

SECTION 26 29 23 VARIABLE FREQUENCY DRIVES

PART 1 - GENERAL

1.1 SCOPE

- A. This section covers ac voltage source, space vector pulse width modulated (PWM) type variable frequency drives for general or high performance constant or variable torque loads as shown on the project drawings or noted in project motor list.
- B. General. Equipment provided under this section shall be fabricated, assembled, erected, and placed in proper operating condition in full conformity with the drawings, specifications, engineering data, instructions and recommendations of the equipment manufacturer, unless the engineer notes exceptions.
- C. Governing Standards. Each variable frequency drive shall be designed, constructed, and tested in accordance with the applicable standards of NEMA, ANSI, UL, IEC, and IEEE and shall be designed for installation in accordance with the NEC. The drives shall be UL listed.

1.2 RELATED DOCUMENTS

- A. Project motor list to contain application description, environmental descriptions for variable frequency drive and motor information (if available). Drawings for the project are provided if applicable.

1.3 SUBMITTALS

- A. Submittals shall be custom prepared by the VFD manufacturer for this specific application. The shop drawing submittals shall include the following information for each size and type of drive being furnished:
 - B. Drawings
 1. Name of manufacturer.
 2. Types and model numbers.
 3. Rated drive power or rated drive output current and rated voltage
 4. Percent efficiency and power losses at 100 percent torque or load and 90 percent speed according to EN 50598-2 (IEC 61800-9-2).
 5. Front and side views with overall dimensions and weights shown; and nameplate legends.
 6. Schematics, including interlocks.
 7. Wiring diagrams, including all internal and external devices and terminal blocks.
 8. List of diagnostic indicators.
 9. Catalog cut sheets
 10. List of spare drives and/or parts to be furnished.
 - C. Manufacturer's field reports. Drives commissioned in the field by the manufacturer are to include start-up report. The report shall include installation overview, application description, drive wiring description and parameter settings as programmed for the application. Comments on drive performance as commissioned shall be also noted in the field report.
 - D. Operation and maintenance data. The information shall be provided in the electronic format and shall include, but not limited to, the following items. Printed manuals, if required, are to be specified in the motor project list.
 1. Operation & maintenance manual
 2. Option descriptions and drawings
 3. Harmonics data

1.4 RELATED STANDARDS

- A. Codes: Provide equipment in full accordance with the latest applicable rules, regulations, and standards of:

1. Local Laws and Ordinances.
 2. State and Federal Laws.
 3. National Electric Code (NEC).
 4. Underwriters Laboratories (UL).
 5. American National Standards Institute (ANSI).
 6. National Electrical Manufacturers Association (NEMA).
 7. Institute of Electrical and Electronics Engineers (IEEE).
 8. International Electrotechnical Commission (IEC).
- B. The VFD shall be UL and cUL listed according to UL 61800-5-1 for use in pollution degree 2 environments and labeled accordingly.
 - C. The complete enclosed drive assembly shall be either UL 508A or UL 61800-5-1 listed.
 - D. The VFD shall comply with the requirements of the European Low Voltage Directive 2014/35/EU, Machinery directive 2006/42/EC, EMC Directive 2014/30/EU, RoHS directive 2011/65/EU, and shall be CE marked accordingly.
 - E. The VFD Safety Integrated function Safe Torque Off (STO) shall be certified as SIL 3 rated according to IEC 61508 and PL e (Performance Level e) rated according to IEC 61800-5-2.
 - F. The VFD shall comply with international efficiency level of IE2 based on the determination of power losses according to EN 50598-2 (IEC 61800-9-2).
 - G. The VFD shall have conformal coated printed circuit boards according to IEC/EN 60721-3-3 for protection against chemical substances.
- 1.5 QUALITY ASSURANCE
- A. The VFD shall be designed and manufactured to a quality management system in accordance with ISO 9001. The VFD shall be supplied by a manufacturer who has considerable experience in the design and manufacturing of VFD of the ratings specified for a period of at least ten (10) years.
- 1.6 DELIVERY, STORAGE AND HANDLING
- A. The construction/installation manager is to protect the inverter against physical shocks and vibration during transport or storage. The equipment shall also be protected against water (rainfall) and excessive temperatures. Installation after a prolonged period of storage may require reform of the capacitors in the inverter. Consult manufacturer for details.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

The variable frequency drive shall be manufactured by Siemens, type SINAMICS G120X and its complete enclosed version shall be type G120XE or pre-approved equal. Approved manufacturers are as follows:

1. SIEMENS
2. SIEMENS Robicon
3. ***[Pre-bid approved equal, meeting the detailed requirements of these specifications.]***
4. ***[No substitutions are permitted.]***

2.2 GENERAL

- A. Provide variable frequency controllers suitable for operating variable or constant torque loads. Controllers shall meet or exceed the ratings listed below:
 1. All components listed shall be integral to the VFD lineup, factory wired and tested as a complete system. VFDs shall be 6-pulse converter types with a minimum 3% line reactors or internal DC link reactors.
 2. For the complete enclosed drive assembly, the main input circuit breaker shall be rated in accordance with NEC and UL requirements and shall be interlocked with the enclosure door, with flange mounted handle to provide positive disconnect of incoming AC power.

