

SECTION 23 09 01
VARIABLE FREQUENCY DRIVES FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and General Requirements, Division 1 Specification Sections apply to the work specified in this section.

1.2 DEFINITIONS

- A. DDC: Direct digital control.
- B. I/O: Input/output.
- C. Interlock: When the term "interlock" is used in the control sequence, it shall mean a hardware interlock. Software interlocks are not acceptable.
- D. LonWorks: A control network technology platform for designing and implementing interoperable control devices and networks.
- E. MS/TP: Master slave/token passing.
- F. PC: Personal computer.
- G. PID: Proportional plus integral plus derivative.
- H. RTD: Resistance temperature detector.

1.3 DESCRIPTION OF WORK

- A. Furnish and install and fit-up in complete working order, with all accessories required, the variable frequency drives (VFD) and monitoring of these drives by the temperature control systems shown on the Drawings and specified herein. The systems shall be properly connected, piped and wired in a manner conforming to the laws, ordinances and codes now in force in the Commonwealth of Kentucky.

1.4 QUALITY ASSURANCE:

- A. Manufacturers: Select a manufacturer from the following listing. Do not use a manufacturer that is not listed below.

- B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering controls that may be incorporated into the Work include, but are not limited to, the following:
 - 1. ABB.
 - 2. Danfoss/Graham
 - 3. Yaskawa
- C. Codes and Standards:
 - 1. Electrical Standards: Provide electrical components of pneumatic control systems which have been UL-listed and labeled, and comply with NEMA standards.
 - 2. NFPA Compliance: Comply with NFPA 90A "Standard for the installation of Air Conditioning and Ventilating Systems" where applicable of controls and control sequences.
 - 3. Kentucky Building Code: Comply with requirements where applicable for controls.
 - 4. The manufacturer of the temperature control system shall be in compliance with ISO-9001 (Model for Quality Assurance in Design/Development, Production, Installation and Servicing).

1.5 SUBMITTALS

- A. Product Data: Include manufacturer's technical literature. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Provide factory shipping cartons for each piece of equipment and control device. Maintain cartons while shipping, storage and handling as required to prevent equipment damage and to eliminate dirt and moisture from equipment. Store equipment and materials inside and protect from weather.

1.7 COORDINATION

- A. Coordinate equipment with Division Section "~~Automatic Temperature Controls~~Direct Digital Control System for HVAC" to achieve interfaces with that control system.

PART 2 - PRODUCTS

2.1 VARIABLE FREQUENCY DRIVES

A. Basic Description:

1. The variable frequency drive (VFD) shall be solid state, with a Pulse Width Modulated (PMW) output waveform (VVI, six-step, and current source drives are not acceptable). The VFD package as specified herein shall be enclosed in a single NEMA 12 enclosure, completely assembled and tested by the manufacturer. The VFD shall employ a full wave rectifier (to prevent input line notching), DC Line Reactor, capacitors, and Insulated Gate Bipolar Transistors (IGBT's) as the output switching device (SCR's, GTO's and Darlington transistors are not acceptable). The drive efficiency shall be 97% or better at full speed and full load. Fundamental power factor shall be 0.98 at all speeds and loads.
2. The VFD shall be specifically designed for variable torque, centrifugal load applications. The Control System Contractor shall perform the following functions from the FMS: remote bypass/auto switching, stop/start, remote speed adjustment, error monitoring and actual speed readout.
3. The VFD shall be suitable for use with any standard NEMA-B squirrel-cage induction motor having a 1.15 or more service factor, or with existing standard NEMA-B squirrel-cage induction motor with nameplate data as shown on the plans. At any time in the future, it shall be possible to substitute any standard motor (equivalent horsepower, voltage and RPM) in the field.
4. Output voltage regulation shall be plus-or-minus 1 per cent from no load to full load.
5. When input speed command is lost, the drive shall continue operation at either last speed command, minimum speed, or a preset speed as determined by the operator.
6. The VFD shall be capable of starting into a spinning load with complete protection and promptly return the motor to set speed. It shall also be capable of bringing windmilling loads to a stop prior to accelerating load in the proper direction by such means as injection braking.
7. All programmable settings, including self diagnostic fault data, shall be held in non-volatile memory and shall not be affected by power outages, brownouts, power dips, etc. The AFD shall have initial programmable settings intact from the factory without the need of battery backup, etc. The start-up technician shall program each AFD to the motor for which it is connected.
8. Programming at the job site to accommodate specific local application requirements, such as frequency avoidance and preset speeds shall be available to the user.
9. Complete efficiency versus load and speed for all VFD ratings shall be readily available from the manufacturer. VFD multiple motor operation at the same frequency and speed shall be possible as long as the sum of the connected motor full load sine wave currents are less than or equal to 90% of the VFD maximum continuous current rating.
10. All high voltage components within the enclosure shall be supplied, protected or enclosed in a method that makes them safe.

