

SECTION 26 29 23

VARIABLE-FREQUENCY MOTOR CONTROLLERS

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.

1.2 SUMMARY

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

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. CE: Conformance Europeene (European Compliance).
- C. CPT: Control power transformer.
- D. EMI: Electromagnetic interference.
- E. IGBT: Insulated-gate bipolar transistor.
- F. LAN: Local area network.
- G. LED: Light-emitting diode.
- H. MCP: Motor-circuit protector.
- I. NC: Normally closed.
- J. NO: Normally open.
- K. OCPD: Overcurrent protective device.
- L. PCC: Point of common coupling.
- M. PID: Control action, proportional plus integral plus derivative.
- N. PWM: Pulse-width modulated.
- O. RFI: Radio-frequency interference.
- P. TDD: Total demand (harmonic current) distortion.
- Q. THD(V): Total harmonic voltage demand.
- R. VFC: Variable-frequency motor controller.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: VFCs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
- B. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified for seismic Zone 4

1.5 ACTION SUBMITTALS

- A. Product Data: For each type and rating of VFC indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.
- B. LEED Submittals:
 - 1. Product Data for Credit EA 5: For continuous metering equipment for energy consumption.
 - 2. Shop Drawings: For each VFC 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.
 - 3. 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 VFC and installed devices.
 - g. Specified Modification
- C. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.
- D. 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 designated operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) to specified levels.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFCs. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.
- B. Qualification Data: For qualified testing agency.

- C. Seismic Qualification Certificates: For VFCs, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based, and their installation requirements.
- D. Product Certificates: For each VFC, from manufacturer.
- E. Source quality-control reports.
- F. Field quality-control reports.
- G. 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.
- H. 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.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section 01 33 23 – Shop Drawings, Product Data and Samples, 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.

1.8 MATERIALS MAINTENANCE SUBMITTALS

- 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 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
 - 2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
 - 3. Indicating Lights: Two of each type and color installed.

4. Auxiliary Contacts: Furnish one spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

1.9 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.
- D. IEEE Compliance: Fabricate and test VFC according to IEEE 344 to withstand seismic forces defined in Division 13 Section 13 05 41 – Seismic Requirements for Non-Structural Components.

1.10 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

1.11 PROJECT CONDITIONS

- A. Environmental 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 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
 2. Ambient Storage Temperature: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
 3. Humidity: Less than 95 percent (noncondensing).
 4. Altitude: Not exceeding 3300 feet (1005 m).
- 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 Contracting Officer Technical Representative (COTR) no fewer than two 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 Contracting Officer Technical Support Representative (COTR) written permission.
 4. Comply with NFPA 70E.

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

1.12 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.

1.13 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
- B. Basis-of-Design Product: Subject to compliance with requirements, provide or comparable product by one of the following:
 - 1. ABB.
 - 2. Baldor Electric Company.
 - 3. Danfoss Inc.; Danfoss Drives Div.
 - 4. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - 5. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - 6. Rockwell Automation, Inc.; Allen-Bradley Brand.
 - 7. Siemens Energy & Automation, Inc.
 - 8. Square D; a brand of Schneider Electric.
 - 9. Toshiba International Corporation.
 - 10. Yaskawa Electric America, Inc; Drives Division.

- C. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C.
- D. Application: Variable torque.
- E. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT, 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.
 - 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; maximum voltage equals input voltage.
- H. Unit Operating Requirements:
 - 1. Input AC Voltage Tolerance: Plus 10 and minus 10 percent of VFC input voltage rating.
 - 2. Input AC Voltage Unbalance: Not exceeding 3 percent.
 - 3. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.
 - 4. Minimum Efficiency: 97 percent at 60 Hz, full load.
 - 5. Minimum Displacement Primary-Side Power Factor: 98 percent under any load or speed condition.
 - 6. Minimum Short-Circuit Current (Withstand) Rating: 65 kA.
 - 7. Ambient Temperature Rating: Not less than 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
 - 8. Ambient Storage Temperature Rating: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
 - 9. Humidity Rating: Less than 95 percent (noncondensing).
 - 10. Altitude Rating: Not exceeding 3300 feet (1005 m).

