

SECTION 26 29 23

VARIABLE-FREQUENCY MOTOR CONTROLLER

PART 1 GENERAL

1.01 SUMMARY

- A. The Variable Frequency Drive (VFD) package shall contain all components required to meet the performance, protection, safety and certification criteria of this specification.

1.02 RELATED SECTIONS

- A. Section 26 05 00 – Common Work Results for Electrical
- B. Section 26 00 00 – Electrical – General Provisions

1.03 REFERENCES

- A. National Fire Protection Association - NFPA 70 - US National Electrical Code.
- B. National Electrical Manufacturers Association - NEMA 250 - Enclosures for Electrical Equipment.
- C. Underwriters Laboratory Inc. – UL 508.
- D. Canadian Standards Association International – CAN/CSA-C22.2 No. 14-05.
- E. International Electrical Code - IEC 146.
- F. Institute of Electrical and Electronics Engineers, Inc. - IEEE 519 - IEEE Standard Practices and Requirements for Harmonic Control in Electrical Power Systems.

1.04 SUBMITTALS

- A. Submit under provisions of Section 01 30 00
- B. Shop Drawings - Approval
 - 1. Elevation Drawings: Include dimensional information and conduit routing locations.
 - 2. Unit Descriptions: Include amperage ratings, enclosure ratings, fault ratings, nameplate information, etc. as required for approval.
 - 3. Wiring Diagrams:
 - a) Power Diagram: Include amperage ratings, circuit breaker frame sizes, circuit breaker continuous amp ratings, etc. as required for approval.
 - b) Control Diagram: Include disconnect devices, pilot devices, etc.
 - 4. Major components list.

C. Product Data Sheets

1. VFD and Operator Interface publications.
2. Data sheets and publications on all major components including but not limited to the following:
 - a) Contactors
 - b) Circuit breaker and fuse (power and control)
 - c) Control power transformers
 - d) Pilot devices
 - e) Relays/Timers

D. Test procedures shall be per the manufacturer's standards.

1.05 CLOSEOUT SUBMITTALS (OPERATION AND MAINTENANCE MANUALS)

A. Submit under provisions of Section 01 30 00

B. Shop Drawings – Final as shipped

1. Elevation Drawings: Include dimensional information and conduit routing locations.
2. Unit Descriptions: Include amperage ratings, enclosure ratings, fault ratings, nameplate information, etc. as required for approval.
3. Wiring Diagrams:
 - a) Power Diagram: Include amperage ratings, circuit breaker frame sizes, circuit breaker continuous amp ratings, etc. as required for approval.
 - b) Control Diagram: Include disconnect devices, pilot devices, etc.

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 - a) Contactors
 - b) Circuit breaker and fuse (power and control)
 - c) Control power transformers
 - d) Pilot devices
 - e) Relays/Timers

D. Test procedures shall be per the manufacturer's standards.

E. Operation and Maintenance Data

1. Service and Contact information
2. VFD and Operator Interface User Manuals
3. Troubleshooting / Service Manuals

1.06 QUALITY ASSURANCE

A. Qualifications:

1. Manufacturers:

- a) The VFD and all associated optional equipment shall be UL listed or recognized.
- b) The VFD shall contain a UL label attached on the inside of the enclosure cabinet.

2. Suppliers:

- a) All inspection and testing procedures shall be developed and controlled under the guidelines of the Supplier's quality system and must be registered to ISO 9001 and regularly reviewed and audited by a third party registrar.
- b) The VFD shall be factory pre-wired, assembled and tested as a complete package.

1.07 DELIVERY, STORAGE, AND HANDLING

- A. Contractor shall coordinate the shipping of equipment with the manufacturer.
- B. Contractor shall store the equipment in a clean and dry space at an ambient temperature range of -25 °C to 55 °C (-13 °F to 130 °F).
- C. The contractor shall protect the units from dirt, water, construction debris and traffic.

