

SECTION 26 29 23

LOW-VOLTAGE VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.1 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, equipment, services, and incidentals as shown, specified, and required to furnish and install low-voltage variable frequency drives, complete and operational.
2. Variable frequency drives required under this Section are low-voltage, voltage source inverter, pulse width modulated.
3. Low-voltage variable frequency drives included in this Section are associated with the following equipment:
 - a. Pumps: Drives may be integral and installed within a packaged pump control panel, or drives may be stand-alone. See drawings for details.

B. Related Sections:

1. Section 26 05 02 - Basic Electrical Work.
2. Section 26 29 15 - Pump Control Panels.

1.2 REFERENCES

A. Standards referenced in this Section are:

1. ISO 9000, Quality Management Systems, Fundamentals and Vocabulary.
2. ISO 9001, Quality Management Systems, Requirements.
3. ISO 9002, Quality Systems, Model for Quality Assurance in Production, Installation and Servicing.
4. NEMA ICS 2, Controllers, Contactors and Overload Relays Rated 600 Volts.
5. NEMA ICS 7, Industrial Control and Systems Adjustable Speed Drives.
6. NEMA MG 1, Motor and Generators.
7. UL 489, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures.
8. UL 508, Industrial Control Equipment.

1.3 QUALITY ASSURANCE

A. Qualifications:

1. Manufacturer:
 - a. Low-voltage variable frequency drive manufacturer shall have not less than five years of experience designing and regularly manufacturing and servicing substantially similar equipment to that required, and upon Engineer's request shall submit documentation of not less than five installations in satisfactory operation for not less than five years each.
 - b. Manufacturer shall be certified under ISO 9000, ISO 9001, or ISO 9002 for materials and equipment specified.

- c. For all required factory tests, low-voltage variable frequency drive manufacturer shall use a factory test facility that has calibrated its testing apparatus in the previous twelve months, and is staffed by qualified, experienced technicians.
- B. Component Supply and Compatibility:
1. Drives specified under this Section employ a low switching frequency or pattern to minimize instantaneous rate of voltage change over time (dv/dt), and the adverse effects of potential bearing currents. Where alternate manufacturers are proposed, obtain manufacturer recommendations regarding elimination of damage due to bearing currents and provide equipment required at no additional cost to Owner.
 2. Each low-voltage variable frequency drive shall be fully compatible with associated driven equipment and motors. Variable frequency drives shall be matched to specific load requirements for each system. Operation of variable frequency drive shall not overstress motor insulation.
 3. To centralize responsibility and to ensure that all equipment is properly coordinated, variable drives specified under this Section shall be obtained from the Supplier of the associated driven equipment.
 4. Similar components of drives associated with each system shall be products of a single manufacturer.

1.4 SUBMITTALS

- A. Action Submittals: Submit the following:
1. Shop Drawings:
 - a. Dimensional information and construction details of enclosures. Enclosure details shall consist of exterior and interior front door with nameplate legends, interior door front and rear views, and terminal block layout.
 - b. Three-line power and control schematic diagrams.
 - c. Wiring diagrams showing the interconnection of conductors to all devices with terminal assignments for remote devices.
 - d. Functional description of system operation.
 - e. VFD heat dissipation at full load, including heat rejection/cooling system.
 2. Product Data:
 - a. Manufacturer's technical specifications.
 - b. Manufacturer's catalog cuts and product literature.
 3. Testing Plans: Not less than thirty days prior to field quality control testing, submit descriptions of proposed field-testing methods, procedures, and apparatus.
- B. Informational Submittals: Submit the following:
1. Certificates: Certification letters from low-voltage variable frequency drive manufacturer and motor manufacturer that the approved driven equipment has been reviewed and that variable frequency drive units and motors are compatible and shall be provided in accordance with the Contract Documents and requirements of the driven equipment.
 2. Field Quality Control Submittals: Within five days of completing field quality control tests and inspections, submit test results with indication of whether all criteria of the Contract Documents for the specified equipment were met.

3. Manufacturer Reports: Within five days of each visit to the Site by manufacturer's representative, submit written report of reason for visit, problems encountered, solutions implemented, and remaining work.

