

Variable Speed Drives Specification

Specification 26 29 23

Revision 00

September 2025

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Amendment Record Sheet

Amendment in Clause No.	Date of Amendment	Description of Changes
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1. GENERAL

1.1. SCOPE OF WORK

- 1.1.1. Labour, Products, equipment, tools, supervision, and services necessary for variable-speed drives (VFDs) Work in accordance with the Contract Documents.

1.2. DESIGN REQUIREMENTS

- 1.2.1. The equipment furnished and the equipment installation, wiring methods and materials used shall conform to the latest edition of the Ontario Electrical Safety Code, Electrical Safety Authority (ESA) Bulletins and Supplements issued by the Electrical Safety Authority, and the applicable Metrolinx Standards. In case of any conflicts, the more stringent requirement shall apply.
- 1.2.2. Design Electrical equipment and systems to all applicable standards of CSA, ULC, IEEE, and ESA.
- 1.2.3. Design electrical equipment and systems to the latest version of GO DRM.
- 1.2.4. Design electrical equipment and systems to standards and codes to the latest editions adopted by and enforced by local Authorities Having Jurisdiction (AHJ).

1.3. RELATE WORKS

- 1.3.1. Section 26 05 00 - Electrical General Requirements.
- 1.3.2. Section 26 05 53 - Electrical Identification and Nomenclature.
- 1.3.3. Section 26 08 00 - Electrical Work Commissioning.
- 1.3.4. Section 26 13 26 - Metal Clad Switchgear.
- 1.3.5. Section 26 23 00 - Low Voltage Switchgear.
- 1.3.6. Section 26 24 19 - Motor Control Centres.
- 1.3.7. Section 26 28 23 - Disconnect Switches.
- 1.3.8. Section 26 28 00 - Circuit Breakers and Fuses.
- 1.3.9. Section 26 29 10 - Motor Starters and Contactors.
- 1.3.10. Section 25 05 10 - Building Automation System.

1.4. REFERENCE STANDARDS

- 1.4.1. Ontario Electrical Safety Code (OESC).

- 1.4.2. Ontario Building Code (OBC).
- 1.4.3. Metrolinx Standards, Drawings and Specifications.
- 1.4.4. GO Design Requirement Manual (DRM).
- 1.4.5. Metrolinx Electrical Safety Document.
- 1.4.6. CSA Z462, Workplace Electrical Safety.
- 1.4.7. CAN3 C235, Preferred Voltage Levels for AC Systems, 0 to 50,000V.
- 1.4.8. CAN/CSA C22.2 No. 5, Moulded Case Circuit Breakers.
- 1.4.9. CAN/CSA C22.2 No. 14, Industrial Control Equipment for Use in Ordinary (Non-Hazardous) Locations.
- 1.4.10. IEC 947 4 1, Part 4, Contactors and Motor Starters.
- 1.4.11. NEMA, National Electronic Manufacturers Association.
- 1.4.12. NEMA ICS 2-2000 (R2005), Controllers, Contactors and Overload Relays Rated 600 V.

1.5. SPARE PARTS

- 1.5.1. Spare parts for each different size and type of VFD shall be provided under Contract.
 - a) 10% power fuses for each size and type, but no less than (3) of each size and type;
 - b) 10% control power fuses for each size and type, but no less than (3) of each size and type;
 - c) 10% indicating lights of each type and colour installed;
 - d) 10% auxiliary contacts for each size and type, but no less than (3) of each size and type; and
 - e) 10% power contacts for each size and type of magnetic contactor installed.
 - f) Spare parts shall be the same type and size utilized in the drives and equipment provided for this Contract. Spare parts shall be packaged individually in boxes that are clearly labelled with part name and manufacturer's part/stock number. Contractor shall deliver all spares as one lot with parts list identifying each part and the equipment wherein the part is applied.

