

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:

1. Requirements for motor controls and variable speed drives.

B. Related Sections:

1. Section 23 05 13 - Common Motor Requirements for HVAC Equipment: Product requirements for motors for placement by this section.
2. Section 23 05 53 - Identification for HVAC Piping and Equipment: Product requirements for pipe identification for placement by this section.
3. Section 23 21 23 - Hydronic Pumps: Execution requirements for piping connections to products specified by this section.
4. Section 23 22 23 - Steam Condensate Pumps: Execution requirements for piping connections to products specified by this section.
5. Section 23 34 00 - HVAC Fan: Product requirements for fans for placement by this section.
6. Section 23 73 00 - Indoor Central-Station Air-Handling Units: Product requirements for air-handling units for placement by this section.
7. Section 23 81 26 - Split-System Air-Conditioners: Product requirements for split-system air-conditioners for placement by this section.

1.02 REFERENCES

- A. Material and Installation shall comply with latest editions of applicable codes, recommended practices and standards, of NEC, NEMA, UL and IBC-NJ Code.
- B. Examine the Contract Documents of Division 26 for coordinating work specified under this section.

1.03 SUBMITTALS

- A. Submit shop drawings and product data in accordance with general conditions.

PART 2 - PRODUCTS

2.01 GENERAL

- A. Furnish and install all motors, and furnish all variable speed drives, combination motor starters/disconnect switches, disconnect switches and starters that are required for controlling the HVAC equipment and motors.

- B. Coordinate with Division 26 work for installation and proper integration of electrical power wiring with the motors and equipment that are provided under Division 23.

2.02 VARIABLE FREQUENCY DRIVES

A. Description

1. This specification is to cover a complete Variable Frequency motor Drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use with a standard NEMA Design B induction motor.
2. The drive manufacturer shall supply the drive and all necessary options as herein specified. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of twenty years. VFD's that are manufactured by a third party and "brand labeled" shall not be acceptable. All VFDs installed on this project shall be from the same manufacture

B. Quality Assurance

1. Referenced Standards:

- a. Institute of Electrical and Electronic Engineers (IEEE)
 - 1) Standard 519-1992, IEEE Guide for Harmonic Content and Control.
- b. Underwriters laboratories
 - 1) UL508C
- c. National Electrical Manufacturer's Association (NEMA)
 - 1) ICS 7.0, AC Adjustable Speed Drives
- d. IEC 16800 Parts 1 and 2
- e. National Electric Code (NEC)
 - 1) NEC 430.120, Adjustable-Speed Drive Systems
- f. International Building Code of New Jersey (IBC-NJ)
 - 1) IBC 2006 Seismic – referencing ASC 7-05 and ICC AC-156

2. Qualifications:

- a. VFDs and options shall be UL listed as a complete assembly. VFD's that require the customer to supply external fuses for the VFD to be UL listed are not acceptable. VFDs with red label UL stickers, requiring additional branch circuit protection are not acceptable. The base VFD shall be UL listed for 100 KAIC without the need for input fuses.

- b. CE Mark – The VFD shall conform to the European Union Electro-Magnetic Compatibility directive, a requirement for CE marking. The VFD shall meet product standard EN 61800-3 for the First Environment restricted level.
- c. The entire VFD enclosure, including the bypass shall be seismically certified and labeled as such in accordance with the 2006 International Building Code (IBC):
 - 1) VFD manufacturer shall provide Seismic Certification and Installation requirements at time of submittal.
 - 2) Seismic importance factor of 1.5 rating is required, and shall be based upon actual shake test data as defined by ICC AC-156.
 - 3) Seismic ratings based upon calculations alone are not acceptable. Certification of Seismic rating must be based on testing done in all three axis of motion.
- d. Acceptable Manufactures
 - 1) ABB ACH Series.
 - 2) approved equal
- e. The VFD manufacturer shall have available a comprehensive, HVAC Drive Computer Based Training (CBT) product. The CBT product shall include detailed, interactive sections covering VFD unpacking, proper mechanical and electrical installation, and programming. The CBT product shall allow the user to provide just-in-time training to new personnel or refresher training for maintenance and repair personnel on the user's site. The CBT product shall be repeatable, precise and shall include record keeping capability. The CBT product shall record answers to simulations and tests by student ID number. The CBT product must be professionally produced and have interactive sections, student tests, and include video clips of proper wiring and installation.