C. Closeout Submittals: Submit the following:

1. Operation and Maintenance Data:
 - a. Submit complete installation, operation and maintenance manuals including test reports, maintenance data and schedules, description of operation, list of recommended spare parts, and spare parts ordering information.
 - b. Manuals shall include record drawings of control schematics, including point-to-point wiring diagrams.
 - c. Include a listing of all programmable drive parameters and their settings at Substantial Completion. Submit parameters as both printed pages in the operations and maintenance manual and in electronic format on compact disc that can be directly uploaded to the drive-in event of drive replacement or repair.
 - d. Comply with Section 01 70 00 – Execution and Closeout Requirements.

D. Maintenance Materials Submittals: Submit the following:

1. Spare Parts and Extra Stock Materials:
 - a. Furnish, tag, and box for shipment and long-term storage spare parts and special tools for low-voltage variable frequency drives. Each set of spare parts and tools shall include manufacturer's recommended spare parts inventory for one year and include, at minimum, the following:

Item	Quantity per HP Rating
1) Transistor and diode modules with accessories	One set
2) Power supply module	One
3) Fans	One set
4) Power fuses	One set of each size and type used
5) Control power fuses	Two sets of each size and type used
6) Pilot lights	Two per ten of each type used

- b. Furnish a list of recommended spare parts for an operating period of one year. Describe each part, the quantity recommended, and current unit price.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Packing, Shipping, Handling, and Unloading:

1. Packing:
 - a. Inspect prior to packing to ensure that assemblies and components are complete and undamaged.
 - b. Protect mating connections.
 - c. Cover all openings into enclosures with-vapor inhibiting, water-repellent material.
 - d. Indoor containers shall be bolted to skids.
2. Upon delivery, check materials and equipment for evidence of water that may have entered equipment during transit.

3. Handling:
 - a. Lift, roll or jack low-voltage variable frequency drive equipment into locations shown.
 - b. Variable frequency drives shall be equipped for handling required for installation. Handle equipment in accordance with manufacturer's requirements.
- B. Storage and Protection:
 1. Store low-voltage variable frequency drive equipment in a clean, dry location with controls for uniform temperature and humidity. Protect equipment with coverings and maintain environmental controls.

PART 2 PRODUCTS

2.1 EQUIPMENT PERFORMANCE

- A. System Performance:
 1. Driven equipment to be controlled by a low-voltage variable frequency drive shall be provided with a customized variable frequency drive. Each drive unit shall include an adjustable frequency controller with associated controls for continuous speed adjustment and protection of the driven equipment. Output speed control of motor shall be continuous throughout speed range of two to 60 Hertz under variable torque load or constant torque as specified for the driven equipment.
 2. Low-voltage variable frequency drives associated with each set of driven equipment shall be similar to each other.
 3. Variable frequency drives shall be UL-listed or ETL-listed and designed, built, and tested in accordance with UL 489, NEMA ICS 2, NEMA ICS 7, and UL 508.

2.2 MANUFACTURERS

- A. Provide low-voltage variable frequency drives by one of the following:
 1. Allen Bradley, Inc.
 2. Siemens-Robicon Corporation
 3. Danfoss Inc.
 4. Or equal.

2.3 ENCLOSURE

- A. Indoors in prefabricated FRP shelters: NEMA 4X, 316 stainless steel.
- B. Indoors in prefabricated, precast concrete enclosures:
 1. When HVAC is provided for the enclosure and where approved of by CFPUA and recommended by the Engineer: NEMA 12. Exterior and interior steel surfaces of switchboard shall be properly cleaned and provided with rust-inhibiting phosphatized coating by switchboard manufacturer. Color and finish of switchboard shall be light gray.
 2. Otherwise, enclosure shall be NEMA 4X, 316 stainless steel.