1.5.2. Maintenance Materials

- a) Operation and Maintenance Data for VFDs to include in emergency, operation, and maintenance manuals. The "Operation and Maintenance Data," shall include the following:
 - 1) Keys, tools, special devices, and other related maintenance materials;
 - 2) Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings;
 - 3) Manufacturer's written instructions for setting field-adjustable overload relays;
 - 4) Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules; and
 - 5) Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

1.6. TRAINING

1.6.1. Provide training as noted below:

- a) Operation Training:
 - 1) Allow for minimum of 2 hours of total on-site time per group that is required to train in all aspects of equipment and system operation; and
 - 2) Schedule separate training sessions for each group on separate days.
- b) Maintenance Training:
- c) Site Electricians: Allow for minimum of 8 hours of total in-class and on-site time per group that is required to train in all aspects of equipment and system operation, repair, and maintenance. Provide training for Metrolinx maintenance personnel to depth that troubleshooting and maintenance can be carried out by Metrolinx; and
- d) Training shall be specific to equipment, model number, and version installed. Provide material for each participant and include record drawings and comprehensive operating and maintenance manual for equipment installed.

1.7. WARRANTY

- 1.7.1. A manufacturer's warranty shall be provided for the work of this Section with a minimum warranty period of five years after acceptance by Metrolinx.

1.8. DELIVERY, STORAGE AND HANDLING

- 1.8.1. Deliver, store, and handle materials in accordance with manufacturer's written instructions.
- 1.8.2. Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- 1.8.3. Storage and Handling Requirements
 - a) Store materials in accordance with manufacturer's recommendations and in a clean, dry, and well-ventilated area;
 - b) Store and protect contactors from nicks, scratches, and blemishes; and
 - c) Replace defective or damaged materials with new.

1.9. SUBMITTALS

- 1.9.1. Product Data Package:
 - a) Submit manufacturer's Product data indicating:
 - 1) Technical data, supplemented by bulletins, component illustrations, detailed views, technical descriptions of items, and parts lists;
 - 2) Manufacturer's instructions, printed product literature and data sheets for VFDs, contactors and include product characteristics, performance criteria, physical size, finish, and limitations;
 - 3) Performance criteria, compliance with appropriate reference standards, characteristics, limitations, and troubleshooting protocol; and
 - 4) Product transportation, storage, handling, and installation requirements.
- 1.9.2. Shop Drawings Package:
 - a) Submit manufacturer's Shop Drawings indicating:
 - 1) Mounting method and dimensions;
 - 2) VFD size and type;
 - 3) Layout of identified internal and front panel components;
 - 4) Enclosure types;
 - 5) Complete electrical wiring diagrams for each type and style of VFD, including electrical schematics and external field device interconnection;

- 6) Electrical wiring diagrams with clearly identified terminal numbers, to field connection, power, and control devices such as motor, safety devices, remote push button station, etc.; and
- 7) PLC Ladder Logic diagram showing complete "Rung" instruction and input/output identification.

1.9.3. Commissioning Package

- a) Submit the following:
 - 1) Commissioning Plan;
 - 2) Commissioning Procedures;
 - 3) Certificate of Readiness; and
 - 4) Attach completed Pre-Start Health and Safety Review Report to the Certificate of Readiness.

1.9.4. Commissioning Closeout Package

- a) Submit the following:
 - 1) Deficiency Report; and
 - 2) Commissioning Closeout Report.

1.9.5. Training

- a) Submit Training Plan, Training Course Material and Training Schedule.

1.9.6. Closeout Submittals Package

- a) Submit the following for incorporation into the Operation and Maintenance:
 - 1) VFD and Control Unit:
 - i) Operation and maintenance data for each type and style of VFD; and
 - ii) Equipment operation and maintenance manuals.
 - 2) Including, but not limited to, the following:
 - i) Instruction books;
 - ii) Recommended renewal parts list; and
 - iii) Provide Ladder Logic (soft copy).

1.10. QUALITY ASSURANCE

- 1.10.1. Refer to Section 26 05 00.
- 1.10.2. Installers' qualifications: Perform work of this Section by manufacturer-approved skilled, qualified, and experienced workers trained in installation of Work of this Section.

