26 29 23 - Low-Voltage Adjustable Frequency Drive System

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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26 29 23 - LOW-VOLTAGE ADJUSTABLE FREQUENCY DRIVE SYSTEM

PART 1 GENERAL

1.01 SCOPE

A. This section applies to all low voltage adjustable frequency drive systems provided for this project. Deviations from this section shall be listed in the driven equipment specification. Where such deviations occur, they shall take prescience over this section. All deviations shall be noted on the submitted materials.

B. This section covers the Work necessary to detail, manufacturer, deliver to the jobsite, including oversight to startup and test the adjustable frequency drive systems including equipment, appurtenances, and services as specified herein.

1.02 REFERENCES

A. The following Specification sections are referenced in this section:

1. Section 01 43 33, Manufacturers’ Field Services.
2. Section 01 78 23, Operation and Maintenance Data.
3. Section 05 50 00, Metal Fabrications.
4. Section 26 20 00, Low-Voltage AC Induction Motors.

B. The following is a list of standards referenced in this section:

1. Electronic Industries Alliance (EIA), Telecommunications Industry Association (TIA): 359-1, Special Colors.
2. 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 Electric Power Systems.
   c. C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
3. National Electrical Manufacturer’s Association (NEMA):
   a. CP 1, Shunt Capacitors.
   b. MG 1, Motors and Generators.
   c. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   d. WC-57, Control Cables.
1.03 DEFINITIONS

A. Terms that may be used in this section:

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

1.04 SYSTEM DESCRIPTION

A. Performance Requirements:

1. Composite drive/motor efficiency (CE) is defined as ratio of motor shaft kW to drive input kW. AFD system minimum composite efficiency requirements:
   a. At 60-Hz drive output and 100 percent load, CE = 92 percent.
   b. At 50-Hz drive output and 60 percent load CE = 89 percent.
   c. At 40-Hz drive output and 30 percent load CE = 84 percent.
   d. At 30-Hz drive output and 12.5 percent load CE = 77 percent.
2. Rated Continuous Operation Capacity: Not less than 1.15 times full load current rating of driven motor, as indicated on the motor nameplates, and suitable for continuous operation at any continuous overload which may be imposed on motor by driven pump operating over specified speed range.
3. Basis for Harmonic Computations: Using Simplified Plant One-Line Diagram for current and voltage distortion computations, furnish harmonic filters, line reactors, isolation transformers, or higher pulse converter arrangements required to meet current/voltage distortion limits.
4. Normal Source Current Harmonic Distortion:
   a. Compute normal source individual and total current harmonic
distortion at the drive power input terminals, in accordance with
IEEE Standard 519. Individual current harmonic distortion and
the total demand distortion expressed as percent of maximum
demand load current $I_L$ shall not exceed values specified in
Table 1 below:

<table>
<thead>
<tr>
<th>Individual Harmonic Order (Odd Harmonics)</th>
<th>Harmonic Current Distortion Percent of Max. Demand Load Current $I_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h &lt;11$</td>
<td>7.0</td>
</tr>
<tr>
<td>$11 h &lt;17$</td>
<td>3.5</td>
</tr>
<tr>
<td>$17 h &lt;23$</td>
<td>2.5</td>
</tr>
<tr>
<td>$23 h &lt;35$</td>
<td>1.0</td>
</tr>
<tr>
<td>$35 h$</td>
<td>0.5</td>
</tr>
<tr>
<td>Total Demand Distortion (TDD)</td>
<td>8.0</td>
</tr>
</tbody>
</table>

b. Limits specified in Table 1 are for drives utilizing 6-pulse
rectifiers. Should manufacturer propose 12-pulse rectifiers, limits
for characteristic harmonics can be increased by a factor of
1.41 times values listed in Table 1.

5. Normal Source Voltage Harmonic Distortion: Compute normal source
voltage harmonic distortion at the drive power input terminals THD
shall not exceed 5 percent, and individual voltage harmonic distortion
shall not exceed 3 percent.