B. Codes/Standards:

1. VFD and options shall be UL listed.
2. The controller and options shall comply with the applicable requirement of the latest standards of ANSI; NEMA ICS-6 for controls and systems; National Electric Code NEC; IEC 801-2, 801-4, 256-4.

C. Quality Assurance: The VFD controller shall be subject to but not limited to the following quality assurance controls, procedures and tests.

1. The manufacturer shall have been actively and continuously engaged in the production of adjustable frequency controllers for a period of at least 10 years and have experience of at least 8 years in commercial HVAC applications.
2. Every VFD shall be functionally tested under motor load and must pass a 4-hour minimum heat run under motor load.

D. Variable Frequency Drive:

1. The VFD manufacturer shall provide, at minimum, the electromechanical construction, basic features, adjustments, general options and modifications and special options as outlined in this specification.

E. Basic Features: The VFD shall have the following basic features:

1. Variable Frequency Drive shall be mounted in a NEMA 12 enclosure.
2. The VFD shall incorporate a full 20 character minimum, alpha/numeric customer interface panel showing all settings, parameters, operating screens, operating data, supervision information and faults in plain English. VFD's employing codes and abbreviations shall not be acceptable.
3. Operators controls shall be mounted on the door of the cabinet and consist of a membrane command center which allows manual stop/start and speed control, local/remote indication and manual/or automatic speed control selection. In addition, the command center will serve as a means to configure controller parameters such as minimum speed, maximum speed, acceleration and deceleration times, volts/Hz ratio, torque boost, etc. Potentiometers will not be allowed for these settings.
4. For ease of Owner and TCC use, the VFD shall also incorporate a speed potentiometer for manual speed control and a hand-off-auto selector switch. Membrane/keypad functions can also be utilized to perform these functions.
5. The controller will be able to follow an external speed signal and respond to remote start/stop contacts wired to the terminal strip while in the automatic/remote mode.
6. Disconnect: Door interlocked fused disconnect shall interrupt all input power from the drive and all internally mounted options. The disconnect handle shall be through-the-door type and shall be padlockable in the "OFF" position.

7. The controller shall contain a U.L. electronic overload circuit designed to protect the A-C motor, operated on the adjustable frequency controller output from extended overload operation on an inverse time basis. A motor thermostat back-up may also be provided.
8. The VFD shall also incorporate programmable protection settings for motor stall, motor under-load, and motor at speeds to protect the motor in applications requiring less than full load/full speed motor requirements.
9. The VFD shall have two programmable/selectable analog inputs which will accept current or voltage input signals for speed reference or for manual put reference or for actual feedback signals for use of the VFD built in proportional integral controller. These analog inputs shall be programmable for filtering, gain and offsets. The VFD shall incorporate a loss or analog input circuit which is programmable and can not only send an external output warning (DO), but also determine a preset speed of the VFD for safety purposes.
10. Automatic restarts will be attempted three times after a power outage, drive fault, safety shutdown such as freezestat or firestat, or external fault, if the drive is in automatic mode. The circuit shall allow the user to select 0, 1, 2 or 3 restart attempts as well as select the dwell time between attempts. The reset time between fault occurrences shall also be selectable. All settings shall be via the membrane command center.
11. The following operating information shall be available to be displayed on the VFD's 20 character (minimum) full alphanumeric display:
 - a. Output frequency
 - b. Output RPM/speed (programmable)
 - c. Motor currents
 - d. Calculated motor power - calculated
 - e. KwHr meter
12. There shall be a minimum of two critical frequency avoidance bands which can be programmed in the field via the membrane command center to enable the controller to avoid certain frequencies which the pump or fan system may resonate at due to reduced speed operation.
13. There shall be seven programmable preset speeds which will force the VFD to a preset speed upon a user contact closures. This feature shall be set digitally by entering via the door mounted membrane command center.
14. Disconnecting the motor for free wheeling operation in periods of power outage is not acceptable.
15. To prevent unnecessary trips, include a speed droop feature which reduces the speed of the drive on transient overload. The drive is to return to the set speed after the transient is removed. Should the acceleration or deceleration rates be too rapid for the moment of inertia of the load, the drive is to automatically compensate to prevent drive trip.

