

SECTION 15172

VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Variable Frequency Drive (VFD).

1.02 RELATED SECTIONS

- A. Section 16195 - Electrical Identification: Engraved nameplates.

1.04 SUBMITTALS

- A. Submit under provisions of Section 01340.
- B. Vendor is required to submit shop drawing for approval. Shop Drawings shall include: Wiring diagrams, electrical schematics, front and side views of enclosures, overall dimensions, conduit entrance locations and requirements, nameplate legends, physical layout and enclosure details.
- C. Product Data: Provide data sheets showing; voltage, short circuit ratings, and weights.
- D. Manufacturer's Installation Instructions and Technical Manuals: Indicate application conditions and limitations of use stipulated by product testing agency specified under regulatory requirements. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of variable frequency drive. Document the sequence of operation, cautions and warnings, spare parts lists and programming guidance.

1.05 QUALITY ASSURANCE

- A. VFD shall have a minimum MTBF (mean time between failures) rating of 28 years (245,280 Hours).
- B. The drive manufacturing facility shall be ISO 9001 and 14001 certified
- C. The drive shall be UL listed, or Canadian UL listed, or CSA listed and comply with EMC Directive 89/336 EEC, Low Voltage Directive 73/23 EEC in

accordance with the European Union's CE directive.

- D. The drive shall utilize efficient "bidirectional switch" technology throughout the entire drive manufacturer's power and voltage range.
- E. The drive shall utilize the same communications architecture, utilizing plug-in communications cards, for high-speed noise immune connectivity throughout the entire drive manufacturer's power range.
- F. The drive manufacturer shall have an analysis laboratory to evaluate the failure of any component. The failure analysis lab shall allow the manufacturer to perform complete electrical testing, x-ray components, and decap or delaminate components and analyze failures within the component.
- G. The drive shall utilize surface mount technology in the manufacturing of internal printed circuit boards and electronics, for maximum reliability.

1.06 OPERATION AND MAINTENANCE DATA

- A. Submit under provisions of Section 01700.
- B. Include instructions for starting and operating VFD, and describe operating limits, which may result in hazardous or unsafe conditions.

1.07 QUALIFICATIONS

- A. Manufacturer must have a minimum of 25 years of documented experience, specializing in variable frequency drives.

1.08 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products to site, under provisions of Section 01610
- B. Accept VFD on site in original packing. Inspect for damage.
- C. Store in a clean, dry space. Maintain factory wrapping, or provide an additional heavy canvas or heavy plastic cover, to protect units from dirt, water, construction debris, and traffic.
- D. Handle carefully, in accordance with manufacturer's written instructions, to avoid damage to components, enclosure, and finish.

1.09 WARRANTY

- A. Provide VFD warranty, for one year from date of startup, not to exceed 18 months from date of shipment. Warranty shall include parts, and labor allowance for repair hours.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. VFD shall be Z1000U type, manufactured by Yaskawa America, Inc.
- B. Motors should be inverter duty rated, per NEMA MG1 parts 30 and 31, for motor-drive compatibility.

2.02 DESCRIPTION

- A. Provide enclosed variable frequency drives suitable for operation at the current, voltage, and horsepower indicated on the schedule. Conform to requirements of NEMA ICS 3.1.

2.03 RATINGS

- A. VFD must operate, without fault or failure, when voltage varies plus 10% or minus 15% from rating, and frequency varies plus or minus 5% from rating.
- B. VFD shall be _____ volts, _____ Hz, 3 Phase
- C. Power Factor: 0.98 minimum for rated operation.
- D. Service factor: 1.0
- E. Operating Ambient Temperature:
NEMA 1 (IP20): -10°C to 40°C (14°F to 104°F)
- F. Ambient storage temperature: -20°C to 60°C (-4°F to 140°F)
- G. Humidity: 0% to 95% non-condensing.
- H. Altitude: to 3,300 feet (1000m), higher altitudes achieved by derating.