The handle and mechanism shall always remain attached to the circuit breaker, even when the enclosure door is open.

3. The VFD manufacturer shall not predict or be responsible for pre-existing voltage distortion on the line or distortion from sources supplied by others. Maximum input voltage unbalance shall be 0.5% as defined in NEMA MG 1 section 14.35.2.
4. The point of common coupling (PCC) for all harmonic calculations and field measurements for both voltage and current distortion shall be defined as the plant designated PCC.

B. Ratings.

1. The VFD shall be at least 94% efficient at full load and 90 percent of speed according to EC 50598 (IEC 61800-9-2) and shall have fundamental power factor ($\cos \phi$) range of 0.95 to 0.99.
2. Rated input voltage: [380 – 480]/[200 – 240]/[500 – 690] volts plus 10 percent and minus 15 percent, three-phase.
3. Rated AC input line frequency: 47 to 63 hertz.
4. Voltage Dip Ride-Through: VFD shall be capable of sustaining continued operation with a 10% dip in nominal line voltage and with a 15% dip for up to 1 minute. Output speed may decline only if current limit rating of VFD is exceeded.
5. Power Loss Ride-through: VFD shall have the capability of riding through power dips up to for 3 to 5 cycles without a controller trip depending on load and operating condition. In this extended ride through, the drive shall use the energy generated by the load inertia of the motor to power the electronic circuits.
6. The output power of VFD shall be up to 700HP (500 HP constant torque, 700HP variable torque) where VFD shares common programming, human machine interface or operator panel or keypad and options.
7. VFD shall have a short-circuit current rating (SCCR) of up to 100,000 amperes rms symmetrical when protected by UL approved fuses or circuit breakers or motor starter protectors (MSP) also known as Type E combination motor controllers (CMC).
8. Motor nameplate voltage: [230]/[460]/[575] volts, three phase 60 hertz (as specified on project motor list).
9. Operating ambient temperature range shall be -4°F to 113°F (-20°C to 45°C) without requiring output current derating.
10. Elevation or altitude: Up to 3,300 ft (1,000 meters) above MSL without output current derating.
11. Humidity at installation location: Non-condensing relative humidity to 95%.
12. The VFD shall be capable of running at a minimum of 135% of rated nameplate current for 3 seconds and then 110% of rated nameplate current for 57 seconds or 110% of rated nameplate current for 60 seconds, at rated temperature for variable torque applications or Low Overload (LO) rating.
13. The VFD shall be capable of running at a minimum 150% of nameplate current for 60 seconds, at rated temperature for constant torque applications or High Overload (HO) rating.

C. Construction

1. The converter section shall be 6-pulse utilizing diodes and the latest IGBT technology for inverter section and Digital microprocessor control.
2. The controller shall produce an adjustable AC voltage/frequency output. It shall have an output voltage regulator to maintain correct output V/Hz ratio despite incoming voltage variations.
3. VFD's high performance control system shall be configured as open loop sensorless or encoderless vector control. Autotuning for vector control optimization shall be provided. In addition, flux current control, programmable multi-point V/Hz curve, Linear V/Hz control, Quadratic V/Hz control shall be provided.
4. Torque control can be configured in the VFD and activated by command input.
5. The controller shall have a continuous output current rating of at least 100% of motor nameplate current.
6. The internal DC bus capacitors shall be designed for a minimum of 10 years. Periodic maintenance replacements of internal capacitors shall not be required.