1.08 WARRANTY

- A. The manufacturer shall provide their standard parts warranty for eighteen (18) months from the date of shipment or twelve (12) months from the date of being energized, whichever occurs first.
- B. This warranty applies to variable frequency drive systems.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. Allen-Bradley – PowerFlex 700 VFD (No substitutions)

2.02 VARIABLE FREQUENCY DRIVE UNIT

- A. Features

- 1. Certifications

- a) Listed to UL508C and CAN/CSA-C22.2 No. 14-05. Packaged drives may be listed to UL508A.
 - b) In conformity with EMC Directive (2004/108/EC). Standards applied; EN 61800-3. Except 600V, Frame 0...4 drives. Frames 7...10 provided as IP00 or NEMA/UL Open style must be installed in a supplementary enclosure which provides adequate attenuation of radiated emissions in order to be compliant with EN 61800-3.
 - c) In conformity with Low Voltage Directive (2006/95/EC). Standards applied; EN 61800-3 and EN 50178.
 - d) TÜV Rheinland – EC-Type-Examination Certificate TUV 05 ATEX 7153 for directive 94/9/EC: Safe turn off of certified ATEX motors used in Group II Category (2) GD potentially explosive atmospheres.
 - e) Australian Communications and Media Authority. All drives except 600V, Frame 0...4 drives are in conformity with Radiocommunications Act: 1992, Radiocommunications Standard: 2008, and Radiocommunications Labeling Notice: 2008. Standards applied: EN 61800-3:2004.
 - f) Tested by Trentec to be compliant with AC156 Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components and 2003 International Building Code for worst-case seismic level for USA excluding site class F. Frames 0...6 only.

- 2. Hardware

- a) Utilize diode bridge or SCR bridge on the input rectifier.
 - b) Utilize DC bus inductor on all six-pulse VFDs only.
 - c) Utilize switching logic power supply operating from the DC bus.
 - d) Incorporate phase to phase and phase to ground MOV protection on the AC input line.
 - e) Utilize gold plated plug-in connections on printed circuit boards.
 - f) Microprocessor based inverter logic shall be isolated from power circuits.
 - g) Utilize latest generation IGBT inverter section.
 - h) Inverter section shall not require commutation capacitors.
 - i) Additional DPI port for handheld and remote HIM options.
 - j) Dedicated Digital Input for hardware enable.
 - k) Conformal coated printed circuit boards - optional.

3. Control Logic

- a) Ability to operate with motor disconnected.
- b) Provide a controlled shut down, when properly protected, with no component failure in the event of an output phase to phase or phase to ground short circuit. Provide annunciation of the fault condition.
- c) Provide multiple programmable stop modes including Ramp, Coast, DC-Brake, Ramp-to-Hold, Fast Braking, and Current Limit Stop.
- d) Provide multiple acceleration and deceleration rates.
- e) Adjustable output frequency up to 420 Hz.
- f) Ability to operate in TorqueProve mode.

4. Motor Control Modes

- a) Selectable Sensorless Vector, Flux Vector, V/Hz, and Adjustable Voltage Control modes selectable through programming.
- b) The drive shall be supplied with a Start-up and Auto-tune mode.
- c) The V/Hz mode shall be programmable for fan curve or full custom patterns.
- d) Capable of Open Loop V/Hz.

5. Current Limit

- a) Programmable current limit from 20 to 160% of rated output current.
- b) Current limit shall be active for all drive states: accelerating, constant speed and decelerating.
- c) The drive shall employ PI regulation with an adjustable gain for smooth transition in and out of current limit.

6. Acceleration / Deceleration

- a) Accel/Decel settings shall provide separate adjustments to allow either setting to be adjusted from 0 to 3600 seconds.
- b) A second set of remotely selectable accel/decel settings shall be accessible through digital inputs.

7. Speed Profiles

- a) Programming capability shall allow the user to produce speed profiles with linear acceleration/deceleration or "S Curve" profiles that provide changing accel/decel rates.
- b) S Curve profiles shall be adjustable.

8. Adjustments

- a) A digital interface can be used for all set-up, operation and adjustment settings.
- b) All adjustments shall be stored in nonvolatile memory (EEPROM).
- c) No potentiometer adjustments shall be required.
- d) EEPROM memory for factory default values shall be provided.
- e) Software must be available for trending and diagnostics, as well as online and offline programming functionality.