- I. Vibration: 9.81m/s^2 (1 G) maximum at 10 to 20 Hz, 2.0m/s^2 (0.2 G) at 20 Hz to 55 Hz.
- J. Minimum Efficiency: 96% at half speed; 98% at full speed.
- K. Starting Torque: 150% starting torque shall be available from 3 Hz to 60 Hz without derating. Drive shall be able to run at 100% current at 0.0 Hz continuously.
- L. Overload capability: 120% of rated FLA (Full Load Amps) for 60 seconds; 150% of rated FLA peak.
- M. Controlled speed range of 40:1
- N. The VFD's shall include EMI/RFI filters. The onboard RFI filter shall allow the entire VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the Second Environment, Category C2. No Exceptions.
- O. Total Harmonic Distortion (THD) compliance to IEEE 519:
The Drive Manufacturer shall provide calculations showing total harmonic current distortion and total harmonic voltage distortion is less than 5%, both with no individual harmonic greater than 3%, at the drive input terminals. Calculations at the transformer are not acceptable. This requirement may be met by VFD's that use Matrix conversion technology. 18-Pulse input VFD's will be accepted in lieu of Matrix conversion technology. VFD's employing the use of 6-Pulse, Passive Filters, 12-Pulse, or "LCL" filter schemes will be rejected. Additional equipment required to meet this performance will be the responsibility of the contractor with no additional cost to the owner.
- P. VFDs must be suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical amperes.

2.04 DESIGN

- A. VFD shall employ microprocessor based inverter logic, isolated from all power circuits.
- B. VFD shall include surface mount technology with protective coating.
- C. VFD shall employ use of matrix conversion technology for direct conversion of

AC to AC. Active AC to DC rectifier schemes are not acceptable and will be rejected. 6 pulse, passive filters, and 12-pulse rectifiers are not acceptable and will also be rejected.

1. Input / Output Section:

VFD input power stage shall convert three-phase AC line power directly into variable AC output. The main circuit shall consist of a compact input filter and bidirectional switches. The bidirectional switches are power devices that carry the full current of the drive. VFD's without direct AC to AC conversion will require integral 18-Pulse Transformer input.

- D. VFD shall have an adjustable carrier frequency, from 4 kHz to 10 kHz.
- E. VFD must include an adjustable dynamic noise control for quiet motor operation.
- F. VFD must have a Harmonic Suppression Priority setting.
- G. VFD shall have embedded Building Automation System (BAS) protocols for network communications; BACnet, Johnson Controls Metasys N2, Siemens P1 Apogee, and Modbus/Memobus. These protocols shall be accessible via a RS-422/485 communication port.
- H. VFD shall include three independent analog inputs. Selectable for either 0-10 VDC or 4-20 mA. Either input shall respond to a programmable bias and gain.
- I. VFD shall include a minimum of seven multi-function digital input terminals, capable of being programmed to determine the function on a change of state. These terminals shall include, but not limited to:
 - 1. Remote/Local operation selection
 - 2. Customer Safeties
 - 3. BAS / Damper Interlock
 - 4. Emergency Override
 - 5. Preset Speed
 - 6. PI control enable / disable
- J. VFD shall include two selectable 0-10 VDC or 4-20 mA analog outputs for monitoring, or "speed tracking" the VFD. The analog output signal will be proportional to output frequency, output current, output power, PI (Proportional & Integral control) feedback or power supply voltage.
- K. VFD shall provide terminals for remote input contact closure, to allow starting in the automatic mode.

- L. VFD shall provide 24 Vdc, 150ma transducer power supply
- M. VFD shall include at least one external fault input, which shall be programmable for a normally open or normally closed contact. These terminals can be used for connection of firestats, freezestats, high pressure limits or similar safety devices.
- N. VFD shall include one fixed "Fault" form "C" contact, and three programmable form "A" contacts capable of being programmed to determine conditions that must be met in order for them to change state. These output relay contacts shall be rated for at least 2A at 120 VAC and shall include, but not limited to:
 - 1. Speed agree detection
 - 2. Damper control
 - 3. Hand / Auto Status
 - 4. No load detection (broken belt alert)
 - 5. Contactor Control for External Bypass
 - 6. Drive Faulted
 - 7. Serial communication status
- O. VFD shall include a power loss ride through capable of 2 seconds.
- P. VFD shall have "hold at zero speed" capability, to stop a fan that is "wind milling" at start or stop.
- Q. VFD shall have a motor preheat function to prevent moisture accumulation in an idle motor.
- R. VFD shall include diagnostic fault indication, time and date stamped faults storage and heatsink cooling fan operating hours.
- S. VFD shall have a digital operator with program copy and storage functions to simplify set up of multiple drives. The digital operator shall be interchangeable for all drive ratings.
- T. VFD shall include a front mounted, sealed keypad operator, with an English language illuminated LCD display. The operator will provide complete programming, program copying, operating, monitoring, real time clock and diagnostic capability. Keys provided shall include industry standard commands for Hand, Off, and Auto functions.
- U. VFD plain language display shall provide readouts of; output frequency in hertz, PI feedback in percent, output voltage in volts, output current in amps, output power in kilowatts, power supply voltage in volts, interface terminal status, heatsink temperature and fault conditions. All displays shall be viewed in an easy-

to-read illuminated LCD.