6. Furnish isolating transformers or series reactors, harmonic filters, or
other devices necessary for proper system operation. 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.

7. When isolation transformers are used, design to meet K-factor
requirements of drive(s) connected.

B. Design Requirements:

1. Design and provide drive system consisting of adjustable frequency
controller, drive motor, certain auxiliary items, and components
necessary for complete operating system.
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.

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 the pulse-width-modulation (PWM) technique to produce the adjustable frequency output.

5. System rated for continuous industrial duty and suitable for use with Standard NEMA MG 1, Design B motors. System provided for use with a submersible pump shall be rated for continuous duty and suitable for use with the supplied motor.

6. Incoming Line Circuit Breaker or Fused Disconnect: Provide positive means of disconnecting incoming power, and overcurrent protection for the drive system. Disconnecting means shall be separate from the drive enclosure.

7. Incoming Line Reactor: Design to minimize harmonic distortion on the incoming power feeder.

1.05 SUBMITTALS

A. All submittal information shall be provided in English.

B. Approval Required Prior to Work Submittal:

1. Overall drive system operating data, including efficiencies, input currents, and power factors, at driven equipment actual load and rated system input voltage, at 0, 40, 60, 80, 100, and 110 percent of rated speed.

2. Individual and total harmonic content (voltage and current) reflected in system normal source supply at driven equipment actual load at 70 and 100 percent of rated speed at locations specified in Simplified Plant One-Line Diagram, and load conditions specified. Normal source system short-circuit available at drive shall be calculated from data furnished in Supplements to this section. Use TDD and THD factors as defined in IEEE Standard 519 to designate total harmonic content.

3. AFD output pulse maximum peak voltage, pulse rise time and pulse rate of rise, including any justification for proposed deviation from specified values. Include motor manufacturer’s certification that motor insulation will withstand long-term overvoltages caused at motor terminals due to specified output pulse data or any proposed deviation from this data.

4. Data on the shelf life of “dc link” capacitor.

5. Complete system rating, including all nameplate data, continuous operation load capability throughout speed range of 0 to 120 percent of rated speed.
6. Complete adjustable frequency controller rating coordinated with motor full load nameplate current rating; list any controller special features being supplied.

7. Controller, reactor, harmonic filter, and isolating transformer (if applicable) dimensional drawings; information on size and location of space for incoming and outgoing conduit.

8. Maximum heat dissipation from enclosure.

9. Should separate enclosures and equipment be necessary for filter elements or power factor correction equipment, provide complete dimensional information including location of space for incoming and outgoing conduit, weight, maximum heat loss, and minimum current carrying capacity and recommended wire size for required interconnecting circuits.

10. Layout of controller face showing pushbuttons, switches, instruments, indicating lights, etc.

11. Complete system operating description.

12. Complete system schematic (elementary) wiring diagrams.

13. Complete system interconnection diagrams between controller, drive motor, and all related components or controls external to system, including wire numbers and terminal board point identification.

14. One-line diagram of system, including component ratings.

15. Description of diagnostic features being provided.

16. Descriptive literature for all control devices such as relays, timers, etc.

17. Itemized bill-of-materials listing all system components.

C. For Information Only Submittals:

1. Statement of Supplier qualifications.

2. Special shipping, storage and protection, and handling instructions.

3. Manufacturer’s printed installation instructions.


5. Certified copy of test report for identical motor tested in accordance with NEMA MG 1-12.53a and IEEE Standard 112, Test Method B, showing rated load, rated speed efficiency meeting or exceeding specified values; motors not as specified will be rejected.

6. Field test reports.

7. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.

8. Suggested spare parts list to maintain equipment in service for a period of 5 years. Include a list of special tools required for checking, testing, parts replacement, and maintenance with current price information.

9. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.

10. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
11. Manufacturer’s Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers’ Field Services.

1.06 QUALITY ASSURANCE

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

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Components and accessories specified in this section shall be products of:

1. Danfoss.
3. ABB.
4. Or approved equal

2.02 SERVICE CONDITIONS

A. Ambient Operating Temperature:

1. Indoor Locations: 32 to 104 degrees F.
2. Outdoor Locations: Minus 23 to 113 degrees F.

B. Storage Temperature: Minus 40 to 158 degrees F.

C. Humidity: 0 to 95 percent relative (noncondensing).

D. Altitude: 0 to 3,300 feet.

E. Frequency Stability: Plus or minus 0.1 percent of maximum frequency.

2.03 COMPONENTS

A. Drive Units:

1. Incorporate a switching power supply operating from a dc bus, to produce a PWM output waveform simulating a 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 a diode bridge rectifier providing a 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 an open circuited output.

7. Input Voltage: 480V ac plus or minus 10 percent.

8. Output Voltage: 0 to 480 volts, three-phase, 0 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 a maximum rate of rise of 500 volts per microsecond. Maximum frequency of PWM AFD output pulse (carrier) frequency of 3,000 -Hz. Should magnitudes of these characteristics be more stressful to motor insulation than specified values, furnish insulation systems on the motors suitable for the proposed values.

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: 125 percent of rated load in rms current for 1 minute following full load, full speed operation.

12. Equipment Short-Circuit Rating: Suitable for connection to system with maximum source three-phase, bolted fault, short-circuit available of 42,000 amps rms symmetrical at 480 volts.

13. Diagnostics: Comprehensive for drive adjustment and troubleshooting:
   a. Memory backup; 100-hour minimum during a power loss.
   b. Status messages will not stop drive from running but will prevent it from starting.
   c. Fault Condition Messages and History: First fault protection function to be activated, ability to store six successive fault occurrences in order. 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.

14. Drive Protection:
   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.

15. 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 6-pulse full wave diode bridge rectifier to provide a constant dc voltage to the drive’s dc bus.

C. Furnish series choke and capacitors on dc bus to reduce ripple in rectifier output and to reduce harmonic distortion reflected into incoming power feeders.

D. Controller: Microprocessor-controlled PWM inverter to convert to dc voltage to variable voltage, adjustable frequency three-phase ac output. The output voltage shall vary proportionally with the frequency to maintain a constant ratio of volts to hertz up to 60-Hz. Above 60-Hz, the voltage shall remain constant, with the drive operating in a constant horsepower output mode.

E. Enclosures:
1. Indoor Enclosure: Manufacturer’s standard open frame or NEMA 250 Type 1 enclosure for wall/rack mounting, completely front accessible, and hinged access covers. Properly sized to dissipate heat generated by controller within limits of specified operating conditions (including ambient temperature and ambient airflow). Enclosure not to exceed dimensions shown on Drawings.

2. Outdoor Enclosure: NEMA 250 Type 3 gasketed dust-tight enclosure for wall/rack mounting, completely front accessible, and hinged access covers. Properly sized to dissipate heat generated by controller within limits of specified operating conditions (including ambient temperature and ambient airflow). Enclosure not to exceed dimensions shown on Drawings.

3. Furnish drive complete with cable termination compartment door, alphanumeric keypad and display, and operator’s controls.

4. Wire outdoor drives drive from below for power and control wiring. Wire indoor drives from above and/or below for power and control wiring.

5. Bundle stranded copper wiring neatly with nylon tie wraps or with continuous plastic spiral binding; label each terminal for permanent identification of leads; identify each wire at each end with heat shrink wire markers; incorporate in as-installed wiring diagrams for wire and terminal numbers shown; wiring across door hinges use 19-strand, NEMA WC-57 Class C stranding looped for proper twist rather than bending at hinge; wire connections internal to panels by crimp-on terminal types.

