Part 1 General

1.1 DESCRIPTION

.1 Refer to mechanical drawings and specifications: a number of fans require a Variable Frequency Drive (VFD) to modulate the air volume required for the operation of ventilation systems.

.2 This specification covers Variable Frequency Drive (VFD) systems designed for speed control of three-phase, 600V standard NEMA Design B induction motors or Inverter Duty rated motors, as per NEMA MG1, parts 30 and 31.

1.2 REFERENCES

.1 Underwriter's Laboratories of Canada (ULC).

.1 UL 508C-04, Standard for Power Conversion Equipment.

.2 International Organization for Standardization (ISO).

.1 ISO 9001:2008, Quality Management Systems – Requirements.

.3 National Electrical Code (NEC-2010).

.4 Institute of Electrical and Electronics Engineers, Inc. (IEEE).

.1 IEEE 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in electric Power Systems.

.5 International Electrotechnical Commision (IEC).

.1 EN/IEC 61800-3, Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods, 2004.

.6 National Electrical Manufacturers Association (NEMA).

.1 NEMA 250-2008, Enclosures for Electrical Equipment (1000 Volts Maximum).

.2 NEMA ICS7-2014, Adjustable Speed Drives.

1.3 SUBMITTALS

.1 Product Data:

.1 Submit manufacturer's printed product literature, specifications and datasheet in accordance with Section 01 00 10 – General Instructions. For each type of VFD include product characteristics, performance criteria, limitations, mounting arrangements, required clearances and service space around equipment, listings, enclosure types and conduit entry locations and sizes.

.2 Provide schematic power and control wiring diagrams and complete list of all standard and optional features.

.2 Quality assurance submittals: submit the following:

.1 Certificates: submit certificates signed by manufacturer certifying that materials comply with specified performance characteristics and physical properties.

.2 Instructions: submit manufacturer's installation instructions.

1.4 QUALITY ASSURANCE

.1 Health and Safety Requirements: do construction occupational health and safety in accordance with Section 01 35 29.06 - Health and Safety Requirements.

.2 VFDs and options shall be ULC listed as a complete assembly and shall comply with the latest requirements of the standards of ANSI, IEEE, NEMA and the National Electric Code.

.3 The complete VFD assembly, including all standard and optional features shall be functionally tested at the factory for proper operation.

Part 2 Products

2.1 GENERAL

.1 The VFD package as specified herein shall be enclosed in a UL Type enclosure (Type 1), completely assembled and tested by the manufacturer in an ISO9001 facility. With the exception of VFD output filters, all equipment and accessories described herein for the operation and adjustment of the VFD shall be installed within the VFD enclosure.

.2 When installed in a plenum or air-handling compartment: the VFD shall have been evaluated by UL and found acceptable for mounting in a plenum location. Manufacturer shall supply a copy of the UL plenum evaluation.

.3 Complete VFD assembly tested to UL 508C, with the appropriate UL/ULC label applied.

.4 The VFD shall be ULC listed for a short circuit current rating (SCCR) of 100 kA and labelled with this rating.

.5 VFD and all necessary controls specified herein to be supplied by a single manufacturer. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of ten (10) years.

.6 All VFDs supplied under this section must be from the same manufacturer.

2.2 FREQUENCY CONTROLLER

.1 The variable frequency drive (VFD) shall be a pulse width modulated (PWM) AC to AC converter utilizing the latest isolated gate bipolar transistor (IGBT) technology. The VFD power electronic system consists of:

.1 Input Section:

.1 VFD input power stage shall convert three-phase AC line power into a fixed DC voltage via a solid state full wave diode rectifier, with MOV (Metal Oxide Varistor) surge protection.

.2 A 5% DC bus impedance to minimize reflected current.

.2 Intermediate Section:

.1 DC bus as a supply to the VFD output Section shall maintain a fixed voltage with filtering and short circuit protection.

.2 DC bus shall be interfaced with the VFD diagnostic logic circuit, for continuous monitoring and protection of the power components.

.3 Output Section

.1 Insulated Gate Bipolar Transistors (IGBTs) shall convert DC bus voltage to variable frequency and voltage.

.2 The VFD shall employ PWM sine coded output technology to power the motor.

.2 Rating:

.1 Input rating: 600 Volts +/- 10%, 3-Phase, 57 to 63 Hz.

.2 Output rating: 0 to 600 Volts, 3-Phase, 3 to 60 Hz.

.3 Overload Capacity: 110% of rated current for 60 seconds and peak overload of 130% of rated current for 2 seconds.