C. Submittals

- 1. Submittals shall include the following information:
 - a. Outline dimensions, conduit entry locations and weight.
 - b. Customer connection and power wiring diagrams.
 - c. Complete technical product description include a complete list of options provided. Any portions of this specification not met must be clearly indicated or the supplier and contractor shall be liable to provide all additional components required to meet this specification.
 - d. Compliance to IEEE 519 – harmonic analysis for particular jobsite including total harmonic voltage distortion and total harmonic current distortion (TDD).

- 1) The VFD manufacturer shall provide calculations; specific to this installation, showing total harmonic voltage distortion is less than 5%. Input filters shall be sized and provided as required by the VFD manufacturer to ensure compliance with IEEE standard 519. All VFD's shall include a minimum of 5% impedance reactors, no exceptions.
- D. The VFD package as specified herein shall be enclosed in a UL Listed Type enclosure, exceeding NEMA enclosure design criteria (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer in an ISO9001 facility. The VFD tolerated voltage window shall allow the VFD to operate from a line of +30% nominal, and -35% nominal voltage as a minimum.
1. Environmental operating conditions: VFDs shall be capable of continuous operation at 0 to 50° C (32 to 122° F) ambient temperature as per VFD manufacturers documented/submittal data or VFD must be oversized to meet these temperature requirements. Not acceptable are VFD's that can only operate at 40° C intermittently (average during a 24 hour period) and therefore must be oversized. Altitude 0 to 3300 feet above sea level, less than 95% humidity, non-condensing. All circuit boards shall have conformal coating.
 2. Enclosure shall be rated UL Type 1 and shall be UL listed as a plenum rated VFD. VFD's without these ratings are not acceptable. NEMA only type 1 enclosures are not acceptable (must be UL Type 1).
- E. All VFDs shall have the following standard features:
1. All VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.
 2. The VFD shall have main power disconnecting means.
 3. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate "bumpless transfer" of speed reference when switching between "Hand" and "Auto" modes. There shall be fault reset and "Help" buttons on the keypad. The Help button shall include "on-line" assistance for programming and troubleshooting.
 4. There shall be a built-in time clock in the VFD keypad. The clock shall have a battery backup with 10 years minimum life span. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault. If the battery fails, the VFD shall automatically revert to hours of operation since initial power up. Capacitor back-up is not acceptable. The clock shall also be programmable to control start/stop functions, constant speeds, PID parameter sets and output Form-C relays. The VFD shall have a digital input that allows an override to the time clock (when in the off mode) for a programmable time frame. There shall be four (4) separate, independent timer functions that have both weekday and weekend settings.
 5. The VFD's shall utilize pre-programmed application macro's specifically designed to facilitate start-up. The Application Macros shall provide one

command to reprogram all parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.

6. The VFD shall have cooling fans that are designed for easy replacement. The fans shall be designed for replacement without requiring removing the VFD from the wall or removal of circuit boards. The VFD cooling fans shall operate only when required. To extend the fan and bearing operating life, the VFD shall cycle the cooling fans on and off as required.
7. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to set point without tripping or component damage (flying start).
8. The VFD shall have the ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.
9. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.
10. The VFD shall have internal 5% impedance reactors to reduce the harmonics to the power line and to add protection from AC line transients. The 5% impedance may be from dual (positive and negative DC bus) reactors, or 5% AC line reactors. VFD's with only one DC reactor shall add an AC line reactor.
11. The input current rating of the VFD shall be no more than 3% greater than the output current rating. VFD's with higher input current ratings require the upstream wiring, protection devices, and source transformers to be oversized per NEC 430.120. Input and output current ratings must be shown on the VFD nameplate.
12. The VFD shall include a coordinated AC transient surge protection system consisting of 4-120 joule rated MOV's (phase to phase and phase to ground), a capacitor clamp, and 5% impedance reactors.
13. The VFD shall provide a programmable loss-of-load (broken belt / broken coupling) Form-C relay output. The drive shall be programmable to signal the loss-of-load condition via a keypad warning, Form-C relay output, and / or over the serial communications bus. The loss-of-load condition sensing algorithm shall include a programmable time delay that will allow for motor acceleration from zero speed without signaling a false loss-of-load condition.
14. The VFD shall have user programmable underload and overload curve functions to allow user defined indications of broken belt or mechanical failure / jam condition causing motor overload
15. The VFD shall include multiple "two zone" PID algorithms that allow the VFD to maintain PID control from two separate feedback signals (4-20mA, 0-10V, and / or serial communications). The two zone control PID algorithm

will control motor speed based on a minimum, maximum, or average of the two feedback signals. All of the VFD PID controllers shall include the ability for "two zone" control.