9. Process PID Control

- a) The drive shall incorporate an internal process PI regulator with proportional and integral gain adjustments as well as error inversion and output clamping functions.
- b) The feedback shall be configurable for normal or square root functions. If the feedback indicates that the process is moving away from the set-point, the regulator shall adjust the drive output until the feedback equals the reference.
- c) Process control shall be capable of being enabled or disabled with a hardware input. Transitioning in and out of process control shall be capable of being tuned for faster response by preloading the integrator.
- d) Protection shall be provided for a loss of feedback or reference signal.

10. Skip Frequencies

- a) Three adjustable set points that lock out continuous operation at frequencies which may produce mechanical resonance shall be provided.
- b) The set points shall have a bandwidth adjustable from Maximum Reverse Speed to Maximum Forward Speed.

11. Fault Reset / Run

- a) The drive shall provide up to nine automatic fault reset and restarts following a fault condition before locking out and requiring manual restart.
- b) The automatic mode shall not be applicable to a ground fault, shorted output faults and other internal microprocessor faults.
- c) The time between restarts shall be adjustable from 0.5 seconds to 30 seconds. Also see **Auto Reset/Run** on page 11.

12. Run on Power Up

- a) A user programmable restart function shall be provided to allow restart of the equipment after restoration of power after long duration power outages. Restart time dependent on presence of incoming signal. Also see **Run on Power Up** on page 11.

13. Fault Memory

- a) The last 8 fault codes shall be stored and time elapsed stamped in a fault buffer.
- b) Information about the drive's condition at the time of the last fault such as operating frequency, output current, dc bus voltage and twenty-seven other status conditions shall be stored.
- c) A power-up marker shall be provided at each power-up time to aid in analyzing fault data.
- d) The last 8 alarm codes shall be stored and time elapsed stamped for additional troubleshooting reference.

14. Overload Protection

- a) The drive shall provide internal class 10 adjustable overload protection.
- b) Overload protection shall be speed sensitive and adjustable.
- c) A viewable parameter shall store the overload usage.

15. Auto Economizer

- a) An auto economizer feature shall be available to automatically reduce the output voltage when the drive is operating in an idle mode (drive output current less than programmed motor FLA). The voltage shall be reduced to minimize flux current in a lightly loaded motor thus reducing kW usage.
- b) When the load increases, the drive shall automatically return to normal operation.

16. Terminal Blocks

- a) Separate terminal blocks shall be provided for control and power wiring.
- b) I/O terminal blocks shall be removable with wiring in place.

17. Flying Start

- a) The drive shall be capable of determining the speed and direction of a spinning motor and adjust its output to "pick-up" the motor at the rotating speed. This feature is disabled by default.

18. Inputs and Outputs

- a) The inputs and outputs shall consist of both analog and digital I/O.
- b) No switches shall be required to configure digital inputs and outputs.
- c) All digital input and output functions shall be fully programmable.
- d) The control terminal blocks shall be rated for 115V AC.
- e) Inputs shall be optically isolated from the drive control logic.
- f) The VFD shall be capable of supporting up to two analog inputs, two analog outputs, six digital inputs, three digital outputs, one Form C relay output, two single function relay outputs (one N.C. and one N.O.), and two positive temperature coefficient (PTC) inputs.

- g) The inputs and outputs shall have the following features:
- i. Analog Inputs:
 - a. Isolated, bipolar, differential, $\pm 10V/0\dots 20$ mA, 11 bit & sign. For $0\dots 20$ mA, a jumper must be installed at terminals 17 & 18 (or 19 & 20). 88k ohm input impedance when configured for voltage & 95.3 ohm for current.
 - b. Analog inputs shall be user programmable for a variety of uses including frequency command and process loop input. Analog inputs shall be user programmable for function scaling (including invert), offset, signal loss detect and square root.
 - ii. Analog Outputs:
 - a. Single-ended bipolar (current output is not bipolar), $\pm 10V/0\dots 20$ mA, 11 bit & sign, Voltage mode - limit current to 5 mA. Current mode - maximum load is 400 ohms.
 - b. The analog output shall be user programmable to be proportional to one of 25 process parameters including output frequency, output current, encoder feedback, output power.
 - c. Programming shall be available to select either absolute or signed values of these parameters.
 - iii. Digital Inputs:
 - a. Quantity of six digital inputs rated:
 - 1) 115V AC, 50/60 Hz - Opto isolated. Low State: less than 30V AC. High State: greater than 100V AC, 5.7 mA.
 - 2) 24V DC - Opto isolated Low State: less than 5V DC. High State: greater than 20V DC, 10 mA DC digital input impedance: 21k ohm
 - b. All inputs shall be individually programmable for multiple functions including: Start, Run, Stop, Auxiliary Fault, Speed Select, Jog and Process PI functions.
 - iv. Digital Outputs:
 - a. Three Digital Relay Outputs, one Form C relay output, two single function relay outputs (one N.C. and one N.O).
 - 1) Maximum Resistive Load: 240V AC/30V DC, 1200 VA, 150W. Maximum Current: 5A, Minimum Load: 10 mA.
 - 2) Maximum Inductive Load: 240V AC/30V DC, 840VA, 105W. Maximum Current: 3.5A, Minimum Load: 10 mA
 - b. Relays shall be programmable to multiple conditions including: Fault, Alarm, Drive Ready, At Speed, At Freq, At Current, and At Torque.
 - c. Timers shall be available for each output to control the amount of time, after the occurring event, that the output relay actually changes state.

