SECTION 23 05 13 – variable frequency drives

1. GENERAL
	* + 1. RELATED DOCUMENTS
				1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
				2. Specifications throughout all Divisions of the Project Manual are directly applicable to this Section, and this Section is directly applicable to them.
				3. Related Specification Sections include but are not limited to the following:

Specification 25 11 00 BAS Basic Materials, Interface Devices, Panels and Sensors

* + - 1. SUMMARY
				1. Perform all Work required to provide and install a complete variable frequency motor drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use on a standard NEMA Design B induction motor.
				2. The drive manufacturer shall supply the drive and all necessary controls as specified.
			2. REFERENCE STANDARDS
				1. The latest published edition of a reference shall be applicable to this Project unless identified by a specific edition date.
				2. All reference amendments adopted prior to the effective date of this Contract shall be applicable to this Project.
				3. All materials, installation and workmanship shall comply with the applicable requirements and standards addressed within the following references:

Standard 519, IEEE Guide for Harmonic Content and Control.

ANSI/UL Standard UL508C, Underwriter’s Laboratories.

ICS 7.0, AC Adjustable Speed Drives, National Electrical Manufacturer’s Association (NEMA).

IEC 16800 Parts 1 and 2.

* + - 1. QUALITY ASSURANCE
				1. Company specializing in manufacturing the products specified in this Section with minimum three (3) years of experience.
				2. VFD and options shall be UL listed as a complete assembly. VFD’s that require the customer to supply external fuses are not acceptable.
				3. VFD and options shall be tested to ANSI/UL Standard 508 and listed by a nationally recognized testing agency such as UL or ETL.
				4. VFD and options shall comply with applicable requirements of the latest Standards of ANSI/UL, IEEE, and the NEC.
			2. SUBMITTALS
				1. Product Data:

Submit product data for components and accessories.

 All VFD’s for this Project shall be supplied by one manufacturer.

Submit Shop Drawings indicating outline dimensions, enclosure construction, lifting and supporting points, electrical one-line diagram, equipment electrical ratings, noise levels (including driven equipment) and total harmonic distortion (voltage and current).

Manufacturer shall provide terminal block to terminal block wiring diagrams coordinated with the Owner to provide a complete and functional operating system. Furnish detailed Drawings showing construction, dimensions, wiring diagrams, and installation procedures for Engineer’s approval.

* + - * 1. Operation and Maintenance Data:

Submit manufacturer’s written installation instructions.

Submit training outline.

Furnish harmonic analysis verifying compliance with specified distortion levels.

Furnish a list of recommended spare parts.