16. If the input reference (4-20mA or 2-10V) is lost, the VFD shall give the user the option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued, as selected by the user. The drive shall be programmable to signal this condition via a keypad warning, Form-C relay output and / or over the serial communication bus.
17. The VFD shall have programmable "Sleep" and "Wake up" functions to allow the drive to be started and stopped from the level of a process feedback signal.

F. All VFDs to have the following adjustments:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed. The lockout range must be fully adjustable, from 0 to full speed.
2. Two (2) PID Set point controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the micro-processor in the VFD for the closed-loop control. The VFD shall have 250 ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID set point shall be adjustable from the VFD keypad, analog inputs, or over the communications bus. There shall be two independent parameter sets for the PID controller and the capability to switch between the parameter sets via a digital input, serial communications or from the keypad. The independent parameter sets are typically used for night setback, switching between summer and winter set points, etc.
3. There shall be an independent, second PID loop that can utilize the second analog input and modulate one of the analog outputs to maintain the set point of an independent process (ie. valves, dampers, etc.). All set points, process variables, etc. to be accessible from the serial communication network.
4. Two (2) programmable analog inputs shall accept current or voltage signals.
5. Two (2) programmable analog outputs (0-20ma or 4-20 ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, Active Feedback, and other data.
6. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC or 24VAC.
7. Three (3) programmable, digital Form-C relay outputs. The relay outputs shall include programmable on and off delay times and adjustable hysteresis. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 A at 250 VAC; Maximum voltage 300 VDC and 250 VAC; continuous current rating of 2 amps RMS. Outputs shall be true Form-C type contacts; open collector outputs are not acceptable.

8. Run permissive circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications), the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a VFD digital input and allows VFD motor operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop and the damper shall be commanded to close. The keypad shall display "start enable 1 (or 2) missing". The safety input status shall also be transmitted over the serial communications bus.
 9. The VFD control shall include a programmable time delay for VFD start and a keypad indication that this time delay is active. A Form C relay output provides a contact closure to signal the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates. The time delay shall be field programmable from 0 – 120 seconds. Start delay shall be active regardless of the start command source (keypad command, input contact closure, time-clock control, or serial communications), and when switching from drive to bypass.
 10. Seven (7) programmable preset speeds.
 11. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.
 12. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise. The VFD shall have selectable software for optimization of motor noise, energy consumption, and motor speed control.
 13. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows higher carrier frequency settings without derating the VFD.
 14. The VFD shall include password protection against parameter changes.
- G. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). All VFD faults shall be displayed in English words. The keypad shall include a minimum of 14 assistants including:
1. Start-up assistant
 2. Parameter assistants
 - a. PID assistant
 - b. Reference assistant
 - c. I/O assistant
 - d. Serial communications assistant

- e. Option module assistant
 - f. Panel display assistant
 - g. Low noise set-up assistant
- 3. Maintenance assistant
- 4. Troubleshooting assistant
- 5. Drive optimizer assistants
- H. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):
 - 1. Output Frequency
 - 2. Motor Speed (RPM, %, or Engineering units)
 - 3. Motor Current
 - 4. Motor Torque
 - 5. Motor Power (kW)
 - 6. DC Bus Voltage
 - 7. Output Voltage
- I. The VFD shall include a fireman's smoke control or purge override input. Upon receipt of a signal from the fire/smoke control station and/or fire alarm system, the VFD shall operate in one of two modes: 1) Operate at a programmed predetermined fixed speed ranging from -500Hz (reverse) to 500Hz (forward). 2) Operate in a specific fireman's override PID algorithm that automatically adjusts motor speed based on override set point and feedback. The mode shall override all other inputs (analog/digital, serial communication, and all keypad commands), except customer defined safety run interlocks, and force the motor to run in one of the two modes above. "Override Mode" shall be displayed on the keypad. Upon removal of the override signal, the VFD shall resume normal operation, without the need to cycle the normal digital input run command.
- J. Serial Communications
 - 1. The VFD shall have an EIA-485 port as standard. The protocols shall be Modbus, Johnson Controls N2, Siemens Building Technologies FLN, BACnet, LonWorks, Profibus, EtherNet, BACnet IP, and DeviceNet. Each individual drive shall have the protocol in the base VFD. The use of third party gateways and multiplexers is not acceptable. All protocols shall be "certified" by the governing authority (i.e. BTL Listing for BACnet). Use of non-certified protocols is not allowed.

