

SECTION 230550 – VARIABLE FREQUENCY DRIVES

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, preassembled, combination VFDs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.
- B. Related Requirements:
 - 1. Section 230513 “Common Motor Requirements for HVAC Equipment.”

1.3 DEFINITIONS

- A. BAS: Building Automation System.
- B. CE: Conformance Europeene (European Compliance).
- C. CPT: Control power transformer.
- D. EMI: Electromagnetic interference.
- E. LCD: Liquid-crystal display.
- F. LED: Light-emitting diode.
- G. OCPD: Overcurrent protective device.
- H. PID: Control action, proportional plus integral plus derivative.
- I. RFI: Radio-frequency interference.
- J. VFD: Variable-frequency drive.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and rating of VFD indicated.
 - 1. Include dimensions and finishes for VFDs.

2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Shop Drawings: For each VFD indicated.

1. Include mounting and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Variable frequency drives shall be included in the development of the Coordination and Installation Drawings, drawn to scale, showing dimensioned layout on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Required working clearances and required area above and around VFDs.
2. Show VFD layout and relationships between electrical components and adjacent structural and mechanical elements.
3. Show support locations, type of support, and weight on each support.
4. Indicate field measurements.

B. Product Certificates: For each VFD from manufacturer.

C. Harmonic Analysis Report: Provide Project-specific calculations and manufacturer's statement of compliance with IEEE 519.

D. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For VFDs to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and motor-circuit protector trip settings.
 - b. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
 - c. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
 - d. 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 DELIVERY, STORAGE, AND HANDLING

- A. VFDs should be delivered, stored and handled in a manner that protects them from damage, moisture, dirt and intrusion of foreign materials.
- B. Store VFDs indoors in clean, dry space with uniform temperature to prevent condensation. Maximum ambient temperature for storage shall be -40 to 120 degrees Fahrenheit.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace VFDs that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Three years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. ABB, Inc.
 - 2. Danfoss Inc.
 - 3. Yaskawa Electric America, Inc.

2.2 SYSTEM DESCRIPTION

- A. General Requirements for VFDs:
 - 1. VFDs and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - 2. Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508A.
- B. Application: Variable torque.
- C. VFD Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested 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 inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
 - 2. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.
- D. 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.

- E. Output Rating: Three phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range; maximum voltage equals input voltage (not applicable to fan arrays).
 - 1. For fan arrays, output rating shall match fan array motor selection.

- F. Unit Operating Requirements:
 - 1. Input AC Voltage Tolerance: Plus 10 and minus 10 percent of VFD input voltage rating.
 - 2. Input AC Voltage Unbalance: Not exceeding 5 percent.
 - 3. Input Frequency Tolerance: Plus or minus 3 percent of VFD frequency rating.
 - 4. Minimum Efficiency: 96 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: 100 kA.
 - 7. Ambient Temperature Rating: Not less than 32 deg F and not exceeding 104 deg F. Operating up to 122 degF shall be possible with 10 percent de-rating if required.
 - 8. Humidity Rating: Less than 95 percent (noncondensing).
 - 9. Altitude Rating: Not exceeding 3300 feet.
 - 10. Vibration Withstand: Comply with NEMA ICS 61800-2.
 - 11. Overload Capability: 1.1 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
 - 12. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
 - 13. Output Carrier Frequency: Selectable; 0.5 to 12 kHz.
 - 14. Stop Modes: Programmable; includes fast, free-wheel, and dc coast or ramp to stop.

- G. Isolated Control Interface: Allows VFDs to follow remote-control signal over a minimum 4:1 speed range.
 - 1. Signal: Electrical.

- H. 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 110 percent of maximum rating.

- I. Self-Protection and Reliability Features:
 - 1. Surge Suppression: Factory installed as an integral part of the VFD, complying with UL 1449 SPD, Type 1 or Type 2.
 - 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/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFDs and motor thermal characteristics, and for providing VFD overtemperature and motor-overload alarm and trip; settings selectable via the keypad.
 - 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 (drive and bypass mode).
 - 9. Short-circuit protection.

10. Motor-overtemperature fault.
- J. Automatic Reset/Restart: Attempt five 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.
- K. Bidirectional Autospeed 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.
- L. Integral Input Disconnecting Means and OCPD:
 1. VFDs Without a Bypass System:
 - a. NEMA KS 1, fusible switch with pad-lockable, door-mounted handle mechanism.
 - b. Disconnect Rating: Not less than 115 percent of VFD input current rating.