11. Vibration Withstand: Comply with IEC 60068-2-6.
 12. Overload Capability: 1.1 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
 13. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
 14. Speed Regulation: Plus or minus 5 percent.
 15. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.
 16. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.
- I. Inverter Logic: Microprocessor based, 32 bit, isolated from all power circuits.
- J. Isolated Control Interface: Allows VFCs 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 percent of maximum rpm.
 2. Maximum Speed: 80 to 100 percent of maximum rpm.
 3. Acceleration: 0.1 to 999.9 seconds.
 4. Deceleration: 0.1 to 999.9 seconds.
 5. Current Limit: 30 to minimum of 150 percent of maximum rating.
- L. Self-Protection and Reliability Features:
1. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent 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. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
 6. Critical frequency rejection, with three 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.
- 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 Autospeed Search: Capable of starting VFC 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 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 with pad-lockable, door-mounted handle mechanism.
1. Disconnect Rating: Not less than 115 percent of VFC input current rating.
 2. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC 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.

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.

- 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 VFC, local automatic control at VFC, 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 faults with time and date stamp for each.
- D. Indicating Devices: Digital display and additional readout devices as required, mounted flush in VFC door and connected to display VFC parameters including, but not limited to:
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).
- E. Control Signal Interfaces:
1. Electric Input Signal Interface:
 - a. A minimum of two programmable analog inputs: 0- to 10-V dc.
 - b. A minimum of six multifunction programmable digital inputs.
 2. Pneumatic Input Signal Interface: 3 to 15 psig (20 to 104 kPa).

3. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:
 - a. to 10-V dc.
 - b. 4- to 20-mA dc.
 - c. Potentiometer using up/down digital inputs.
 - d. Fixed frequencies using digital inputs.
4. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc operator-selectable "x"- to "y"-mA dc which can be configured for any of the following:
 - 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).
5. Remote Indication Interface: A minimum of two 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.
- F. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.
 1. Number of Loops: One.
- G. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms and energy usage. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.
 1. Network Communications Ports: Ethernet and RS-422/485.
 2. Embedded BAS Protocols for Network Communications: Johnson Metasys N2; protocols accessible via the communications ports.

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 at input terminals of all VFCs to less than 5 percent and THD(V) to 3 percent.

- B. 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.
- C. Input Line Conditioning
- D. Output Filtering.
- E. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.
- F. EMI/RFI Filtering.

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: Manual operation only; requires local operator selection at VFC. Transfer between power converter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.
- C. 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.
- D. 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.
 - 1. Bypass Contactor: Load-break, NEMA-rated contactor.
 - 2. Output Isolating Contactor: Non-load-break, NEMA-rated contactor.
 - 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 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.
 - 1. Bypass Contactor: Load-break, NEMA-rated contactor.
 - 2. Input and Output Isolating Contactors: Non-load-break, NEMA-rated contactors.
 - 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.
- F. Bypass Contactor Configuration: Full-voltage (across-the-line) Reduced-voltage (autotransformer).

1. NORMAL/BYPASS selector switch.
2. HAND/OFF/AUTO selector switch.
3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.
4. Contactor Coils: Pressure-encapsulated type with coil transient suppressors.
 - 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.
5. Control Circuits: 120-V ac; obtained from integral CPT, with primary and secondary fuses, with CPT control power source of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.
 - a. CPT Spare Capacity: 50 VA.
6. Overload Relays: NEMA ICS 2.
 - a. Melting-Alloy Overload Relays:
 - 1) Inverse-time-current characteristic.
 - 2) Class 10 tripping characteristic.
 - 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 tripping characteristic.
 - 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 tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

- 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.
- e. External overload reset push button.

