

SECTION 15175 – VARIABLE FREQUENCY DRIVES

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this Section.

1.2 WORK INCLUDED

- A. Furnish and install variable frequency drives (VFD's) for mechanical equipment as scheduled on the drawings and specified herein. The term VFD shall refer to the entire assembly including but not limited to the by-pass.
- B. The VFD's shall comply with the latest applicable standards of ANSI, IEEE, NEMA, NEC, UL and City Test Lab. The controllers shall be rated as indicated. As a minimum, the full load output current of the drive shall be equal to the equivalent motor horsepower as listed by NEC Table 430-150.
- C. Drive horsepowers shall be minimum size as indicated. Coordinate size with driven equipment manufacturer.
- D. Provide UL listed, accessory reactors to be UL listed. Bypass panels shall be constructed of UL recognized components assembled in a UL listed enclosure in strict accordance with the NEC for electrical safety. In addition the assembly shall be UL listed.

1.3 RELATED SECTIONS

- A. Examine all drawings and criteria sheets and all other Sections of the Specifications for requirements which affect work under this Section whether or not such work is specifically mentioned in this Section.

1.4 REFERENCES

- A. Applicable provisions of the following Codes and Trade Standard Publications shall apply to the work of this Section, and are hereby incorporated into, and made a part of the Contract Documents.

B. Material standards shall be as specified or detailed hereinafter and as follows:

1. IEEE: Institute of Electrical and Electronic Engineers
2. NEMA: National electrical Manufacture's Association
3. MG 1-78: Motors and Generators
4. NEC: National Electrical Code
5. ANSI: American National Standards Institute
6. UL: Underwriter's Laboratories

1.5 SUBMITTALS

A. See Section 15050 and General Condition for additional requirements.

B. Product Data: Provide product description and list of materials, including the following:

1. Harmonic calculations
 - a. List of all drives.
 - b. Simplified one line diagram indicating linear as well as drives, transformers and PCC.
 - c. Technical description of the program used for the calculations.
 - d. Description of all inputs and outputs from the program.
2. Complete drawings furnished and approved before proceeding with manufacture. Drawings shall consist of a specific bill of materials, connection diagrams and suitable outline drawings showing details necessary to locate conduit stub-ups and field wiring.
 - a. Details including all labeling.
 - b. Assembled panel short circuit rating and how it will be labeled.
 - c. Heat release of the drive.
3. Description of field testing.
 - a. Proposed schedule of testing indications coordination with occupancy.
4. Manufacturer's Instructions: Indicate installation procedures that ensure acceptable workmanship and installation standards will be achieved.

1.6 QUALITY ASSURANCE

A. Manufacturers must have more than ten (10) years of documents experience in the design, testing and manufacturing of specified or similar products.

- B. Manufacturer must provide written certification that the products provided meet or exceed the specification requirements. An executive officer of the company must sign the written certification.

1.7 WARRANTY

- A. Attention is directed to provisions of the General Conditions and Supplementary General Conditions regarding guarantees and warranties for work under this Contract.
- B. Manufacturers shall provide guarantees for work under this Contract. However, such guarantees shall be in addition to and not in lieu of all other liabilities which the manufacturer and the Contractor may have by Law or by other provisions of the Contract Documents.
- C. All materials, items of equipment and workmanship furnished under each Section shall carry the standard warranty against all defects in material and workmanship. Any fault due to defective or improper material, equipment, workmanship or design which may develop shall be made good, forthwith, by and at the expense of the Contractor including all other damage done to areas, materials and other systems resulting from this failure.
- D. The Contractor shall guarantee that all elements of the systems provided under his Contract, are of sufficient capacity to meet the specified performance requirements as set forth herein or as indicated.
- E. Upon receipt of notice from the Owner's representative of failure of any part of the systems or equipment during the warranty period, the affected part or parts shall be replaced by the Contractor, within three (3) working days, at no cost to the Owner.
- F. The Contractor shall furnish a written guarantee covering the above requirements before the final payment is made.

PART 2 – PRODUCTS

2.1 VARIABLE FREQUENCY DRIVES

- A. General
 - 1. Provide a complete variable frequency drive (VFD) (in a single enclosure) of capacity, quantity and characteristics as described in this specification and as shown and scheduled on the drawings. Acceptable manufacturers contingent on compliance with specifications are:
 - a. 30 HP and Larger (**18-Pulse or Greater Units Only**)
 - 1) ABB
 - 2) Halmar Robocon Group

- 3) Square D
- 4) General Electric
- 5) Yaskawa

Note: 6-pulse units will be rejected.

