

Guide Specification for
VARIABLE SPEED DRIVES with Optional Bypass

PART 1: GENERAL

1.01 SCOPE

- A. This specification describes the electrical, mechanical, environmental, agency and reliability requirements for three phase, variable speed drives as specified herein and as shown on the contract drawings.

1.02 REFERENCES

- A. The variable speed drives and all components shall be designed, manufactured and tested in accordance with the latest applicable standards.
1. Institute of Electrical and Electronic Engineers (IEEE)
 - a. IEEE 519-2014: Guide for harmonic content and control
 2. Underwriters Laboratories (UL508C: Power Conversion Equipment)
 - a. UL
 - b. cUL
 3. National Electrical Manufacturer's Association (NEMA)
 - a. ICS 7.0: Industrial Controls & Systems for VSDs.
 4. EN 61000-3-12, EN 61800-3 (1996) +A11 (2000) Category C2
 - a. Fulfill all EMC immunity requirements
- B. In case of conflict between the requirements of this section and those of the listed documents, the requirements of this section shall prevail.

1.03 SUBMITTALS

1.03.1 SUBMITTAL FOR REVIEW / APPROVAL

- A. The following information shall be submitted to the Engineer.
1. Dimensioned outline drawing.
 2. Control Schematic diagram.
 3. Power and control connection diagram(s)
- B. Submit four (4) copies of the above information.

1.03.2 SUBMITTAL FOR INFORMATION

- A. When requested by the Engineer the following product information shall be submitted:
1. Product bulletins
 2. Technical product data sheets
 3. Harmonic analysis result

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1.03.3 SUBMITTAL FOR CLOSE-OUT

- A. The following information shall be submitted for record purposes prior to final payment.
 - 1. Final as-built drawings and information for items listed section in 1.04.1.
 - 2. Installation information.

1.04 QUALIFICATIONS

- A. The supplier of the assembly shall be the manufacturer of the electromechanical power components used within the assembly, such as bypass contactors, power distribution circuit breakers, when specified. These parts, when specified, shall have a commonality with other manufacturer's products.
- B. For the equipment specified herein, the manufacturer shall be ISO 9001 certified.
- C. The supplier of this equipment shall have produced similar electrical equipment for a minimum period of ten (10) years. When requested by the Engineer, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.
- D. Variable Speed Drives shall be on the basis of Johnson Controls® VSD FP Series II for function and quality. Approved Equal: Eaton Electrical HMX, HVX and SVX Series.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

1.06 OPERATION AND MAINTENANCE MANUAL

- A. Five (5) copies of the equipment operation and maintenance manuals shall be provided.
- B. Operation and maintenance manuals shall include the following information:
 - 1. Instruction books
 - 2. Recommended renewal parts list.
 - 3. Drawings and information required by section 1.03.3

PART 2: PRODUCTS**2.01 VARIABLE SPEED DRIVES (VSD)**

- A. Where shown on the drawings, variable speed drives 1 through 125 HP shall have the following features:
 - 1. The VSDs shall be rated for 480 Vac (optional input voltages of 208 Vac through 50 HP, 230 Vac through 50 HP). The VSD shall provide microprocessor based control for three-phase induction motors. The controller's full load output current rating shall be based on variable torque application at 40° C ambient and 1.5-10 kHz switching frequency to reduce motor noise and avoid increased motor losses.