19. Reference Signals

- a) The drive shall be capable of using the following input reference signals:
 - i. Pulse In
 - ii. Analog inputs
 - iii. Preset speeds
 - iv. Remote potentiometer
 - v. Digital MOP
 - vi. Human Interface Module
 - vii. Communication modules

20. Loss of Reference

- a) The drive shall be capable of sensing reference loss conditions.
- b) In the event of loss of the reference signal, the drive shall be user programmable to the following:
 - i. Fault the drive and coast to stop.
 - ii. Issue a minor fault - allows the drive to continue running while some types of faults are present.
 - iii. Alarm and maintain last reference.
- c) When using a communications network to control the drive, the communications adapter shall have these configurable responses to network disruptions and controller idle (fault or program) conditions:
 - i. Fault
 - ii. Stop
 - iii. Zero Data
 - iv. Hold Last State
 - v. Send Fault Configuration

21. Metering

- a) At a minimum, the following parameters shall be accessible through the Human Interface Module, if installed:
 - i. Analog In values in mA and Volts
 - ii. Commanded Speed in Hz or RPM
 - iii. Commanded Torque in %
 - iv. Output Current in Amps
 - v. Output Voltage in Volts
 - vi. Output Power in kW
 - vii. Elapsed MWh
 - viii. DC Bus Voltage
 - ix. Output Frequency
 - x. Drive Temperature
 - xi. Last eight faults
 - xii. Elapsed Run Time

22. Faults

- a) At a minimum, the following faults shall be accessible through the Human Interface Module:
 - i. Power Loss
 - ii. Undervoltage
 - iii. Overvoltage
 - iv. Motor Overload
 - v. Heat Sink Overtemperature
 - vi. Maximum Retries
 - vii. Phase to Phase and Phase to Ground Faults

2.03 VFD PACKAGED DRIVES

A. Features

1. Ratings

- a) Voltage
 - i. Capable of accepting nominal plant power of 480V AC at 60Hz.
 - ii. The supply input voltage tolerance shall be $\pm 10\%$ of nominal line voltage.
- b) Displacement Power Factor
 - i. Six-pulse VFD shall be capable of maintaining a minimum true power factor (Displacement P.F. X Distortion P.F.) of 0.95 or better at rated load and nominal line voltage, over the entire speed range.
 - ii. Eighteen-pulse VFD shall be capable of maintaining a minimum true power factor (Displacement P.F. X Distortion P.F.) of 0.98 or better at rated load and nominal line voltage, over the entire speed range.
- c) Efficiency
 - i. A minimum of 96.5% (+/- 1%) at 100% speed and 100% motor load at nominal line voltage.
 - ii. Control power supplies, control circuits, and cooling fans shall be included in all loss calculations.
- d) Operating ambient temperature range without derating: 0 °C to 40 °C (32 °F to 104 °F)
- e) Operating relative humidity range shall be 5% to 95% non-condensing.
- f) Operating elevation shall be up to 1000 Meters (3,300 ft) without derating.

2. Sizing

- a) Systems rated at Normal Duty loads shall provide 110% overload capability for up to one minute and 150% for up to 3 seconds.
- b) Systems rated at Heavy Duty loads shall provide 150% overload capability for up to one minute and 180% for up to 3 seconds.

