

HEATING, VENTILATING & AIR CONDITIONING [23 ## ##]
VARIABLE FREQUENCY DRIVES

PART 1. GENERAL

1.01 DESCRIPTION

- A. This specification is to cover a complete Variable Frequency Drive (VFD), consisting of a pulse width modulated (PWM) inverter designed for use with induction (asynchronous) motors, permanent magnet motors, Synchronous reluctance motors (SynRM) and permanent magnet-assisted synchronous reluctance motors (PMa-SynRM).
- B. The drive manufacturer shall supply the VFD (drive) and all necessary options as specified. All VFD's (drives) installed on this project shall be from the same manufacturer and use a core parameter architecture that has been in widespread use for at least 15 years. The manufacturer shall have been engaged in the production of VFD's (drives) for a minimum of 50 years. VFD's (Drives) that are manufactured by a third party and "brand labeled" shall not be acceptable.
- C. This specification is intended to supplement a VFD (Drive) schedule. The VFD (Drive) schedule identifies the optimized Bill of Material (BOM) for the project and includes quantity, size, voltage, enclosure rating, options, and harmonic mitigation requirements, as required.

1.02 QUALITY ASSURANCE

- A. Referenced Standards and Guidelines
 - 1. Conformité Européene (CE)
 - a. CE mark 2006/42/EC MD
 - b. CE mark 2014/35/EU LVD
 - c. CE mark 2014/30/EU EMC
 - 2. National Electrical Manufacturers Association (NEMA)
 - a. NEMA ICS 3.1 - Safety Standards for Construction and Guide for Selection, Installation and Operation of Variable Frequency Drive Systems
 - b. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum)
 - 3. Institute of Electrical and Electronic Engineers (IEEE)
 - a. IEEE 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
 - b. IEEE C62.41
 - 4. International Building Code (IBC)
 - a. IBC 2018, 2021, 2024 Seismic – ref ASCE 7-16 and ICC AC-156

5. CSA Group
 - a. CSA 22.2 No. 274-2017 (Adjustable Speed Drives)
6. BACnet International
 - a. BTL Listed
7. Underwriters Laboratory
 - a. UL Listed
8. LZGH2 certified
 - a. Annex JJ of UL/CSA 60335-2-40 compliant (A2L refrigerant)

B. Qualifications

1. SCCR rating - drives must be suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical amperes when installed in accordance with the manufacturer's guidelines.
2. CE Mark – drives shall conform to the European Union Electromagnetic Compatibility directive, a requirement for CE marking. The VFD shall meet product standard EN 61800-3 for the First Environment restricted distribution (Category C2). VFDs that only meet the Second Environment (Category C3, C4) shall be supplied with filters to bring the base drive into compliance with the First Environment levels.
3. Seismic Certification – the VFD shall be capable of structurally and operationally withstanding the seismic response criteria as defined in the International Building Code (IBC), ASCE 7, and California Department of Health Care Access and Information (HCAI). The VFD shall be tested in compliance with AC-156 to meet the IBC seismic certification as follows: $SDS \leq 2.5$ ($z/h=0$), $SDS \leq 2.0$ ($z/h \leq 1$), $I_p \leq 1.5$.
4. The base drive shall be SEMI-F47 certified. The drive must tolerate voltage sags to 50% for up to 0.2 seconds, sags to 70% for up to 0.5 seconds, and sags to 80% for up to one second.
5. Acceptable Manufacturers
 - a. Yaskawa HV600 Series
 - b. Alternate manufacturer's requests shall be submitted in writing to the Engineer for approval at least 20 working days prior to bid. Approval does not relieve the supplier of specification requirements.
6. VFD shall have a minimum design life of 10 years.

1.03 SUBMITTALS

A. Submittals shall include the following information:

1. Shop Drawings: Wiring diagrams, electrical schematics, front and side views of enclosures, overall dimensions, conduit entrance locations and requirements, nameplate legends, physical layout and enclosure details.
2. Product Data: Provide data sheets showing; voltage, ratings of customer use switching and over-current protective devices, short circuit ratings, and weights.
3. 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, troubleshooting procedures, spare parts lists and programming guidance.

1.04 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products to site.
- 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.

1.05 WARRANTY

- A. Provide VFD warranty, for two years from date of startup, not to exceed 30 months from date of shipment. Warranty shall include parts, and labor allowance for repair hours, or replacement of the complete drive as determined by the manufacturer's technical support.

