SECTION 262923 – VARIABLE FREQUENCY DRIVES

Latest Update 05-03-2023 See underlined text for Edits.

(Engineer shall edit specifications and blue text in header to meet project requirements. This includes but is not limited to updating Equipment and/or Material Model Numbers indicated in the specifications and adding any additional specifications that may be required by the project. Also turn off all "Underlines".)

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this section and all other sections of Division 26.

1.2 SUMMARY

A. Section includes separately enclosed, pre-assembled, combination VFDs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

B. UMB VFD Application:

1. Motors 5 HP and Smaller: Motors 5 HP and smaller shall be variable speed ECM motors with combination starter, disconnect and auxiliary contacts to interface with the BAS.

2. Motors 7.5 HP and Larger: Motors 7.5 HP and larger shall be equipped with a VFD for each motor including required accessory to interface with the BAS.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. CPT: Control power transformer.

C. EMI: Electromagnetic interference.

D. IGBT: Insulated-gate bipolar transistor.

E. LAN: Local area network.

F. LED: Light-emitting diode.

G. MCP: Motor-circuit protector.

H. NC: Normally closed.

I. NO: Normally open.

J. OCPD: Overcurrent protective device.

K. PCC: Point of common coupling.

L. PID: Control action, proportional plus integral plus derivative.

M. PWM: Pulse-width modulated.

N. RFI: Radio-frequency interference.

O. TDD: Total demand (harmonic current) distortion.

P. THD(V): Total harmonic voltage demand.

Q. VFD: Variable-frequency motor controller.

R. VFD: Variable-frequency drive (synonymous with VFD).

1.4 SUBMITTALS

A. General Submittal Requirements: Comply with the UMB General Conditions. For general requirements see Architectural Specification Division 01 Section "Submittal Procedures" and Division 260000 “Basic Electrical Requirements”.

B. In addition to the requirements identified in Architectural Specification Division 01 Section "Submittal Procedures" the fire alarm contractor shall also comply with the following:

1. UMB requires the Variable-Frequency Drive Submittal to be submitted electronically as one (1) complete submission as a “pdf” file for review. Partial Submittals will be rejected.

a. The complete submittal must be reviewed and approved by the A/E and the UMB Fire Marshal before installation can take place. The submission shall include the following:

1) Product data
2) Shop drawings (See Paragraph ‘E’ below for requirements)
3) Harmonic Analysis Study, Report and Calculations

C. Product Data: For each type and rating of VFD indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.

D. LEED Submittals:

1. Product Data for Credit EA 5: For continuous metering equipment for energy consumption.

E. Shop Drawings: For each VFD indicated. Include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.

1. Show tabulations of installed devices, equipment features, and ratings. Include the following:

a. Each installed unit's type and details.
b. Factory-installed devices.
c. Enclosure types and details.
d. Nameplate legends.
e. Short-circuit current (withstand) rating of enclosed unit.
f. Features, characteristics, ratings, and factory settings of each VFD and installed devices.
g. Specified modifications.

2. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.

F. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible operating scenarios, including recommendations for VFD input filtering to limit TDD and THD (V) at each VFD at the defined PCC to specified levels.

< Consult & Coordinate with UMB for Requirements and Delete if not required>

1. Harmonic Calculations: The VFD manufacturer shall supply harmonic calculations made in accordance with the latest version of IEEE 519 showing the specified THVD, line notching and the specified THCD limits are met. Calculations shall assume worst case system conditions. System single-line, 480V transformer data, generator data and primary fault current data can be found in the Overcurrent Protective Device Coordination Study and can be obtained from the Electrical Contractor. The calculations shall include:

a. All input data and assumptions

b. Explanation of method used to perform the analysis

c. All calculations and computer printouts used in the analysis, including input documentation

d. A system impedance diagram based on Electrical single-line diagram

e. All calculations shall be made in accordance with IEEE 519 with all drives at 100% speed. The point of common coupling shall be the primary connection of the transformer supplying that group of devices. These calculations shall be done with the transformer loaded to no more than 70% of its nominal capacity. These calculations shall also be done with all 12-pulse or greater drives running as well as the smaller drives running.

f. A detailed description of the tests, procedures and supporting calculations required to substantiate the installed systems compliance with the THD limits.

