16269
Variable-Frequency Drives

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Change History

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<td>10/17/14</td>
<td>Add text to paragraphs B. #4 and B. #5 for clarity.</td>
<td>2 – 16269, B, #4 &amp; #5 (Variable Frequency Drives; System Design and Performance Requirements)</td>
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<td>Add text to paragraph #2. Add new paragraph #3 between current #2 and #3, with renumbering.</td>
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<td>10/17/14</td>
<td>Add Eaton/ Cutler-Hammer to the list of acceptable Manufacturers.</td>
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<td>4/19/13</td>
<td>Remove all from the Manufacturers List except ABB &amp; Yaskawa.</td>
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A. Summary

This section contains design criteria for variable-frequency drives (VFDs).
B. System Design and Performance Requirements

1. At a minimum, VFD performance must comply with IEEE 519-1992, or the latest standard, and with Yale University design standards, Section 15950: Energy Management and Controls Systems. (Refer to Section 01420: Consolidated Reference List.)

2. All VFDs must include pulse width modulated (PWM) technology, with diode bridge front ends and insulated gate bipolar transistors in the output sections that use soft switching.

3. Assign overall responsibility for coordinating compatibility in the specifications with either the VFD vendor or driven load motor vendor.

4. All VFD 10 to 50 HP must prove from harmonic calculation whether line reactors, filters, etc. should be used or not used based on:
   - The total harmonics voltage distortion is less than 3 percent.
   - The total harmonics current distortion is less than 5 percent at the power connection.
   - The total voltage distortion is less than 3 percent.
   - The total harmonics current distortion is less than 5 percent at the point of common coupling.

5. All VFDs for loads of 50 HP or higher shall use line reactors or be equipped with a VFD that uses a 12–18 pulse PWM or passive filter drive design.

6. Harmonics calculations for 50 HP and larger VFDs must prove that:
   - The total harmonics voltage distortion is less than 3 percent.
   - The total harmonics current distortion is less than 5 percent at the power connection.
   - The total voltage distortion is less than 3 percent.
   - The total harmonics current distortion is less than 5 percent at the point of common coupling.

7. All installations must include either an isolation transformer or line reactor. In areas sensitive to radiated energy, installed VFDs must be equipped with RFI filters.
8. For variable-torque applications, the VFD overload capability must be 110 percent, for one minute in every 10 minutes, of the inverter current rating. For constant-torque applications, the VFD overload capability must be 150 percent, for one minute, of the inverter current rating. VFDs shall have an adjustable current limit capability of up to 120% during acceleration, for accelerating high initial loads.

9. Provide a strip heater, ventilation fan, and supplemental cooling with automatic temperature control for outdoor and conditioned space applications.

10. All VFDs must have an adjustable carrier frequency range of 750 Hz to 15 kHz.

11. All VFDs must be equipped with AUTO restart for instances in which the power system returns to normal after a power line transient (overcurrent, overvoltage, or undervoltage) or outage. Their current limit set to motor nameplate amps during run, for automatic speed reduction to operate at, or less than, motor FLA to allow for trip-free operation.

12. All VFDs must have a minimum efficiency of 95 percent and a minimum power factor of 95 percent at full load.

13. All motors that are connected to VFD drives shall contain winding thermistors.

14. VFDs must have short-circuit capability to meet the highest short-circuit rating in its voltage class in the system. VFDs must have a minimum short circuit rating of 65 RMS kAIC (100 RMS kAIC with a DC bus reactor) without additional input fusing. All bypasses must include UL-listed short-circuit protection and separate UL-listed motor overload devices. DC bus as a supply to the VFD output section shall maintain a dixed voltage with filtering and short circuit protection utilizing a DC bus fuse for protection of VFD components in the event of any output failure.

15. The VFDs shall be capable of starting into a rotating load (forward or reverse) and accelerating or decelerating to setpoint without safety tripping or component damage (flying start).

16. The VFDs shall be equipped with an automatic extended control power loss ride through circuit, which shall utilize the inertia of the load to keep the drive powered.

17. The VFD shall be capable of sensing a loss of load (examples: broken belt, no water in pump) and signal the loss of load condition.