2. Each VFD shall be provided with integral communication card suitable for direct, ready and easy communication with BMS.
3. The BACnet connection shall be an EIA-485, RS/TP interface operating at 9.6, 19.2, 38.4, or 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:
 - a. Data Sharing – Read Property – B.
 - b. Data Sharing – Write Property – B.
 - c. Device Management – Dynamic Device Binding (Who-Is; I-Am).
 - d. Device Management – Dynamic Object Binding (Who-Has; I-Have).
 - e. Device Management – Communication Control – B.
4. If additional hardware is required to obtain the BACnet interface, the VFD manufacturer shall supply one BACnet gateway per drive. Multiple VFDs sharing one gateway shall not be acceptable.
5. Serial communication capabilities shall include, but not be limited to; run-stop control, speed set adjustment, proportional/integral/derivative PID control adjustments, current limit, accel/decel time adjustments, and lock and unlock the keypad. The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature. The DDC shall also be capable of monitoring the VFD relay output status, digital input status, and all analog input and analog output values. All diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote VFD fault reset shall be possible.
6. Serial communication in bypass shall include, but not be limited to; bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the DDC to monitor feedback such as, current (in amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The DDC shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible.
7. The VFD / bypass shall allow the DDC to control the drive and bypass digital and analog outputs via the serial interface. This control shall be independent of any VFD function. The analog outputs may be used for modulating chilled water valves or cooling tower bypass valves. The drive and bypass' digital (Form-C relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the drive and bypass' digital inputs shall be capable of being monitored by the DDC system. This allows for remote monitoring of which (of up to 4) safeties are open.

8. The VFD shall include an independent PID loop for customer use. The independent PID loop may be used for cooling tower bypass value control, chilled water value / hot water valve control, etc. Both the VFD PID control loop and the independent PID control loop shall continue functioning even if the serial communications connection is lost. As default, the VFD shall keep the last good set point command and last good DO & AO commands in memory in the event the serial communications connection is lost and continue controlling the process.
- K. EMI / RFI filters. All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level with up to 100 feet of motor cable. No Exceptions. Certified test reports shall be provided with the submittals confirming compliance to EN 61800-3, First Environment.
- L. All VFD's through 75HP at 480 V shall be protected from input and output power mis-wiring. The VFD shall sense this condition and display an alarm on the keypad. The VFD shall not sustain damage from this power mis-wiring condition.
- M. Features – Features to be furnished and mounted by the drive manufacturer. All features shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.
1. A complete factory wired and tested bypass system consisting of an output contactor and bypass contactor per paragraph 2.02 N.
 2. Fieldbus adapters - Protocols such as LonWorks, DeviceNet, Ethernet IP (ControlNet over Ethernet & ModBus TCP), BACnet IP, and Profibus shall be provided. Coordinate with appropriate communications protocol with BMS vendor.
- N. Bypass Controller
1. A complete factory wired and tested bypass system consisting of a door interlocked, padlockable circuit breaker, output contactor, bypass contactor, and fast acting VFD input fuses are required. UL Listed motor overload protection shall be provided in both drive and bypass modes.
 2. The bypass enclosure door and VFD enclosure must be mechanically interlocked such that the disconnecting device must be in the "Off" position before either enclosure may be accessed. Provide bypass interlock for use by qualified personnel. Bypass contactor shall be NEMA rated and shall be equipped with solid-state electronic overloads.
 3. The VFD and bypass package shall have a UL listed short circuit current rating (SCCR) of 100,000 amps and this rating shall be indicated on the UL data label.
 4. The drive and bypass package shall be seismic certified and labeled to the IBC:
 - a. Seismic importance factor of 1.5 rating is required, and shall be based upon actual shake table test data as defined by ICC AC-156.