.4 Minimum efficiency at full load: 95%.

.5 Displacement power factor (all speed): 0.96.

.3 Galvanic isolation shall be provided between the VFD's power circuitry and control circuitry to ensure operator safety and to protect connected electronic control equipment from damage caused by voltage spikes, current surges, and ground loop currents. VFDs not including either galvanic or optical isolation on both analog I/O and discrete digital I/O shall include additional isolation modules.

.4 VFD shall minimize the audible motor noise through the use of an adjustable carrier frequency. The carrier frequency shall be automatically adjusted to optimize motor and VFD operation while reducing motor noise. VFDs with fixed carrier frequency are not acceptable.

.5 Protective Features:

.1 Fused input for both VFD and bypass modes.

.2 UL508 (I^2t) electronic motor overload protection.

.3 Protection against input transients, loss of AC line phase, output short circuit, output ground fault, over voltage, under voltage, VFD over temperature and motor over temperature. The VFD shall display all faults in plain language. Alpha-numeric codes are not acceptable.

.4 Protect VFD from input phase loss. The VFD should be able to protect itself from damage and indicate the phase loss condition. During an input phase loss condition, the VFD shall be able to be programmed to either trip off while displaying an alarm, issue a warning while running at reduced output capacity, or issue a warning while running at full commanded speed. This function is independent of which input power phase is lost.

.5 VFD shall include a "signal loss detection" algorithm with adjustable time delay to sense the loss of an analog input signal. It shall also include a programmable time delay to eliminate nuisance signal loss indications. The functions after detection shall be programmable.

.6 VFD shall catch a rotating motor operating forward or reverse up to full speed without VFD fault or component damage.

.7 Selectable over-voltage control shall be provided to protect the drive from power regenerated by the motor while maintaining control of the driven load.

.8 VFD shall include current sensors on all three output phases to accurately measure motor current, protect the VFD from output short circuits, output ground faults, and act as a motor overload. If an output phase loss is detected, the VFD will trip off and identify which of the output phases is low or lost.

.9 The VFD shall have temperature controlled cooling fan(s) for quiet operation, minimized losses, and increased fan life. At low loads or low ambient temperatures, the fan(s) may be off even when the VFD is running.

.6 Line Conditioning and Filtering:

.1 Include internal mounted components to mitigate harmonic distortion, provide protection from input transients and reduce EMI/RFI emissions as required for each application. At a minimum, each VFD shall include the following:

.1 AC Line:

.1 The VFD shall have internal 5% impedance reactors to reduce the harmonics to the power line and to add protection from AC line transients.

.2 The 5% impedance may be from DC link choke or 5% AC line reactors.

.3 For VFDs above 10HP provide both DC chokes and AC line reactors with a combined impedance of 8%.

.2 Motor Filter:

.1 Provide a RLC type filter at the drive output to protect the motor from high voltage transients and reduce high frequencies at the VFD output. Complete with UL Type 1 enclosure for mounting beside VFD.

.3 EMI / RFI filters:

.1 All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard IEC/EN 61800-3 for the First Environment restricted level with up to 100 feet of motor cable. Certified test reports shall be provided with the submittals confirming compliance to IEC/EN 61800-3, First Environment.

2.3 CONTROL PANEL

.1 The frequency controller and its protections are mounted directly in the control panel enclosure, complete with an interlocked, padlockable disconnect switch on the panel's front door.

.2 On the panel front door, a microprocessor based operator interface allows the user to adjust/verify the VFD's operating parameters, running speed and output, as well as visualizing VFD status and alarm conditions.

.3 User Interface:

.1 Hand, Off and Auto keys shall be provided to start and stop the VFD and determine the source of the speed reference. It shall be possible to either disable these keys or password protect them from undesired operation.

.2 There shall be an “Info” key on the keypad. The Info key shall include “on-line” context sensitive assistance for programming and troubleshooting.

.3 The VFD shall be programmable to provide a digital output signal to indicate whether the VFD is in Hand or Auto mode. This is to alert the Building Automation System whether the VFD is being controlled locally or by the Building Automation System.

.4 Password protected keypad with alphanumeric, graphical, backlit display can be remotely mounted. Two levels of password protection shall be provided to guard against unauthorized parameter changes.

.5 All VFDs shall have the same customer interface. The keypad and display shall be identical and interchangeable for all sizes of VFDs.

.6 Display shall be programmable to communicate in multiple languages including English, French and Spanish.

.7 A red FAULT light, a yellow WARNING light and a green POWER-ON light shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.

