

SECTION 26 29 23
LOW-VOLTAGE ADJUSTABLE FREQUENCY DRIVE SYSTEM

PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Electronic Industries Alliance (EIA): 359-A-1, Special Colors.
2. Hydraulic Institute Standards (HIS).
3. Institute of Electrical and Electronics Engineers (IEEE):
 - a. 112, Standard Test Procedure for Polyphase Induction Motors and Generators.
 - b. 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
 - c. C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
4. National Electrical Manufacturer's Association (NEMA):
 - a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
 - b. CP 1, Shunt Capacitors.
 - c. MG 1, Motors and Generators.
 - d. WC 57, Standard for Control, Thermocouple Extensions, and Instrumentation Cables.
5. National Fire Protection Association (NFPA): 79, Electrical Standard for Industrial Machinery.

1.02 DEFINITIONS

A. Terms that may be used in this section:

1. AFD: Adjustable frequency drive. Variable frequency drive (VFD) is used interchangeably with ASD.
2. CMOS: Complementary metal oxide semiconductor.
3. CSI: Current source inverter.
4. EMU: Energy monitoring unit.
5. GTO: Gate turn-off thyristor.
6. MPR: Motor protection relay.
7. MTBF: Mean time between failure.
8. PWM: Pulse width modulation.
9. ROM: Read only memory.
10. RTD: Resistance temperature detector.
11. RTU: Remote Telemetry Unit.
12. Rated Load: Load specified for equipment.

13. Rated Speed: Nominal rated (100 percent) speed specified for equipment.
14. TDD: Total demand distortion.
15. THD: Total harmonic distortion.
16. TTL: Transistor transistor logic.

1.03 SYSTEM DESCRIPTION

A. Requirements:

1. Rated Continuous Operation Capacity: Not less than 1.15 times full load current rating of driven motor, as indicated on motor nameplate, and suitable for continuous operation at full load torque for greater than 3 hours.
2. For drives operating motors 25 hp and larger, furnish isolating phase shifting transformers for 18-pulse operation.
3. For drives operating motors greater than or equal to 7.5 hp and less than 25 hp provide 18-pulse or 12-pulse with passive filtering on the line side of the drive with contactors to remove capacitors from circuit when drive is less than 30 percent loaded.
4. For drives operating motors greater than or equal to 1/2 hp and less than 5 hp provide 3 percent line reactors.
5. HVAC drives less than 10 hp can use 12-pulse drives but must be heavy-duty rated for constant torque, not variable torque rated.
6. Furnish necessary devices and circuits to prevent operation of one drive from adversely affecting operation of other drives supplied from same transformer or same bus.

B. Design Requirements:

1. Drive system consisting of adjustable frequency controller, drive motor, auxiliary items, and components necessary for complete operating system. Coordinate drives with process mechanical vendors to ensure proper operation and configuration.
2. Other equipment is being powered from same bus as adjustable frequency drives. Ensure proper operation of drives and other loads under normal and emergency conditions.
3. Furnish AFDs rated on basis of actual motor full load nameplate current rating times the service factor and for continuous operation of longer than 3 hours at full rated torque of the motor served. Do not derate for variable torque loads.
4. Drive System: Convert incoming three-phase, 60-Hz ac power to variable voltage, adjustable frequency output for adjustable speed operation of a standard ac induction squirrel-cage motor, using pulse-width-modulation (PWM) technique to produce adjustable frequency output.

5. System rated for continuous industrial duty (100 percent rated torque for greater than 3 hours of operation) and suitable for use with NEMA MG 1, Design B motors.
6. Incoming Line Circuit Breaker: Provide positive means of disconnecting incoming power, and overcurrent protection for drive system.

C. SERVICE CONDITIONS

1. Ambient Operating Temperature: 32 degrees F to 104 degrees F.
2. Storage Temperature: Minus 40 degrees F to 158 degrees F.
3. Humidity: 0 percent to 95 percent relative (noncondensing).
4. Altitude: See Section 01 67 00, Product Requirements
5. Frequency Stability: Plus, or minus 0.1 percent of maximum frequency.