5. Drive Isolation Fuses - To ensure maximum possible bypass operation, fast acting fuses, exclusive to the VFD, shall be provided to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection. This maintains bypass operation capability in the event of a VFD failure. Bypass designs which have no such fuses, or that incorporate fuses common to both the VFD and the bypass, will not be accepted.
6. The system (VFD and Bypass) tolerated voltage window shall allow the system to operate from a line of +30%, -35% nominal voltage range. The system shall incorporate circuitry that will allow the drive or bypass contactor to remain "sealed in" over this voltage tolerance at a minimum.
7. The bypass shall maintain positive contactor control through the voltage tolerance window of nominal voltage +30%, -35%. This feature is designed to avoid contactor coil failure during brown out / low line conditions and allow for input single phase operation when in the VFD mode. Designs that will not allow input single phase operation in the VFD mode are not acceptable.
8. Motor protection from single phase power conditions - the bypass system must be able to detect a single phase input power condition while running in bypass, disengage the motor in a controlled fashion, and give a single phase input power indication. Bypass systems not incorporating single phase protection in bypass mode are not acceptable.
9. The bypass system shall NOT depend on the VFD for bypass operation. The bypass system shall be designed for standalone operation and shall be completely functional in both Hand and Automatic modes even if the VFD has been removed from the system for repair / replacement. Serial communications shall remain functional even with the VFD removed.
10. Serial communications – the bypass shall be capable of being monitored and / or controlled via serial communications. On-board communications protocols shall include ModBus; Johnson Controls N2; Siemens Building Technologies FLN (P1); and BACnet.
11. Serial communication capabilities shall include, but not be limited to; bypass run-stop control; the ability to force the unit to bypass; and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the DDC to monitor feedback such as, current (in amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The DDC shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible. The following additional status indications and settings shall be transmitted over the serial communications bus and / or via a Form-C relay output – keypad "Hand" or "Auto" selected, bypass selected, and broken belt indication. The DDC system shall also be able to monitor if the motor is running in the VFD mode or bypass mode over serial communications. A minimum of 50 field serial communications points shall be capable of being monitored in the bypass mode.
12. The bypass serial communications shall allow control of the bypass' digital outputs via the serial interface. This control shall be independent of any bypass function or operating state. The bypass' digital (relay) outputs may

be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the bypass' digital inputs shall be capable of being monitored by the DDC system.

13. There shall be an adjustable motor current sensing circuit for the bypass and VFD modes to provide proof of flow (broken belt) indication. The condition shall be indicated on the keypad display, transmitted over the building automation protocol and/or via a Form-C relay output contact closure. The broken belt indication shall be programmable to be a system (drive and bypass) indication. The broken belt condition sensing algorithm shall be programmable to cause only a warning or a fault and / or system shutdown.
14. The digital inputs for the system shall accept 24VAC or 24VDC. The bypass shall incorporate an internally sourced power supply and not require an external control power source. The bypass power board shall supply 250 ma of 24 VDC for use by others to power external devices.
15. There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad command, time-clock control, digital input, or serial communications) the bypass shall provide a dry contact closure that will signal the damper to open (motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a bypass system input and allows motor operation. Up to four separate safety interlock inputs shall be provided. When any safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. This feature will also operate in Fireman's override / smoke control mode.
16. The bypass control shall monitor the status of the VFD and bypass contactors and indicate when there is a welded contactor contact or open contactor coil. This failed contactor condition shall be indicated on the bypass LCD display, programmed to fire a Form-C relay output, and / or over the serial communications protocol.
17. The bypass control shall include a programmable time delay for bypass start and keypad indication that this time delay is in process. A Form C relay output provides a contact closure to signal the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates at full speed in the bypass mode. The time delay shall be field programmable from 0 – 120 seconds.
18. There shall be a keypad adjustment to select manual or automatic transfer bypass. The user shall be able to select via keypad programming which drive faults will result in an automatic transfer to the bypass mode and which faults require a manual transfer to bypass. The user may select whether the system shall automatically transfer from drive to bypass mode on the following drive fault conditions:
 - a. Over current
 - b. Over voltage
 - c. Under voltage
 - d. Loss of analog input

19. The following operators shall be provided:
 - a. Bypass Hand-Off-Auto
 - b. Drive mode selector
 - c. Bypass mode selector
 - d. Bypass fault reset
20. The bypass shall include a two line, 20 character LCD display. The display shall allow the user to access and view:
 - a. Energy savings – in US dollars
 - b. Bypass motor amps
 - c. Bypass input voltage– average and individual phase voltage
 - d. Bypass power (kW)
 - e. Bypass faults and fault logs
 - f. Bypass warnings
 - g. Bypass operating time (resettable)
 - h. Bypass energy (kilowatt hours – resettable)
 - i. I/O status
 - j. Parameter settings / programming
 - k. Printed circuit board temperature
21. The following indicating lights (LED type) or keypad display indications shall be provided. A test mode or push to test feature shall be provided.
 - a. Power-on (Ready)
 - b. Run enable
 - c. Drive mode selected
 - d. Bypass mode selected
 - e. Drive running
 - f. Bypass running
 - g. Drive fault
 - h. Bypass fault
 - i. Bypass H-O-A mode