.8 Last (10) VFD faults are recorded in the controller memory with the following information: date, time, fault description VFD output (V, amps and frequency) at time of fault.

.9 Five (5) simultaneous meter displays shall be available. They shall include at a minimum, frequency, motor current, motor voltage, VFD output power, VFD output energy, VFD temperature in degrees, among others.

.10 A run permissive circuit shall be provided to accept a “system ready” signal to ensure that the VFD does not start until dampers or other auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of initiating an output “run request” signal to indicate to the external equipment that the VFD has received a request to run.

.11 VFD shall be programmable to display feedback signals in appropriate units, imperial and metric.

.12 VFD shall be programmable to sense the loss of load. The VFD shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. To ensure against nuisance indications, this feature must be based on motor torque, not current, and must include a proof timer to keep brief periods of no load from falsely triggering this indication.

.13 Standard Control and Monitoring Inputs and Outputs:

.1 Four (4) dedicated, programmable digital inputs shall be provided for interfacing with the systems control and safety interlock circuitry.

.2 Two (2) terminals shall be programmable to act as either as digital outputs or additional digital inputs.

.3 Two (2) programmable relay outputs, shall be provided for remote indication of VFD status.

.1 Each relay shall have an adjustable on delay / off delay time.

.4 Two (2) programmable analog inputs shall be provided that can be either direct-or-reverse acting.

.1 Each shall be independently selectable to be used with either an analog voltage or current signal.

.2 The maximum and minimum range of each shall be able to be independently scalable from 0 to 10 V dc and 0 to 20 mA.

.3 A programmable low-pass filter for either or both of the analog inputs must be included to compensate for noise.

.4 The VFD shall provide front panel meter displays programmable to show the value of each analog input signal for system set-up and troubleshooting,

.5 One (1) programmable analog current output (0.4 to 20 mA) shall be provided for indication of VFD status. This output shall be programmable to show the reference or feedback signal supplied to the VFD and for VFD output frequency, current and power. It shall be possible to scale the minimum and maximum values of this output.

.6 It shall be possible through serial bus communications to read the status of all analog and digital inputs of the VFD.

.7 It shall be possible to command all digital and analog output through the serial communication bus.

.14 Optional Control and Monitoring Inputs and Outputs:

.1 It shall be possible to add optional modules to the VFD in the field to expand its analog and digital inputs and outputs.

.2 These modules shall use rigid connectors to plug into the VFD's control card.

.3 The VFD shall automatically recognize the option module after it is powered up. There shall be no need to manually configure the module.

.4 Modules may include such items as:

.1 Additional digital outputs, including relay outputs.

.2 Additional digital inputs.

.3 Additional analog outputs.

.4 Additional analog inputs, including Ni or Pt temperature sensor inputs.

.5 It shall be possible through serial bus communications to control the status of all optional analog and digital outputs of the VFD.

.4 Standard programmable firefighter's override mode allows a digital input to control the VFD and override all other local or remote commands. It shall be possible to program the VFD so that it will ignore most normal VFD safety circuits including motor overload. The VFD shall display FIREMODE whenever in firefighter's override mode. Firemode shall allow selection of forward or reverse operation and the selection of a speed source or preset speed, as required to accommodate local fire codes, standards and conditions.

.5 A real-time clock shall be an integral part of the VFD.

.1 It shall be possible to use this to display the current date and time on the VFD's display.

.2 The real-time clock shall be able to time and date stamp all faults recorded in the VFD fault log.

.6 Adjustments:

.1 The VFD shall have a manually adjustable carrier frequency that can be adjusted in 0.5 kHz increments to allow the user to select the desired operating characteristics. The VFD shall also be programmable to automatically reduce its carrier frequency to avoid tripping due to thermal loading.

.2 Four (4) preset speeds per setup shall be provided for a total of sixteen (16).

.3 Each setup shall have two programmable ramp up and ramp down times. Acceleration and deceleration ramp times shall be adjustable over the range from 1 to 3,600 seconds.

.4 Each setup shall be programmable for a unique current limit value. If the output current from the VFD reaches this value, any further attempt to increase the current produced by the VFD will cause the VFD to reduce its output frequency to reduce the load on the VFD. If desired, it shall be possible to program a timer, which will cause the VFD to trip off after a programmed time period.

.5 If the VFD trips on one of the following conditions, the VFD shall be programmable for automatic or manual reset: external interlock, under-voltage, over-voltage, current limit, over temperature, and VFD overload.

.6 The number of restart attempts shall be selectable from 0 through 20 or infinitely and the time between attempts shall be adjustable from 0 through 600 seconds.