18. The VFD shall have programmable "Sleep" and "Wake up” functions to allow the drive to be started and stopped from the level of a process feedback signal.
C. Submittals

1. Designer Submittals
Submit calculations for VFD sizing. Size all VFDs based on the rated voltage at full-load amps. If the vendor requires de-rating of the VFD when running at maximum carrier frequency, then compensate by increasing the drive size.

2. Construction Documents

a. Product Data
   (1) Provide shop drawings including a power three-line drawing, a complete logic/controls diagram, and product data under provisions of the Contract Documents that apply to the work in this section.
   (2) Provide a list of all factory and field setpoint values.
   (3) Submit manufacturer’s installation instructions under provisions of the Contract Documents that apply to the work in this section.

b. Product Certificates Signed by Manufacturer
   (1) The VFD manufacturer is responsible for the cost of all equipment required to meet IEEE-519-1992, at no additional costs to the user. Equipment that can be provided includes AC input line reactors, DC bus reactors and/or harmonic trap filters. In order to determine what harmonic filtering equipment is required, the VFD manufacturer must conduct a harmonics analysis of the site prior to the bid.
   (2) For 50 HP or larger VFDs, provide harmonics analysis calculations based on system configuration, short-circuit availability, and full load application.
   (3) Vendor shall provide harmonic analysis calculations if the total HP of all VFDs exceeds 40 HP. These calculations shall be based on full load applications.
   (4) Harmonic analysis shall be required for VFD submittal review.
c. Test Reports
   (1) Provide a copy of the factory check and test report.
   (2) Provide a copy of the field check and test report with parameters setting values.
   (3) Provide total harmonic current distortion and total harmonic voltage and current distortion test results.

d. Operations and Maintenance Data
   Provide complete operation, troubleshooting, and maintenance information in the operation and maintenance manual.
   (1) Submit operation and maintenance data under provisions of the Contract Documents that apply to the work in this section.
   (2) Include assembly views and replacement parts lists.

D. Quality Assurance
   1. Manufacturer’s specializing in manufacture, assembly, and field performance of VFDs must have at least ten (10) years experience.

E. Product Standards
   1. VFDs, with all options, must be UL listed as a complete assembly.
   2. Products must conform to IEEE 519-1992, NEMA, or the latest standard, and IEC 16800 Parts 1 & 2.

F. Manufacturers
   1. VFDs must be ISO 9001 certified, furnished in accordance with Yale University design standards, Section 15950: Energy Management and Controls Systems, and installed by the electrical contractor.
   2. Subject to compliance with the design requirements, provide products by one of the following manufacturers:
      ABB
      Eaton/Cutler-Hammer
      Yaskawa
Yale University Design Standards  
Section 16269: Variable-Frequency Drives

3. Other models must be approved by Utilities / Engineering.

G. Materials

All VFDs and VFD accessories must be contained in a single metal enclosure. Refer to standards section 16130 – Raceways and Boxes for NEMA enclosure requirements. As a minimum, use a NEMA 12 enclosure for mounting VFDs in a supply air or humid equipment room.

H. Equipment

1. VFDs must be capable of being isolated for maintenance during bypass mode operations. Use magnetic transfer contactors to control the bypass remotely and locally.
2. Provide at least two critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed.
3. Provide at least two programmable digital contact relay outputs for status and alarms. Relays shall be capable of programmable on and off delay times.
4. Provide five programmable digital inputs for interfacing with external devices.
5. Provide at least two programmable preset digital inputs for preset speed selection.
6. Provide two independently adjustable acceleration and deceleration ramps. The VFD shall Ramp or Coast to a stop, as selected by the user.
7. Provide a communication protocol that is compatible to Yale such as Johnson Control on ALS building automation system; programmed to interface the driver to the Johnson Controls Metasys and/or automatic logic control design. Use the latest manufacturer’s communication protocol.
8. Provide a manual speed control potentiometer and Hand/Off/Auto selector.
9. Two (2) programmable analog inputs shall accept a current or voltage signal for speed reference, or for reference and actual (feedback) signals for PID controller.
10. One (1) programmable analog output proportional to frequency, motor speed, output voltage, output current, motor torque, motor power (kW), DC bus voltage, active reference, and other data.
11. Seven (7) programmable preset speeds.
12. All VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating.