1.11. HARMONIC DISTORTION STUDY AND DISTORTION LIMITS

- 1.11.1. Harmonic Distortion Study
 - a) VFD manufacturer shall prepare a comprehensive pre-equipment selection harmonic distortion study of the system. The study shall conform to the requirements of IEEE 519, except as modified herein. The study shall include harmonics from existing equipment, as well as the harmonics from equipment provided under this Section. In addition, the study shall include the electrical utility service connection, main service switchboard, distribution switchboards, motor control centers (MCCs), and all interconnecting power cables and busing. The harmonic distortion study shall demonstrate compliance with the harmonic distortion limits specified herein. The harmonic distortion study shall be submitted as part of the shop drawing package.
 - b) The harmonic distortion study shall be based on a computer-aided system circuit simulation of the total actual system performed through the 50th harmonic, with information and data obtained from the local utility, Contract Documents, and equipment manufacturers. Unless indicated otherwise in the Contract Documents, the harmonic analyses shall be performed without any linear loads. The harmonic distortion study shall clearly describe all assumptions, computer input information, voltage and current distortion results, and comparison of results to specified limits.
 - c) If the harmonic distortion study indicates the need for harmonic suppression equipment, including line reactors, passive filters, isolation transformers, 12-pulse VFDs, or 18-pulse VFDs, these shall be provided to mitigate harmonic distortion. Harmonic suppression utilizing active front-end VFDs is acceptable.

1.12. HARMONIC DISTORTION LIMITS

- 1.12.1. The harmonic distortion values resulting from the operation of all or any combination of VFDs operating at full load and without any linear loads shall be limited to the following:
 - a) Maximum allowable Total Harmonic Voltage Distortion, THD Voltage shall be 8%;
 - b) Maximum allowable individual frequency harmonic voltage distortion shall be 5%; and

- c) Maximum allowable individual frequency harmonic current distortion; Total Harmonic Current Distortion, THD Current; and Total Demand Distortion, TDD shall be within the limits of IEEE 519.
- 1.12.2. Compliance with the specified limits shall be verified by on-site field measurements of the harmonic distortion, performed with and without VFDs operating. Field measurements shall be obtained by an independent third-party testing firm, after satisfactory full-load operation of the equipment.

2. PRODUCTS

2.1. GENERAL

- 2.1.1. If more than 3 single VFDs are required, then an MCC shall be used to house the VFDs and controls.
- 2.1.2. VFDs shall be controlled and monitored by the BAS and SCADA.
- 2.1.3. VFD controllers shall comply with the applicable standards and codes as shown on the Contract Documents.
- 2.1.4. VFD controllers shall be combination type, with VFD controller and one of the following, if required:
 - a) Circuit breaker;
 - b) By-pass contactor; or
 - c) Disconnecting means, with external operating handle with lock-open padlocking positions and ON-OFF position indicator.
- 2.1.5. Fuses in VFD controllers shall be CSA certified Form 1, current and energy limiting type 200 kA interrupting capacity with NEMA Class "J" rejection type mountings.
- 2.1.6. Size fuses installed in VFD controllers or in disconnect switches used in conjunction with VFD controllers, for motor and branch circuit protection in accordance with fuse manufacturer's recommendations.
- 2.1.7. A control unit shall start or stop the motor via the motor VFD controller. This control unit shall be of a Programmable Logic Controller (PLC), basic hard-wired circuitry or other means as indicated on the Contract Documents.
- 2.1.8. VFD controller control wiring shall be minimum, gauge 2.5 sq. mm (# 14 AWG) RW90 insulated.