F. Operator Interface:

1. Controls: Mount drive local control on front of enclosure and include membrane type keypad for the following operator functions:
   a. Start (when in local mode).
   b. Stop (when in local mode).
   c. Speed increase (when in local mode).
   d. Speed decrease (when in local mode).
   e. Parameter mode selection (recall programmed parameters).
   f. LOCAL/OFF/REMOTE control selection (in remote, furnish for remote RUN command and speed increase/decrease via remote serial communications).
   g. Fault reset, manual for all faults (except loss of ac voltage which is automatic upon return).
   h. RUN/preset speed.
   i. Parameter lock (password or key switch lockout of changes to parameters).
   j. Start disable (programmed code).

2. 24 volt dc circuits for control power and operator controls from internal control power source.
3. Arrange component and circuit such that failure of any single component cannot cause cascading failure(s) of any other component(s).

4. Alphanumeric Display: During normal operation and routine test, the following parameters shall be available:
   a. Motor current (percent of drive rated current).
   b. Output frequency (Hertz).
   c. Output voltage.
   d. Running time.
   e. Local/remote indicator.
   f. Status of digital inputs and outputs.
   g. Analog input and output values.
   h. Output motor current per leg.
   i. All test points.

5. Adjustable Parameters: Set drive operating parameters and indicate in a numeric form. Potentiometers may not be used for parameter adjustment. Minimum setup parameters available:
   a. Frequency range, minimum, maximum.
   b. Adjustable acceleration/deceleration rate.
   c. Volts per Hertz (field weakening point).
   d. Active current limit/torque limit, 0 to 140 percent of drive rating.
   e. Adjustable voltage boost (IR compensation).
   f. Preset speed (adjustable, preset operating point).
   g. Provision for adjustment of minimum and maximum pump speed to be furnished as function of remote speed signal.

G. Signal Interface:

1. Serial Communications: Provide PROFIBUS communications interface capable of transmitting and receiving the following:
   a. RUN command.
   b. SPEED command, set to comply with operating speed range designated in driven equipment specifications.
   c. DRIVE RUNNING output.
   d. DRIVE FAULT output (common for all fault conditions).
   e. DRIVE IN REMOTE MODE output.
   f. ACTUAL FREQUENCY output.
   g. ACTUAL LOAD output.
   h. Drive diagnostics.

2. Digital Input: High temperature contact closure input from field mounted motor temperature monitoring relay.

H. Accessories:

1. Identification per 26.05.02:2.03
2. Lifting Lugs: Equipment weighing over 100 pounds.
3. Anchor Bolts: Type 316 stainless steel, sized by equipment manufacturer, and as specified in Section 05 50 00, Metal Fabrications.
2.04 FACTORY FINISHING
A. Enclosure: Manufacturer’s standard

2.05 SOURCE QUALITY CONTROL
A. Factory Inspections: Inspect control panels for required construction, electrical connection, and intended function.
B. Factory Tests and Adjustments: Test one control panels identical to that furnished.
C. Record test data for report.
D. Functional Test: Perform manufacturer’s standard.
E. Motor Test: See Section 26 20 00, Low-Voltage AC Induction Motors.

2.06 GENERAL
A. Anchorage: Type 316 Stainless Steel, sized by equipment manufacturer, ½ inch minimum diameter, and as specified in section 05 50 00.01, Metal Fabrication

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. Record test data for report.
B. Test Equipment:
   1. Provide diagnostic plug-in test card complete with instructions, multiposition selector switch, and meters or built-in diagnostic control panel or ROM-based processor for monitoring ac, dc, and digital signals to assist in troubleshooting and startup of drive.
3.03 MANUFACTURERS’ SERVICES

A. Furnish manufacturer’s representative at Site in accordance with Section 01 43 33, Manufacturers’ Field Services, for installation assistance, inspection, equipment testing, and startup assistance as required by the motor driven equipment specifications.