- V. VFD shall have an internal time clock. The internal time clock shall include a back up via battery. The time clock will be used to date and time stamp faults and record operating parameters at the time of fault. The internal time clock can be programmable to control start/stop functions, constant speeds, PID parameter sets and output Form-C relays.

- W. VFD unit shall include the following meters to estimate use of energy:
 - 1. Elapsed Time Meter
 - 2. Kilowatt Meter
 - 3. Kilowatt Hour Meter
 - 4. Energy Savings Meter

- X. VFD shall include a user selectable PI control loop, to provide closed loop set point control capability, from a feedback signal, eliminating the need for closed loop output signals from a building automation system. The PI controller shall have a differential feedback capability for closed loop control of fans and pumps for pressure, flow or temperature regulation in response to dual feedback signals.

- Y. VFD shall have an independent, PI loop that can be used with a second analog input that will vary the VFD analog output and maintain a set point of an independent process (valves, dampers....).

- Z. The VFD shall include HVAC specific application macros. The macros can be used to help facilitate start-up. The macros will provide initialization to program all parameters and customer interfaces for a particular application (Fans, Pumps and Cooling Towers) to reduce programming time.

- AA. An energy saving sleep function shall be available in both open loop (follower mode) and closed loop (PI) control, providing significant energy savings while minimizing operating hours on driven equipment. When the sleep function senses a minimal deviation of a feedback signal from set point, or low demand in open loop control, the system reacts by stopping the driven equipment. Upon receiving an increase in speed command signal deviation, the drive and equipment resume normal operation.

- BB. VFD shall include loss of input signal protection, with a selectable response strategy including speed default to a percent of the most recent speed.

- CC. VFD shall include electronic thermal overload protection for both the drive and

motor. The electronic thermal motor overload shall be approved by UL. If the electronic thermal motor overload is not approved by UL, a separate UL approved thermal overload relay shall be provided in the VFD enclosure

DD. VFD shall include the following program functions:

1. Critical frequency rejection capability: 3 selectable, adjustable dead bands.
2. Auto restart capability: 0 to 10 attempts with adjustable delay between attempts.
3. Ability to close fault contact after the completion of all fault restart attempts.
4. Stall prevention capability.
5. "S" curve soft start / soft stop capability.
6. Bi-directional "Speed search" capability, in order to start a rotating load.
7. 14 preset and 1 custom volts per hertz pattern.
8. Heatsink over temperature speed fold back capability.
9. Terminal status indication.
10. Program copy and storage in a removable digital operator.
11. Programmable security code.
12. Current limit adjustment capability, from 30% to 200% of rated full load current of the VFD.
13. Motor pre-heat capability.
14. Input signal or serial communication loss detection and response strategy.
15. Anti "wind-milling" function capability.
16. Automatic energy saving function.
17. Undertorque/Overtorque Detection.
18. Fan failure detection and selectable drive action.
19. "Bumpless" transfer between Hand and Auto modes
20. Seven preset speeds.
21. VFD shall include factory settings for all parameters, and the capability for those settings to be reset.
22. VFD shall include user parameter initialization capability to re-establish project specific parameters.
23. VFD shall include programmable HVAC specific application macros.
24. USB Type B port for quick and easy PC Connection.

25. VFD shall include the capability to adjust the following functions, while the VFD is running:
 1. Speed command input.
 2. Acceleration adjustment from 0 to 6000 seconds.
 3. Deceleration adjustment from 0 to 6000 seconds.
 4. Select from 7 preset speeds.
 5. Analog monitor display.
 6. Removal of digital operator.

2.05 PRODUCT OPTIONS

Note to the Consulting Engineer: See Appendix One to Select Options to be Applied to a Specific Project

2.06 FABRICATION

- A. All standard and optional features shall be included in a single NEMA 1, plenum rated enclosure with a UL certification label.

