C
- C. The supplier of this equipment shall have produced similar electrical equipment for a minimum period of ten (10) years. When requested by the Engineer, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.
- D. Adjustable Frequency Drives shall be on the basis of Eaton Electrical HVX Series for function and quality. No "Approved Equal".

1.08 REGULATORY REQUIREMENTS

1.09 DELIVERY, STORAGE, AND HANDLING

- A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

1.10 FIELD MEASUREMENTS

1.11 OPERATION AND MAINTENANCE MANUALS


- A. Five (5) copies of the equipment operation and maintenance manuals shall be provided.
- B. Operation and maintenance manuals shall include the following information:
 - 1. Instruction books
 - 2. Recommended renewal parts list.
 - 3. Drawings and information required by Section 1.04.3

1.12 EXTRA PRODUCTS

PART 2 PRODUCTS

2.01 MANUFACTURERS


A. Eaton

B.  _____C.  _____

Naming specific vendors does not imply acceptance of their standard products nor relieve them from meeting these specifications in their entirety.

2.02 ADJUSTABLE FREQUENCY DRIVES (AFD)

- A. Where shown on the drawings, adjustable frequency drives 1 through 2000 Horsepower (HP) Variable Torque (VT) shall have the following features:
1. The AFDs shall be rated for 480 Vac (optional input voltages of 208, 240 Vac through 30 HP). The AFD shall provide microprocessor based control for three-phase induction motors. The controller's full load output current rating shall be based on Variable Torque application at 40° C ambient and 1-16 kHz switching frequency below 50 HP and 1-10 kHz 50 HP and above to reduce motor noise and avoid increased motor losses.
 2. The AFD shall be of the Pulse Width Modulated (PWM) design converting the utility input voltage and frequency to a variable voltage and frequency output via a two-step operation. Adjustable Current Source AFD are not accepted. Insulated Gate Bipolar Transistors (IGBT's) shall be used in the inverter section. Bipolar Junction Transistors, GTO's or SCR's are not accepted. The AFD shall run at the above listed switching frequencies.
 3. The AFD shall have an efficiency at full load and speed that exceeds 95% for AFD below 15 HP and 97% for drives 15 HP and above. The efficiency shall exceed 90% at 50% speed and load.
 4. The AFD shall maintain a minimum line side displacement power factor of 0.96, regardless of speed and load.
 5. The AFD shall have a one (1) minute overload current rating of 110% for variable torque applications.
 6. The AFD shall be capable of operating any NEMA design B squirrel cage induction motor, regardless of manufacturer, with a horsepower and current rating within the capacity of the AFD.
 7. The AFD shall have an integral EMI/RFI filter as standard.
 8. The AFD shall limit harmonic distortion reflected onto the utility system to voltage and current levels as defined by IEEE 519-1992 for general systems applications, by utilizing the standard 3% nominal impedance integral AC three-phase line reactor. DC link chokes are not accepted.
 9. All harmonic calculations shall be done based on the kVA capacity, X/R ratio and the impedance of the utility transformer feeding the installation, as noted on the drawings,

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and the total system load. The calculations shall be made with the point of common coupling (PCC) being the point where the utility feeds multiple customers.

10. ☒ Total harmonic distortion shall be calculated under worst case conditions in accordance with the procedure outlined in IEEE 519-1992. Copies of these calculations are to be made available upon request. The contractor shall provide any needed information to the AFD supplier three (3) weeks prior to requiring harmonic calculations.
11. The system containing the AFD shall comply with the 5% level of total harmonic distortion of line voltage and the line current limits as defined in IEEE 519-1992. If the system cannot meet the harmonic levels with the AFD provided with the standard input line reactor or optional input isolation transformer, the AFD manufacturer shall supply an eighteen pulse, multiple bridge rectifier AC to DC conversion section with phase shifting transformer for all drives above 75 HP. This eighteen pulse rectifier converter shall result in a multiple pulse current waveform that will more nearly approximate a true sine wave to reduce voltage harmonic content on the utility line. The phase shifting transformer shall be of a single winding type to optimize its KVA rating and harmonic cancellation capability. Harmonic filters are not accepted above 75 HP.
12. The AFD shall be able to start into a spinning motor (flying start). The AFD shall be able to determine the motor speed in any direction and resume operation without tripping. If the motor is spinning in the reverse direction, the AFD shall start into the motor in the reverse direction, bring the motor to a controlled stop, and then accelerate the motor to the preset speed.
13. Standard operating conditions shall be:

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- a. Incoming Power: Three-phase, ☒ [208] [240] [480] Vac (+10% to -15%) and 50/60 Hz (+/-5 Hz) power to a fixed potential DC bus level.
 - b. Frequency stability of +/-0.05% for 24 hours with voltage regulation of +/-1% of maximum rated output voltage.
 - c. Speed regulation of +/- 0.5% of base speed.
 - d. Load inertia dependant carryover (ridethrough) during utility loss.
 - e. Insensitive to input line rotation.
 - f. Humidity: 0 to 95% (non-condensing and non-corrosive).
 - g. Altitude: 0 to 3,300 feet (1000 meters) above sea level.
 - h. Ambient Temperature: -10 to 40 °C (VT).
 - i. Storage Temperature: -40 to 70 °C.
14. Control Functions
 - a. Frequently accessed AFD programmable parameters shall be adjustable from a digital operator keypad located on the front of the AFD. The AFD shall have a 3 line alphanumeric programmable display with status indicators. Keypads must use plain English words for parameters, status, and diagnostic messages. Keypads that are difficult to read or understand are not accepted, and particularly those that use alphanumeric code and tables. Keypads shall be adjustable for contrast with large characters easily visible in normal ambient light.

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- b. The keypad shall include a Hand-Off-Auto membrane selection and an Inverter/Bypass membrane selection. When in “Hand” the AFD will be started and the speed will be controlled from the up/down arrows. When in “Off”, the AFD will be stopped. In “Auto”, the AFD will start via an external contact closure or a communication network and the AFD speed will be controlled via an external speed reference.
 - c. The keypad shall have copy / paste capability.
 - d. Upon initial power up of the AFD, the keypad shall display a start up guide that will sequence all the necessary parameter adjustments for general start up.
 - e. Standard advanced programming and trouble-shooting functions shall be available by using a personal computer’s RS-232 port and Windows™ based software. In addition the software shall permit control and monitoring via the AFD’ RS232 port. The manufacturer shall supply a diskette with the required software. An easily understood instruction manual and software help screens shall also be provided. The computer software shall be used for modifying the drive setup and reviewing diagnostic and trend information as outlined in this section through Section 18. Provide one copy of the advanced programming software.
 - f. The operator shall be able to scroll through the keypad menu to choose between the following:
 - 1. Parameter Menu
 - 2. Keypad Control
 - 3. System Menu
 - 4. Expander Boards
 - 5. Monitoring Menu
 - 6. Operate Menu
 - g. The following setups and adjustments, at a minimum, are to be available:
 - 1. Start command from keypad, remote or communications port
 - 2. Speed command from keypad, remote or communications port
 - 3. Motor direction selection
 - 4. Maximum and minimum speed limits
 - 5. Acceleration and deceleration times, two settable ranges
 - 6. Critical (skip) frequency avoidance
 - 7. Torque limit
 - 8. Multiple attempt restart function
 - 9. Multiple preset speeds adjustment
 - 10. Catch a spinning motor start or normal start selection
 - 11. Programmable analog output
15. The AFD shall have the following system interfaces:
- a. Inputs – A minimum of six (6) programmable digital inputs, two (2) analog inputs and serial communications interface shall be provided with the following available as a minimum:
 - 1. Remote manual/auto
 - 2. Remote start/stop
 - 3. Remote forward/reverse

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4. Remote preset speeds
5. Remote external trip
6. Remote fault reset
7. Process control speed reference interface, 4-20m Adc
8. Potentiometer or process control speed reference interface, 0 –10 Vdc
9. RS-232 programming and operation interface port
- b. Outputs – A minimum of two (2) discrete programmable digital outputs, one (1) programmable open collector output, and one (1) programmable analog output shall be provided, with the following available at minimum.
 1. Programmable relay outputs with one (1) set of Form C contacts for each, selectable with the following available at minimum:
 - i. Fault
 - ii. Run
 - iii. Ready
 - iv. Reversing
 - v. Jogging
 - vi. At speed
 - vii. In torque limit
 - viii. Motor rotation direction opposite of commanded
 - ix. Over-temperature
 2. Programmable open collector output with available 24 Vdc power supply and selectable with the following available at minimum:
 - i. Fault
 - ii. Run
 - iii. Ready
 - iv. Reversing
 - v. Jogging
 - vi. At speed
 - vii. In torque limit
 - viii. Motor rotation direction opposite of commanded
 - ix. Overtemperature
 3. Programmable analog output signal, selectable with the following available at minimum:
 - i. Output frequency
 - ii. Frequency reference
 - iii. Motor speed
 - iv. Output current
 - v. Motor torque
 - vi. Motor power
 - vii. Motor voltage
 - viii. DC link voltage
 - ix. PID controller reference value