- C. Outdoors: NEMA 4X, 316 stainless steel.
- D. Provide each low-voltage variable frequency drive with freestanding or wall/rack-mounted front-access, filtered and gasketed enclosure. Enclosure shall house all components required for the associated variable frequency drive.
- E. Enclosure shall provide adequate cooling for components within and include positive ventilation. For stand-alone VFDs located in NEMA 4X enclosures, provide packaged air conditioning unit attached to the VFD enclosure. Air conditioner shall include rotary compressor, environmentally friendly HFC refrigerant, replicable filter, built-in condensate evaporator and power from VFD assembly.
- F. Enclosure shall include circuit breaker disconnect switch. Circuit breakers shall be in accordance with UL 489. Switch handle shall be suitable for padlocking and be through-the-door type with handle height not exceeding six (6) feet. Operation of switch shall remove the service supply from all internal components. Power devices shall be suitable for interrupting capacity of RMS symmetrical amperes as indicated in the project drawings. Include current limiting semi-conductor fuses where required for protection of solid-state components.
- G. Enclosure door shall include an operator interface for access to controller's digital keypad and display.
- H. Equip enclosure front with nameplates for identification of equipment and operating functions. Nameplates shall be in accordance with Section 26 05 02 - Basic Electrical Work, Identification for Electrical Systems.
- I. Equip enclosure with phenolic type terminal blocks suitably labeled for all internal and remote wiring requirements, plus twenty percent spare.

2.4 ADJUSTABLE FREQUENCY CONTROLLER

- A. General:
 - 1. Adjustable frequency controller shall be microprocessor-based, pulse width modulated design, suitable for operation on a 480-volt, three-phase supply. Controller shall produce an adjustable AC voltage/frequency output to vary speed of driven equipment. Controller shall consist of the following sections:
 - a. Six-pulse diode bridge converter input section.
 - b. Fixed DC bus section.
 - c. Six-pulse power transistor inverter output section.
 - 2. Controller switching frequency shall be adjustable and allow operation at 5,000 Hertz or less. Controller technology shall include a switching scheme that reduces the dv/dt of output supply.
 - 3. Equip controller with a three-percent DC bus reactor or input line reactor.
 - 4. Controller's solid state converter input section switching devices shall have 1600 volt PIV rating.
 - 5. Overload rating of 110 percent variable torque, 150 percent constant torque for one minute.
 - 6. RMS harmonic content of output current shall be less than five percent of fundamental current.

7. Able to withstand output terminal line-to-line short circuits without component failure.

B. Operating Criteria:

1. Operating criteria shall be in accordance with the following:
 - a. Ambient temperature range of zero to 40 degrees C.
 - b. Operational humidity of up to 90 percent non-condensing.
 - c. Altitude up to 3,300 feet above sea level.
 - d. Nominal voltage of 480-volts plus or minus ten percent, three-phase, three-wire. Include an under-voltage feature to allow trip-free operation down to 35 percent undervoltage.
 - e. Nominal frequency of 60 Hertz plus or minus three Hertz.
 - f. Input power factor of 95 percent displacement power factor at all operating speeds.
 - g. Efficiency of 96 percent at full speed and full load.

C. Features:

1. Controller shall have the following features:
 - a. Digital keypad and display module shall provide parameter setting, adjustments, and monitoring of control functions and faults. Display messages shall be in English.
 - b. Serial communication port shall allow connecting to programmable controller interface using manufacturer standard protocol.
 - c. Independent acceleration/deceleration rates shall provide two to 600 seconds minimum. When called to stop, motor shall decelerate to minimum speed before stopping.
 - d. Power loss feature shall allow five cycle ride-through capability for input supply interruptions.
 - e. Time delay automatic restart shall allow restart after controller fault conditions with programmable attempts.
 - f. Coasting motor restart shall allow controller to restart into a coasting motor without damage or tripping. Coasting motor restart feature shall allow switching from bypass mode to low-voltage variable frequency drive mode while operating, without shutdown.
 - g. Isolated control inputs and outputs.

D. Protection:

1. Controller shall have protective functions as follows:
 - a. Input line metal oxide varistor transient protection.
 - b. Electronic over-current trip instantaneous and inverse time overload protection with thermal memory retention.
 - c. Over-temperature trip temperature protection.
 - d. Current limit trip protection.
 - e. Input line over- and under-voltage trip protection.
 - f. Ground fault trip protection.

NTS: RETAIN ARTICLE "2.5", BELOW, WHEN REQUIRED; OTHERWISE, DELETE.
COORDINATE THE REQUIREMENT FOR DRIVE BYPASS STARTERS AND ASSOCIATED
COMPONENTS WITH CFPUA.