2.5 OPTIONAL FEATURES

- A. Multiple-Motor Capability: VFC suitable for variable-speed service to multiple motors. Overload protection shuts down VFC and motors served by it, and generates fault indications, when overload protection activates.
 - 1. Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.
 - 2. Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.
 - 3. Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.
- B. Damper control circuit with end of travel feedback capability.
- C. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
- D. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
- E. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from the firefighter's control station smoke-control fan controller, this password-protected input:
 - 1. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).
 - 2. Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
 - 3. Forces VFC to transfer to Bypass Mode and operate motor at full speed.
 - 4. Causes display of Override Mode on the VFC display.
 - 5. Reset VFC to normal operation on removal of override signal automatically.
- F. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
- G. Remote digital operator kit.
- H. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

2.6 ENCLOSURES

- A. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.
 - 1. Dry and Clean Indoor Locations: Type 1.
 - 2. Outdoor Locations: Type 4X.
 - 3. Kitchen Wash-Down Areas: Type 4X.
 - 4. Other Wet or Damp Indoor Locations: Type 4.
 - 5. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.
- B. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFC as "Plenum Rated."

2.7 ACCESSORIES

- A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFC enclosure cover unless otherwise indicated.
 - 1. Push Buttons, Pilot Lights, and Selector Switches: Heavy-duty type.
 - 2. Push Buttons: Covered Shielded types.
 - 3. Pilot Lights: LED types; push to test.
 - 4. Selector Switches: Rotary type.
 - 5. 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 bypass contactor auxiliary contact(s).
- 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.
 - 2. Kilowatt meter.
 - 3. Kilowatt-hour meter.
- F. 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.

- G. 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.
- H. Cooling Fan and Exhaust System: For NEMA 250, Type 12; UL 508 component recognized: Supply fan, with stainless steel intake and exhaust grills and filters; 120 - V ac; obtained from integral CPT.
- I. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
- J. Spare control-wiring terminal blocks wired.

2.8 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2.
 - 1. Test each VFC while connected to its specified motor.
 - 2. Verification of Performance: Rate VFCs according to operation of functions and features specified.
- B. VFCs 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 VFCs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance.
- B. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC 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 designated operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC 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 VFCs 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 VFCs on walls with tops at uniform height and with disconnect operating handles not higher than 79 inches (2000 mm) 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 13 Section 13 05 41 – Seismic Requirements for Non-Structural Components.
- C. Floor-Mounting Controllers: Install VFCs on 4-inch (100-mm) nominal thickness concrete base. Comply with requirements for concrete base specified in Division 03 Section 03 30 00 - Cast-in-Place Concrete.
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) 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 VFC on roofs with tops at uniform height and with disconnect operating handles not higher than 79 inches (2000 mm) 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. Structural-steel channels are specified in Division 13 Section 13 05 41 – Seismic Requirements for Non-Structural Components.
- E. Seismic Bracing: Comply with requirements specified in Division 13 Section 13 05 41 – Seismic Requirements for Non-Structural Components.
- F. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
- G. Install fuses in control circuits if not factory installed.
- 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 VFCs, components, and control wiring. Comply with requirements for identification specified in Division 26 Section 26 05 53 – Identification for Electrical Systems.
 - 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.

2. Label each VFC with engraved nameplate.
 3. Label each enclosure-mounted control and pilot device.
- B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.5 CONTROL WIRING INSTALLATION

- A. Install wiring between VFCs and remote devices and facility's central-control system. Comply with requirements in Division 27 Section – Communication Horizontal Cabling.
- 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 FIELD QUALITY CONTROL

- A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- C. 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 assist in testing.
- D. Acceptance Testing Preparation:
1. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
 2. Test continuity of each circuit.
- E. Tests and Inspections:
1. Inspect VFC, wiring, components, connections, and equipment installation Test and adjust controllers, components, and equipment.
 2. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.
 3. Test continuity of each circuit.

4. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Contracting Officer Technical Representative (COTR) 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:
 9. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFC. Remove front panels so joints and connections are accessible to portable scanner.
 10. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFC 11 months after date of Substantial Completion.
 11. 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.
 12. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.
- F. VFCs will be considered defective if they do not pass tests and inspections.
- G. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.7 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.

3.8 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 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify Contracting Officer Technical Representative (COTR) 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 26 05 11 – REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- F. Set field-adjustable pressure switches.

3.9 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 VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.10 DEMONSTRATION

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

--- END OF SECTION 26 29 23 ---