1) The description shall include information on the proposed test equipment and test conditions.

2) Include the name and qualifications of the firm which will conduct the field test.

g. Each point of common coupling shall be defined as the primary of the side of the transformer that feeds that group of drives. At the point of common coupling, the following numbers shall meet with the maximum load on the transformer no greater than 70% of its nominal capacity.
1) Total harmonic voltage distortion is less than 3%
2) Total harmonic current distortion is less than 5% and harmonic table requirements $I_{sc}/I_L<20$.

Note: Six (6) Pulse drives will not be accepted for over 175hp drives, even if this calculation is met.

h. Submittals without calculations will not be reviewed

G. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFDs. Show VFD layout and relationships between electrical components and adjacent structural and mechanical elements including raceway stub-ups and field wiring. Show support locations, type of support, and weight on each support. Indicate field measurements.

H. Qualification Data: For qualified testing agency.

I. Product Certificates: For each VFD, from manufacturer.

J. Source quality-control reports.

K. Field quality-control reports.

L. Operation and Maintenance Data: For VFDs to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
2. Manufacturer's written instructions for setting field-adjustable overload relays.
3. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
4. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

M. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.

N. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with NFPA 70.

1.6 DELIVERY, STORAGE, AND HANDLING

A. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and [install temporary electric heating, with at least 250 W per controller] [connect factory-installed space heaters to temporary electrical service]. <Engineer to Edit for Project Requirements>

1.7 PROJECT CONDITIONS

A. Environmental and Operating Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions unless otherwise indicated:

1. Ambient Temperature: Not less than 0^0F and not exceeding 120^0F.
2. Ambient Storage Temperature: Not less than minus 4^0F and not exceeding 140^0F

3. Humidity: Less than 95% (noncondensing and non-corrosive).
4. Altitude: Not exceeding 3300 feet.
5. Incoming 3-phase 480 VAC power: +5% or -10% at 60 Hz.
6. A 50% voltage sags for thirty (30) cycles.

B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify Architect no fewer than ten (10) days in advance of proposed interruption of electrical systems.
2. Indicate method of providing temporary electrical service.
3. Do not proceed with interruption of electrical systems without Owner's written permission.
4. Comply with NFPA 70E.

C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFDs, including clearances between VFDs, and adjacent surfaces and other items.

1.8 COORDINATION

A. Coordinate features of motors, load characteristics, installed units, and accessory devices to be compatible with the following:

1. Torque, speed, and horsepower requirements of the load.
2. Ratings and characteristics of supply circuit and required control sequence.
3. Ambient and environmental conditions of installation location.

B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

D. Submit written, signed off coordination statement confirming input control signal is compatible with automatic controls and/or building automation control system.

1.9 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Power Fuses: Equal to [Five (5)] <Insert number> percent of quantity installed for each size and type, but no less than [one] <Insert number> of each size and type.
2. Control Power Fuses: Equal to [Five (5)] <Insert number> percent of quantity installed for each size and type, but no less than [one] <Insert number> of each size and type.
3. Indicating Lights: [One (1)] <Insert number> of each type and color installed.
4. Auxiliary Contacts: Furnish [One (1)] <Insert number> spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish [One (1)] <Insert number> spares for each size and type of magnetic contactor installed.
6. <Insert extra materials>.

1.10 WARRANTY/GUARANTEE

A. See Division 26 Specification Section "Basic Electrical Requirements' for warranty and guarantee requirements.

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFDs that fails in materials or workmanship within specified warranty period.

1. Warranty Period: [Five (5)] <Insert number> years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Acceptable Manufacturers: Subject to compliance with ANSI, IEEE and NEMA requirements, and unless otherwise indicated all VFD's shall be products manufactured by one (1) of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit – SVX Series.
2. Square D – S-FLEX 212 AC Drives.
3. Danfoss
4. Yaskawa – HV600 Series.
5. ABB drives are not acceptable to UMB.