- j. Automatic transfer to bypass selected
 - k. Safety open
 - l. Damper opening
 - m. Damper end-switch made
22. The Bypass controller shall have six programmable digital inputs, and five programmable Form-C relay outputs. This I/O allows for a total System (VFD and Bypass) I/O count of 24 points as standard. The bypass I/O shall be available to the BMS / DDC system even with the VFD removed.
23. The on-board Form-C relay outputs in the bypass shall be programmable for any of the following indications.
- a. System started
 - b. System running
 - c. Bypass override enabled
 - d. Drive fault
 - e. Bypass fault
 - f. Bypass H-O-A position
 - g. Motor proof-of-flow (broken belt)
 - h. Overload
 - i. Bypass selected
 - j. Bypass run
 - k. System started (damper opening)
 - l. Bypass alarm
 - m. Over temperature
24. The bypass shall provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in VFD or Bypass mode. The remote start/stop contact shall operate in VFD and bypass modes. The terminal strip shall allow for independent connection of up to four (4) unique safety inputs.
25. The bypass shall include a supervisory control mode. In this bypass mode, the bypass shall monitor the value of the VFD's analog input (feedback). This feedback value is used to control the bypass contactor on and off state. The supervisory mode shall allow the user to maintain hysteresis control over applications such as cooling towers and booster pumps even with the VFD out of service.

26. The user shall be able to select the text to be displayed on the keypad when an external safety opens. Example text display indications include "FireStat", "FreezStat", "Over pressure" and "Low suction". The user shall also be able to determine which of the four (4) safety contacts is open over the serial communications connection.
27. Class 10, 20, or 30 (programmable) electronic motor overload protection shall be included.
28. The VFD Product Warranty shall be 24 months from the date of certified start-up, not to exceed 30 months from the date of shipment. The warranty shall include all parts, labor, travel time and expenses. A toll free 24/365 technical support line shall be available.

2.03 SOLID-STATE REDUCED-VOLTAGE COMBINATION MOTOR STARTERS

- A. Manufacturers: Subject to requirements of the specification, provide the following manufacturer's products by one of the following or approved equal:
 1. Allen-Bradley
 2. Eaton/Cutler-Hammer
 3. General Electric
 4. Schneider Electric/Square D
 5. Siemens
- B. Reduced Voltage Combination Motor Starters
 1. The solid-state reduced-voltage combination starters shall be UL and CSA listed. The solid-state reduced-voltage starter shall be an integrated unit with power SCRs, logic board, paralleling bypass contactor, and electronic overload relay fusible disconnect switch enclosed in a single enclosure.
 2. The SCR-based power section shall consist of six (6) back-to-back SCRs and shall be rated for a minimum peak inverse voltage rating of 1500 volts PIV.
 3. Units using triacs or SCR/diode combinations shall not be acceptable.
 4. Resistor/capacitor snubber networks shall be used to prevent false firing of SCRs due to dv/dt effects.
 5. The logic board shall be mounted for ease of testing, service and replacement. It shall have quick disconnect plug-in connectors for current transformer inputs, line and load voltage inputs and SCR gate firing output circuits.
 6. The logic board shall be identical for all ampere ratings and voltage classes and shall be conformally coated to protect environmental concerns.