* + - 1. DELIVERY, STORAGE and HANDLING
				1. Deliver, store, protect and handle products to the Project Site under provisions of Division 01 and Division 20.
				2. Accept products on Site in factory-fabricated protective container with factory installed shipping skids and lifting lugs. Inspect for damage.
				3. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures and finish.
			2. EXTRA MATERIALS
				1. Submit two insulated‑handle tools designed for pulling fuses in accordance with ANSI/IEEE C37.46.
				2. Refer to Section 26 28 13 for fuse requirements.
			3. warranty
				1. VFD shall be unconditionally warranted by the manufacturer for two (2) years from the date of Substantial Completion, not to exceed 30 months from date of shipment.
				2. Warranty shall include all parts, labor, shipping, field service or technician time, labor or travel expenses, and verbal or written correspondence with the VFD manufacturer or VFD manufacturer’s representatives. Include correspondence which might be incidental to the proper installation and operation of the equipment.
1. PRODUCTS
	* + 1. GENERAL
				1. All materials shall meet or exceed all applicable referenced standards, federal, state and local requirements, and conform to codes and ordinances of authorities having jurisdiction.
				2. Furnish complete VFD controllers that convert incoming fixed frequency three-phase AC power into a variable frequency and voltage for controlling the speed of three-phase AC motors. The motor current shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current suitable for centrifugal pump and fan control and to eliminate the need for motor derating.
				3. **[NOTE TO ENGINEER: BYPASS MUST BE INCLUDED BY ENGINEER IN EQUIPMENT SCHEDULES. CONFIRM DURING DESIGN. INCLUDE BYPASS IN ALL APPLICATIONS IN WHICH THE FULL LOAD DESIGN IS AT 60 HZ.]** Contractor shall check equipment schedules on the Contract Drawings to determine if the VFD “bypass” switch option is required to allow the motor to run if the controller malfunctions. If the “bypass” switch option is not required, articles and statements in this section do not apply, and the Contractor shall provide one spare VFD for each equivalent horsepower motor or equipment power load indicated on the Contract Drawings.
				4. VFD manufacturer shall verify compatibility of motor furnished on equipment. One controller shall control the speed of one motor with the exception being a wall fan technology system **[NOTE TO ENGINEER: VFD arrangement for wall fan application requires approval of the Owner’s Representative.]**
				5. VFD shall convert 3 phase, 60 Hz utility power to adjustable voltage and frequency, 3 phase AC power for stepless motor speed control from 10 percent to 100 percent of the motor’s 60 Hz speed. Input voltage characteristics are 480 volts, 3 phase, 60 Hz.
				6. VFD shall include a converter section. The converter section shall convert fixed frequency and voltage AC utility power to a variable DC voltage. VFD’s that use silicon controlled rectifiers in the converter bridge shall also include 5 percent reactors. Isolation transformers are not acceptable in lieu of line reactors.
				7. VFD shall include an inverter section. The inverter section shall invert the variable DC voltage into a PWM wave form; adjustable voltage and frequency output for stepless motor speed control.
				8. Individual or simultaneous operation of VFD’s shall not add more than 5 percent total harmonic voltage distortion and no more than 5 percent total harmonic current distortion (per IEEE 516-1992) to the normal bus.

VFD manufacturer shall perform harmonic analysis based on the electrical one-line diagram.

The VFD manufacturer shall provide calculations specific to this installation, showing total harmonic voltage distortion is less than 5 percent.

Input line filters shall be sized and provided as required by the VFD manufacturer to ensure compliance with IEEE Standard 519. All VFD’s shall include a minimum of 5 percent impedance reactors, no exceptions.

* + - * 1. VFD shall include a coordinated AC transient protection system consisting of 4-120 joule rated MOV’s (phase to phase and phase to ground), a capacitor clamp, and 5 percent impedance reactors.
				2. Alternate Harmonics Specification:

Input line reactors and DC Bus filtered chokes (factory installed and wired in the drive enclosure) shall be provided to allow reliable operation on a typical commercial power distribution system and to minimize harmonics reflected onto the input line.

Shall not interfere with computer and other electronic systems in the building.

If not inherently protected, provide a suitable isolation transformer.

The system shall not produce spikes on the incoming line.

Any inverter that generates sufficient electrical line noise to interfere with operation of sensitive building equipment shall be field modified or replaced by the inverter supplier at no additional cost to the Owner.

* + - * 1. EMI / RFI filters. All VFD’s shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product Standard EN 61800-3 for the First Environment restricted level.
				2. Low voltage logic and 115V control circuits shall be electrically isolated from the power circuits. Signal circuit common shall be grounded.
				3. VFD shall include a power ride‑through feature to allow continuous operation up to a three-cycle line loss.
				4. Two independently adjustable accel and decel ramps with 1 to 1800 seconds adjustable time ramps. Extended time periods are also acceptable.
				5. VFD shall have full function output current limit adjustable from 10 to 100 percent. At the factory with compatible motor, provide at least three lock-out ranges (50 rpm maximum each), two of which can be used to correct any run test problems.
				6. Components shall be pretested and complete VFD shall have full burn‑in under full load for a minimum of 12 hours. Provide at least three lockout ranges (50 rpm maximum), two of which can be used to correct run test problems.
				7. Ambient noise generated by the VFD shall be limited to an amount equal to the system noise level as designated by the latest ASHRAE noise level guidelines for such equipment at each octave band. Noise level criteria at different octave bands and mid‑frequencies shall be furnished with the submittal data.
				8. VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and audible motor noise.
			1. Manufacturers
				1. Toshiba .
				2. ABB.
			2. Enclosure
				1. VFD shall be enclosed in a UL Listed Type 12 enclosure. Enclosure shall be UL listed as a plenum rated VFD. The VFD tolerated voltage window shall allow operation from a line of +30 percent nominal, and -35 percent nominal voltage as a minimum.
				2. Environmental operating conditions: 0 to 40 degrees C continuous. VFD’s that can operate at 40 degrees C intermittently (during a 24-hour period) are not acceptable and must be oversized. Altitude from 0 to 3300 feet above sea level, less than 95 percent humidity, non-condensing. VFD’s without these ratings are not acceptable.
				3. The following operator controls shall be located on the front of the enclosure:

Bypass Hand-Off-Auto.