B. Exception to Acceptable VFD Manufacturers: Variable frequency drives for equipment such as AHU's, chillers, cooling towers and domestic water booster pumps shall be products provided by the equipment manufacturer, be factory mounted and comply with the requirements of this section including but not limited to remote metering and BAS interface. Except for ABB products, it is UMB's desire that VFD's provided by equipment manufacturers be by one (1) of the acceptable manufacturers listed above.

C. General Requirements for VFDs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and [UL 508C] <Insert standard>.

D. Application: Constant torque] [and] [variable torque] <Insert application>.

E. VFD Description: Variable-frequency power converter (PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency. The VFD shall convert the fixed voltage and frequency available from the utility or campus wide system to a variable voltage and frequency output via a two (2) step operation. VFD's utilizing a third power section will not be acceptable. Efficiency shall exceed 95% at 100% speed and load. Line side displacement power factor shall exceed 0.95 regardless of speed and load. The VFD shall be rated for 110% current for 1 minute for variable torque loads and 150% current for one (1) minute for constant torque loads.

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

F. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

G. Output Rating: Three-phase; 10 to [60 Hz, with voltage proportional to frequency throughout voltage range] [66 Hz, with torque constant as speed changes]; maximum voltage equals input voltage. <Engineer to Edit for Project Requirements>

H. Unit Operating Requirements:

1. Input AC Voltage Tolerance: Plus 10% and minus 15% of VFD input voltage rating.
2. Input AC Voltage Unbalance: Not exceeding 5%.
3. Input Frequency Tolerance: Plus or minus 3% of VFD frequency rating.
4. Minimum Efficiency: 96% at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 96% under any load or speed condition.
6. Minimum Short-Circuit Current (Withstand) Rating: [65] [100] kA.
7. Ambient Temperature Rating: Not less than 14^0F and not exceeding 120^0F.

8. Ambient Storage Temperature Rating: Not less than minus 4^0F and not exceeding 140^0F.
9. Humidity Rating: Less than 95% (noncondensing).
10. Altitude Rating: Not exceeding 3300 feet.
11. Vibration Withstand: Comply with IEC 60068-2-6.
12. Overload Capability: 1.5 times the base load current for sixty (60) seconds; minimum of 1.8 times the base load current for three seconds.
13. Starting Torque: Minimum 100% of rated torque from 3 to 60 Hz.
14. Speed Regulation: Plus or minus 5%.
15. Output Carrier Frequency: Selectable; 0.5 to [15] <insert number> kHz.
16. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.
17. VFD's above 200hp: 12-Pulse, THVD < 5%, THCD<8% & harmonic table requirements for I_{sc}/I_L =20-50, THD=8.0.
18. VFD's 200hp and Less: 6-Pulse, THVD<5%, THCD<8% & harmonic table requirements for I_{sc}/I_L <20, THD=5.0%.

I. Inverter Logic: Microprocessor based, thirty two (32) bit, isolated from all power circuits.

J. Isolated Control Interface: Allows VFDs to follow remote-control signal over a minimum 40:1 speed range.

1. Signal: Electrical.
2. Signal: Pneumatic.

K. Internal Adjustability Capabilities:

1. Minimum Speed: 5% to 25% of maximum rpm.
2. Maximum Speed: 80% to 100%of maximum rpm.
3. Current Limit: 30% to minimum of 150% of maximum rating.
4. Minimum frequency (4-60 Hz)
5. Maximum frequency (40-120 Hz)
6. Four (4) preset speeds (4-120 Hz) initiated by contact closures
7. Four (4) acceleration times (2-300 seconds)
8. Four (4) de-acceleration times (2-300 seconds)
9. Minimum speed dwell time (0-18 seconds)
10. Voltage boost (0-40V) for starting torque control
11. Adjustable Carrier Frequency (700-10,000 Hz) for motor noise reduction or flexible switching technology. This adjustment shall be without derating the drive or motor.
12. Current Limit (70% - 120%)Critical Frequency Avoidance (2 bands with 10 Hz adjustable widths

