VARIABLE FREQUENCY DRIVES

1.1 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: +/-10% 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: 98% under any load or speed condition.
   6. Minimum Short-Circuit Current (Withstand) Rating: 100 kA.
   7. Ambient Temperature Rating: Not less than 32 °F and not exceeding 104 deg F. Operating up to 122 °F shall be possible with 10 percent de-rating if required.
   8. Humidity Rating: Less than 95%(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% 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% of maximum rpm.
   2. Maximum Speed: 80 to 100% 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% 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 With a Bypass System:
a. UL 489, thermal-magnetic circuit breaker with pad-lockable, door-mounted handle mechanism.
b. Disconnect Rating: Not less than 115% of NFPA 70 motor full-load current rating or VFD input current rating, whichever is larger.
2. 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% of VFD input current rating.

1.2 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, 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.

1.3 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).

1.4 BYPASS SYSTEMS

Inclusion of bypass systems shall be up to the discretion of the designer, but the specific application shall be approved by University Facilities. When used, bypass systems must meet the requirements below.

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 full-voltage (across-the-line) type bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and 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, IEC-rated contactor.
   2. Output Isolating Contactor: Non-load-break, IEC-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.

1.5 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. VFDs With a Bypass System: Forces VFD to transfer to bypass mode and operate motor at full speed.
   4. Causes display of override mode on the VFD display.

5. Reset VFD to normal operation on removal of override signal automatically.

D. Communication Port: RJ-45 port.

1.6 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."

C. Input and output cabling compartment shall be at least one size larger than manufacturers standard to accommodate variable frequency rated shielded output motor wiring installed in conduit.

1.7 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.

1.8 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.

2.1 INSTALLATION

A. All connections from drives to motors shall be made with dedicated VFD cabling.

B. 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.

C. 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.

D. Seismic Bracing: Comply with requirements specified in Section 26 05 48.16 "Seismic Controls 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. Comply with NECA 1.

G. Controllers shall be located so that door can be fully opened without interference.

2.2 IDENTIFICATION

A. Identify VFDs, components, and control wiring. Comply with requirements for identification specified in Section 23 05 53 "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.
4. Attach a factory provided and permanently mounted weatherproof sun resistant label stating Manufacturer's name, model number, catalog number, part number, serial number, SCCR rating, input voltage/frequency and phase, output voltage/frequency and phase, kW/HP rating of VFD, type of enclosure and temperature rating and other information as required by manufacturer and applicable codes and listings. The label shall be conspicuously mounted on the exterior of the VFD completely visible after full installation and in operation without requiring any tools for observation of label.