2.2. VARIABLE SPEED DRIVES (VFD)

- 2.2.1. Motors shall be provided with ULC-listed variable frequency drive (VFD) control systems.
- 2.2.2. The VFD shall have been evaluated by ULC and found acceptable for mounting in a plenum or other air handling compartment. Manufacturer shall supply a copy of the ULC plenum evaluation upon request.
- 2.2.3. The VFD package as specified herein shall be enclosed in a CSA Type enclosure.
- 2.2.4. The VFD shall provide full rated output from a line of +10% to -15% of nominal voltage across an ambient temperature range of -15 °C to 40 °C (5 °F to 104 °F).

- 2.2.5. The VFD shall be tested to UL 508C. The appropriate UL label shall be applied. VFD shall be manufactured in ISO 9001, 2000 certified facilities.
- 2.2.6. The VFD and any optional panels, of any type (bypass, etc.) shall be UL listed for a short circuit current rating of 100 kA and labelled with this rating.
- 2.2.7. The VFD shall convert incoming fixed-frequency three-phase AC power into an adjustable frequency and voltage for controlling the speed of three-phase AC motors. The motor current shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current for the driven load and to eliminate the need for motor derating. When properly sized, the VFD shall allow the motor to produce full rated power at rated motor voltage, current, and speed without using the motor's service factor. VFDs utilizing sine-weighted/coded modulation (with or without 3rd harmonic injection) shall provide data verifying that the motors will not draw more than full load current during full load and full speed operation.
- 2.2.8. The VFD shall provide full motor torque at any selected frequency from 20 Hz to base speed while providing a variable torque V/Hz output at reduced speed. This is to allow driving direct drive fans without high-speed derating or low-speed excessive magnetization, as would occur if a constant torque V/Hz curve were used at reduced speeds. Breakaway torque of 160% shall be available.
- 2.2.9. The VFD shall convert three-phase, 60 Hz utility power to adjustable voltage and frequency, three-phase, AC power for stepless motor speed control from 10% to 100% of the motor's 60 Hz speed. Input voltage shall be 208 VAC or 600 VAC, three-phase.
- 2.2.10. The VFD power input stage shall convert three-phase AC line power to a fixed DC bus voltage. This will be accomplished with a six-pulse input design, and the input voltage rectifier shall employ a three-phase full-wave diode bridge with metal oxide varistor (MOV) three-phase protection; VFDs utilizing controlled SCR rectifiers shall not be acceptable.
- 2.2.11. The VFD output power shall vary frequency to the motor from 6 to 60 Hz, with resultant motor speed varying at the motor nameplate rated speed, with output voltage variation from zero to motor rated voltage for optimum volts per hertz (V/Hz) ratio for pump loads.
- 2.2.12. The VFD shall utilize the same Advanced Control Panel (keypad) user interface.
- a) Plain English text:
- 1) The display shall be in complete English words for programming and fault diagnostics.

- 2) Safety interlock and run permissive status shall be displayed using predetermined application-specific nomenclature, such as: Damper end switch or vibration trip. Customized terms, such as: AHU-1 End Switch or CT-2 Vibration, shall also be available.
- b) There shall be a built-in time clock in the control panel with 10-year battery backup.
- c) I/O Summary display with a single screen shall indicate and provide:
 - 1) The status/values of all analog inputs, analog outputs, digital inputs, and relay outputs.
 - 2) The function of all analog inputs, analog outputs, digital inputs, and relay outputs.
 - 3) The ability to force all inputs and outputs to either a high, low, or specific value.
- d) The VFD shall automatically backup parameters to the control panel. The VFD shall be capable of storing two additional unique manual backup parameter sets as required.
- e) The control panel shall be removable and capable of remote mounting.