2.07 SOURCE QUALITY CONTROL

- A. In-circuit testing of all printed circuit boards shall be conducted, to insure the proper mounting and correct value of all components.
- B. Final printed circuit board assemblies shall be functionally tested, via computerized test equipment. All tests and acceptance criteria shall be preprogrammed. All test results shall be stored as detailed quality assurance data.
- C. All fully assembled controls shall be functionally tested, with fully loaded induction motors. The combined test data shall then be analyzed, to insure adherence to quality assurance specifications.
- D. Inspect and production test, under load, each completed VFD assembly.

PART 3 EXECUTION

3.01 EXAMINATION

- A. Verify that surface is suitable for VFD installation.
- B. Do not install VFD until the building environment can be maintained, within the

service conditions required by the manufacturer.

3.02 INSTALLATION

- A. Install VFD where indicated, in accordance with manufacturer's written instructions and NEMA ICS 3.
- B. Tighten accessible connections and mechanical fasteners after placing VFD.
- C. Provide a nameplate label on each VFD with, full load amperes, model number, and voltage/phase rating.

3.03 FIELD QUALITY CONTROL

- A. Field inspection and testing to be performed under provisions of Section 01400.
- B. Inspect completed installation for physical damage, proper alignment, anchorage, and grounding.

3.04 MANUFACTURER'S FIELD SERVICES

- A. Prepare and start systems under provisions of Section 01400.

3.05 ADJUSTING

- A. Carry out adjusting work under provisions of Section 01700. Make final adjustments to installed VFD, to assure proper operation of HVAC systems.

END OF SECTION

APPENDIX ONE

PRODUCT OPTIONS

Note to the Consulting Engineer: Select Options to be Applied to this Project, Insert in the Appropriate Specification Section

- A. Two Contactor Manual Bypass shall be provided when indicated by the schedule. VFD and bypass package shall be NEMA 1 rated, fully pre-wired and ready for installation as a single UL listed device. Bypass shall include the following:
1. Drive output, and bypass contactors, to isolate the VFD from the motor, when the motor is running in the bypass mode. These contactors shall be electrically and software interlocked to ensure safe operation.
 2. 120 VAC control transformer, with fused primary.
 3. Motor overload relay, to protect the motor while operating in the bypass mode.
 4. Main input circuit breaker with a pad-lockable handle operating mechanism, able to achieve a SCCR panel rating of 100kAIC.
 5. Control and safety circuit terminal strip.
 6. Current transformers on the output of the Drive/Bypass package for displaying motor current in both modes of operation as well as verification that the motor is running.
 7. Provide BACnet, Johnson Controls Metasys N2, Siemens P1 Apogee, and Modbus communication protocols as standard, with the ability to configure controller parameters view controller monitors, control I/O, clear faults and view controller status in both drive and bypass modes.
 8. Door mounted control keypad with; Drive/Bypass selector keys, Hand/Off/Auto selector keys, Normal/Test selector keys.
 9. Door mounted control keypad with LCD display for “Control Power”, “Drive Ready”, “Drive Run”, “Drive Selected”, “Drive Fault”, “Drive/Test”, “Bypass Selected”, “Bypass Run”, “Motor OL”, ”Safety Open” “BAS Interlock”, “Auto Run”, Auto Transfer”, “Smoke Purge”, “Hand Mode”, “Off Mode”, and “Auto Mode”..
 10. Drive/Bypass selector keys, to allow switching between the Drive and Bypass mode.
 11. Hand/Off/Auto selector keys shall provide the following operation and be programmed to operate in any of these modes upon power-up:

- Hand Position - The drive is given a start command, operation is via the local speed input (digital operator/keypad). If in bypass mode, the motor is running.
 - Off Position - The start command is removed, all speed inputs are ignored, power is still applied to the drive. If in bypass mode, the motor is stopped.
 - Auto Position - The drive is enabled to receive a start command and speed input from a building automation system. If in bypass mode, the motor start/stop is controlled by the building automation system
12. Eight Programmable digital inputs (24Vdc, 8mA) shall be provided for Auto Transfer to bypass, Safety Interlock, BAS Interlock, and numerous other bypass specific functions.
 13. Four Programmable form C relays (24Vdc/120 VAC, 2 Amp) for: “Motor Run”, “Damper Actuator”, “Auto Transfer”, “Drive Run”, “Hand Mode”, “Auto Mode”, “System Fault”, “Bypass Run” or ”Serial Com Run”.
 14. Damper control circuit with end of travel feedback capability. This circuit shall also include two adjustable wait time functions. One is a run delay time where the drive will operate at a preset speed before the damper opens to pressurize the system. The other time function is an interlock wait time, so if the damper has not fully opened within the specified time, a fault will be declared.
 15. Line voltage sensors to monitor for brownout, blackout and single phase conditions.
- B. Three Contactor Manual Bypass shall be provided when indicated by the schedule. VFD and bypass package shall be NEMA 1 rated, fully pre-wired and ready for installation as a single UL listed device. Bypass shall include the following:
1. Drive output, and bypass contactors to isolate the VFD from the motor, when the motor is running in the bypass mode. These contactors shall be electrically and software interlocked to ensure safe operation.
 2. 120 VAC control transformer, with fused primary.
 3. Motor overload relay, to protect the motor while operating in the bypass mode.
 4. Main input circuit breaker with a pad-lockable handle operating mechanism, able to achieve a SCCR panel rating of 100kAIC.
 5. Control and safety circuit terminal strip.
 6. Current transformers on the output of the Drive/Bypass package for displaying motor current in both modes of operation as well as verification that the motor is running.
 7. Provide BACnet, Johnson Controls Metasys N2, Siemens P1 Apogee, and Modbus communication protocols as standard, with the ability to configure controller parameters view controller monitors, control I/O, clear faults and view controller status in both drive and bypass modes.
 8. Door mounted Keypad with; Drive/Bypass selector keys, Hand/Off/Auto selector keys, Normal/Test selector keys.

9. Door mounted control keypad with LCD display for “Control Power”, “Drive Ready”, “Drive Run”, “Drive Selected”, “Drive Fault”, “Drive Test”, “Bypass Selected”, “Bypass Run”, “Motor OL”, ”Safety Open” “BAS Interlock”, “Auto Run”, Auto Transfer”, “Smoke Purge”, “Hand Mode”, “Off Mode”, and “Auto Mode”.
10. Drive/Bypass selector keys, to allow switching between the Drive and Bypass mode.
11. Hand/Off/Auto selector keys shall provide the following operation and be programmed to operate in any of these modes upon power-up:
12. Normal/Test selector keys, to allow VFD trouble shooting while operating in bypass mode. This option is only available with the 3 contactor style bypass.
13. Hand Position - The drive is given a start command, operation is via the local speed input (digital operator/keypad). If in bypass mode, the motor is running.
14. Off Position - The start command is removed, all speed inputs are ignored, power is still applied to the drive. If in bypass mode, the motor is stopped.
15. Auto Position - The drive is enabled to receive a start command and speed input from a building automation system. If in bypass mode, the motor start/stop is controlled by the building automation system
16. Eight Programmable digital inputs (24Vdc, 8mA) shall be provided for Auto Transfer to bypass, Safety Interlock, BAS Interlock, and numerous other bypass specific functions.
17. Four Programmable form C relays (24Vdc/120 VAC, 2 Amp) for: “Motor Run”, “Damper Actuator”, “Auto Transfer”, “Drive Run”, “Hand Mode”, “Auto Mode”, “System Fault”, “Bypass Run” or ”Serial Com Run”.
18. Damper control circuit with end of travel feedback capability. This circuit shall also include two adjustable wait time functions. One is a run delay time where the drive will operate at a preset speed before the damper opens to pressurize the system. The other time function is an interlock wait time, so if the damper has not fully opened within the specified time, a fault will be declared.
19. Line voltage sensors to monitor for brownout, blackout and single phase conditions.

C. Enclosure:

1. NEMA / UL TYPE 1 Enclosure
3. NEMA / UL TYPE 3R enclosures for outdoor installations.

D. Engraved cabinet nameplates shall be provided.

E. Additional options

1. Multiple motor operation; Two motor “OR” control; Multiple motor “AND” control shall be provided.
2. Two motor “OR” control allows local or remote motor operation selection between two individual motors (motor #1 “OR” motor #2).
3. Multiple motor “AND” control allows the operation of several motors from one drive (motor #1, motor #2, “AND” motor # 3 are operated at the same speed via the output from one drive).
4. Serial communication capability for Echelon LonWorks and EtherNet/IP shall be provided.
5. PC software and cable for parameter upload/download/graphing shall be provided.
6. Drive Service Switch.
7. Soft Start Bypass.
8. Output Reactor (5%).