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2. The VSDs shall be of the Pulse Width Modulated (PWM) design converting the utility input voltage and frequency to a variable voltage and frequency output via a two-step operation. Adjustable Current Source VSDs are not accepted. Insulated Gate Bipolar Transistors (IGBTs) shall be used in the inverter section. Bipolar Junction Transistors, GTOs or SCRs are not accepted. The VSD shall run at the above listed switching frequencies.
3. The VSD shall have an MOV on the input side as standard.
4. The VSDs shall have efficiency at full load and speed that exceeds 97. The efficiency shall exceed 90% at 50% speed.
5. The VSDs shall maintain a minimum line side displacement power factor of 0.96, regardless of speed and load for VSDs less than 75 HP. The VSDs shall maintain a minimum line side displacement power factor of 0.99, regardless of speed and load for motors greater than 75 HP.
6. The VSDs shall have a one (1) minute overload current rating of 110% for variable torque applications.
7. The VSDs shall be capable of operating any NEMA design B squirrel cage induction motor, regardless of manufacturer, with a horsepower and current rating within the capacity of the VSD.
8. The VSDs shall have an integral EMI/RFI filter as standard.
9. The VSDs shall limit harmonic distortion reflected onto the utility system to voltage and current levels as defined by IEEE 519-2014 for general systems applications.
10. Any harmonic calculations shall be done based on the kVA capacity, X/R ratio and the impedance of the utility transformer feeding the installation, as noted on the drawings, and the total system load. The calculations shall be made with the point of common coupling (PCC) being the point where the utility feeds multiple customers.
11. Total harmonic distortion shall be calculated based on total demand distortion conditions as defined in IEEE 519-2014. Copies of these calculations are to be made available upon request. The contractor shall provide any needed information to the VSD supplier three (3) weeks prior to requiring harmonic calculations.
12. The system containing the VSDs shall comply with the 5% level of total harmonic distortion of line voltage and the line current limits as defined in IEEE 519-2014. If the system cannot meet the harmonic levels with the VSDs provided with the standard input line reactor or optional input isolation transformer, the VSD manufacturer shall supply an eighteen pulse, multiple bridge rectifier ac to dc conversion section with phase shifting transformer for all drives above 75 HP. This eighteen pulse rectifier converter shall result in a multiple pulse current waveform that will more nearly approximate a true sine wave to reduce voltage harmonic content on the utility line. The phase shifting transformer shall be of a single winding type to optimize its KVA rating and harmonic cancellation capability.
13. The VSDs shall be able to start into a spinning motor. The VSDs shall be able to determine the motor speed in any direction and resume operation without tripping. If the motor is spinning in the reverse direction, the VSDs shall start into the motor in the reverse direction, bring the motor to a controlled stop, and then accelerate the motor to the preset speed.

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14. Standard operating conditions shall be:¹
- a. Incoming Power: Three-phase, 208 / 230 / 480 (+10% to -10%) and 50/60 Hz (+10 to -5%) power to a fixed potential DC bus level.
 - b. Frequency stability of +/-0.05% for 24 hours with voltage regulation of +/-1% of maximum rated output voltage.
 - c. Speed regulation of +/- 0.5% of base speed.
 - d. Load inertia dependent carryover (ride through) during utility loss.
 - e. Insensitive to input line rotation.
 - f. Humidity: 0 to 95% (non-condensing and non-corrosive).
 - g. Altitude: 0 to 3,300 feet (1000 meters) above sea level.
 - h. Ambient Temperature: -10 to 40 °C (VT).
 - i. Storage Temperature: -40 to 70 °C.
15. Control Functions
- a. VSD software shall include energy optimization algorithm. The software algorithm shall compare output voltage to the motor load. The output voltage is optimized to reduce the motor core losses and maintain a high enough voltage to prevent the motor from becoming unstable.
 - b. VSD software shall include an onboard energy savings calculator that allows local kW cost to be used
 - c. Frequently accessed VSD programmable parameters shall be adjustable from a digital operator keypad located on the front of the VSD. Keypads must use plain English words for parameters, status, and diagnostic messages. Keypads that are difficult to read or understand are not accepted, and particularly those that use alphanumeric code and tables. Keypads shall be adjustable for contrast with large characters easily visible in normal ambient light.
 - d. The keypad shall include a Hand-Off-Auto membrane selection and an Inverter/Bypass membrane selection. When in “Hand” the VSD will be started and the speed will be controlled from the keypad. When in “Off”, the VSD will be stopped. In “Auto”, the VSD will start via an external contact closure or a communication network and the VSD speed will be controlled via an external speed reference.
 - e. The keypad shall have copy / paste capability.
 - f. Upon initial power up of the VSD, the keypad shall display a startup guide that will sequence all the necessary parameter adjustments for general start up.

¹ Consultant to choose correct system voltage

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- g. Standard advanced programming and trouble-shooting functions shall be available by using a personal computer's USB port and Windows® based software. In addition the software shall permit control and monitoring via the VSD's RS485 port. The manufacturer shall supply the required software. An easily understood instruction manual and software help screens shall also be provided. The computer software shall be used for modifying the drive setup and reviewing diagnostic and trend information as outlined in this section through section 18.
 - h. The operator shall be able to scroll through the keypad menu to choose between the following:
 - 1. Monitor
 - 2. Parameters
 - 3. Diagnostics
 - 4. I/O and Hardware
 - 5. User Settings
 - 6. Favorites
 - 7. Direct Access ID
 - i. The following setups and adjustments, at a minimum, are to be available:
 - 1. Start command from keypad, remote or communications port
 - 2. Speed command from keypad, remote or communications port
 - 3. Motor direction selection
 - 4. Maximum and minimum speed limits
 - 5. Acceleration and deceleration times, two settable ranges
 - 6. Critical (skip) frequency avoidance
 - 7. Torque limit
 - 8. Multiple attempt restart function
 - 9. Multiple preset speeds adjustment
 - 10. Catch a spinning motor start or normal start selection
 - 11. Programmable analog output
16. The VSD shall have the following system interfaces:
- a. Inputs – A minimum of six (6) programmable digital inputs, two (2) analog inputs shall be provided with the following available as a minimum:
 - 1. Remote HOA Hand/Off/Auto
 - 2. Remote forward/reverse
 - 3. Remote preset speeds
 - 4. Remote external fault