2.2.13. All drives shall have the following hardware features/characteristics as standard:

- a) Two (2) programmable analog inputs, two (2) programmable analog outputs, six (6) programmable digital inputs, and three (3) programmable Form-C relay outputs;
- b) The drive shall include an isolated USB port for interface between the drive and a laptop;
- c) An auxiliary power supply rated at 24 VDC, 250 mA shall be included;
- d) At a minimum, the drives shall have internal impedance equivalent to 5% to reduce the harmonics to the power line. 5% impedance may be from dual (positive and negative DC link) chokes, or AC line reactor. Drives with only one DC link choke shall add an AC line choke integral to the drive enclosure;
- e) The VFD shall have variable-speed primary cooling fans;
- f) The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 135% overload for 2 seconds every minute;
- g) The input current rating of the drive shall not be greater than the output current rating;

- h) Circuit boards shall be coated per IEC 60721-3-3; Chemical gasses Class 3C2 and Solid particles Class 3S2;
- i) Coordinated AC transient surge protection system consisting of 4 MOVs (phase-to-phase and phase-to-ground), a capacitor clamp, and internal chokes. The MOVs shall comply with UL 1449 4th Edition; and
- j) The drive shall include a robust DC bus to provide short-term power-loss ride through. An inertia-based ride-through function should help maintain the DC bus voltage during power loss events. Drives with control power ride through only are not acceptable.

2.2.14. All drives shall have the following software features as standard:

- a) A Fault Logger that stores the last 16 faults in non-volatile memory. The most recent 5 faults save at least 9 data points, including but not limited to: Time/date, frequency, DC bus voltage, motor current, DI status, temperature, and status words;
- b) An Event Logger that stores the last 16 warnings or events that occurred, in non-volatile memory. Events shall include, but not limited to: Warning messages, checksum mismatch, run permissive open, start interlock open, automatic reset of a fault, power applied, auto start command, auto stop command, modulating started, and modulating stopped;
- c) Programmable start method. Start method shall be selectable based on the application and function, even if the motor was freewheeling in the reverse direction: Flying-start, Normal-start, and Brake-on-start;
- d) Programmable loss-of-load (broken belt/coupling) indication. This function to include a programmable time delay to eliminate false loss-of-load indications;
- e) Motor heating function to prevent condensation buildup in the motor. Motor heating adjustment, via parameter, shall be in "Watts.";
- f) There shall be a run-permissive circuit for damper or valve control;
- g) Four separate start interlock (safety) inputs shall be provided. The control panel will display the specific safeties that are open;
- h) The drive shall include a switching frequency control circuit that reduces the switching frequency based on actual drive temperature. It shall be possible to set a minimum and a target switching frequency;
- i) The ability to automatically restart after non-critical faults;
- j) PID functionality shall be included in the drive;

- k) Drive shall be compatible with an accessory that allows the control board to be powered from an external 24 VDC/VAC source;
- l) A computer-based software tool shall be available to allow a laptop to program the drive. The drive shall be able to support programming without the need for line voltage. All necessary power shall be sourced via the laptop USB port; and
- m) The drive shall include a fireman's override mode.

2.2.15. The following display/control parameters shall be located on the front of the enclosure:

- a) Hand/Off/Auto selector to start and stop the motor. In the auto position, the drive shall start/stop from a remote contact closure. In the auto position, motor speed shall be determined by the follower signal. In the manual position, motor speed shall be determined by manual adjustment.

2.2.16. Security Features

- a) The drive manufacturer shall clearly define cybersecurity capabilities for their products;
- b) The drive shall include passcode protection against parameter changes;
- c) A checksum feature shall be used to notify the owner of unauthorized parameter changes made to the drive; and
- d) The "Hand" and "Off" control panel buttons shall have the option to individually disabled (via parameter) for drives mounted in public areas.

2.2.17. Network Communications

- a) The drive shall have an EIA-485 port with removable terminal blocks. The onboard protocols shall be BACnet MS/TP, Modbus, and Johnson Controls N2. The VFD shall be provided with communication cards for BACnet/IP and LonWorks;
- b) The drive shall have the ability to communicate via two protocols at the same time, one onboard protocol and one option card-based protocol; and
- c) The embedded BACnet connection shall be an MS/TP interface. The drive shall be BTL Listed to Revision 14 or later.

2.2.18. Disconnect - A circuit breaker or disconnect switch shall be provided where indicated on the Contract Documents. The disconnect shall be door interlocked and padlockable. Drive input fusing shall be included on all packaged units that include a disconnecting means. All disconnect configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508A label.