- b. 25 HP and Less
 - 1) ABB
 - 2) Halmar Robocon Group
 - 3) Square D
 - 4) General Electric
 - 5) Yaskawa
2. All VFDs (6 & 18 pulse) shall be of the same manufacturer.
3. Each drive and assembly shall be U.L. listed and labeled.
 - a. Label shall include the AIC rating for the assembly which shall not be less than 100,000 AIC. Any unit shipped without such label shall be removed from the job with NO EXCEPTIONS. This also includes six pulse drives with or without bypasses.
4. Each drive shall be mounted with it's accessories in a single cabinet.
5. Installation and start-up services for the equipment shall be covered by this specification.
6. Input control signal shall be compatible with automatic controls and/or building automation control system. Submit written, signed off coordination with submittal.
7. Complete drawings shall be furnished and approved before proceeding with manufacture. Drawings shall consist of a specific bill of materials, connection diagrams and suitable outline drawings showing details necessary to locate conduit stub-ups and field wiring.
8. The VFD shall comply with the latest applicable standards of ANSI, IEEE and NEMA. The controllers shall be rated as shown in the drawings. As a minimum, the full load output current of the drive shall be equal to the equivalent motor horsepower as listed by NEC Table 430-150.
9. Drive horsepowers shall be minimum size as indicated. Coordinate size with driven equipment manufacturer.
10. The VFD manufacturer shall supply with submittal information, harmonic calculations made in accordance with IEEE 519-1992 Standards showing the specified THVD, line notching and the specified THCD limits are met. Calculations shall assume worst case system conditions. System 1-line, 480V transformer data, standby generator data, and primary fault current data required to make these calculations are provided in the system short circuit study and can be obtained from the Electrical Contractor. The submittal shall include, as a minimum, the following information:
 - a. All input data and assumptions.
 - b. Explanation of method used to perform the analysis.

- c. All calculations and computer printouts used in the analysis, including input documentation.
 - 1) List all drives and accessories.
 - 2) Explanation of all inputs
 - 3) Explanation of all outputs.
- d. A system impedance diagram based on the Electrical one-line diagrams. It shall be the drive manufactures responsibility to obtain all information required.
- e. All calculations shall be in accordance with IEEE 519 with all drives at 100% speed. The point of common coupling shall be the secondary connection of the transformer supplying that group of devices. These calculations shall be done with the transformer loaded to no more than 70% of its nominal capacity. These calculations shall also be done with all 18-pulse or greater drives running as well as the smaller drives running.
- f. Each point of common coupling shall be defined as the secondary side of the transformer that feeds that group of drives. At the point of common coupling, the following numbers shall meet with the maximum load on the transformer no greater than 70% of its nominal capacity.
 - 1) **Total harmonic voltage distortion is less than 3%**
 - 2) **Total harmonic current distortion is less than 5% and harmonic table requirements $I_{SC} / I_L < 20$**
 - 3) **Note: 6-pulse drives will not be accepted on 30 HP drives or larger, even if this calculation is met.**
- g. A detailed description of the tests, procedures and supporting calculations required to substantiate the installed systems compliance with the specified THD limits.
 - 1) The description shall include information on the proposed test equipment and test conditions.
 - 2) Include the name and qualifications of the firm which will conduct the field tests.
- h. **Submittals without calculations will not be reviewed.**
- 11. Drives shall be capable of the full rated motor horsepower at all carrier frequencies of that drive.

B. Construction

- 1. VFDs 30 HP and Larger
 - a. VFDs 30 HP and larger shall be 18-pulse (or greater) input. Provide data and calculations showing the drive harmonics do not exceed the following numbers at the power connection to the drive.

- 1) Total harmonic voltage distortion: Less than 3%
- 2) Total harmonic current distortion: Less than 5% and harmonic table requirements for $I_{SC}/I_L < 20$.

Note: These are the maximum harmonics that can be generated by each of these drives.

b. The use of the following devices is permitted:

- 1) A.C. Line reactors
- 2) DC chokes
- 3) KMP Transformers
- 4) KMP + XFMR Filter Transformers

c. The use of the following devices is not permitted:

- 1) Passive filters.
- 2) Broad band filters.

2. VFDs 25 HP and Less

a. VFDs 25 HP and less shall be 6-pulse (or greater) input. Provide data and calculations showing the drive harmonics.

b. 5% line reactors shall be provided on each drive as a minimum.

c. The use of the following devices is not permitted:

- 1) Passive filters.
- 2) Broad band filters.

d. The use of the following devices is permitted:

- 1) Changing additional drives to 18 pulse or greater.