L. Self-Protection and Reliability Features:

1. Input transient protection by means of surge suppressors to provide three (3) phase protection against damage from supply voltage surges 10% or more above nominal line voltage.
2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
3. Under- and overvoltage trips.
4. Inverter overcurrent trips.
5. VFD and Motor Overload/Over temperature Protection: Microprocessor-based thermal protection system for monitoring VFDs and motor thermal characteristics, and for providing VFD over temperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
6. Critical frequency rejection, with [three (3)] <Insert number> selectable, adjustable deadbands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
8. Loss-of-phase protection.
9. Reverse-phase protection.
10. Short-circuit protection.
11. Motor overtemperature fault.
12. <Insert protection or reliability feature>.

M. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.

N. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.

O. Bidirectional Auto speed Search: Capable of starting VFD into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.

P. Torque Boost: Automatically varies starting and continuous torque to at least one and one half (1.5) times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

Q. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

R. Integral Input Disconnecting Means and OCPD: [NEMA AB 1, instantaneous-trip circuit breaker] [NEMA AB 1, thermal-magnetic circuit breaker] with pad-lockable, door-mounted handle mechanism. <Engineer to Edit for Project Requirements>

1. Disconnect Rating: Not less than 115% of VFD input current rating.

2. Disconnect Rating: Not less than 115% of NFPA 70 motor full-load current rating or VFD input current rating, whichever is larger.
3. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.
4. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
5. [NC] [NO] alarm contact that operates only when circuit breaker has tripped. <Engineer to Edit for Project Requirements>

2.2 CONTROLS AND INDICATION

A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.
7. Run/Stop selection and LED indication (keypad or remote)
8. Speed control selection and LED indication
9. Forward/Reverse selection
10. Manual speed adjustment
11. Frequency meter
12. Motor RPM
13. Ammeter
14. Output Voltage
15. Elapse Time Meter

B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.

    a. Control Authority: Supports at least four conditions: Off, local manual control at VFD, local automatic control at VFD, and automatic control through a remote source.

C. Historical Logging Information and Displays:

1. Real-time clock with current time and date.
2. Running log of total power versus time.

3. Total run time.
4. Fault log, maintaining last [four (4)] <Insert number> faults with time and date stamp for each.
5. <Insert information or display>.

D. Indicating Devices: Digital display [and additional readout devices as required,] mounted flush in VFD door and connected to display VFD parameters including, but not limited to: <Engineer to Edit for Project Requirements>

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).
11. <Insert parameter>.

E. Control Signal Interfaces:

1. Electric Input Signal Interface:

   a. A minimum of [two (2)] <Insert number> programmable analog inputs: [0- to 10-V dc] [4- to 20-mA dc].
   b. A minimum of [six (6)] <Insert number> multifunction programmable digital inputs.

2. Pneumatic Input Signal Interface: 3 psig to 15 psig.

3. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:

   a. RS485
   b. Keypad display for local hand operation.
   c. 0- to 10-V dc.
   d. 4- to 20-mA dc.
   e. Potentiometer using up/down digital inputs.
   f. Fixed frequencies using digital inputs.
   g. <Insert signal input>.

4. Output Signal Interface: A minimum of two (2) programmable analog output signal(s) ([0- to 10-V dc] [4- to 20-mA dc], which can be configured for any of the following: <Engineer to Edit for Project Requirements>

a. Output frequency (Hz).
b. Output current (load).
c. DC-link voltage (V dc).
d. Motor torque (percent).
e. Motor speed (rpm).
f. Set point frequency (Hz).
g. <Insert indication>.

5. Remote Indication Interface: A minimum of [two (2)] <Insert number> programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

a. Motor running.
b. Set point speed reached.
c. Fault and warning indication (overtemperature or overcurrent).
d. PID high- or low-speed limits reached.
e. <Insert indication>.