1.04 SUBMITTALS

A. Action Submittals:

1. Controller dimensional drawings; information on size and location of space for incoming and outgoing conduit.
2. Maximum heat dissipation from enclosure and clearances required.
3. Layout of controller face showing pushbuttons, switches, instruments, and indicating lights.
4. Complete system operating description.
5. Complete system schematic (elementary) wiring diagrams.
6. Complete system interconnection diagrams between controller, drive motor, and related components or controls external to system, including wire numbers and terminal board point identification.
7. One-line diagram of system, including component ratings.
8. Description of diagnostic features being provided.
9. Descriptive literature for control devices such as relays and timers.
10. Itemized bill-of-materials listing system components.
11. Specific description of provisions, such as filtering and harmonic suppression, being used.
12. Anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Software Submittals:

1. Submit preliminary configuration including standard configurations.
2. Submit final configuration for all devices for the Project, I/O signals, all controls, and any other configuration required for implementation.
3. Final Documentation included as part of the O&M data.

C. Informational Submittals:

1. Statement of Supplier qualifications.
2. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
3. Special shipping, storage and protection, and handling instructions.
4. Manufacturer's printed installation instructions.
5. Factory functional test reports.
6. Certified copy of test report for identical motor tested in accordance with NEMA MG 1-12.53a and IEEE 112, Test Method B, showing rated load, rated speed efficiency meeting or exceeding specified values; motors not as specified will be rejected.
7. Field test reports.
8. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection and Testing.
9. Suggested spare parts list to maintain equipment in service for period of 1 year. Include list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
10. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
11. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
12. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 79 00, Demonstration and Training.

1.05 QUALITY ASSURANCE

- A. Supplier: Minimum 5 years' experience in furnishing similar size and type adjustable frequency, controlled speed, drive systems.

1.06 EXTRA MATERIALS

- A. Furnish, tag, and box for shipment and storage the following spare parts:
1. Fuses: One complete set of spare fuses of each current rating, both power and control.
 2. Lights: One complete set of spare indicating lights.
 3. Paint: One pint, to match enclosure exterior finish in color and quality.

PART 2 PRODUCTS

2.01 PHYSICAL CHARACTERISTICS

- A. The maximum allowable footprint for a configured drive system, including phase-shift transformers, filters, reactors, contactors, drive, and all appurtenances, shall be 36 inches wide by 26 inches deep by 105 inches tall.

2.02 FUNCTIONAL CHARACTERISTICS

- A. Rated Continuous Operation Capacity: All drives shall be rated not less than 1.15 times full load current rating of driven motor, as indicated on motor nameplate, and suitable for continuous operation at full load torque for greater than 3 hours.
- B. Drives operating motors 25 hp and larger, furnish isolating phase shifting transformers for 18-pulse operation.
- C. Drives operating motors greater than or equal to 7.5 hp and less than 25 hp provide 18-pulse or 12-pulse with passive filtering on the line side of the drive with contactors to remove capacitors from circuit when drive is less than 30 percent loaded.
- D. For drives operating motors greater than or equal to 1/2 hp and less than 7.5 hp provide 3 percent line reactors.
- E. HVAC drives less than 10 hp can use 12-pulse drives but must be heavy-duty rated for constant torque, not variable torque rated.
- F. Furnish necessary devices and circuits to prevent operation of one drive from adversely affecting operation of other drives supplied from same transformer or same bus.
- G. Adjustable current source AFD's are not acceptable.
- H. Drives packages shall have a listed interrupting rating of 65,000 amps symmetrical.

2.03 PERFORMANCE CHARACTERISTICS

- A. The harmonics introduced by the adjustable frequency drives at the point of common coupling (PCC) shall meet the requirements of IEEE 519-2014 for General Systems. For purposes of this specification the PCC shall be the termination of the 480 volt utility feeder to the facility first point of disconnect. All drives shall have manufacturer documented maximum total current distortion of 5 percent to ensure harmonic compliance.
- B. The power system has a standby diesel generator rated 1,250 kW at 0.8 PF. In addition to the paragraph above, the harmonic distortion shall meet the distortion levels shown in Table 2 of IEEE 519-2014 for ISC/IL<20. The contractor shall provide the following data for the standby generator in order to perform the calculations: Voltage, kW, kVA and Subtransient Reactance (X"d), and total maximum demand ampere load for generator operation.