3. Harmonic Table

ISC / I _L	Harmonic Order (Odd Harmonics)					THD
	H<11	11<h17	17<h23	23<h35	35<h	
<20	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.5	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

4. 18 Pulse Transformer
 - a. Auto transformer
 - 1) Voltage 480.
 - 2) Input variation less than 3%.
 - 3) Insulation Class 220°C
 - 4) Temperature rise 150°C
 - 5) With 7.5% AC input line reactors for proper current balance.
 - 6) Output Voltage unbalance less than 2% for each bridge
 - 7) Output current shall be 1/3 of rated input
 - b. Isolation Transformer.
 - 1) Voltage 480.
 - 2) Input variation less than 3%.
 - 3) Output Voltage unbalance less than 2% for each bridge
 - 4) Output current shall be 1/3 of rated input
5. All Drives
 - a. The VFD shall be of the pulse width modulated (PWM) design converting the fixed utility voltage and frequency to a variable voltage and frequency output via a 2-step operation. VFDs utilizing a 3rd power section are not acceptable. Efficiency shall exceed 96% at 100% speed and load. Line side displacement power factor shall exceed (0.95) regardless of speed and load. The VFD shall be rated for 110% current for (1) minute for variable torque loads and 150% current for (1) minute for constant torque loads.
 - b. VFD's located indoors shall be housed in a signal NEMA 1 metal enclosure (including 18-pulse transformer, filters, line reactor, and other required accessories).
 - c. Drives located outside shall be provided with a single NEMA 3R enclosure and an independent heating and cooling system to maintain manufacturer's ambient operating conditions.
 - d. Drives located other than outside (submit list of all drives individually indicating):
 - 1) Space drive is located.
 - 2) Space ventilation is adequate, space air conditioning is adequate or the size of the cooling provided in the drive.
 - 3) Space heating is adequate or the size of the heater provided in the drive.
 - e. Standard operating conditions shall be:
 - 1) Incoming 3-phase 480 VAC power, +5% or -10%, 60 Hz.
 - 2) Humidity 0 to 95% (non-condensing and non-corrosive).
 - 3) Altitude 0'-0" to 3,300'-0" above sea level.
 - 4) Ambient temperature 0° to 40°C.

- f. VFDs shall include the following system interfaces:
- 1) Speed reference interface with a differential amplifier or isolated input 0-10 VDC or 4-20 mADC signal.
 - 2) Run relay with an isolated set of Form C contacts.
 - 3) Minimum of 2 programmable contacts.
 - 4) Trip contacts (Form C).
 - 5) VFD will accept an external trip contact and indicate so on the display.
 - 6) Dedicated terminal blocks for interface with maintained remote start contacts.
 - 7) Output signal proportional to output frequency (0-10 VDC or 4-20 mADC).
 - 8) Output signal proportional to output current (0-10 VDC or 4-20 mADC).
 - 9) Provided with communications chip to provide complete interface with the ATC control and automation system.
- g. The VFD shall include the following protective features:
- 1) Lockable Fused disconnect (or breaker) rated for 100,000 AIC.
 - 2) Electronic instantaneous overcurrent protection.
 - 3) DC bus undervoltage protection.
 - 4) DC bus overvoltage protection.
 - 5) Ability to withstand output line-to-line short circuits without component failure.
 - 6) Status indication via an LED display of the following protective functions:
 - a) DC Bus Undervoltage
 - b) Overcurrent
 - c) DC Bus Overvoltage
 - d) Controller Overtemperature
 - e) Overload
 - f) Overload Warning
 - g) Overfrequency and Phase Loss
 - h) A single light to indicate a VFD trip is not acceptable.
 - 7) Overload capability shall be 110% of the inverter rating for (1) minute.
 - 8) Selectable auto restart.
 - 9) VFD will catch a motor spinning in the forward or reverse direction upon starting.
 - 10) Upon loss of the input signal (4-20 mA), the drive will stop or go to preset speed.
- h. Standard adjustments shall include:
- 1) Minimum frequency (4-60 Hz)
 - 2) Maximum frequency (40-120 Hz)