- a. Voltage dip ride through: The VFD shall be capable of sustaining operation with a 30% dip in nominal line voltage. Output speed may decline only if current limit rating of the VFD is exceeded.
 - b. Power loss ride through: The VFD shall be capable of a 5 cycle power loss ride through without fault activation.
16. Compliance to IEEE 519 -- Harmonic analysis for particular jobsite including total voltage harmonic distortion and total current distortion.
- F. Manufacturer shall perform and submit calculations, specific to this project, which show that the theoretical line notching and voltage distortion comply with IEEE-519, Special Applications Criteria (10% notching, 3% distortion). If line notching and/or voltage distortion exceed these values, then provide equipment to provide this level of filtration. Obtain information for sizing line filtering equipment (such as transformer sizes and impedances, feeder sizes, capacitor locations, etc.) from Electrical Plans or from General Contractor/Electrical Contractor.
- G. Protective Circuits and Features: The VFD shall include the following protective circuits and features:
 1. Fast acting semiconductor fuses specifically sized for protection of the AFC.
 2. DV/DT and DI/DT protection for semiconductors.
 3. Instantaneous Electronic Trip for the following faults:
 - a. Motor current exceeds 110% for longer than one minute of controller maximum sine wave current rating
 - b. Output phase-to-phase circuit condition
 - c. Total ground fault under any operating condition
 - d. High input line voltage
 - e. Low input line voltage
- H. The VFD shall have the following protection circuits and display on the 20 character alphanumeric display the appropriate faults. Fault notification must be in plain English. Fault codes are not acceptable.
 1. Overcurrent trip device - to continuously monitor peak currents and provide instantaneous shutdown without component failure when the high limit is surpassed.
 2. Over-voltage trip -- selectable to protect motor AFC
 3. Under-voltage trip -- 65% of AFC rating
 4. Ground fault -- Running on start at motor
 5. Motor overload - I^2T -- UL-NEC-overload
 6. Motor under-load trip -- warning or fault
 7. VFD overtrip -- Over heat sink limits
- I. Three "last faults" shall be kept in non-voltage memory for ease of troubleshooting.

1. Metal oxide varistors.

J. Adjustments: The following adjustments shall be followed:

1. Maximum frequency (0 to 120 Hz) with factory setting at 60 Hz.
2. Minimum frequency (0 to 60 Hz) with factory setting at 6 Hz.
3. Acceleration (2 to 3200 seconds) factory set at 60 seconds.
4. Deceleration (2 to 3200 seconds) factory set at 60 seconds.
5. Adjustable U/Hz, U/Hz² and automatic H/Hz⁽²⁾ setting for energy savings.
6. Voltage offset or boost with factory setting at 100% torque.
7. Current limit (50 to 100%) sine wave current rating factory set at 100%.

K. Service Conditions: The VFD shall be designed and constructed to operate within the following service conditions:

1. Suitable for continuous operation at an ambient temperature of 0°C. to 40°C. Elevation up to 3300 feet altitude with a relative humidity to 95% non-condensing.
2. A-C line variation of 440 vac +10% -5% frequency.

L. Electronic Bypass:

1. Provide U.L. Listed microprocessor based bypass controller for each variable frequency drive, for manual or automatic transfer to line power via contactors. Provide means of limiting speed to specified value when drive is manually switched to bypass (when system is operating on emergency power). Coordinate with Automatic Control System Supplier.
2. Provide a keypad to control the bypass controller mounted on the enclosure door. The bypass keypad shall include a one line diagram and status LED's to indicate the mode of operation, drive and bypass status and ready and enable conditions. When in the "Drive" mode, the bypass contactor is open and the drive output contactor is closed. In the "Bypass" position, the drive output contactor is open and the bypass contractor is closed via Start/stop command.
 - a. Provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. External safety interlocks shall remain fully functional whether the system is in Hand, Auto, Drive or Bypass modes.
 - b. Automatic/manual bypass operation shall be selectable in the standard microprocessor based bypass design.
 - c. Provide a door/cover interlocked disconnect switch to disconnect all input power from the drive, bypass and all internally mounted options. The disconnect handle shall be through the door, and be pad-lockable in the "Off" position.
 - d. Provide fast acting semi-conductor fuses exclusive to the VFD - to disconnect from the line prior to clearing upstream branch circuit protection.

- e. Provide Class 20 or 30 electronic motor overload protection in the microprocessor bypass to protect the motor in bypass mode.

M. LonWorks Board

- 1. Provide LonWorks board to allow communications to LonWorks networks.

N. Installation:

- 1. Installation shall be the responsibility of the Mechanical Contractor. The Contractor shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
- 2. Power wiring shall be completed by the Electrical Contractor. The Contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
- 3. This Contractor shall be responsible for interlock with remote disc.

O. Start-Up:

- 1. 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 Owner, and a copy kept on file at the manufacturer.

P. Electrical Power -- Three phase, 60 cycle, 460 volts.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.2 INSTALLATION OF VFD

- A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on the Drawings.
- B. Connect and configure equipment and software to achieve sequence of operation specified.

3.3 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, **test, and adjust** field-assembled components and equipment installation, including connections, **and to assist in field testing**. Report results in writing.
- B. Perform the following field tests and inspections and prepare test reports:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
 - 2. Test and adjust controls and safeties.
 - 3. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
 - 4. Test each system for compliance with sequence of operation.
 - 5. Test software and hardware interlocks.

3.4 ADJUSTING

- A. This Contractor shall work with the Balancing Contractor to provide verification of CFM, current, voltage, RPM for each VFD.

3.5 CLEANING

- A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum cabinet.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain VFD.
 - 1. Train Owner's maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
 - 2. Review data in maintenance manuals.
 - 3. Schedule training with Owner, through Architect, with at least seven days' advance notice.

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