PART 2. PRODUCTS

2.01 Variable Frequency Drives

- A. The drive package as specified herein and defined on the drive schedule shall be enclosed in a UL Type enclosure (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer to ISO9001 standards.
 - 1. For standard non-configured or non-bypass drive models enclosure options shall be UL Type 1, UL Type 12, and UL Open Type; size-dependent.
 - 2. For configured or bypass packages, enclosure options shall be UL Type 1, UL Type 12, and UL Type 3R.
- B. VFD must have the minimum range of horsepower ratings: 1 to 100 HP at 208/240 VAC; 1 to 250 HP at 480 VAC.
- C. VFD shall employ microprocessor based inverter logic, isolated from all power circuits.
- D. VFD shall include surface mount technology with protective coating, able to meet IEC

60721-3-3, levels 3C2 and 3S2.

- E. VFD shall be able to be mounted with the heatsink out the back of the enclosure to achieve UL Type 12 on the backside: 208V/240 V, up to 60 HP, 460 V, up to 125 HP.
- F. VFD shall employ a PWM (Pulse Width Modulated) power electronic system, consisting of:
 - 1. Input Section:
 - a. VFD input power stage shall convert three-phase AC line power into a fixed DC voltage via a solid-state full wave diode rectifier, with MOV (Metal Oxide Varistor) surge protection
 - b. An internal 5% split choke on both positive and negative sides of the DC bus reduces harmonics for cleaner power and power line transient protection.
 - 2. Intermediate Section:
 - a. DC bus as a supply to the VFD output section shall maintain a fixed voltage with filtering and short circuit protection.
 - b. DC bus shall be interfaced with the VFD diagnostic logic circuit, for continuous monitoring and protection of the power components.
 - 3. Output Section:
 - a. Insulated Gate Bipolar Transistors (IGBTs) shall convert DC bus voltage to variable frequency and voltage.
 - b. The VFD shall employ PWM sine coded output technology to power the motor.
- G. VFD shall have selectable control methods to control induction, interior permanent magnet (IPM), surface permanent magnet (SPM), and synchronous reluctance motors. VFD shall be able to control the motor without (open loop) a feedback device (encoder, resolver, etc.).
- H. Motor disconnect capability. When parameter settings are properly configured, the drive shall have the ability to sustain the opening and re-closing of a disconnect switch between the drive and motor during operation without fault or damage to the drive.
- I. Auto-tuning capability for all motors for easy commissioning.
- J. VFD shall offer a low noise, low carrier frequency function.
- K. VFD should be able to be mounted next to each other with zero clearance for UL Type 1 ratings 208 V/240 V up to 40 HP and 480V up to 100 HP.
- L. 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.
 - 1. Drives shall be capable of continuous full load operation under the following

environmental operating conditions:

- a. Open Chassis: -10°C to 50°C (14°F to 122°F), with de-rating for up to 60°C (140°F)
 - b. UL Type 1: -10°C to 40°C (14°F to 104°F), with de-rating for up to 60°C (140°F)
 - c. UL Type 12: -10°C to 40°C (14°F to 104°F), with de-rating for up to 50°C (122°F)
 - d. Altitude 0 to 1000 m (0 to 3,300 ft) above sea level.
 - i. 1000 m to 4000 m (3281 ft to 13123 ft) with appropriate de-rating
- M. Humidity 5 to 95%, non-condensing.
- N. Ambient storage temperature: -20°C to 70°C (-4°F to 158°F).
- O. Displacement Power Factor: 0.98 over entire range of operating speed and load.
- P. Service factor: 1.0
- Q. Minimum Efficiency: 97% at full load.
- R. Vibration: 9.81 m/s² (1 G) maximum at 10 to 20 Hz; 208V/240 V, up to 10HP, 460 V, up to 25 HP; 5.9 m/s² (0.6 G); 208 V/240 V, 15 HP and above, 460 V, 30 HP and above; 1.96 m/s² (0.2 G) at 20 Hz to 55 Hz
- S. All drives shall utilize a tri-color visual indicator to provide unique visual indications of different status and operating conditions. Visual indications may be in the form of color, combination of colors, and/or flashing patterns. At least three lamps must be used and the following conditions must have a unique visual display pattern:
1. Drive Ready
 2. Drive Fault
 3. Run Prohibit
 4. Alarm
 5. Drive Running with Zero Speed Reference
 6. Safe Torque Off – Active
 7. Safe Torque Off – Fault
 8. Drive Running
- T. All drives shall utilize a removable keypad/display. The following keypad features shall be included:
1. Display shall be in complete English words for parameter settings and fault diagnostics. (alpha-numeric codes alone are not acceptable)
 2. Keypad shall be capable of 32 character descriptions and support at least the following languages: English, French, Spanish, Portuguese, German,