6. Remote Metering: Provide "kW" and "kWh" values via the embedded BAS Network Communications.

F. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFD status, alarm and energy usage. Allows VFD to be used with an external system within a multidrop LAN configuration; settings retained within VFD's nonvolatile memory.

1. Embedded BAS Protocols for Network Communications: Manufacturer shall provide one (1) of the following protocols:

a. BACNET MS/TP
b. BACNET IP
c. Siemens P1
d. MODBUS TCP
e. NOTE: MODBUS RTU is not an option

<Engineer to Coordinate with UMB and Edit for Project Requirements>

2.3 LINE CONDITIONING AND FILTERING

A. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD and THD (V) at the defined PCC per IEEE 519.

B. Input Line Conditioning: <Insert requirements>.

C. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for [Category C2] <Insert category>.

D. EMI/RFI Filtering: <Insert requirements>.

2.4 BYPASS SYSTEMS

A. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

B. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.

C. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller [; with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode]. <Engineer to Edit for Project Requirements>

1. Bypass Contactor: Load-break, [IEC] [NEMA]-rated contactor. <Engineer to Edit for Project Requirements>
   Output Isolating Contactor: Non-load-break,[IEC] [NEMA]-rated contactor. <Engineer to Edit for Project Requirements>
2. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

D. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller [; with input isolating switch and barrier] arranged to isolate the power converter input and output and permit safe testing [and troubleshooting] of the power converter, both energized and de-energized, while motor is operating in bypass mode. <Engineer to Edit for Project Requirements>

1. Bypass Contactor: Load-break, [IEC] [NEMA]-rated contactor. <Engineer to Edit for Project Requirements>
2. Input and Output Isolating Contactors: Non-load-break, [IEC] [NEMA]-rated contactors. <Engineer to Edit for Project Requirements>
3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

E. Bypass Contactor Configuration: Full-voltage (across-the-line).
1. HAND/OFF/AUTO selector switch.
2. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFD while the motor is running in the bypass mode.
3. Contactor Coils: Pressure-encapsulated type [with coil transient suppressors]. <Engineer to Edit for Project Requirements>

a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.

c. Control Circuits: [24] [120] V ac; obtained from integral CPT, with primary and secondary fuses of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices. The CPT shall be a constant-voltage control power transformer. CPT Spare Capacity: 100> VA.<Engineer to Edit for Project Requirements>

4. Overload Relays: NEMA ICS 2.

a. Melting-Alloy Overload Relays:

1) Inverse-time-current characteristic.
2) [Class 10] [Class 20] [Class 30] tripping characteristic. <Engineer to Edit for Project Requirements>
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

b. Bimetallic Overload Relays:

1) Inverse-time-current characteristic.
2) [Class 10] [Class 20] [Class 30] tripping characteristic. <Engineer to Edit for Project Requirements>
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
4) Ambient compensated.
5) Automatic resetting.

c. Solid-State Overload Relays:

1) Switch or dial selectable for motor-running overload protection.
2) Sensors in each phase.

3) [Class 10] [Class 20] [Class 10/20 selectable] tripping characteristic selected to protect motor against voltage and current unbalance and single phasing. <Engineer to Edit for Project Requirements>
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.

d. [NC] [NO] isolated overload alarm contact. <Engineer to Edit for Project Requirements>

e. External overload reset push button.

2.5 OPTIONAL FEATURES

A. <Coordinate with UM and include optional features>

2.6 ENCLOSURES

A. VFD Enclosures: NEMA 250, to comply with environmental conditions at installed location.

1. Dry and Clean Indoor Locations: Type 1.
2. Outdoor Locations: Type 4X non-metallic.
3. Other Wet or Damp Indoor Locations: Type 4X non-metallic.
4. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.
5. Mechanical and Electrical Rooms: NEMA Type 12.

B. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFD as "Plenum Rated."

2.7 ACCESSORIES Match to Enclosed Controllers

A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFD enclosure cover unless otherwise indicated.