- 2.2.19. Bypass - Bypass drive packages shall be provided when indicated on the Contract Documents. All drive/bypass configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508A label.
- a) The VFD and bypass package shall be a complete factory-wired and tested bypass system consisting of a padlockable disconnect device, drive output contactor, bypass contactor, and drive input fuses;
 - b) The bypass control shall be powered by a three-phase switch-mode power supply with a voltage tolerance of +30% /-35%;
 - c) The VFD and bypass package shall be seismic certified and labelled;
 - d) All bypass packages shall utilize an LCD bypass control panel (keypad) user interface. The bypass control panel shall be a separate display from the drive control panel;
 - e) All bypasses shall have the following hardware features/characteristics as standard:
 - 1) Six (6) digital inputs and five (5) Form-C relay outputs;
 - 2) Drive isolation fuses shall be provided. Bypass designs which have no such fuses, or that only incorporate fuses common to both the drive and the bypass, are not acceptable;
 - 3) The bypass shall be able to detect a single-phase input power condition while running in bypass, disengage the motor, and provide a single-phase input power indication; and
 - 4) The bypass shall be designed for stand-alone operation and be completely functional in both Hand and Automatic modes, even if the drive and/or drive's control board has failed.
 - f) All bypasses shall have the following software features:
 - 1) Programmable loss-of-load (broken belt/coupling) indication shall be functional in drive and bypass mode;
 - 2) Run permissive and start interlock control functionality shall be functional in bypass mode;
 - 3) The bypass control shall monitor the status of the drive and bypass contactors and indicate when there is a welded contactor contact or open contactor coil;
 - 4) The bypass shall include a selection for either manual or automatic transfer to bypass; and

- 5) The drive and bypass shall be designed to operate as an integrated system when in Override mode. There shall be four selectable Override modes: Bypass only, drive only, drive then transfer-to-bypass upon fault, and force to stop.

2.3. CONTROL TRANSFORMER

- 2.3.1. 150 VA single-phase, dry-type, control transformer with primary voltage as indicated and 120 V secondary, complete with secondary fuse, installed with starter as indicated. Capacity shall be increased where indicated on the Contract Documents.
- 2.3.2. Size control transformer for control circuit load plus 25% spare capacity.
- 2.3.3. Power supply shall be located downstream of main disconnect device supplying power to the starter.
- 2.3.4. The secondary shall be fused on one leg and grounded on the other (X2).
- 2.3.5. Primary fuses shall be installed on both legs on all starters.
- 2.3.6. Control fuses shall be HRC type.
- 2.3.7. Accessories
 - a) Pushbutton: LED illuminated, NEMA 12 as required;
 - b) Selector switches: heavy-duty, oil-tight as required; and
 - c) Indicating lights: LED, heavy-duty, oil-tight, type and colour as indicated.

2.4. CIRCUIT BREAKERS (WHERE APPLICABLE)

- 2.4.1. Bolt-on thermal-magnetic type with a minimum interrupting rating as indicated on the Contract Documents.
- 2.4.2. Equipped with automatic, trip-free, non-adjustable, inverse-time, and instantaneous magnetic trips for less than 400 A. The magnetic trip shall be adjustable from 5x to 10x for breakers 400 A and greater.
- 2.4.3. Additional features shall be as follows:
 - a) A rugged, integral housing of moulded insulating material;
 - b) Silver alloy contacts;
 - c) Arc quenchers and phase barriers for each pole;
 - d) Quick-make, quick-break, operating mechanisms; and

-
- e) A trip element for each pole, a common trip bar for all poles, and one operator for all poles.

2.5. ENCLOSURES

- 2.5.1. Enclosures shall be NEMA-type rated 1, 3R, 4X or 12 as required per the installed environment.
- 2.5.2. Enclosure doors shall be interlocked to prevent opening unless the disconnecting means is open. A "defeater" mechanism shall allow for inspection by qualified personnel with the disconnect means closed. Provide padlocking provisions.
- 2.5.3. All metal surfaces shall be thoroughly cleaned, phosphatized, and factory primed prior to applying light gray baked enamel finish.