- Italian, Greek, Polish, Czech, Turkish, Russian, Japanese, and Chinese.
3. Keypad shall include a user-replaceable battery to maintain real time clock settings during power-off conditions. The 10 most recent faults with associated time stamps shall be stored.
 4. Keypad shall include the following controls:
 - a. Four navigation keys (Up, Down, Left, Right), a dedicated Enter key, and three multi-function keys to simplify setting parameters and operation. Hand, Off, and Auto keys shall be provided using a unique color for each to easily determine function at a glance.
 - b. The three multi-function keys shall be located below the graphical display, labeled F1, F2, and F3. Their current function shall be indicated on the display in the area directly above the key. When in any screen outside of the home menu, multi-function key F2 shall become the “Home” key and when depressed immediately bring the user back to the home screen.
 5. Required keypad indicator LEDs
 - a. Alarm/fault – red
 - b. Auto/Run – green
 - c. Hand/Run – green
 6. The keypad shall be removable, capable of remote mounting.
 7. The drive shall be able to operate with the keypad removed.
 8. The LCD screen shall be backlit with the ability to adjust the screen brightness and contrast. A user-selectable timer shall be available to dim the display and save power when not in use.
 9. The LCD screen shall be organized with the following dedicated areas available during operation:
 - a. Status row – showing time, drive status, current screen status
 - b. Status message row – additional information
 - c. Monitor area – to view active variables
 - d. Function key bank – showing functions for F1-F3 keys
 10. Custom Displays
 - a. The LCD screen shall be configurable to display operating values in any of the following formats:
 - i. Bar graph displaying up to three monitors.
 - ii. Analog gauge for a single monitor.
 - iii. Trend plot, with the ability to plot up to two selected monitors over a time period, up to 60 minutes.
 - b. Full screen fault and alarm displays.
 - i. The LCD shall support the option to display fault or alarm statuses as a line item or full-screen.
 11. The drive shall automatically backup parameters to the keypad memory. In addition to the automatic backup, the drive shall allow three additional unique backup parameter sets to be stored. Backup files shall include a time and date stamp. In the event of a drive failure, the keypad of the

original drive can be installed on the replacement drive, and parameters from that keypad can be downloaded into the replacement drive.

12. User parameter default values

- a. When set, the drive is capable of saving customer parameters to an isolated area of memory. The user shall then be able to perform a “user initialization”, effectively resetting the entire drive to a pre-defined customer parameter set.

13. Memory: keypad to be equipped with a standard Micro SD slot which is capable of accepting memory cards as large as 32GB, for the purposes of data logging.

U. Starting Torque: 140% starting torque shall be available from 3 Hz to 60 Hz.

V. Overload capability: 110% of rated current for 60 seconds.

W. Single phase operation: VFD shall have the ability to use single-phase line voltage and produce a three-phase output for the motor. This mode of operation shall be recognized with an approved de-rating chart for all models.

X. Controlled speed range:

- a. Open Loop V/Hz (Induction motor) – 40:1
- b. EZ Open Loop Vector (Induction motor) – 1:10
- c. Open Loop Vector (Permanent magnet) – 1:20
- d. EZ Open Loop Vector (Permanent magnet) – 1:10

Y. Total Harmonic Distortion (THD) compliance: Given the information provided by the customer’s electric power single line diagram and distribution transformer data, the VFD manufacturer shall carry out an analysis of the system. The analysis reviews the potential for the proposed equipment, and any existing equipment, to meet IEEE 519 (tables 10.2 and 10.3) recommendations at the Point of Common Coupling (PCC). The result of the analysis shall determine if additional power quality improvement measures should be included in the proposal to meet the THD recommendations of IEEE 519. The PCC shall be at the primary side of the main distribution transformer.