7. The paralleling run bypass contactor shall energize when the motor reaches 90 of full speed and close/open under one (1) times motor current.
8. The paralleling run bypass contactor shall utilize an intelligent coil controller to limit contact bounce and optimize coil voltage during varying system conditions.
9. The coil shall have a lifetime warranty.
10. Starter shall be provided with electronic overload protection as standard and shall be based on inverse time-current algorithm. Overload protection shall be capable of being disabled during ramp start for long acceleration loads via a DIP switch setting on the device keypad.
11. Overload protection shall be adjusted via the device keypad and shall have a motor full load ampere adjustment from 30 to 100% of the maximum continuous ampere rating of the starter.
12. Starter shall have selectable solid-state electronic overload class setting of 5, 10, 20 or 30 via a DIP switch setting on the device keypad.
13. Starter shall be capable of either an electronic or mechanical reset after a fault.
14. Units using bimetal overload relays are not acceptable.
15. Over temperature protection (on heat sink) shall be standard.
16. Starters shall provide protection against improper line-side phase rotation as standard. Starter will shut down if a line-side phase rotation other than A-B-C exists. This feature can be disabled via a DIP switch on the device keypad.
17. Starters shall provide protection against a phase loss or unbalance condition as standard. Starter will shut down if a 50% current differential between any two phases is encountered. This feature can be disabled via a DIP switch on the device keypad.
18. Start shall provide protection against a motor stall condition as standard. This feature can be disabled via a DIP switch on the device keypad.
19. Starter shall provide protection against a motor jam condition as standard. This feature can be disabled via a DIP switch on the device keypad.
20. Starter shall be provided with a form C normally open (NO), normally closed (NC) contact that shall change state when a fault condition exists. Contacts shall be rated 60 VA (resistive load) and 20 VA (inductive load). In addition, an LED display on the device keypad shall indicate type of fault (Overtemp, Phase Loss, Jam, Stall, Phase Reversal, and Overload).
21. Provide at least two (2) spare contacts for future use.
22. The following control function adjustments on the device keypad are required:
 - a. Selectable Torque Ramp Start or Current Limit Start

- b. Adjustable Kick Start Time, 0-2 seconds
 - c. Adjustable Kick Start torque, 0-85%
 - d. Adjustable Ramp Start Time; 0.5-180 seconds
 - e. Adjustable Initial Starting Ramp Torque; 0-85%
 - f. Adjustable Smooth Stop Ramp Time; 0-60 seconds.
23. Maximum continuous operation shall be at 115% of continuous ampere rating.

C. Enclosures:

- 1. The enclosures shall be wall mountable NEMA 1 for indoor and NEMA 3R for outdoor installation.
- 2. Starters shall have a fusible type disconnect switch with Class R fuse clips.
- 3. Each starter shall be provided with a set of fuses matching the characteristics of the load being served.

D. Indication:

- 1. Each starter shall be equipped with HOA selector switch, start-stop pushbutton, red "run" pilot light, green "stop" pilot light and two (2) NO/2 NC auxiliary contacts.

E. Factory Testing:

- 1. 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.
- 2. The manufacturer shall provide three (3) certified copies of factory test reports.

F. Field Quality Control:

- 1. Provide the services of a qualified factory-trained manufacturer's representative to assist the Contractor in installation and start-up of the equipment specified under this section. The manufacturer's representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, connections and adjustments, and testing of the assembly and components contained herein.
- 2. The following minimum work shall be performed by the Contractor under the technical direction of the manufacturer's service representative.
 - a. Inspection and final adjustments
 - b. Operational and functional checks of controllers/starters and spare parts.

3. The Contractor shall provide three (3) copies of the manufacturer's field start-up report.
- G. Manufacturer's Certification:
1. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations.
 2. The Contractor shall provide three (3) copies of the manufacturer's representative's certification.
- H. Training:
1. The Contractor shall provide a training session for up to five (5) owner's representatives for 2 normal workdays at a jobsite location determined by the owner.
 2. The training representative shall be conducted by a manufacturer's qualified representative.
 3. The training program shall consist of the following:
 - a. Instructions on the proper maintenance and operation of the equipment.

2.04 MOTOR STARTERS AND CONTROLS

- A. All motor controllers and starters integral shall be in accordance with the following:
1. All individually mounted motor controllers and starters shall be of the following type:
 - a. Combination fused switch and magnetic controller with solid-state overload protection, low voltage protection and solid-state reduced voltage start.
 - b. Manual toggle switch operation 2-pole or single-pole starter with overload protection in approved UL Type 1 enclosure. Similar to BAS-IP by Cerus for single phase starters. Starter shall have on/off disconnect switch, concealed hand/automatic switch with manual reset and "Power, run and fault" indicating lights.
 2. Provide UL Class RK-1 time-delay, current limiting fuses for all combination starters. Fuses shall be selected based on the fuse manufacturer's motor sizing tables and shall be coordinated with the upstream use or circuit breaker.
 3. Starters shall be NEMA rated contactors with solid-state electronic motor overload protection and solid-state reduced voltage start.
 4. All starters shall be provided with thermal overload protection in all phase legs. Starters for 3-phase motors shall be equipped solid-state electronic

overload units, which shall also provide single phase protection. Single phase manual starters shall be equipped with melting alloy overload relays.