3. Auto Reset/Run
 - a) For faults other than those caused by a loss of power or any other non-critical fault, the drive system shall provide a means to automatically clear the fault and resume operation.
4. Ride-Through
 - a) The VFD system shall attempt to ride through power dips up to 20% of nominal. The duration of ride-through shall be inversely proportional to load. For outages greater than 20%, the drive shall stop the motor and issue a power loss alarm signal to a process controller, which may be forwarded to an external alarm signaling device.
5. Run on Power Up
 - a) The VFD system shall provide circuitry to allow for remote restart of equipment after a power outage. Unless indicated in the contact drawings, faults due to power outages shall be remotely resettable. The VFD system shall indicate a loss of power to a process controller, which may be forwarded to an external alarm signaling device. Upon indication of power restoration the process controller will attempt to clear any faults and issue a run command, if desired.
6. Communications
 - a) VFD shall be capable of communicating on multiple networks.
 - b) VFD shall be capable of supporting the following network options:
 - i. BACnet MS/TP RS485
 - ii. ControlNet Coax
 - iii. ControlNet Fiber
 - iv. DeviceNet
 - v. EtherNet/IP
 - vi. Interbus
 - vii. CANopen
 - viii. Modbus/TCP
 - ix. PROFIBUS DP
 - x. RS-485 DF1
 - xi. RS-485 HVAC
 - xii. Remote I/O

7. Enclosure Door Mounted Human Interface Module (HIM)

- a) VFD shall provide a HIM with integral LCD display, operating keys and programming keys.
- b) An enclosure door-mounted HIM, rated NEMA/UL Type (1) or (4/12), shall be provided ***[Choose one of the options, then delete the other and this text]***.
- c) An optional VFD-mounted HIM, rated NEMA/UL Type (1), may be provided and shall be capable of connecting via a separate cable for use as a handheld terminal.
- d) The HIM shall have the following features:
 - i. A seven (7) line by twenty-one (21) character backlit LCD display with graphics capability.
 - ii. Shall indicate drive operating conditions, adjustments and fault indications.
 - iii. Shall be configured to display in the following three distinct zones:
 - a. The top zone shall display the status of direction, drive condition, fault / alarm conditions and Auto / Manual mode.
 - b. The middle zone shall display drive output frequency.
 - c. The bottom zone shall be configurable as a display for either programming menus / information or as a two-line user display for two additional values utilizing scaled units.
 - iv. Shall provide digital speed control.
 - v. The keypad shall include programming keys, drive operating keys (Start, Stop, Direction, Jog and Speed Control), and numeric keys for direct entry.

B. Enclosure

1. Shall be rated NEMA/UL Type (1) or (12) ***[Choose one of the options, then delete the other and this text]***.
2. Shall be painted per the manufacturer's standard.
3. Shall provide entry and exit locations for power cables.
4. Shall contain a label for UL508.
5. The drive system nameplate shall be marked with system Short Circuit Current Rating (SCCR).

C. Drive Enclosure Input Disconnect

1. Provide an enclosure door interlocked disconnect with fusing, or thermal magnet circuit breaker, or motor circuit protector ***[Choose one of the options, then delete the other and this text]***.
2. Operator Handles
 - a) Provide externally operated main disconnect handle.
 - b) Handles shall have provisions for locking in the Off position.

D. Branch Circuit Protection

1. Input fusing, motor circuit protector (MCP), or thermal magnet circuit breaker shall be provided ***[Choose one of the options, then delete the other and this text]***.

E. Bypass *[Delete bypass option choices not used.]*

1. Manual Bypass Option:

- a) Shall provide a means to manually switch a single motor from drive control to bypass (across the line operation).
- b) Shall provide separate drive output and bypass contactors (IEC). The contactors shall be electrically and mechanically interlocked.
- c) Shall provide a Drive/Off/Bypass selector switch, mounted on the enclosure door, for selection of Drive and Bypass modes of operation.
- d) Provide a Class 10 overload for motor protection while operating in the bypass mode.