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5. Remote fault reset
 6. Process control speed reference interface, 4-20 mA DC
 7. Potentiometer or process control speed reference interface, 0 -10V DC
 8. RS485 programming and operation interface port
- b. Outputs – A minimum of two (2) programmable Form C relay outputs, (1) programmable Form A relay output, and (1) programmable analog output shall be provided, with the following available at minimum.
1. Programmable relay outputs selectable with the following available at minimum:
 - a. Fault
 - b. Run
 - c. Ready
 - d. Reversing
 - e. Preset Speed
 - f. At speed
 - g. Wrong Direction
 - h. Damper Control Relay
 - i. Over-temperature Alarm
 2. Programmable analog output signal, selectable with the following available at minimum:
 - a. Output frequency
 - b. Frequency reference
 - c. Motor speed
 - d. Output current
 - e. Motor torque
 - f. Motor power
 - g. Motor voltage
 - h. DC link voltage
 - i. PID controller set point value
 - j. PID controller output value
 - k. PID controller feedback value
 - l. PID controller error value
- c. Capability of two additional expandable I/O interface cards. Upon installation, software shall automatically identify the interface card and activate the appropriate parameters. This should be done without adding any new software.

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17. Monitoring and Displays

- a. The VSD's display shall be a multi-line graphic type window capable of displaying nine (9) lines of text and the following thirteen (13) status indicators:
 1. Run
 2. Forward
 3. Reverse
 4. Stop
 5. Ready
 6. Alarm
 7. Fault
 8. I/O Terminal
 9. Keypad
 10. Fieldbus
 11. Hand
 12. Auto
 13. Off
- b. The VSD's keypad shall be capable of displaying the following monitoring functions at a minimum and be able to monitor any nine of them on a single screen:
 1. Motor Speed (RPM and %)
 2. Analog Input 1
 3. Analog Input 2
 4. Output frequency
 5. Motor current
 6. Motor torque
 7. Motor power (kW and %)
 8. Motor voltage
 9. DC-link voltage
 10. Heat sink temperature
 11. Motor temperature
 12. Run time hours (resettable)
 13. Power on hours (resettable)
 14. Total megawatt hours
 15. Megawatt hours (resettable)

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16. Digital inputs status
17. Analog and relay outputs status
18. PID references
- c. The VSD's keypad shall be able to measure in the following units:
 1. Temperature in Fahrenheit
 2. Temperature in Celsius
 3. PSIG
 4. BAR
 5. FEET
 6. Inches of Water Column
 7. Gallons per Minute
 8. Feet per Minute
 9. Cubic Feet per Minute
 10. Parts per Million
 11. %
18. Protective Functions
 - a. The VSD shall include the following protective features at minimum:
 1. Overcurrent
 2. Overvoltage
 3. System fault
 4. Undervoltage
 5. Input line supervision
 6. Output phase supervision
 7. Undertemperature
 8. Overtemperature
 9. Motor stalled
 10. Motor overtemperature
 11. Motor underload
 - b. The VSD shall provide ground fault protection during power-up, starting, and running. VSDs with no ground fault protection during running are not accepted.
19. Diagnostic Features
 - a. Active Faults
 1. The last 10 faults shall be recorded and stored in sequential order.
 2. Fault code and description of fault shall be displayed on the keypad.

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3. Fault or alarm display shall blink
 4. Display drive data at time of fault (including date and time of occurrence)
 5. In the event several faults occur simultaneously, the sequence of active faults shall be viewable.
 6. During a fault, the drive must be able to identify the following:
 - a. Code
 - b. ID
 - c. State
 - d. Date
 - e. Time
 - f. Operating Time
 - g. Motor Current
 - h. Output Frequency
 - i. Output Voltage
 - j. DC-Link Voltage
 - k. Motor Control Status
 - l. Motor Temperature
 - m. Heat Sink Temperature
 - b. Fault History
 1. The last 40 faults shall be recorded and stored in sequential order.
 2. Display drive data (including date and time) at time of fault
20. Additional features included in the VSDs:¹
- a. A fused or non-fused device shall provide a disconnect means with provision for lockout. The handle position shall indicate ON and OFF condition. Operator shall be interlocked with cover to prevent opening with disconnect in the ON position.
 - b. A complete factory wired and tested bypass system consisting of an output contactor and bypass contactor that is electrically and mechanically interlocked. Both contactors must to be fully rated at the current of the drive and motor.
 - c. The VSD shall have an option to control the bypass via SA Bus communications.
 - d. Isolation switch to allow the VSD to completely disconnect all three phases from the line for maximum drive isolation.
 - e. The following indicating lights shall be provided on the keypad.