7. The controller(s) shall be suitable for use with any standard NEMA design asynchronous (induction) motor, permanent magnet synchronous motor (PMSM) and synchronous reluctance motor (SRM).
8. VFD shall be able to be located at least up to 150 meters from a motor with the shielded cables for VFDs rated up to 20hp or above 400hp. For VFDs rated between 25hp and 400hp, the motor cable length shall be up to 200 meters when shielded cables are used. The use of output reactors or filters shall be required when the shielded cables are needed for longer distances.
9. All fans or blowers shall be turned on only when the drive is running.
10. The VFD product family shall be available in 9 mechanical sizes as IP20 and UL Open Type units, as follows:

Frame size	W x H x D (mm)	W x H x D (in.)	Weight (lbs.)
FSA	73 x 232 x 209	2.9 x 6.8 x 8.3	8
FSB	100 x 275 x 209	5.9 x 8.0 x 9.1	13.7
FSC	140 x 295 x 209	7.4 x 13.1 x 9.8	17
FSD	200 x 472 x 239	10.8 x 16.5 x 10.2	43
FSE	275 x 551 x 239	10.8 x 19.6 x 10.2	63.3
FSF	305 x 709 x 360	13.8 x 25.0 x 14.6	156.6
FSG	305 x 999.4 x 360	12.8 x 60.4 x 21.5	264.6
FSH	548 x 1696 x 393	21.6 x 66.8 x 15.5	357.2
FSJ	801 x 1621 x 393	31.5 x 63.8 x 15.5	551.2

11. The VFD keypad or operator panel or operator interface shall be pluggable high-resolution graphical color keypad with integral LCD display and shall have depth of 9 mm or 0.4 inch. The keypad shall also have door mounting option for the complete enclosed drive assembly.
12. The VFD shall have conformal coated printed circuit boards in compliance with minimum Class 3C2 rating according to IEC/EN 60721-3-3 for protection against chemical substances and optionally shall comply with Class 3C3 rating according to IEC/EN 60721-3-3 when required per project specifications for the VFD operation in the harsh environment where corrosive gases such as Sulphur dioxide (SO₂), Hydrogen sulfide (H₂S), Chlorin (Cl), Ammonia (NH₃) etc. are inevitable.
13. Silent motor operation shall be possible when using high switching frequencies. The drive de-rating for higher switching frequencies shall be available.
14. The VFD shall have complete inverter and motor protection.
15. The VFD shall be capable of stopping the load without the use of a braking resistor by selecting either DC braking or compound braking function.
16. The VFD shall be capable of providing SIL 3/PL e rated Safe Torque Off (STO) hardware-based safety function to protect against active movement of the drive according to IEC 61508 and IEC 61800-5-2.
17. The VFD shall be capable of firmware upgrades using a Micro Memory Card (MMC) or Secure Digital (SD) Card.

D. Basic Features

1. The keypad of operator panel shall be capable of controlling the VFD and setting drive parameters and shall include the following features:
 - a. The digital display must present all diagnostic message and parameter values in English or metric engineering units, without the use of codes.
 - b. The digital keypad shall include at a minimum a manual start pushbutton, manual stop pushbutton, Hand/Auto pushbutton and additional control devices to scroll and enter numerical values.
 - c. A plain English user menu, rather than codes, shall be provided in software in nonvolatile memory as a guide to parameter setting and resettable in the field through the keypad.
 - d. The digital display shall be selectively configured to display parameter names with set point and actual values selectable in percent or physical units, and up to three quasi-analog bar graphs of any parameter values. Parameter values to be displayed shall include

- 1.) Speed in rpm.
 - 2.) Output current in amperes.
 - 3.) Output Frequency in hertz.
 - 4.) DC bus voltage.
 - 5.) Output voltage.
 - 6.) Total 3-phase output power in kW or HP.
 - 7.) Torque in Nm
 - 8.) Kilowatt-hour meter.
 - 9.) Elapsed time running meter
2. The VFD shall have intuitive quick commissioning for the application, motor data and control information using high resolution graphical color keypad. In addition, to ensure personnel safety, the VFD shall offer wireless commissioning and diagnostic option using pluggable Wi-Fi module which can be used in conjunction with any mobile device (smart phone, laptop or tablet) to program the VFD wirelessly from up to maximum 50 meters (164 feet) away.
 3. In addition, the drive shall provide automatic calibrate or autotuning routine to optimize motor electrical characteristics within the VFD.
 4. Binary Connector (BiCo) technology for customizing signals as required by the application.
 5. The VFD shall include a customer selectable automatic restart feature. When enabled, the VFD shall automatically attempt to restart after a trip condition (programmable to allow for individual fault selection) resulting from for example supply failure, instantaneous overcurrent, overvoltage, or overload. For safety, the drive shall shut down and require manual reset and restart if the automatic reset/restart function (programmable for up to 10 attempts) is not successful within a customer programmable time period (programmable for up to 600s).
 6. VFD shall have the capability of communicating via an RS-485 serial port or industrial Ethernet port
 - a. Serial communications shall be available for USS, Modbus RTU, BACnet MS/TP or Profibus protocols.
 - b. Industrial Ethernet communications shall be available for Profinet or EtherNet/IP protocols.
 - c. Data communication shall be preconfigured and not require special programming to access parameter values, status, and fault data.
 7. VFD shall provide Four skip frequencies to avoid operation at critical frequency.
 8. VFD shall have a PID regulator for set point control
 9. The VFD shall be specifically designed for pumps, fans, and compressors applications.
 10. VFD shall have the following internal pump-specific functions available:
 - a. Deragging or blockage protection
 - b. Pipe filling
 - c. Multi-pump control:
 - 1.) Pump switchover
 - 2.) Stop mode
 - 3.) Service mode
 - 4.) Cascade control mode
 - d. Blockage, leakage, and dry-running protection
 - e. Cavitation protection
 - f. Condensation protection
 - g. Frost protection
 11. VFD shall have the following internal fan-specific functions available:
 - a. Flying restart
 - b. Automatic restart
 - c. Skip frequency bands
 - d. Fire mode
 - e. No load, torque, and rotation (belt) monitoring with sensor
 12. VFD shall have the following internal general energy efficiency and system performance functions available:
 - a. Energy Optimization to reduce motor losses