2.04 DESIGN

Z. VFD shall have the following embedded communication protocols accessible via a RS485 communication port. The termination resistor shall be embedded and selectable (enabled/disabled).

a. BACnet MS/TP (max 76.8 kbps)

- i. BACnet MS/TP connection shall be equipped with a network health monitor. This monitor shall display a value between 0-100% indicating the relative health of the BACnet network

connection. This health factor shall be determined by the number of CRC errors, token losses, token retries, and net deadtime perceived.

- b. APOGEE FLN (4.8 kbps)
- c. Metasys N2 (9.6 kbps)
- d. Modbus (max 115.2 kbps)

AA. VFD shall include two independent multi-function analog inputs, individually selectable for unipolar voltage or current. One of the inputs shall also be selectable for PTC. Each input shall have a programmable bias and gain. The inputs shall be individually programmed for, but not limited to:

- 1. Frequency Reference
- 2. PID/Emergency Override PID Setpoint
- 3. PID/Emergency Override Feedback
- 4. Motor Temperature
- 5. Torque Limit

BB. VFD shall include seven independent multi-function digital input terminals that can be set for sinking/sourcing and internal/external power supplies. When applicable, the digital inputs shall have inverse-logic capability. The inputs shall be individually programmed for, but not limited to:

- 1. 16 Multi-step Frequency References plus Jog
- 2. Hand/Auto Selection
- 3. Drive Enable
- 4. Fault Reset
- 5. Fast Stop
- 6. Low City Water Alarm
- 7. BAS Interlock

CC. VFD shall include two independent analog outputs, selectable for unipolar voltage or current. The outputs shall be individually programmed for, but not limited to:

- 1. Output Frequency
- 2. Output Current
- 3. Motor Speed
- 4. Output Power
- 5. Output Torque
- 6. Anti-No-Flow Timer

DD. VFD shall include one fixed form "C" Fault contact and three programmable multi-function form "A" contacts. When applicable, the relay contacts shall have an inverse-logic capability. Output relay contacts shall all be rated for 2A at 250 VAC or 30 VDC and shall be programmed for, but not limited to:

- 1. Speed Agree

2. Zero Speed
3. Drive Ready
4. During Run
5. BAS Interlock
6. Transducer Loss
7. Maintenance Notification

EE. VFD shall include auxiliary power input for the purpose of powering control circuit while main power is removed. When powered by 24Vdc, all control circuits including expansion cards, and keypad, shall be completely functional.

FF. VFD shall include enhanced pump control features and shall be programmed for, but not limited to:

1. Easy Sleep/Wakeup PID
2. No Flow/Deadhead Protection
3. Submersible Motor Thrust Bearing Control
4. Automatic System Restart
5. Sleep Boost
6. Low and High Pressure Feedback Detection
7. Power Loss Utility Start Delay Timer
8. Loss of Prime/Pump Dry-run Protection
9. Pre-charge Control
10. Optional Dual Transducer Feedback or Redundancy
11. Impeller De-scaling/De-ragging Control

GG. VFD shall include network multiplexing features for up to four drives and shall be programmed for, but not limited to:

1. Stage/De-stage Control
2. Lead/Lag Pump Alteration
3. Transducer Redundancy

HH. VFD shall include 150mA of 24Vdc power for customer use. This capacity shall be in addition to power required to operate the VFD's digital inputs.

II. VFD shall include a control power loss ride through capable of 2 seconds or greater.

JJ. VFD shall have a fault trace function to capture relevant monitor values at the time of the most recent fault.

KK. VFD shall have preventative maintenance monitors for predicting the remaining life of IGBTs, cooling fans, bus capacitors and pre-charge relays.

LL. VFD shall have the following minimum protective functions: overheat, motor overload, VFD overload, short circuit, overvoltage, undervoltage, input phase loss, output

phase loss, output ground fault and overcurrent.