2.5 BYPASS CIRCUIT

A. General:

1. Provide each low-voltage variable frequency drive with contactor bypass capability. Mount bypass equipment within variable frequency drive enclosure.
2. Bypass configuration shall consist of output and bypass contactors, and line side isolation circuit breaker.
3. Bypass arrangement shall allow full speed operation of driven equipment while maintaining complete isolation of adjustable frequency controller.
4. Bypass circuit devices shall be in accordance with NEMA ICS 2.

B. Bypass Starter Configuration:

1. Motors rated less than 50 HP: Full voltage, across the line.
2. Motors rated 50 HP and greater: Reduced voltage, solid state starter.
3. NORMAL / BYPASS selector switch.

C. Contactors:

1. Contactors shall be single speed full voltage, electrically operated, 600-volt, three-pole, industrial duty with ampere ratings as required for driven equipment.
2. Contactors shall have removable main contacts, 120-volt magnetic coil and interlocking contacts. Arrange interlocking contacts to prevent output and bypass contactors from being closed at the same time.
3. Bypass contactor shall include a low-voltage variable frequency drive/bypass selector switch and associated controls for manual selection of operating mode. Bypass contactor shall include transfer timer to provide an adjustable off delay when switching from variable frequency drive to bypass.

D. Overload Relays:

1. Provide three overload relays, one for each phase for bypass circuit of each low-voltage variable frequency drive.
2. Electronic Overloads: Relays shall be electronic type. Electronic relays shall be multi-function, adjustable, current sensing type, and include overload, phase-unbalance, phase-loss, and equipment type ground fault in one package.
3. Relays shall be manual reset type and include normally open auxiliary contact for alarm indication.

2.6 CONTROLS

A. General:

1. Equip each low-voltage variable frequency drive control system with relays, switches, fuses, indicating lights, and components required for a complete, functional system.

2. Variable frequency drive control shall be powered from a suitably sized and protected control power transformer.
 3. Variable frequency drive control shall include status indicators, controller, and system fault condition displays and operating controls. Provide status indicators and operating controls associated with drive control on front door of enclosure.
 4. Control arrangement shall be such that variable frequency drive internal electronic supply voltage is isolated from field wiring.
- B. Control and Pilot Devices:
1. Relays shall be standard, latching type, and pneumatic or solid-state time delay type. Provide relays with contacts rated ten amps, quantity as required.
 2. Pilot devices shall be heavy duty type, rated 10 amps continuous. Indicating lights shall be push-to-test LED type.
- C. Control Power: Integral control power transformers and/or power supplies.
- D. Operation:
1. Controls for each low-voltage variable frequency drive shall consist of all devices necessary for the following:
 - a. Stop/Start and Speed Control: Stop/start and speed control shall respond to drive-mounted selector switch. With switch in "REMOTE" position, stop/start and speed control shall be based on a stop/start contact and four- to 20-mADC speed signal from remote process control panel. With switch in "LOCAL" position, stop/start control shall be based on remote stop/start pushbuttons located adjacent to driven equipment, and speed control shall be based on drive-mounted speed potentiometer.
 - b. Emergency Stop Control: Emergency stop control shall respond to remote stop pushbutton located adjacent to driven equipment. When activated driven equipment shall stop immediately in all operating modes.
 - c. Motor Over-temperature Shutdown: Motor over-temperature control shall respond to remote contact that activates on motor over-temperature. When over-temperature is detected, driven equipment shall stop.
- E. Auxiliary Features:
1. Provide each low-voltage variable frequency drive with the following:
 - a. Status Indicators: Status indicators shall include separate pilot lights for indication of motor run (green), and bypass mode (blue).
 - b. Shutdown Indicators: Shutdown indicators shall include separate pilot lights (red) for each shutdown condition. Arrange shutdown indication circuitry so that, when activated, indicator requires manual reset.
 - c. Contact Outputs: Contact outputs shall include separate dry contacts for remote indication of motor run, seal water alarm for equipment with seal water systems, each shutdown condition, and controller faults.
 - d. Speed Output: Speed output shall include four- to 20-mADC signal for remote indication of motor speed.
- F. Wiring and Device Identification:
1. Provide control wiring and device identification for each low-voltage variable frequency drive:

- a. Identify all control conductors with permanent type wire markers. Each wire shall be identified by a unique number and shall be attached to wire at each termination point.
- b. Identify each control device with permanent type marker. Each device shall be identified by a unique number and shall be attached to each device.
- c. Numbering system for each wire and control device shall be identified on wiring diagrams and shall reflect actual designations used in the Work.