- 3) Minimum of three (3) preset speeds (4-120 Hz) initiated by contact closures
 - 4) Minimum of three (3) acceleration times (2-300 seconds)
 - 5) Minimum of three (3) deceleration times (2-300 seconds)
 - 6) Minimum speed dwell time (0-18 seconds)
 - 7) Voltage boost (0-40V) for starting torque control
 - 8) Adjustable Carrier frequency 700-8,000 Hz for motor noise reduction or flexible switching technology. This adjustment shall be without derating the drive or motor.
 - 9) Current limit (70-120%)
 - 10) Critical frequency avoidance ([2] bands with 10 Hz adjustable widths)
- i. Door mounted operator controls and status indication from the LED display shall include:
- 1) Run/stop selection and LED indication (keypad or remote)
 - 2) Speed control selection and LED indication
 - 3) Forward/Reverse selection
 - 4) Manual speed adjustment
 - 5) Frequency meter
 - 6) Motor RPM
 - 7) Ammeter
 - 8) Output voltage
 - 9) Elapsed time meter
- j. The keypad shall have an LED display. The reverse button and the programming functions may be locked out if desired.
6. The following list of options shall be included:
- a. Input lockable disconnect rated 100,000 AIC.
 - b. Thermal motor overcurrent relay.
 - c. Bypass which includes an output contactor electrically and mechanically interlocked with a bypass contactor, run relay including control logic, status lights and a thermal motor overcurrent relay. The complete bypass system and Inverter/Off/Bypass selector switch shall be packaged in a single VFD enclosure. The bypass shall include a starter.
 - d. Electronics shall allow VFD to follow discrete increase speed and discrete decrease speed contact closures from a photohelic or similar device.
 - e. 120V control transformer and circuitry.
 - f. Output line reactors or output filters when the drive location and the motor are more than 100 feet apart.
 - g. Interior heaters shall be provided to maintain the minimum drive temperature when the drive is off.

- h. A Customer Interlock Terminal Strip – provide a separate terminal strip for connection of fire, smoke, freeze contacts and external start command. All external interlocks and start/stop contacts shall function with drive in hand, auto or bypass.
 - 1) Damper control circuit shall be operable in the hand, auto and bypass.
- 7. Service
 - a. The VFD manufacturer shall provide a start-up service package for all VFDs provided. Service shall include inspector for final adjustment, operational checks, and a final report for record purposes. The service package shall include a (1) year parts and labor warranty and 2 year parts warranty each from date of written acceptance and be performed by local factory trained service engineers. The service center must be permanently located within (200) miles of the job site and able to provide 24-hour service.
- 8. Protection
 - a. The VFD shall be protected against damage at all times. The drive shall be stored in a clean, dry environment with temperature and humidity within the range as specified by the drive manufacturer. Space heaters shall be energized controlled storage as recommended by the manufacturer. Storage space shall be environmentally controlled.
- 9. Factory Tests and Checks
 - a. VFD power semiconductors and diodes shall be 100% inspected and tested, including load testing.
 - b. Small signal semiconductors, resistors, capacitors and diodes shall be lot sampled. Testing shall include parameter, as well as functional characteristics.
 - c. All printed circuit boards shall be tested under a temperature cycling (0°C to +65°C) 24-hour load test and then functionally tested via fault finder bench equipment prior to unit installation.
 - d. All final assemblies shall be tested at full load with application of line-to-line and line-to-ground bolted faults. The VFD shall trip electronically without device failure.
 - e. After all tests have been performed, each VFD shall undergo a 24-hour burn-in test. The drive shall be burned-in at 100% inductive or motor load for (24) hours without an unscheduled shutdown.
- 10. A (1) day training course for Owner's personnel shall be presented by representatives of the manufacturer at the jobsite.

PART 3 – EXECUTION

3.1 VFD INSTALLATION

- A. Install in accordance with manufacturer recommendations, Contract Drawings, and reviewed submittals.
- B. Install to meet the Local and State Electrical Code and so as to ensure easy accessibility for service, removal, or replacement of all components.
- C. Provide supplemental steel, support, rods and hangers necessary to hang or mount VFDs.
- D. Receive and inspect VFDs to ensure they are without defect. Defective or damaged VFDs shall be returned to the manufacturer.
- E. Protect equipment to prevent damage from water, dirt, or accident. Protection shall include, but not be limited to, temporary plastic wrap to maintain equipment in original factory condition.
- F. Wiring installation and handling shall be in accordance with manufacturer's recommendations.
- G. Provide field testing (as described in Paragraph F, of this above Section).

3.2 FIELD TESTS AND CHECKS

- A. Testing, checkout and start-up of the VFD equipment shall be performed under the technical direction of the manufacturer's service engineer. Under no circumstances are any portions of the drive system to be energized without authorization from the manufacturer's representative.
- B. The Contractor shall provide independent harmonic testing by an independent testing company. Provide readings with printouts of the harmonic current at each harmonic as well as the total voltage distortion. The following readings shall be provided:
 - 1. At each point of common coupling:
 - a. With all drives running with load
 - b. With all drives off
 - 2. At the power connection to each drive:
 - a. With the drive running loaded
 - b. With drive off

3. All the above data shall be submitted to the Architect for review. If these tests shown that the drives are not in compliance with the Specifications, the drive manufacturer shall make all changes required to comply with the Specifications at no cost to the Owner. If required, this could mean replacing the drives that are not in compliance.
4. A copy of all tests and checks performed in the field, complete with meter readings and recordings, where applicable, shall be submitted to the Owner for this record.

END OF SECTION