- x. PID controller actual value 1
 - xi. PID controller actual value 2
 - xii. PID controller error value
 - xiii. PID controller output
- c. Capability of two additional expandable I/O interface cards. Upon installation, software shall automatically identify the interface card and activate the appropriate parameters. This should be done without adding any new software.
16. Monitoring and Displays
- a. The AFD display shall be a LCD type capable of displaying three (3) lines of text and the following thirteen (13) status indicators:
 - 1. Run
 - 2. Forward
 - 3. Reverse
 - 4. Stop
 - 5. Ready
 - 6. Alarm
 - 7. Fault
 - 8. Input/Output (I/O) Terminal
 - 9. Keypad
 - 10. Bus/communication
 - 11. Hand
 - 12. Auto
 - 13. Off
 - b. The AFD keypad shall be capable of displaying the following monitoring functions at a minimum:
 - 1. Motor Speed (RPM and %)
 - 2. Frequency reference
 - 3. Output frequency
 - 4. Motor current
 - 5. Motor torque
 - 6. Motor power
 - 7. Motor voltage
 - 8. DC-link voltage
 - 9. Heatsink temperature
 - 10. Motor run time (resetable)
 - 11. Total operating days counter
 - 12. Operating hours (resetable)
 - 13. Total megawatt hours
 - 14. Megawatt hours (resetable)
 - 15. Voltage level of analog input
 - 16. Current level of analog input
 - 17. Digital inputs status

18. Digital and relay outputs status
 19. Motor temperature rise
 20. PID references
17. Protective Functions
- a. The AFD shall include the following protective features at minimum:
 1. Over-current
 2. Over-voltage
 3. System fault
 4. Under-voltage
 5. Input line supervision
 6. Output phase supervision
 7. Under-temperature
 8. Over-temperature
 9. Motor stalled
 10. Motor over temperature
 11. Motor under-load
 12. Logic voltage failure
 13. Microprocessor failure
 14. Brake chopper supervision
 15. DC Injection braking
 - b. The AFD shall provide ground fault protection during power-up, starting, and running. AFD with no ground fault protection during running are not accepted.
18. Diagnostic Features
- a. Active Faults
 - b. The last 10 faults shall be recorded and stored in sequential order
 - c. Fault code and description of fault shall be displayed on the keypad.
 - d. Fault or alarm LED shall blink
 - e. Display drive data at time of fault
 - f. In the event several faults occur simultaneously, the sequence of active faults shall be viewable.
 - g. During a fault, the drive must be able to identify the following:
 1. Drive Speed
 2. Running hours
 3. Running Days
 4. Amps during fault
 5. Motor Power
 6. Motor Torque
 7. DC bus Voltage
 8. Drive Temperature
 - h. Fault History
 1. The last 30 faults shall be recorded and stored in sequential order.
 2. Display drive data at time of fault

19. Additional features included in the AFD:
- a. The following indicating lights shall be provided on the keypad.
 1. Drive Ready
 2. Drive Run
 3. Drive Fault
 - b. The current withstand rating of the drive shall be 100,000 AIC. The rating of the complete drive assembly shall be UL tested and listed at 65kAIC.
 - c. Communication card for interface with [ModBus RTU][Johnson Controls Metasys N2][LonWorks][Siemens Apogee P1][BACnet] control system.
 - d. The AFD shall have a cooling fan that is field replaceable using non-screw accessibility.
20. Enclosure
- a. The AFD shall be designed in a NEMA Type [1] [12] [3R] enclosure. Packaging of the drive shall be designed and manufactured by the manufacturer of the drive for quality assurance.
 - b. The AFD shall have complete front accessibility with easily removable assemblies.
 - c. Cable entry shall be bottom entry.
21. Options
- a. Three contactor bypass shall include a drive input disconnect, an AFD input isolation contactor, bypass contactor and an AFD output contactor that is electrically and mechanically interlocked with the bypass contactor. This circuit shall include control logic, status lights and motor overcurrent relays. The complete bypass system [Inverter-Off-Bypass] [Hand-Off-Auto with Inverter-Bypass] selector switch(s), and Inverter/Bypass pilot lights shall be packaged with the AFD. The unit may be set up for [manual] [automatic] bypass operation upon an AFD trip.
 - b. Two contactor bypass shall include a drive input disconnect, bypass contactor and an AFD output contactor that is electrically and mechanically interlocked with the bypass contactor. This circuit shall include control logic, status lights and motor overcurrent relays. The complete bypass system [Inverter-Off-Bypass] [Hand-Off-Auto with Inverter-Bypass] selector switch(s), and Inverter/Bypass pilot lights shall be packaged with the AFD. The unit may be set up for 1[manual] [automatic] bypass operation upon an AFD trip.
 - c. Pneumatic process follower allowing motor speed control proportional to a 3-15 PSIG pneumatic signal
 - d. Motor dv/dt filter for use on motor cable runs exceeding 100 feet for motors with a peak voltage insulation rating less than 1600 Vac.
 1. The dv/dt filter shall be located at the AFD and shall reduce the dv/dt clamp any voltage overshoots of the AFD output. It will return the energy in the voltage overshoots to the AFD Dc bus. A power dissipating resistance device is not acceptable. Filter shall be a Cutler-Hammer MotorRx