- MM. VFD shall have a USB-OTG port for easy connection to a computer or mobile device (tablet or smartphone). VFD shall not require any other power source (other than what is provided from the USB connection) to gain read/write access to all VFD settings, and to flash VFD firmware. Neither main input power nor auxiliary control input power shall be necessary.
- NN. VFD supplier shall provide free PC and Mobile software that includes online and offline parameter management, application wizards, oscilloscope function, network configurator for Ethernet, parameter conversion tool and diagnostic functions.
- OO. VFD supplier shall provide free cloud storage with secure access for the purpose of storing drive settings and other data associated with each application.
- PP. VFD shall provide plain language readouts of output frequency in hertz, PID feedback in percent, output voltage in volts, output current in amps, output power in kilowatts, DC bus voltage in volts, interface terminal status, heatsink temperature and fault conditions.
- QQ. VFD shall have an independent PID loop that can be used to vary the VFD output to maintain a set point of an independent process.
- RR. VFD shall include loss of input signal protection with a selectable responses including running at a preset speed.
- SS. VFD shall include electronic thermal overload protection for both the drive and motor. The electronic thermal motor overload shall be approved by UL with thermal memory selection.
- TT. VFD shall include an embedded category 3 Safe Torque Off (STO) solution, TUV certified to EN/ISO 13849-1 (PLe) and IEC 62061 (SIL3).
- UU. VFD shall use 24 VDC cooling fans for all ratings. Fans shall be mounted at the top of the drive for easier access.
- VV. VFD shall include the following program functions:
 - 1. Capability to reset all parameters back to the factory settings.
 - 2. Capability to reset all parameters back to a user-defined set of parameters.
 - 3. Capability to see only the parameters that have been modified.
 - 4. Ability to set the motor speed in Hertz, RPM, percent or custom units.
 - 5. Critical frequency rejection capability: 3 selectable, adjustable dead bands.
 - 6. Auto restart capability: 0 to 10 attempts with adjustable delay between attempts.
 - 7. Ability to close fault contact after the completion of all fault restart attempts.
 - 8. Kinetic energy braking function for deceleration upon power loss.

9. High Slip Braking function stops the motor in up to half the time.
10. Overvoltage suppression function for cyclic regenerative loads.
11. Stall prevention capability.
12. "S-curve" soft start / soft stop capability with four programmable corners.
13. Four sets of acceleration/deceleration times, selectable via digital input.
14. Acceleration/deceleration adjustment from 0 to 6000 seconds.
15. Bi-directional Speed search capability, in order to start a rotating load.
16. Multiple preset and 1 custom volts per hertz pattern.
17. Programmable security code to prevent parameter setting changes.
18. Heatsink overtemperature speed fold back capability.
19. Terminal status indication.
20. Motor thermistor input.
21. Reverse direction lockout.
22. Torque limit adjustment from 0% to 300% of rated torque of the motor.
23. Input signal or serial communication loss detection and selectable response.
24. Automatic energy saving function.
25. Undertorque/Overtorque Detection.
26. Overexcitation braking function to quickly stop the motor.
27. Cooling fan failure detection and selectable drive action.
28. Ability to remove digital operator during VFD operation.
29. Motor preheat function.
30. Up to four PID setpoints.
31. Emergency override modes.

2.05 PRODUCT OPTIONS

- A. VFD shall have the following optional accessories:
 1. Fieldbus Adapters: LonWorks
 2. Ethernet Media Adapters (single and/or multiport): EtherNet/IP, Modbus TCP/IP, BACnet/IP.
 3. Remote Keypad Mounting Kit: rated UL Types 1, 12, 3R, and 4X.

2.06 SOURCE QUALITY CONTROL

- A. Inspect and test, under load, each completed VFD at the completion of production using a computerized, automated testing fixture. All test results shall be stored as detailed quality assurance data.

PART 3. EXECUTION

3.01 EXAMINATION

- B. Verify that surface is suitable for VFD installation.
- C. Do not install VFD until the installation 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.

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 the system.