2. Automatic Bypass Option:

- a) Shall provide a means to automatically (upon a drive fault) switch a single motor from drive control to bypass (across the line operation).
- b) Shall provide separate drive output and bypass contactors (IEC). The contactors shall be electrically and mechanically interlocked.
- c) Shall provide a Drive/Off/Bypass selector switch, mounted on the enclosure door, for selection of Drive and Bypass modes of operation.
- d) Shall provide a Auto Bypass/Off/On selector switch, mounted on the enclosure door, for selection of Auto Bypass mode of operation.
- e) Provide a Class 10 overload for motor protection while operating in the bypass mode.

3. SMC Flex (RVSS) / Pump Option Bypass:

- a) Shall provide a means to switch a single motor from drive control to bypass via a soft start (across the line operation).
- b) Shall provide separate drive output and bypass contactors (IEC). The contactors shall be electrically and mechanically interlocked.
- c) Shall provide a Drive/Off/Bypass selector switch, mounted on the enclosure door, for selection of Drive and Bypass modes of operation.
- d) Provide a Class 10/20/30 overload for motor protection while operating in the bypass mode.
- e) Shall provide smooth deceleration when stopping in bypass mode.
- f) Shall provide a door-mounted HIM.
- g) Shall provide bypass fusing on input of RVSS bypass unit.

F. Control Power Transformer

1. Provide a control power transformer mounted and wired inside of the drive system enclosure.
2. The transformer shall be rated for the VFD power requirements.

G. Harmonic Mitigation Techniques

1. Drive Input Line Reactor

- a) Provide a drive input line reactor mounted within the drive system enclosure for drives that are less than 100 horsepower.
- b) The line reactor shall meet the following specifications:
 - i. The construction shall be iron core with an impedance of (3 or 5) percent ***[Choose one of the options, then delete the other and this text]***.
 - ii. The winding shall be copper or aluminum wound.
 - iii. The insulation shall be Class H with a 115 °C rise over 50 °C ambient.
 - iv. The unit shall be rated for system voltage, ampacity, and frequency.

2. 18-pulse VFD (greater than 100 horsepower) with Auto Transformer

- a) Provide VFD with a single 18-pulse converter.
 - i. The converter bridge shall be a parallel 18-pulse diode bridge assembly with DC snubber (board or assembly). Diodes shall be rated (devices) with a blocking voltage minimum of 1600V.
 - ii. The converter shall incorporate 1000V three phase block style MOV protection rated 85 °C.
- b) The drive system shall incorporate an 18-pulse phase shifting auto transformer with line reactor as an assembly. The 18-pulse assembly shall be wired into the VFD System enclosure where possible. The auto transformer shall have the following minimum features:
 - i. Rated for input rectifier duty and matched to VFD overload capability.
 - ii. Copper or aluminum wound.
 - iii. Class 180 or 220 insulation.
 - iv. Power factor of 0.98 or better at rated load and nominal line voltage.
 - v. Open core construction.
 - vi. One normally closed thermoswitch contact in each coil wired into a VFD control circuit.
- c) The drive system shall be compliant with IEEE519-1992 standards at the input VFD terminals based upon the input power phase imbalance within 0.5% of nominal line voltage and under full VFD output current ratings.

H. Auxiliary Relays

1. Provide relays for Drive Alarm, Drive Fault, Drive Run, and System Status Faults (as required).
2. The relays shall be Allen-Bradley 700-HC (two N.O. & two N.C.). The relay contacts shall be rated for 115V AC/30V DC, 5.0 amp resistive, 2.5 amp inductive.

I. Control Interface

1. The control terminals shall be rated for 115V AC.
2. The control interface shall provide input terminals for access to VFD functions that include start, stop, external fault, speed select, and enable, as required.

J. Motor Heater Control

1. The drive system shall provide the drive control circuitry to energize an existing motor heater whenever the motor is not running via remote power.
2. The heater control shall be interlocked with the drive and/or bypass and shall be energized whenever the motor is not running. The source shall be remotely provided.
3. A pilot light with LED (Allen-Bradley Bulletin 800T (30mm) or Bulletin 800F (22 mm), NEMA Type 4/13 **[Choose one of the options, then delete the other and this text]**) shall be mounted on the drive system enclosure door for indication of Motor Heater On.