3. EXECUTION

3.1. INSTALLATION

- 3.1.1. Install all equipment in accordance with the manufacturer's written instructions, Ontario Electrical Safety Code (OESC), requirements and standards specified herein, and as shown on the Contract Documents. Each VFD unit shall be installed with clearance in front of the enclosure to satisfy all OESC requirements.
- 3.1.2. All equipment furnished under this Section shall be installed and adjusted under the supervision of a factory-trained service engineer.
- 3.1.3. Install arc flash hazard label in accordance with the Arc Flash Studies performed per Contract Documents.
- 3.1.4. Ensure correct fuses and overload devices elements installed.
- 3.1.5. Install VFDs as a standalone unit or as part of motor control centre in suitably sized buckets as indicated in the Contract Documents. Ground doors in accordance with OESC.
- 3.1.6. Starters and VFDs components, accessories, and safety requirements shall be identical for standalone or motor control centre installation.
- 3.1.7. Provide output filter (dv/dt filter) as standalone unit in a separate enclosure, complete with drip hood external to VFD unit.
- 3.1.8. Install control unit enclosure adjacent to respective VFD units as a stand-alone unit unless indicated otherwise.
- 3.1.9. Install contactors and connect power wires and auxiliary control devices.
- 3.1.10. Identify contactors with nameplates or labels indicating panel and circuit number.

3.2. TESTING AND STARTUP

- 3.2.1. Upon completion of manufacturing, each VFD unit shall be factory inspected and load tested. In addition, all VFD unit control logic shall be factory tested by simulating external control signals.
- 3.2.2. Manufacturer or supplier of the equipment furnished under this Section shall furnish the services of competent factory-trained personnel to provide technical assistance during installation and start-up of the VFD equipment.
- 3.2.3. Prior to the commencement of field testing, manufacturer's service engineer shall perform the following:

- a) Set and/or adjust all operating parameters according to the manufacturer's written instructions and as per the Contract Documents requirements for VFD features, which may be enabled or disabled through the operator interface;
- b) Provide a complete listing of all VFD operating parameters (control settings and setpoints for all controller inputs); and
- c) Provide written certification stating that the VFD equipment, including controls, has been properly installed and adjusted, and is ready for operation.

3.3. FIELD TESTING

- 3.3.1. VFD field testing shall be conducted concurrently with field testing of the driven equipment.
- 3.3.2. Field testing shall demonstrate satisfactory operation of all interlocks, alarms, and normal operational sequences.
- 3.3.3. Harmonic distortion field tests shall be conducted to determine the voltage distortion and current distortion, and compliance with specified limits. Measurements shall include phase-to-phase, phase-to-neutral, and neutral-to-ground. Measurements shall be obtained over the full range of VFD operation and shall include individual voltage and current harmonic values up to the 50th harmonic as well as total harmonic distortion (THD) and total demand distortion (TDD). Graphs of the test results shall be submitted for speed values of 60%, 80%, and 100%. Also, testing shall be performed with no VFD units operating, then one unit, then two units, then three units, etc., operating simultaneously (no concurrent linear loads).
- 3.3.4. A written report covering the service engineer's inspection findings, field test readings, field test results, comparison of field test results to specified values/limits, and final listing of all VFD operating parameters (control settings and setpoints for all controller inputs) shall be submitted.

3.4. COMMISSIONING

- 3.4.1. Place As-Built wiring diagram of installed equipment in motor starters.
- 3.4.2. Perform Commissioning in accordance with Section 26 08 00 Electrical Commissioning Work and with Metrolinx Standards, manufacturers' recommendations, and NETA standards.
- 3.4.3. Manufacturer's technical representative shall be present for commissioning at no extra cost to Metrolinx.

END OF SECTION