- b. Eco mode to adjust output motor voltage to improve energy savings
 - c. Bypass mode
 - d. Hibernation or sleep mode
 - e. Energy/Flow Calculator
 - f. Support of high efficiency motors including permanent magnet and synchronous reluctance motors
 - g. Real time clock and programmable timers
13. VFD shall have the following internal functions to increase system up-time:
- a. Keep running mode
 - b. Kinetic buffering
 - c. Essential service mode
 - d. Dual Ramp
 - e. Multi-speed setpoints
 - f. No load, torque, and rotation (belt) monitoring with sensor
- E. Enclosure
1. For a complete enclosed drive assembly all VFD components shall be factory mounted and wired on a dead front, grounded, in at least UL Type 1 (NEMA 1) rated enclosure. If a free-standing enclosure is provided, then it shall be suitable for mounting on a concrete housekeeping pad.
- F. Protective Features and Circuits
1. The controller shall include the following protective features, faults, and alarms.
 - a. Instantaneous overcurrent and overvoltage trip.
 - b. Undervoltage and power loss protection.
 - c. Power unit over temperature alarm and protection.
 - 1.) Upon sensing an over temperature condition, the VFD is to be programmable to either limit its output to maintain the temperature below its limit, or to automatically trip.
 - d. Ground fault (when connected to a solidly grounded supply). A separate monitor shall be supplied, where shown on the drawings, for other types of high resistance or ungrounded supply systems.
 - e. An electronic or solid-state overload circuit
 - 1.) It shall be designed to protect an AC motor operated by the VFD output from extended overload operation on an inverse time basis (I squared T trip).
 - 2.) This electronic overload shall be UL and NEC recognized as adequate motor protection.
 - 3.) No additional hardware such as motor overload relays or motor thermostats shall be required.
 - 4.) VFD shall be capable of Thermal sensor detection, thermistor, or thermostat for motor over temperature
 - 5.) VFD shall provide protection against opening or shorting of motor leads.
 - f. When power is restored after a complete power outage, the VFD shall be capable of catching the motor while it is still spinning and restoring it to proper operating speed without the use of an encoder.
 - g. The VFD shall be protected from damage due to the following:
 - 1.) Three-phase short circuit on VFD output terminals.
 - 2.) Loss of input power due to opening of VFD input disconnect device or utility power failure during VFD operation.
 - 3.) Loss of one (1) phase of input power.
 - h. The VFD shall be able to withstand the following fault conditions without damage to the power circuit components:
 - 1.) Failure to connect a motor to the VFD output.
 - 2.) VFD output open circuit that may occur during operation.
 - 3.) VFD output short circuit that may occur during operation.
 - i. Microprocessor fault/memory chip error.
 - j. DC bus over voltage trip.