K. Hand/Off/Auto Selector Switch

1. Provide a "Hand/Off/Auto" selector switch, mounted on the enclosure door.
2. The "Hand/Off/Auto" selector switch shall start the drive in the "Hand" mode and stop the drive in the "Off" mode.
3. In the "Auto" mode the drive shall be started and stopped from a remote "RUN" contact.
4. In all modes, Auxiliary and Enable inputs to the drive control interface board must be present before the drive will start.
5. When a HIM is present, the stop function shall always be available to stop the drive regardless of the selected mode ("Hand" or "Auto"). The HIM will be non-functional (except for the display and programming) when the switch is in "Off" mode. The HIM shall stop the drive if the switch is in the "Auto" mode with the remote start contact initiated.
6. The drive speed reference shall be controlled from the HIM, unless a separate door-mounted potentiometer is provided, when in "Hand" mode (factory default setting).
7. The drive speed reference shall be controlled by a remote 4...20 mA input when in "Auto" mode.
8. The device shall be an Allen-Bradley Bulletin 800T (30mm) or Bulletin 800F (22 mm) **[Choose one of the options, then delete the other and this text]**, NEMA Type 4/13, mounted on the drive system enclosure door.

L. Drive Disable Mushroom Push Button

1. Provide a maintained mushroom style push button, mounted on the enclosure door that when pushed, will open the drive enable input.
2. The device shall be an Allen-Bradley Bulletin 800T (30mm) or Bulletin 800F (22 mm) **[Choose one of the options, then delete the other and this text]**, NEMA Type 4/13, mounted on the drive system enclosure door.

M. Pilot Lights

1. Provide LED pilot lights, mounted on the enclosure door, for indication of the following status:
 - a) Run
 - b) Drive Fault
 - c) Control Power On
 - d) Motor Fault
2. The device shall be an Allen-Bradley Bulletin 800T (30mm) or Bulletin 800F (22 mm) **[Choose one of the options, then delete the other and this text]**, NEMA Type 4/13, mounted on the drive system enclosure door.

N. Motor Run Time Meter

1. Provide a digital, non-resettable, door-mounted elapsed time meter.
2. The meter shall be electrically interlocked with the Drive Run relay and Bypass contactor to indicate actual motor operating hours.

O. Output Filtering **[Choose one of the options, then delete the other and this text]**.

1. 3% output line reactor
2. 5% output line reactor
3. 1321 Reflected Wave Reduction (RWR) output filter
4. DV/DT output filter (may affect the system SCCR rating)

PART 3 EXECUTION

3.01 EXAMINATION

- A. Verify that location is ready to receive equipment.
- B. Verify that the building environment can be maintained within the service conditions required by the manufacturer of the VFD.

3.02 INSTALLATION

- A. Installation shall be in compliance with all manufacturer requirements, instructions and drawings.

3.03 START-UP SERVICE

- A. At a minimum, the start-up service shall include:
 1. Perform pre-Power Check
 2. Megger Motor Resistances: Phase-to-Phase and Phase-to-Ground
 3. Verify system grounding per manufacturer's specifications
 4. Verify power and signal grounds
 5. Check connections
 6. Check environment

- B. Drive Power-up and Commissioning:
 - 1. Measure Incoming Power Phase-to-Phase and Phase-to-Ground
 - 2. Measure DC Bus Voltage
 - 3. Measure AC Current Unloaded and Loaded
 - 4. Measure Output Voltage Phase-to-Phase and Phase-to-Ground
 - 5. Verify input reference signal
- C. All measurements shall be recorded.
- D. Drive shall be tuned for system operation.
- E. Drive parameter listing shall be provided.

3.04 TRAINING

- A. Manufacturer to provide a quantity of (__) (__) -hour sessions of on-site instruction.
- B. The instruction shall include the operational and maintenance requirements of the variable frequency drive.
- C. The basis of the training shall be the variable frequency drive, the engineered drawings and the user manual. At a minimum, the training shall:
 - 1. Review the engineered drawings identifying the components shown on the drawings.
 - 2. Review starting / stopping and speed control options for the controller.
 - 3. Review operation of the Human Interface Module for programming and monitoring of the variable frequency drive.
 - 4. Review the maintenance requirements of the variable frequency drive.
 - 5. Review safety concerns with operating the variable frequency drive.

END OF SECTION