- C. A harmonic analysis of the system shall be made consisting of the current and voltage harmonics expected from the addition of the adjustable frequency drives for all harmonics through the 50th per tables 1 and 2 of IEEE 519-2022 except that the allowable voltage THD at less than 1,000 volts shall be 5 percent. This analysis shall be included as part of the bid submittal.
- D. The phase-shifting transformer shall be a single wound transformer rated 480 Volts with a UL recognized 180 degree C insulation system. Required performance shall be obtained without exceeding a temperature rise in a 50 degree C ambient below 250 hp and for 40 degrees C maximum ambient above 250 hp.
- E. The use of 12-pulse rectifiers with harmonic traps is acceptable on drive supplying motors rated less than 25 hp. All system components including the rectifier and phase shifting transformer shall be integral to the drive enclosure and shipped from the factory as an assembly. Separate components do not meet the intent of this specification and will not be considered as equivalent.
- F. Drives rated less than 25 hp shall utilize an 18 pulse rectifier or a 12 pulse rectifier with passive filter. If a filter is used, the winding shall be copper with class H insulation rated 115 degrees C over 50 degrees C ambient. Capacitors shall have contactors that remove them from the circuit if the drive load drops below 30 percent.

2.04 COMPONENTS

- A. Drive Units:
 - 1. Incorporate switching power supply operating from dc bus, to produce PWM output waveform simulating sine wave and providing power loss ride through of 2 milliseconds at full load, full speed.
 - 2. Current-limiting semiconductor fuses for protection of internal power semiconductors.
 - 3. Employ diode bridge rectifier providing constant displacement power factor of 0.95 minimum at all operating speeds and loads.
 - 4. Use transistors for output section, providing a minimum 97 percent drive efficiency at full speed, full load.
 - 5. Employ dc power discharge circuit so that after removal of input power dc link capacitor voltage level will decay below 50 volts dc within 1 minute after de-energizing following NEMA CP 1 and NFPA 79. Design dc link capacitor for a MTBF of 5 years.
 - 6. Operate with open circuited output.
 - 7. Input Voltage: 480V ac plus or minus 10 percent.
 - 8. Output Voltage: 0 volt to 480 volts, three-phase, 0-Hz to 66-Hz, minimum.

9. Maximum peak voltage of PWM AFD output pulse of 1,000 volts, with pulse rise time of not less than 2 microseconds, and maximum rate of rise of 500 volts per microsecond. Carrier frequency of PWM AFD output pulse shall be adjustable from 2,000-Hz to 20,000-Hz.
10. Motor Audible Noise Level: When operating throughout speed range of PWM AFD, no more than 3 dBA above that designated in NEMA MG 1 for same motor operated at constant speed with a 60-Hz supply voltage.
11. Short-Time Overload Capacity: 150 percent of rated load in rms current for 1 minute following full load, full speed operation.
12. Equipment Short-Circuit Interrupting Rating: 65,000 amps symmetrical.
13. Furnish drives with output 3 percent load reactors mounted within equipment enclosure.
14. Diagnostics:
 - a. Comprehensive for drive adjustment and troubleshooting:
 - 1) Memory battery backup; 100-hour minimum during power loss.
 - 2) Status messages will not stop drive from running but will prevent it from starting.
 - 3) Fault Condition Messages and History: First fault protection function to be activated, ability to store six successive fault occurrences in order.
 - a) Minimum faults numerically:
 - (1) Overcurrent (time and instantaneous).
 - (2) Overvoltage.
 - (3) Undervoltage (dc and ac).
 - (4) Overtemperature (drive, motor windings, motor bearing, pump bearing).
 - (5) Serial communication fault.
 - (6) Short-circuit/ground fault (motor and drive).
 - (7) Motor stalled.
 - (8) Semiconductor fault.
 - (9) Microprocessor fault.
 - (10) Single-phase voltage condition.
15. Drive Protection:
 - a. Fast-acting semiconductor fuses.
 - b. Overcurrent, instantaneous overcurrent trip.
 - c. Dc undervoltage protection, 70 percent dropout.
 - d. Dc overvoltage protection, 130 percent pickup.
 - e. Overtemperature, drive, inverter, converter, and dc link components.
 - f. Overtemperature, motor, and pump.
 - g. Single-phase protection.
 - h. Reset overcurrent protection (manual or automatic reset).
 - i. Active current limit/torque limit protection.
 - j. Semiconductor fault protection.
 - k. Short-circuit/ground fault protection.