1. Push Buttons, Pilot Lights, and Selector Switches: Heavy-duty type.

a. Push Buttons: [Covered] [Lockable] [Recessed] [Shielded] [Shrouded] [Unguarded] types; momentary. <Engineer to Edit for Project Requirements>
b. Pilot Lights LED types; Green for de-energized state, red for energized state, amber for warning and white for alarm ; push to test.

c. Selector Switches: Rotary type.
d. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

B. [NC] [NO] [Reversible NC/NO] bypass contactor auxiliary contact(s). <Engineer to Edit for Project Requirements>

C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.

D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.

E. Supplemental Digital Meters:

1. Elapsed-time meter.
Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, [Type 4X] [Type 12] enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings. <Engineer to Edit for Project Requirements>

F. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, [Type 4X] [Type 12] enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings. <Engineer to Edit for Project Requirements>

G. Cooling Fan and Exhaust System: For NEMA 250, Type 1; UL 508 component recognized: Supply fan, with composite intake and exhaust grills and filters; 120 -V ac; obtained from integral CPT.

H. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.

I. Spare control-wiring terminal blocks [; unwired] [; wired]. <Engineer to Edit for Project Requirements>

J. Control Power Ride-Through Capability: Provide constant voltage control power transformer or other means to ensure drive can withstand a minimum voltage dip/sag for up to 0.5 seconds. This includes all contactors, relays, etc.

K. Wiring Access Option: Coordinate with installer and select the correct wiring access panel option (i.e., top or bottom) for each VFD enclosure.

L. A Customer Interlock Terminal Strip: Provide a separate terminal strip for connection of fire, smoke, freeze contacts and external start command. All external interlocks and strat/stop contacts shall function with drive in hand, auto or bypass.

M. Output Line Reactors or Filters: Provide when the drive is separated from the motor by more than fifty (50) feet.

N. Door Interlock Circuit Breaker rated at 65,000 AIC with 5% total line impedance.

O. Thermal motor overcurrent relay.

2.8 SOURCE QUALITY CONTROL

A. Testing: Test and inspect VFDs according to requirements in [NEMA ICS 61800-2] <Insert standard>.

1. Test each VFD while connected to [its specified motor] [a motor that is comparable to that for which the VFD is rated]. <Engineer to Edit for Project Requirements>

2. Verification of Performance: Rate VFDs according to operation of functions and features specified.

B. VFDs will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFDs, with Installer present, for compliance with requirements for installation tolerances, <insert Project-specific conditions,> and other conditions affecting performance.

B. Examine VFD before installation. Reject VFDs that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFD installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 HARMONIC ANALYSIS STUDY

A. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible operating scenarios, including recommendations for VFD input filtering to limit TDD and THD (V) at each VFD at the defined PCC to specified levels.

B. Prepare a harmonic analysis study and report complying with IEEE 399 and NETA Acceptance Testing Specification.

3.3 INSTALLATION

A. Coordinate layout and installation of VFDs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Wall-Mounting Controllers: Install VFDs on walls with tops at uniform height and with disconnect operating handles not higher than seventy nine (79) inches above finished floor unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with Division 26 Section "Hangers and Supports for Electrical Systems."

C. Floor-Mounting Controllers: Install VFDs on four (4) inch nominal thickness concrete base. Comply with requirements for concrete base specified in Division 03 Section "[Cast-in-Place Concrete] [Miscellaneous Cast-in-Place Concrete]. <Engineer to Edit for Project Requirements>

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on eighteen (18) inch centers around the full perimeter of concrete base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

D. Roof-Mounting Controllers: Install VFD on roofs with tops at uniform height and with disconnect operating handles not higher than seventy nine (79) inches above finished roof surface unless otherwise indicated, and by bolting units to curbs or mounting on freestanding, lightweight, structural-steel channels bolted to curbs. Seal roof penetrations after raceways are installed.

1. Curbs and roof penetrations are specified in Division 07 Section "Roof Accessories."
2. Structural-steel channels are specified in Division 26 Section "Hangers and Supports for Electrical Systems."

E. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

F. Install fuses in each fusible-switch VFD.

G. Install fuses in control circuits if not factory installed. Comply with requirements in Division 26 Section "Fuses."

H. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.

I. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

J. Comply with NECA 1.

3.4 IDENTIFICATION

A. Identify VFDs, components, and control wiring. Comply with requirements for identification specified in Division 26 Section "Identification for Electrical Systems."

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFD with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFDs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFD units.

3.5 CONTROL WIRING INSTALLATION

A. Install wiring between VFDs and remote devices and the building automation system. Comply with requirements in Division 26 Section "Control-Voltage Electrical Power Cables."

B. Bundle, train, and support wiring in enclosures.

C. Connect selector switches and other automatic control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic control devices that have no safety functions when switches are in manual-control position.
2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.6 FACTORY TESTS AND CHECKS

A. VFD power semiconductors and diodes shall be 100% inspected and tested, including load testing.

B. Small signal semiconductors, resistors, capacitors and diodes shall be lot sampled. Testing shall include parameter, as well as, functional characteristics.

C. All printed circuit-boards shall be tested under a temperature cycling (0^0C to $+65^0$C) 24-hour load test and then functionally tested via fault finder bench equipment prior to unit installation.

D. All final assemblies shall be tested at full load with application of line-to-line and line-to-ground bolted faults. The VFD shall trip electronically without device failure.

E. After all tests have been performed, each VFD shall undergo a twenty four (24) hour burn-in test. The drive shall be burned-in at 100% inductive or motor load for twenty four (24) hours without an unscheduled shutdown.

F. After the burn-in cycle is complete, each VFD shall be provided by the manufacturer upon request prior to shipment.

3.7 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to direct testing.

2. Testing, checkout and startup of the VFD equipment shall be performed under the technical direction of the manufacturer’s service engineer. Under no circumstances are any portions of the drive system to be energized without authorization from the manufacturer’s representative.

3. The contractor shall provide independent harmonic testing by an independent testing company. Readings with printouts of the harmonic current at each harmonic, as well as, the total voltage distortion. The following readings shall be provided:

   a. At each point of common coupling:

      1) With all drives running with load
      2) With all drives off

   b. At the power connection to each drive:

      1) With the drive running loaded
      2) With drive off

   c. All the above data shall be submitted to the Owner for review. If these tests show the drives are not in compliance with the specifications, the drive manufacturer shall make all changes required to comply with the specifications at no cost to the Owner. If required, this could mean replacing the drives that are not in compliance.

   d. A copy of all the tests and checks performed in the field, complete with meter readings and recordings, where applicable, shall be submitted to the Owner.

C. Acceptance Testing Preparation:

1. Test insulation resistance for each VFD element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

D. Tests and Inspections:

1. Inspect VFD, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each VFD element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at VFD locations are within 10% of motor nameplate rated voltages. If outside this range for any motor, notify Owner before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:

    a. Initial Infrared Scanning: After Substantial Completion, but not more than sixty (60) days after Final Acceptance, perform an infrared scan of each VFD. Remove front panels so joints and connections are accessible to portable scanner.
    b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFD eleven (11) months after date of Substantial Completion.
    c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

E. VFD's will be considered defective if they do not pass tests and inspections.

F. Prepare test and inspection reports, including a certified report that identifies the VFD and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.8 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. <Insert startup steps if any>.

3.9 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between

starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes or eleven (11) times for NEMA Premium Efficient motors if required. Where these maximum settings do not allow starting of a motor, notify Owner before increasing settings.

D. Set the taps on reduced-voltage autotransformer controllers.

E. Set field-adjustable circuit-breaker trip ranges as specified in Division 26 Section "Overcurrent Protective Device Coordination Study."

F. Set field-adjustable pressure switches.

3.10 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFDs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

C. The VFD shall be protected against damage at all times. The drive shall be stored in a clean, dry environment with temperatures and humidity within the range specified by the drive manufacturer. Space heaters shall be energized controlled storage as recommended by the manufacturer. Storage space shall be environmentally controlled.

3.11 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, reprogram, and maintain VFDs.

END OF SECTION 262923