2.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: VFDs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7. The designated VFDs shall be tested and certified by an NRTL as meeting the ICC-ES AC 156 test procedure requirements.
 1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2.4 CONTROLS AND INDICATION

- A. 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.
- B. Historical Logging Information and Displays:
 1. Real-time clock with current time and date and battery backup.
 2. Running log of total power versus time.
 3. Total run time.
 4. Fault log, maintaining last three faults with time and date stamp for each.
- C. 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:
 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).
- D. Control Signal Interfaces:
1. Electric Input Signal Interface:
 - a. A minimum of two programmable analog inputs: 0- to 10-V dc or 4- to 20-mA dc.
 - b. A minimum of six multifunction programmable digital inputs.
 2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS system for HVAC or other control systems:
 - a. 0- to 10-V dc.
 - b. 4- to 20-mA dc.
 - c. Fixed frequencies using digital inputs.
 3. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc or 4- to 20-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).
 4. 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.
- E. 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: Two.
- F. Interface with BAS System for HVAC: Factory-installed hardware and software shall interface with BAS system for HVAC to monitor, control, display, and record data for use in processing reports. VFD settings shall be retained within VFD's nonvolatile memory.
1. Hardwired Points:
 - a. Monitoring: On-off status.
 - b. Control: On-off operation.
 2. Communication Interface: The standard protocols shall be Modbus, Johnson Controls N2, Siemens Building Technologies FLN, and BACnet. Communication shall interface with BAS system for remotely control and monitor from an operator workstation. Control

features and monitoring points displayed locally at control panel shall be available through the BAS system and mapped to graphical user interfaces.

2.5 LINE CONDITIONING AND FILTERING

- A. Input Line Conditioning: Based on the manufacturer's harmonic analysis study and report, provide input filtering to limit total demand (harmonic current) distortion and total harmonic voltage demand at the defined point of common coupling to meet IEEE 519 recommendations. Provide minimum 5 percent impedance AC line reactor or DC bus chokes of equivalent impedance.
- B. Output Filtering: For separation between motor and VFD of greater than 100 feet, provide dV/dT filters.
- C. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for the First Environment restricted level (Category C2).

2.6 OPTIONAL FEATURES

- A. Multiple-Motor Capability: VFD suitable for variable-speed service to multiple motors. Overload protection shuts down VFD 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.
- B. Damper control circuit with end-of-travel feedback capability.
- C. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from the firefighter's control station or 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. VFDs Without a Bypass System: Forces VFD to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
 - a. Final speed setting to be determined during commissioning, testing, and balancing of the ventilation system.
 - 3. Causes display of override mode on the VFD display.
 - 4. Reset VFD to normal operation on removal of override signal automatically.
- D. Communication Port: RJ-45 port.

2.7 ENCLOSURES

- A. VFD Enclosures: NEMA 250, to comply with environmental conditions at installed location.
 - 1. Dry and Clean Indoor Locations: Type 1.
 - 2. Mechanical Rooms and Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12:

3. Outdoor Locations: Type 4X.
4. Wash-Down Areas: Type 4X, stainless steel.
5. Other Wet or Damp Indoor Locations: Type 4.

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

2.8 ACCESSORIES

- A. Phase-Failure: Solid-state sensing circuit with isolated output contacts for hard-wired connections.
- B. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
- C. Programming Tools: To support the drive's life cycle from startup and monitoring, to backup, and performance tuning.

2.9 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect VFDs according to manufacturers' standard procedures and in accordance with ISO 9001, latest revision.
1. Test each VFD while connected to a full motor load that is comparable to that for which the VFD is rated, at rated drive amperes at 105 degrees Fahrenheit in a temperature chamber.
 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. Test and inspection reports shall be available upon request.

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, and other conditions affecting performance of the Work.
- 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. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Wall-Mounting Controllers: Install with tops at uniform height and with disconnect operating handles not higher than 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.
- B. Roof-Mounting Controllers: Install VFD on roofs with tops at uniform height and with disconnect operating handles not higher than 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.
- C. Seismic Bracing: Comply with requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."
- D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
- E. Comply with NECA 1.
- F. Controllers shall be located so that door can be fully opened without interference.

3.3 IDENTIFICATION

- A. Identify VFDs, components, and control wiring. Comply with requirements for identification specified in Section 230553 "Identification for HVAC Piping and Equipment."
 - 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.

3.4 FIELD QUALITY CONTROL

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

- C. 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 percent of motor nameplate rated voltages. If outside this range for any motor, notify Architect before starting the motor(s).
 - 5. Test each motor for proper phase rotation.
 - 6. Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives 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. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. VFDs will be considered defective if they do not pass tests and inspections.
- E. 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.

3.5 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.

3.6 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 instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to 6 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 8 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 Architect before increasing settings.
- D. Set field-adjustable circuit-breaker trip ranges.

- E. Set field-adjustable pressure switches.
- F. All field adjustments shall be recorded and kept in cabinet with drawings.

3.7 STORAGE AND PROTECTION

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

3.8 DEMONSTRATION

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

END OF SECTION 230550