- l. Serial communication fault protection.
 - m. Microprocessor fault.
 - n. Surge protection for transient overvoltage (6,000 volts, 80 joule surge, tested per IEEE C62.41).
 - o. Visual display of specific fault conditions.
16. Operational Features:
- a. Use manufacturer's standard unless otherwise indicated.
 - b. Sustained power loss.
 - c. Momentary power loss.
 - d. Power interruption.
 - e. Power loss ride through (0.1 second).
 - f. Start on the fly.
 - g. Electronic motor overload protection.
 - h. Stall protection.
 - i. Slip compensation.
 - j. Automatic restart after power return (ability to enable/disable function).
 - k. Critical frequency lockout (three selectable points minimum, by 1.5-Hz steps in 10-Hz bands, to prevent resonance of system).
 - l. Drive maintenance system software for complete programming and diagnostics.
 - m. Ground fault protection, drive, and motor.
 - n. Operate with no motor connected to output terminals.
- B. Rectifier: Three-phase 18-pulse full wave diode bridge rectifier to provide constant dc voltage to drive's dc bus.
- 1. Provide 6-pulse and 12-pulse diode bridge rectifiers where allowed by these specification requirements.
- C. Input Filter:
- 1. For 6-pulse drives (where allowed) provide 3 percent line reactors.
 - 2. For 12-pulse drives (where allowed) provide passive filters with capacitor drop out contactors below 30 percent of rated load.
 - 3. Reactors and filters shall be housed in AFD/MCC enclosure.
- D. Output Filter:
- 1. Provide 3 percent output line reactor for applications with motor lead lengths less than 300 feet.
 - 2. Provide output dV/dT filter for drives with motor lead lengths 300 feet and longer. Filter shall include energy recovery clamping circuit to reduce voltage drop at motor.
 - 3. Filter shall be housed in AFD enclosure, or in same MCC compartment as AFD.

- E. Furnish series choke and capacitors on dc bus to reduce ripple in rectifier output and to reduce harmonic distortion reflected into incoming power feeders.
- F. Controller: Microprocessor-controller PWM inverter to convert to dc voltage to variable voltage, adjustable frequency, three-phase ac output. Output voltage shall vary proportionally with frequency to maintain constant ratio of volts to hertz up to 60-Hz; above 60-Hz, voltage shall remain constant with drive operating in constant horsepower output mode.
- G. Enclosure:
 - 1. Interior to Motor Control Centers where shown on the Drawings: See Section 26 24 19, Low-Voltage Motor Control.
 - 2. Cable termination compartment door interlocked main circuit breaker, defeatable (lockable in the open position), alphanumeric keypad and display, and operator's controls.
 - 3. Size forced-ventilation for periodic operation to cool each unit with maximum room ambient temperature of 95 degrees F. Furnish redundant fans such that if one fan fails remaining fans furnish adequate ventilation for drive when operating at maximum capacity. Furnish filters on ventilation intakes.
 - 4. Wiring:
 - a. Bundle stranded copper wiring neatly with nylon tie wraps or with continuous plastic spiral binding.
 - b. Label each terminal for permanent identification of leads.
 - c. Identify each wire at each end with imprinted mylar adhesive-back wire markers.
 - d. Incorporate in as-installed wiring diagrams for wire and terminal numbers shown.
 - e. Wiring across door hinge, use 19-strand, NEMA WC 57 Class C stranding looped for proper twist rather than bending at hinge.
 - f. Wire connections internal to panels by crimp-on terminal types.
 - g. For multiple enclosure systems, complete interconnection wiring with gasketed enclosure openings for wiring.
 - h. Multipoint plug receptacles for control wiring crossing equipment shipping splits.
 - 5. Selector switches, indicating lights, potentiometers, instruments, protective devices, and major system components identified by means of mechanically attached, engraved, laminated nameplates.