2.7 SOURCE QUALITY CONTROL

A. Tests:

1. Perform factory tests on each low-voltage variable frequency drive prior to shipping. Tests shall consist of simulating expected load to be driven by operating load through speed ranges specified for driven equipment, for minimum of two hours per drive unit.
2. Provide factory control and alarm tests on each drive unit by simulating each control signal and each alarm function to verify proper and correct drive unit action.

PART 3 EXECUTION

3.1 INSPECTION

- A. Examine conditions under which the Work will be installed and notify Engineer in writing of conditions detrimental to proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected.

3.2 INSTALLATION

- A. Install equipment in accordance with manufacturer's recommendations and instructions and in conformance with Laws and Regulations, and the Contract Documents.
- B. Unless otherwise shown or indicated, install equipment on concrete bases in accordance with Section 26 05 02 - Basic Electrical Work, Hangers and Supports for Electrical Systems.
- C. Install equipment with sufficient access and working space provided for ready and safe operation and maintenance.
- D. For installations against masonry walls, provide an insulation board, ¼-inch minimum thickness, between equipment and wall for corrosion protection. Trim board neatly within outline of equipment.
- E. Install all terminations, lugs, and required appurtenances necessary to properly terminate power supplies.
- F. Install control wiring terminations and appurtenances necessary to complete installing control and monitoring devices.

- G. Immediately prior to Substantial Completion, replace all enclosure filters and frames provided under this Contract with new filters and frames, except expanded metal filter types. Immediately prior to Substantial Completion, clean expanded metal filters.

3.3 FIELD QUALITY CONTROL

A. Site Tests:

1. After installation, inspect, adjust, and test each low-voltage variable frequency drive at the Site. Testing and inspection shall be in accordance with manufacturer's recommendations and be performed by manufacturer's factory-trained representative. Through Contractor, manufacturer's factory-trained representative shall inform Owner and Engineer when equipment is correctly installed and ready to be energized. Do not energize equipment without permission of Owner.
2. Perform the following equipment inspection and testing and provide reports documenting procedures and results.
 - a. Verify all device settings and drive adjustments.
 - b. Inspect all mechanical and electrical interlocks and controls for proper operation.
 - c. Test each drive through specified speed ranges and loads for a minimum of two hours per drive unit.
 - d. Test each drive by using actual control signal for remote and local operation.
 - e. Test each drive alarm function.
 - f. Perform other tests recommended by equipment manufacturer.

B. Manufacturer Services:

1. Post-installation Check: Manufacturer's factory-trained representative shall check and approve the installed equipment before initial operation. Manufacturer shall calibrate, set and program low-voltage variable frequency drives provided.
2. Manufacturer's factory-trained representative shall adjust the system to final settings as specified in Article 3.4 of this Section.
3. Manufacturer's factory-trained representative shall test the system as specified in Paragraph 3.3.A of this Section. Representative shall operate and test the system in presence of Engineer and verify that equipment is in conformance with the Contract Documents.
4. Representative shall revisit the Site as often as necessary until all deficiencies are corrected, prior to readiness for final payment.
5. Provide services of manufacturer's factory-trained representatives to correct defective Work within 72 hours of notification by Owner during the correction period specified in the General Conditions as may be amended by the Supplementary Conditions.
6. Replacement parts or equipment provided during the correction period shall be equal to or better than original.
7. Training: Provide services of qualified factory trained specialists from manufacturer to instruct Owner's operations and maintenance personnel in recommended operation and maintenance of equipment.

3.4 ADJUSTING

- A. Immediately prior to Substantial Completion, when testing is acceptably completed and low-voltage variable frequency drives are operating, manufacturer's representative shall return to the Site and make final adjustments as required to each variable frequency drive furnished under this Section.

END OF SECTION