.7 An automatic "start delay" may be selected from 0 to 120 seconds. During this delay time, the VFD shall be programmable to either apply no voltage to the motor or apply a DC braking current if desired.

.8 Four programmable critical frequency lockout ranges to prevent the VFD from operating the load at a speed that causes vibration in the driven equipment shall be provided. Semi-automatic setting of lockout ranges shall simplify the set-up.

2.4 BYPASS WITH MAGNETIC CONTACTORS

.1 Bypasses shall be furnished and mounted by the drive manufacturer. All VFD with bypass configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

.2 Description:

.1 A complete factory wired and tested bypass system consisting of a door interlocked, padlockable circuit breaker, output contactor, bypass contactor, and fast acting VFD input fuses. UL Listed motor overload protection shall be provided in both drive and bypass modes.

.2 The bypass enclosure door and VFD enclosure must be mechanically interlocked such that the disconnecting device must be in the "Off" position before either enclosure may be accessed.

.3 Drive Isolation Fuses - To ensure maximum availability of bypass operation, fast acting fuses, exclusive to the VFD, shall be provided to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection. This maintains bypass operation capability in the event of a VFD failure.

.4 Motor protection from single phase power conditions - the bypass system must be able to detect a single phase input power condition while running in bypass, disengage the motor in a controlled fashion, and give a single phase input power indication.

.5 Motors 20 HP or greater must be protected with thermistor type motor protection relays, in both VFD or Bypass mode.

.6 The bypass system shall be designed for stand-alone operation and shall be completely functional in both Hand and Automatic modes even if the VFD has been removed from the system for repair / replacement.

.7 Serial communications – the bypass shall be capable of being monitored and / or controlled via the serial communications.

.8 The bypass shall include the ability to select the operating mode of the system (VFD/Bypass) from either the bypass keypad or digital input.

2.5 INCLUDED OPTIONS

.1 With the exception of output filters, all optional features shall be built and mounted by VFD manufacturer. These optional features shall be ULC listed by the VFD manufacturer as a complete assembly and carry a ULC label.

.2 All panels shall be marked for their short circuit current rating in compliance with ULC.

2.6 SERVICE CONDITIONS

.1 Ambient temperature, continuous, full speed, full load operation:

.1 -10 to 40°C.

.2 Cancelled.

.2 0 to 95% relative humidity, non-condensing.

.3 Plenum rated (UL-1995 standard or NEMA12) as indicated.

2.7 VFD SCHEDULE

SYSTEM	MOTOR (HP)	BYPASS	PLENUM RATED	REMARKS
P-3A	10	yes	No	
P-3B	10	yes	No	

Part 3 Execution

3.1 MANUFACTURER'S INSTRUCTIONS

.1 Compliance: comply with manufacturer's written recommendations and specifications, including product technical bulletins, handling, storage and installation instructions, and datasheet.

3.2 START-UP SERVICE

.1 Factory start-up shall be provided for each drive by a factory authorized and certified service technician. A start-up form shall be filled out for each drive with a copy provided to the owner, and a copy kept on file at the manufacturer. Verification shall include: proper operation and installation of the VFD, its optional features, interface wiring and serial communications to the building automation system.

.2 Harmonic filtering: Given the information provided on the electric power single line diagram and distribution transformer data, the VFD manufacturer shall carry out an analysis of the system. The analysis must review the potential for the proposed equipment to meet IEEE-519 recommendations (maximum 3% Total Harmonic Distortion). If, as a result of the analysis, it is determined that additional filter equipment is required to meet the IEEE-519 recommendations, then the cost of such equipment shall be carried by the VFD supplier. Provide a report indicating the results of the analysis and any additional filter requirements to the Departmental Representative for review.

3.3 WARRANTY

.1 The complete VFD shall be warranted by the manufacturer for a period of 36 months from the date of start-up. The warranty shall include parts, labour, travel costs and living expenses incurred by the manufacturer to provide factory authorized on-site service. The warranty shall be provided by the VFD manufacturer and not a third party. A written warranty statement shall be provided with the submittals.

3.4 CLEANING

.1 Upon completion and verification of performance of installation, remove surplus materials, excess materials, rubbish, tools and equipment.

3.5 TRAINING

.1 Provide the services of certified technician, from the manufacturer or its authorized distributor, to provide instruction on operation and maintenance of the VFD assembly, all included accessories and the user control interface. Allow for a total of four (4) hours of training.

.2 Provide training materials (documentation, CD, video, etc.) for O&M use.

END OF SECTION