13. The VFDs shall utilize pre-programmed application macros specifically designed to facilitate start-up.

14. All VFD installations must be equipped with a micro-processor PID controller that will allow a pressure or flow signal to be connected to the VFD.

15. If the input reference (4-20mA or 2-10V) is lost, the AFD shall give the user the option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued, as selected by the user.

16. The customer terminal strip shall be isolated from the line and ground.

17. VFDs must provide the following minimum protections:
   - DC bus under-voltage
   - Over-current
   - Ground fault
   - DC bus over-voltage
   - Controller over-temperature
   - Overload
   - Motor stall
   - Over-frequency
   - Single phase

18. VFDs must provide the following minimum operator controls and digital displays:

   b. Switch selectable Auto Transfer to bypass, Safety Interlock circuit and BAS Interlock circuit functions.

   c. Normal/Test selector keys, shall allow testing and adjustment of the VFD, while the motor is running in the bypass mode.
d. Hand/Off/Auto selector keys shall provide the following operation common to both VFD and bypass modes of operation:
   - **Hand Position** – The drive is given a start command, operation is via the local speed input (digital operator/keypad). If in bypass mode, the motor is running.
   - **Off Position** – The start command is removed, all speed inputs are ignored, power is still applied to the drive. If in bypass mode, the motor is stopped.
   - **Auto Position** – The drive is enabled to receive a start command and speed input from a building automation system. If in bypass mode, the motor start/stop is controlled by the building automation system.

   - Damper control circuit with end of travel feedback capability
   - Run/Stop selection with LED indication
   - Speed control setting with LED indication
   - Frequency meter
   - Motor RPM
   - Ammeter
   - DC Output voltage
   - Elapse time meter (resettable)
   - Calculated Motor Torque
   - Output Voltage
   - Heatsink Temperature
   - Analog Input Values
   - Analog Output Value
   - Keypad Reference Values
   - kWh meter (resettable)
   - Digital input status
   - Digital output status
19. Serial Communications
   a. The VFD shall be able to communicate with PLC’s, DCS’s, and DDC’s. VFDs shall have embedded Building Automation System (BAS) protocols for network communications; Johnson Metasys N2, Siemens System 600 APOGEE, and Modbus/Memobus. These protocols shall be accessible via a RS-422/485 communication port.
   b. Serial communications capabilities shall include, but not be limited to, run-stop control; speed set adjustment, proportional/integral/derivative PID control adjustments, current limit, and accel/decel time adjustments. The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed/frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), relay outputs, and diagnostic warning and fault information. Additionally, remote (LAN) VFD fault reset shall be possible. A minimum of 15 field parameters shall be capable of being monitored.
   c. The VFD’s shall allow the DDC to control the drive's digital and analog outputs via the serial interface. The serial communications interface shall allow for DO (relay) control and AO (analog) control. In addition, all drive digital and analog inputs shall be capable of being monitored by the DDC system.
   d. The VFD’s shall have the capability of accepting fiber optic cables for connection to standard ABB fieldbus adapters. Communications between the drive and fieldbus adapters shall be at 1 Mega Baud.
   e. The VFD shall be connectable to a PC based software tool capable of operating, programming, and monitoring the drive as well as diagnosing faults.

I. Accessories or Special Features
   1. Customer Interlock Terminal Strip.
   2. Door interlocked disconnect or circuit breaker, padlockable in off position.
   3. Manual Transfer to line power via contactors and including class 20 bimetal motor thermal overload relays and fuse or circuit breaker protection while in bypass operation complete with automatic bypass capability.
   4. For VFD’s on air systems using smoke isolation dampers and/or on 100 % Outside Air Systems, provide auxiliary contacts so when the fan motor is commanded on in either the normal (hand or auto) or bypass positions, the VFD shall not ramp or bypass contactor pull in until a permissive contact closure (from a damper end switch) is supplied to the VFD proving the smoke isolation dampers and/or the Outside Air dampers are open.
J. Special Requirements
1. Deliver products to site under provisions of the Contract Documents that apply to the work in this section.
2. Store and protect products under provisions of the Contract Documents that apply to the work in this section.