5. Provide all starters with an external overload reset button, mounted in the starter cover.
6. Provide three-position, maintained contact rotary selector switch (H-O-A) in starter covers for all automatically controlled motors. Pushbuttons are not required where H-O-A switches are used.
7. Provide 120V control power transformers in all controllers. Control power transformers shall be provided with two primary and one secondary fuse. Fuses shall be UL Class CC time delay type.
8. Provide all necessary auxiliary contacts and transformers in starters as required. Provide time delay relays for all interlocked motors. Provide at least two spare contacts for future use.
9. All pilot lights shall be LED type with red or green jewel as indicated. Provide pilot lights where required as follows:
 - a. Starters with start-stop pushbutton: 1 pilot light to indicate "Motor On".
 - b. Starters with H-O-A switches: 1 pilot light to indicate "Motor On".
10. Each controller, mounted in NEMA type enclosure. Enclosures shall be as follows:
 - a. Exterior: NEMA 3R stainless steel.
 - b. Interior, dry locations: NEMA 1.
11. Enclosure sizes and wiring terminals shall be suitable for the use of both copper power and control conductors.
12. Starters shall be subject to the approval, as to limit of inrush current, as set up by the Utility Company. In general, magnetic starters shall be located close to the equipment controlled.

2.05 REMOTE DEVICES

- A. Remote "Emergency stop" maintained contact switch, "Hand-off-auto" selector switch, pilot light, and similar devices, shall be of same manufacture as the associated starter, and shall be oiltight.
- B. Remote pilot light shall be neon type with series resistor.
- C. Remote "Emergency Stop" and other contact making devices shall be pilot duty rated.
- D. Wiring shall be connected so as to prevent unintentional starting by the grounding of any wire or wires outside of the starter enclosure.

- E. Remote "Emergency Stop" push buttons shall be Westinghouse "PB-1", maintained contact, red button marked stop, black button marked 'RESET'.

2.06 FACTORY FURNISHED CONTROL PANELS

- A. The packaged control panel furnished with duplex pumps and compressors shall be provided with a circuit breaker or fusible switch for each pump circuit and a magnetic starter with three (3) overloads for each motor. A control power transformer shall be provided and served via a transfer relay with power taken from the load side of each incoming line circuit breaker.

PART 3 - EXECUTION

3.01 GENERAL

- A. Motors installed, not in strict compliance with the above, shall be replaced at no cost to the Owner.

3.02 ELECTRICAL WIRING

- A. Provide all necessary wiring diagrams indicating wire size and connections as required for the proper operation of the equipment.
- B. Contractor shall be responsible for replacing all fuses in the electrical systems during construction which blow due to tests or malfunction of his motorized or non-motorized electrical equipment. Contractor shall be responsible to provide contacts, relays, transformers and accessories as required for operation of system.

3.03 INSTALLATION

- A. Mounting:
 - 1. Install motor controllers plumb and in alignment; with channel bolted to the floor slab and structure above.
 - 2. Make required mechanical and electrical connections including those indicated on approved shop drawings.
 - 3. Touch-up paint all marred factory finishes.
 - 4. Provide metal channel support steel system for all wall-mounted devices.
- B. Overload Elements:
 - 1. Provide in accordance with motor nameplate current, service factor and ambient temperature.
 - 2. With clamp-on ammeter verify loading of motors. Where overloading occurs, do not increase thermal elements unless directed by Architect.

- C. Tighten and torque electrical connections in accordance with manufacturer's instruction and UL 486.

3.04 TESTING

- A. Coordinate testing of starter with testing of the motor and the system associated with the motor.

3.05 REMOTE MAINTAINED CONTACT EMERGENCY STOP AND RESET PUSHBUTTONS

- A. Remote maintained contact emergency stop and reset pushbuttons shall be wired ahead of all other motor control devices and shall interrupt the motor control circuit in both the "Hand" and "Automatic" positions.

3.06 VFD Installation

- A. 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 VFD installation manual.
- B. Power wiring shall be completed by the electrical contractor, to NEC code 430.122 wiring requirements based on the VFD input current. Caution: VFDs supplied without internal reactors have substantially higher input current ratings, which may require larger input power wiring and branch circuit protection. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

END OF SECTION