¹ Consultant to choose options required

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1. Drive/Bypass Ready (Flashing in Bypass Mode)
 2. Drive/Bypass Run
 3. Drive Fault
 - f. The current withstand rating of the drive shall be 100,000 AIC. For 480V input voltage and below, the combined withstand rating of drive and bypass must be 65,000 AIC or higher.
 - g. Communication card for interface with Johnson Controls Metasys[®] control system [N2 bus / XT bus / SA bus (BACnet[®] MSTP) or LonWorks[®]].
 - h. Communication capability via expansion card to support RS-485 (Johnson Controls Metasys-SA Bus)
 - i. The VSD shall have a cooling fan that is field replaceable using non-screw accessibility.
21. Enclosure¹
- a. Two-contactor design utilizing low voltage coils.
 - b. Drive and bypass fully integrated. Bypass configured between the control and power sections of the VSD.
 - c. HOA and bypass integrated into the keypad design.
 - d. The VSD and bypass shall be designed in a NEMA Type 1 or NEMA Type 3R enclosure to provide enhanced protection against radiated EMI/RFI.
 - e. The NEMA Type 3R enclosures shall come with conduit hole plugs for unused holes.
 - f. The NEMA Type 3R enclosures shall come with a space heater as standard.
 - g. The NEMA Type 3R enclosures shall be capable of integrating with air handlers to provide forced air cooling of the VSD as standard.
 - h. The VSD shall have complete front accessibility with easily removable assemblies.
 - i. Cable entry shall be top or bottom entry.
22. The VSD manufacturer shall maintain, as part of a national network, engineering service facilities within 250 miles of project to provide start-up service, emergency service calls, repair work, service contracts, maintenance and training of customer personnel.

PART 3: EXECUTION

3.01 FACTORY TESTING

- A. The following standard factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest version of UL and NEMA standards.

¹Specification writer to select as required

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1. All printed circuit boards shall be functionally tested via automatic test equipment prior to unit installation.
 2. All final assemblies shall be tested at full load with application of line-to-line and line-to-ground bolted faults. The Variable speed Drive shall trip electronically without device failure.
 3. After all tests have been performed; each VSD shall undergo a burn-in test. The drive shall be burned in at 100% inductive or motor load without an unscheduled shutdown.
 4. After the burn-in cycle is complete, each VSD shall be put through a motor load test before inspection and shipping.
- B. The manufacturer shall provide three (3) certified copies of factory test reports.
- C. All testing and manufacturing procedures shall be ISO 9002 certified.

3.02 FIELD QUALITY CONTROL

- A. Provide the services of a qualified manufacturer's employed Field Service Engineer or authorized service representative to assist the Contractor in installation and start-up of the equipment specified under this section. The manufacturer's service representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, installation as specified in manufacturer's installation instructions, wiring, application dependent adjustments, and verification of proper VSD operation.
- B. The following minimum work shall be performed by the Contractor under the technical direction of the manufacturer's service representative.
1. Inspection and final adjustments.
 2. Operational and functional checks of VSDs and spare parts.
 3. The contractor shall certify that he has read the drive manufacturer's installation instructions and has installed the VSD in accordance with those instructions.
- C. The Contractor shall provide three (3) copies of the manufacturer's field start-up report before final payment is made.

3.03 MAINTENANCE / WARRANTY SERVICE

- A. Standard warranty is thirty (30) months from the date of shipment and covers the factory repair or replacement of the defective unit.
- B. Warranty is thirty-nine (39) months from date of shipment when an authorized service representative performs start up and includes parts and labor.

3.04 FIELD TESTING

- A. Optional field testing

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1. The VSD manufacturer shall perform harmonic measurements at the point where the utility feeds multiple customers (PCC) to verify compliance with IEEE 519-1992. A report of the voltage THD and current TDD shall be sent to the engineer. The contractor shall provide labor, material, and protection as needed to access the test points. The readings shall be taken with all drives and all other loads at full load, or as close as field conditions allow.

3.05 TRAINING

- A. The Contractor shall provide a training session for up to __ owner's representatives for __ hours or __ normal workdays with a maximum of __ trips at a job site location determined by the owner. Training and instruction time shall be in addition to that required for start-up service.
- B. The training shall be conducted by the manufacturer's qualified representative.
- C. The training program shall consist of the following:
 1. Instructions on the proper operation of the equipment.
 2. Instructions on the proper maintenance of the equipment.