K. Quality Control Testing
1. All printed circuit boards shall be completely tested and burned-in before being assembled into the completed VFD. The VFD shall then be subjected to a computerized systems test (cold), burn-in, and computerized systems test (hot). The burn-in shall be at 104°F (40°C), at full rated load.
2. All testing and manufacturing procedures shall be ISO 9001 certified.

L. Installation Guidelines
1. Install Variable Frequency Drives in accordance with manufacturer’s instructions. VFD installation and power wiring shall be the responsibility of the Electrical Contractor. VFD LV instrument, control wiring and piping shall be the responsibility of the Mechanical Contractor.
2. Provide four-inch concrete mounting pads for outdoor or mechanical room floor installations. The distance between the VFD and the load must be as close as practicable. If the distance is more than 50 feet, consult with the VFD and electric motor vendors to determine whether an output filter is required.
3. Use a metallic conduit for all power wiring.
4. Provide a dedicated ground conductor from the power source to the VFD and from the VFD to the motor.
5. Do not install VFDs in a plenum or on air handlers, unless the drives are equipped with vibration isolators. Do not install VFDs near corrosive areas.
6. Maintain the minimum clearance between VFD cabinets recommended by the manufacturer.
7. Use twisted-pair and shielded control cables for all analog and serial communication wiring.
8. Use dedicated conduit for power wirings.
9. Use dedicated conduit for all control/communication signal inputs.
10. Use dedicated conduit for all control/communication signal outputs.
11. On installations that require a disconnecting means a motor disconnect switch shall be furnished with a “pre-break” auxiliary contact on the disconnect switch to disable the run permissive circuit.

M. Startup and Training

1. Warranty and Startup Services
   a. The VFD manufacturer shall provide a start up service package for all VFDs provided. Service shall include inspection, final adjustment, operational checks, and a final report for record purpose. Start Up service shall be performed by a factory approved and certified technician.
   b. To be included with start up service, for a period of 36 months after initial start up, the VFD manufacturer shall include a full parts and labor on-site warranty at no additional costs.
   c. VFD manufacturer shall conduct on-site Harmonic measurements before and after start-up of the VFD's. Results of the measurements showing harmonic contribution of VFD's shall be provided to the Engineer one month after start up.

2. Harmonic Testing
   After the factory service engineer has properly tested and started the VFD (see Startup and Training), the contractor must provide an independent testing contractor to conduct harmonic testing. The testing contractor must furnish readings with printouts of the total harmonic current distortion at each harmonic, as well as the total voltage and current distortion. These readings must be taken as described in subparagraphs 1 and 2 below.
   a. At each point of common coupling:
      • With VFDs running at full load
      • With all VFDs off
b. At each VFD power connection:
   • With the VFD running at full load
   • With the VFD off

3. Training
   Provide Yale University’s operations personnel with one day of on-site training delivered by a factory-certified representative.
A. Summary

This section contains design criteria for transient voltage surge suppression (TVSS) systems incorporated in unit substation switchboards, independent switchboards, or panels rated at 600 volts or less.
B. System Design and Performance Requirements

1. The TVSS shall be integral or external with the panelboard or switchboard and shall be installed or shipped loose along with the switchboard or panelboard from the manufacturer’s factory. These units shall be a solid state design, parallel-connected, sine-wave tracking suppress and filtering modules.

2. The TVSS shall be designed in accordance with NEMA Standard LS 1 and UL 1449 Second Edition.

3. The system shall provide protection in the following modes:
   a. Main distribution boards or panels: Normal mode suppression line to line, line to neutral, common mode suppression line to ground and neutral to ground except ungrounded delta configuration.
   b. Branch distribution panels or switchboards: Normal modes of protection in a 3 phase WYE system are L/N, L/G and N/G. These modes are prevalent throughout the Yale Facilities electrical system and each is a potential pathway for surge activity. Each shall be protected.