H. Operator Interface:

1. Controls:
 - a. Mount drive local control on front door of enclosure and include control switch and membrane type keypad for the following operator functions:
 - 1) Start (when in local mode).
 - 2) Stop (when in local mode).
 - 3) Speed increase (when in local mode).
 - 4) Speed decrease (when in local mode).
 - 5) Parameter mode selection (recall programmed parameters).
 - 6) LOCAL/OFF/REMOTE control selection (in remote, furnish for remote RUN command digital input and speed increase/decrease via remote 4 mA to 20 mA analog signal).
 - 7) Fault reset, manual for faults, except loss of ac voltage which is automatic upon return.
 - 8) RUN/preset speed.
 - 9) Parameter lock, password or key switch lockout of changes to parameters.
 - 10) Start disable, key switch or programmed code.
2. Control circuit disconnect shall de-energize circuits in units that are not de-energized by main power disconnect device.
3. 120 volts, single-phase, 60-Hz circuits for control power and operator controls from internal control power transformer. Furnish power for motor space heaters rated 120 volts.
4. Arrange component and circuit such that failure of a single component cannot cause cascading failure(s) of other component(s).
5. Alphanumeric Display:
 - a. During normal operation and routine test, the following parameters shall be available:
 - 1) Motor current (percent of drive rated current).
 - 2) Output frequency (Hertz).
 - 3) Output voltage.
 - 4) Running time.
 - 5) Local/remote indicator.
 - 6) Status of digital inputs and outputs.
 - 7) Analog input and output values.
 - 8) Output motor current per leg.
 - 9) All test points.
6. Adjustable Parameters:
 - a. Set drive operating parameters and indicate in numeric form. Potentiometers may not be used for parameter adjustment. Minimum setup parameters available:
 - 1) Frequency range, minimum, maximum.
 - 2) Adjustable acceleration/deceleration rate.
 - 3) Volts per Hertz (field weakening point).

- 4) Active current limit/torque limit, 0 percent to 140 percent of drive rating.
- 5) Adjustable voltage boost (IR compensation).
- 6) Preset speed (adjustable, preset operating point).
- 7) Provision for adjustment of minimum and maximum pump speed to be furnished as function of 4 mA to 20 mA remote speed signal.
- 8) Carrier frequency from 2-kHz to 20-kHz.

I. Signal Interfaces:

1. Digital Input:
 - a. As shown on the Control Diagrams on the Drawings.
 - b. 120V ac.
2. Digital Output:
 - a. As shown on the Control Diagrams on the Drawings.
 - b. 120V ac.
3. Analog Input:
 - a. As shown on the Control Diagrams on the Drawings.
 - b. 4 mA to 20 mA signal.
4. Analog Output:
 - a. As shown on the Control Diagrams on the Drawings.
 - b. 4 mA to 20 mA signal.
5. Network Communications:
 - a. An Ethernet Module shall be provided to communicate drive parameters to SCADA. Control will be done via hardwire signals as shown on the Control Diagrams on the Drawings.

J. Accessories:

1. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in readily visible location.
2. Lifting Lugs: Equipment weighing over 100 pounds.
3. Anchor Bolts: Sized by equipment manufacturer, and as specified in Section 05 50 00, Metal Fabrications.

2.05 FACTORY FINISHING

A. Enclosure:

1. Primer: One coat of rust-inhibiting coating.
2. Finish:
 - a. Interior: One coat white enamel.
 - b. Exterior: One coat manufacturer's standard gray enamel or EIA 359-A-1, No. 61.

2.06 SOURCE QUALITY CONTROL

- A. Factory Inspections: Inspect AFD's for required construction, electrical connection, and intended function.
- B. Factory Tests and Adjustments: Test all AFDs actually furnished.
- C. Record test data for report.
- D. Functional Test: Perform manufacturer's standard.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Install in accordance with manufacturer's printed instructions.

3.02 FIELD QUALITY CONTROL

- A. Functional Test:
 - 1. Conduct on each controller.
 - 2. Inspect controller for electrical supply termination connections, interconnections, proper installation, and quiet operation.
 - 3. Vibration Test:
 - a. Complete assembly, consisting of motor, load, and flexible shafting, connected and in normal operation shall not develop amplitudes of vibration exceeding limits recommended by HIS.
 - b. Where loads and drives are separated by intermediate flexible shafting, measure vibration both at top motor bearing and at two points on top pump bearing, 90 degrees apart.
 - 4. Record test data for report.
- B. Performance Test:
 - 1. Conduct on each controller.
 - 2. Perform under actual or approved simulated operating conditions.
 - 3. Test for continuous 12-hour period without malfunction.
 - 4. Demonstrate performance by operating continuous period while varying application load, as input conditions allow, to verify system performance.
 - 5. Record test data for report.

3.03 MANUFACTURERS' SERVICES

A. Manufacturer's Representative:

1. Present at Site or classroom designated by Contracting Officer for minimum person-days listed below, travel time excluded:
 - a. 2 person-days for installation assistance and inspection.
 - b. 2 person-days for functional and performance testing and completion of Manufacturer's Certificate of Proper Installation.
 - c. 1 person-day for prestartup classroom or Site training.
 - d. 1 person-day for facility startup.

- B. See Section 01 79 00, Demonstration and Training and Section 01 91 14, Equipment Testing and Facility Startup.

END OF SECTION