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1. A properly sized line reactor shall be installed at the AFD output to reduce dv/dt levels and the resultant peak voltage overshoots at the motor terminals.
22. The AFD manufacturer shall maintain, as part of a national network, engineering service facilities within 250 miles of project to provide start-up service, emergency service calls, repair work, service contracts, maintenance and training of customer personnel.

PART 3 EXECUTION

3.01 EXAMINATION

3.02 FACTORY TESTING

- A. The following standard factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest version of UL and NEMA standards.
 1. All printed circuit boards shall be functionally tested via automatic test equipment prior to unit installation.
 2. All final assemblies shall be tested at full load with application of line-to-line and line-to-ground bolted faults. The Adjustable Frequency Drive shall trip electronically without device failure.
 3. After all tests have been performed, each AFD shall undergo a burn-in test. The drive shall be burned in at 100% inductive or motor load without an unscheduled shutdown.
 4. After the burn-in cycle is complete, each AFD shall be put through a motor load test before inspection and shipping.
- B. The manufacturer shall provide three (3) certified copies of factory test reports.
- C. All testing and manufacturing procedures shall be ISO 9001 certified.

3.03 INSTALLATION

3.04 FIELD QUALITY CONTROL

- A. Provide the services of a qualified manufacturer's employed Field Service Engineer or authorized service representative to assist the Contractor in installation and start-up of the equipment specified under this section. Field Service personnel shall be factory trained with periodic updates and have experience with the same model of AFD's on the job site. **Sales representatives will not be accepted to perform this work.** The manufacturer's service representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, installation as specified in manufacturer's installation instructions, wiring, application dependant adjustments, and verification of proper AFD operation.
- B. The following minimum work shall be performed by the Contractor under the technical direction of the manufacturer's service representative.
 1. Inspection and final adjustments.
 2. Operational and functional checks of AFDs and spare parts.

3. The contractor shall certify that he has read the drive manufacturer's installation instructions and has installed the AFD in accordance with those instructions.
- C. The Contractor shall provide three (3) copies of the manufacturer's field start-up report before final payment is made.

3.05 MAINTENANCE/WARRANTY SERVICE


- A. Standard warranty is twenty-four (24) months from the date of shipment and covers the factory repair or replacement of the defective unit.
- B. Warranty is thirty-six (36) months from date of shipment when an authorized service representative performs start up and includes parts, labor and travel time.

3.06 FIELD TESTING

- A. Optional field testing
 1. The AFD manufacturer shall perform harmonic measurements at the point where the utility feeds multiple customers (PCC) to verify compliance with IEEE 519-1992. A report of the voltage THD and current TDD shall be sent to the engineer. The contractor shall provide labor, material, and protection as needed to access the test points. The readings shall be taken with all drives and all other loads at full load, or as close as field conditions allow.

3.07 TRAINING

- A. The Contractor shall provide a training session for up to ____ owner's representatives for ____ normal workdays with a maximum of ____ trips at a job site location determined by the owner. Training and instruction time shall be in addition to that required for start-up service.
- B. The training shall be conducted by the manufacturer's qualified representative.
- C. The training program shall consist of the following:
 1. Instructions on the proper operation of the equipment.
 2. Instructions on the proper maintenance of the equipment.

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