- k. Critical frequency avoidance circuit. Four (4) set points selective from 0 to maximum frequency. Bandwidth of set points shall be adjustable.
 - l. Current limit circuit to automatically phase back output current and frequency to prevent excessive currents from damaging motor insulation (frequency output rollback)
 - 2. The following conditions shall cause an orderly drive shutdown and lockout:
 - a. Overcurrent at start-up
 - b. Instantaneous over current
 - c. Over temperature of VFD or external fault
 - d. Motor over temperature
 - e. Ground fault in motor output circuit
 - f. Over voltage during shut down
 - g. Motor I squared T trip
 - 3. The VFD should be able to track the sequence of alarms and faults over time using a real time clock
- G. Parameter Log
 - 1. All drive setting adjustments and operation parameters shall be stored in a parameter log.
 - a. It lists allowable maximum and minimum points and the present set values.
 - b. It shall be accessible, depending on the communication option or requirement, via a RS-232, RS-485 serial or Ethernet port and on the keypad display.
 - c. The controller shall have a slot to allow the parameter log to be downloaded on to a compact flash memory card by using the keypad
 - d. The drive shall have the capability to be reset to factory conditions via parameter change.
- H. Input / Output Features
 - 1. Two programmable analog inputs (4-20mA/0-20mA/0-10V)
 - 2. One fully programmable analog output (0-20mA/0-10V)
 - 3. Minimum six fully programmable electrically isolated digital inputs (24V DC)
 - 4. Minimum three fully programmable 250V AC relay outputs as digital outputs
 - 5. One motor temperature sensor input (PTC, KTY/Pt100/Pt1000/Ni1000)
 - 6. Minimum one electrically isolated failsafe digital safety input for Safe Torque Off (STO) safety function.
 - 7. The VFD shall be also capable of extending the inputs and outputs additionally using optional IO extension module as follows.
 - a. One scalable and programmable analog input (0-20mA/0-10V)
 - b. Two fully programmable analog outputs (0-20mA/0-10V)
 - c. Two fully programmable electrically isolated digital inputs (24V DC)
 - d. Four fully programmable 250V AC relay outputs as digital outputs (4-20mA/0-20mA/0-10V)
 - e. One motor temperature sensor input (Pt1000/Ni1000)
- I. Diagnostic Features and Fault Handling
 - 1. The VFD shall include a comprehensive microprocessor based digital diagnostic system which monitors its own control functions and displays faults and operating conditions.
 - 2. The drive shall record and display the last faults and warning messages that occurred in the drive.
 - 3. A "Fault Log" shall be accessible via bus communications as well as line by line on the operator panel display. The "FAULT LOG" shall record, store, and display the following for the 64 most recent events.
 - a. Time stamp
 - b. Type of fault
 - 4. All faults and events shall be stored and with English descriptions in addition to fault codes.
 - 5. First-time users shall be supported by dialog menus, with a standard graphics-based display maximizing clarity when setting the drive parameters. First commissioning is guided by wizards, which handle all the basic settings in the drive. This shall enable a drive to be

up and running after only setting the preliminary parameters within the drive configuration process.

6. The software shall allow configuration including but not limited to the following:
 - a. Digital and analog I/O terminals
 - b. Bus interface
 - c. Set point channel (e.g. fixed set points)
 - d. Speed control (e.g. ramp-function generator, limits)
 - e. Diagnostics
7. Experts shall be able to gain rapid access to the individual parameters via the keypad or operator panel without having to use a computer to navigate dialogs.
8. In addition, the following functions shall be available for optimization purposes
 - a. Motor identification
 - b. Self-optimization
9. Modifications
 - a. Any modifications to a standard product required to meet this specification shall be performed by the VFD manufacturer only. Distributor or system integrator changes to the VFD manufacturer's product are specifically disallowed

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Verify that mounting surface is suitable for controller installation.
- B. Do not install controller until building environment can be maintained within the service conditions required by the manufacturer.
- C. Inspect completed installation for physical damage, proper alignment, anchorage, and grounding.
- D. The manufacturer shall have the capability and personnel to assist in the start-up, training, service, and maintenance of the equipment.
- E. The contractor shall provide all labor, materials, equipment, and incidentals required, and install, place in operation and field test the variable frequency drive(s).

3.2 ADJUSTMENTS AND CLEANING

- A. Remove debris from drives and wipe dust and dirt from all components.

3.3 TESTING

- A. Check tightness of all accessible mechanical and electrical connections to assure they are torqued to the minimum acceptable manufacture's recommendations.
- B. Check all installed panels for proper grounding, fastening and alignment. Incoming inspection of components and raw materials based on strategic supplier base and experience.
- C. All drives subject to routine tests (megger, functional, no load operation and final inspection).

3.4 WARRANTY

- A. The VFD manufacturer shall warrant that the VFD supplied are free of non-conformities in workmanship and materials for no more than thirty months from the date of shipment with the product registration.
- B. The VFD manufacturer shall extend the warranty up to additional five years based on the project requirements.

3.5 SPARE PARTS

- A. The following spare parts shall be furnished:
 1. One full drive including power module, control unit, and operator panel.
 2. Three of each type of fuse rated 460V or less for a complete enclosed drive system.
 3. Three of each type of pilot lamp for a complete enclosed drive system.

END OF SECTION