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 Electronic Bypass shall be provided when indicated by the schedule. VFD and bypass package shall be UL Type 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. Electronic motor overload relay, to display motor amps and protect the motor while operating in the bypass mode.
 4. Disconnect switch, with a pad-lockable through-the-door handle mechanism.
 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 , Modbus/Memobus, Siemens Apogee, Johnson Controls Metasys 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. BACnet MS/TP connection shall be equipped with a network health monitor. This monitor shall display a value between 0-100% indicating the relative health of the BACnet network connection. This health factor shall be determined by the number of CRC errors, token losses, token retries, and net deadtime perceived.
 9. Door mounted control panel with; Drive/Bypass selector keys, Hand/Off/Auto selector keys, Normal/Test selector keys. Hand/Off/Auto keys shall be uniquely colored.
 10. 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”, “Emergency Override”, “Hand Mode”, “Off Mode”, and “Auto Mode”..
 11. Drive/Bypass selector keys, to allow switching between the Drive and Bypass mode.
 12. 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
13. Eight Programmable digital inputs (24Vdc, 8mA) shall be provided for Auto Transfer to bypass, Safety Interlock, BAS Interlock, and numerous other bypass specific functions.
 14. 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”.
 15. 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.
 16. Line voltage sensors to monitor for brownout, blackout and single phase conditions. Fault levels for each condition must be adjustable to ensure the proper settings pursuant to each application.
 17. Selectable energy savings and harmonic reduction mode. Drive automatically switches to Bypass (Across-the-line) when motor is running 60 Hz for a set time and automatically switches back when frequency reference changes.
 18. Green Contactor Mode. When enabled output and motor contactors remain open when the bypass is in an idle state without a run command.
 19. Bypass shall be configured with zero cross switching, whereas the contactors shall only change state at the zero voltage crossing point in the AC waveform. Restricting contactor state-change to this condition will reduce contact arcing which extends contact life and minimizes electrical noise.
- 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. Electronic motor overload relay, to display motor amps and protect the motor while operating in the bypass mode.
 4. Disconnect switch, with a pad-lockable through-the-door handle mechanism.
 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 , Modbus/Memobus, Siemens Apogee, Johnson Controls Metasys communication protocols as standard 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. BACnet MS/TP connection shall be equipped with a network health monitor. This monitor shall display a value between 0-100% indicating the relative health of the BACnet network connection. This health factor shall be determined by the number of CRC errors, token losses, token retries, and net deadtime perceived.
 9. Door mounted control panel with; Drive/Bypass selector keys, Hand/Off/Auto selector keys, Normal/Test selector keys.
 10. 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”, “Emergency Override”, “Hand Mode”, “Off Mode”, and “Auto Mode”.
 11. Drive/Bypass selector keys, to allow switching between the Drive and Bypass mode.
 12. Hand/Off/Auto selector keys shall provide the following operation and be programmed to operate in any of these modes upon power-up:
 13. 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.
 14. 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.
 15. 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.
 16. 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
 17. Eight Programmable digital inputs (24Vdc, 8mA) shall be provided for Auto Transfer to bypass, Safety Interlock, BAS Interlock, and numerous other bypass specific functions.
 18. 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”.
 19. 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.
 20. Line voltage sensors to monitor for brownout, blackout and single phase conditions. Fault levels for each condition must be adjustable to ensure the proper settings pursuant to each application.
 21. Selectable energy savings and harmonic reduction mode. Drive automatically switches to Bypass (Across-the-line) when motor is running 60 Hz for a set time and automatically switches back when frequency reference changes.
 22. Green Contactor Mode. When enabled output and motor contactors remain open

- when the bypass is in an idle state without a run command.
23. Bypass shall be configured with zero cross switching, whereas the contactors shall only change state at the zero voltage crossing point in the AC waveform. Restricting contactor state-change to this condition will reduce contact arcing which extends contact life and minimizes electrical noise.
- C. Redundant Drive Package shall be provided when indicated by the schedule. Two VFD drives (Drive A, Drive B) shall be supplied in a UL Type 1 or Type 12 rated, fully pre-wired and ready for installation as a single UL listed device. Redundant drive package shall include the following as standard:
1. Lockable main input disconnect switch.
 2. Semiconductor fuses for each VFD.
 3. Output contactor for each VFD
 4. 115V control transformer and transfer logic.
 5. Damper control circuit with end of travel feedback with two adjustable wait time functions.
 6. "Fault Transfer" selector switch
 7. "Drive A -Auto - Drive B" selector switch.
 8. "Hand-Off-Auto" selector switch.
 9. "External Fault" pilot light.
 10. "Drive A Fault" pilot light.
 11. "Drive B Fault" pilot light.
 12. "Drive A Run" pilot light.
 13. "Drive B Run" pilot light.
 14. Single power input/output wiring points
 15. Single control wiring points
 16. Two door mounted drive control keypads.
- D. Main input circuit breaker with a pad-lockable through-the-door handle mechanism, able to achieve a SCCR panel rating of 100kAIC.
- E. Enclosure:
- 1 NEMA / UL TYPE 12 Enclosure
 - 2 NEMA / UL TYPE 3R enclosures for outdoor installations.
- F. Engraved cabinet nameplates shall be provided.

G. Additional options

1. Communication capability for Echelon LonWorks, EtherNet/IP, and BACnet/IP shall be provided.
2. PC software and cable for parameter upload/download/graphing shall be provided.
3. Mobile Android software for wired or wireless Bluetooth app connectivity shall be provided.