4. The system design shall be tested to withstand a minimum of 10,000 Category C3 (10kA, 20 kV) Bi-wave surges.

5. The TVSS shall have a surge current rating based on exposure curves and not necessarily uniform throughout our buildings on campus. Where used at service entrances, consideration should also be given to protect against temporary overvoltage and power surge events.

6. The noise filtering shall reject a minimum of 41 dB at 100 kHz. The frequency bandwidth of all noise attenuation shall be from 10 kHz to 400 MHz.

7. Protection modes and UL1449SVR for Grounded WYE circuits should be as follows: L/N: 400V@208Y/120V and 900V @480Y/277V; L/G: 500V@208Y/120V and 1000V @480Y/277V; N/G: 500V @208Y/120V and 900V @480Y/277V.

8. The listed AIC rating of TVSS shall be no less than the system available short circuit rating at the point of TVSS installation per a Short Circuit Study.

9. An integral disconnect switch or circuit breaker is required for TVSS isolation.
C. Submittals

Warranty
Manufacturer shall warranty the entire system against defective materials and workmanship for a period of five (5) years from date of Substantial Completion including the field service to repair or replace components at no cost to the owner.

Construction Documents
1. Submit the following construction documents:
   a. Shop drawings and product data
   b. Operation and maintenance instructions.
2. Material Certified Test Reports Signed by Manufacturer
   a. Maximum Surge Current Test Reports demonstrating that the TVSS has been tested to the specified rating. Reports shall clearly demonstrate that the tests have been performed on a complete system including fusing and monitoring.
   b. Provide test data demonstrating that the TVSS is capable of surviving the minimum specified repetitive rating.
   c. Provide test reports demonstrating that the TVSS has been tested to the specified AIC rating.

D. Product Standards
Products shall conform to the following standards:
1. Refer to Section 01064 Electrical Regulatory and Directive Standards.
2. L 1449 2nd edition Transient Voltage Surge Suppressors and UL 1283 Electromagnetic Interference Filters.
3. NEMA LS 1, “Low Voltage Surge Protection Devices”.
5. ISO 9001 certified manufacturer.

E. Manufacturers
Subject to compliance with the design requirements, provide products by one of the following manufacturers:

1. General Electric
2. Square D
3. Eaton
4. Libert
5. Current Technology

F. Equipment
TVSS shall include the following provisions:

1. LED indication lights for phase and protection status.
2. Audible alarm, with silencing button, to indicate when the protection has failed.
3. A surge event six–digit counter with reset push button.
4. One set of normally closed or normally open dry contact rated 5 A and 250 VAC for remote monitoring of protection status. Coordinate the communication protocol with power monitoring system or building monitoring system.

G. Extra Materials
1. If the TVSS is a modular construction, provide one of each type and size spare module.
H. Quality Control Testing

1. Test TVSS per above mentioned product standards.
2. Perform completely quality control checks before shipment.
3. Test TVSS to verify the surge current rating of 250 kA per phase.
4. Test TVSS to prove that it has the capability of surviving 10,000 Category C3 bi-wave impulses without failure per IEEE C62.41 Standard.
5. Provide test data to demonstrate that the TVSS have a short circuit rating of 250 kAIC.

I. Installation Guidelines

1. The leads length between the TVSS and the protected load shall be kept as close (short) as possible. In applications that exceed 6 feet in termination length, use of a low impedance cable is required. One example of this type of cable is HPI cable, manufactured by Current Technology.
2. Install TVSS at service entrance on load side for all 480V systems, with ground lead bonded to service entrance ground. TVSS shall be installed for all services that have 200 amps or above.
3. Install TVSS for panelboard or auxiliary panels, do not bond neutral and ground.

J. Field Quality Control

1. After installing TVSS, but before electrical circuitry has been energized, test for compliance with requirements.
2. Complete startup check according to manufacturer’s written instructions.
3. Perform each visual and mechanical inspection and electrical test stated in NETA ATS, “Surge Arresters, Low-Voltage Surge Protection Devices” Section.
4. Remove and replace malfunctioning units or components and retest as specified above.

End of Section