Drive mode selector.

Bypass mode selector.

Bypass fault reset.

Provide the following indicating lights (LED type). In addition, provide test mode or push to test feature:

Power-on (ready).

Run enable (safeties) open.

Drive mode select damper opening.

Bypass mode selected.

Drive running.

Bypass running.

Drive fault.

Bypass fault.

Bypass H-O-A mode.

Automatic transfer to bypass selected.

Safety open.

Damper opening.

Damper end-switch made.

Provide the following relay (form C) outputs from the bypass:

System started.

System running.

Bypass overttide enabled.

Drive Fault.

Bypass fault (motor overload or underload-broken belt).

Bypass H-O-A position.

* + - * 1. Digital inputs for the system shall accept 24V or 115VAC (selectable).
				2. Customer Interlock Terminal Strip: Provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in Hand, Auto, or Bypass modes (not functional in fireman’s override 2). The remote start/stop contact shall operate in VFD mode.
				3. Dedicated digital input that will transfer motor from VFD mode to bypass mode upon dry contact closure for fireman’s override. Two modes of operation are required:

The first mode forces the motor to bypass operation and overrides both the VFD and bypass H-O-A switches and forces the motor to operate across the line (test mode). The system will only respond to the digital inputs and motor protections.

The second mode operates as the first, but will also defeat the overload and singe-phase protection for bypass and ignore all keypad and digital inputs t the system 9run until destruction).

* + - * 1. Include a “run permissive circuit” that will provide a normally open contact whenever a run command is provided (local or remote start command in VFD or bypass mode). The VFD system (VFD or bypass) shall not operate the motor until it receives a dry contact closure from a damper or valve end-switch. When the VFD system safety interlock (fire detector, freezestat, high static pressure switch, etc) opens, the motor shall coast to a stop and the run permissive contact shall open, closing the damper or valve.
				2. Include Class 20 or 30 (selectable) electronic motor overload protection.
			1. Bypass
				1. Furnish where indicated on the Drawings, a complete factory wired and tested bypass system consisting of an output contactor and bypass contactor. Overload protection shall be provided in both drive and bypass modes.
				2. Bypass to be furnished, built, and mounted by the VFD manufacturer.
				3. Provide an internal switch to select manual or automatic bypass.
				4. Provide an adjustable current sensing circuit for the bypass to provide loss of load indication (broken belt) when in the bypass mode.
				5. Door interlocked, padlockable disconnect that will disconnect all input power from the drive and all internally mounted options.
				6. Fused VFD only disconnect (service switch). Fast acting fuses exclusive to the VFD – fast acting fuses allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection, maintaining bypass capability. Bypass designs, which have no such fuses, or that incorporate fuses common to both the VFD and the bypass will not be accepted. The following contactor bypass schemes are not acceptable.

Door interlocked main input disconnect switch.

Power on light.

“Drive-off-bypass” manual mode selector switch.

* + - * 1. The bypass shall incorporate an internally sourced power supply and shall not require an external power source.
			1. Display / keypad
				1. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three (3) operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):

Output frequency.

Motor speed (RPM, percent, or engineering units).

Motor current.

Calculated motor torque.

Calculated motor power (kW).

DC bus voltage.

Output voltage.

* + - * 1. Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). The keypad shall use the following assistants:

Start-up assistants.

Parameter assistants.

Maintenance assistant.

Troubleshooting assistant.

* + - * 1. VFD shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. Keypad shall be removable, capable of remote mounting and shall allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFD’s.
				2. Keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate “bumpless transfer” of speed reference when switching between “Hand” and “Auto” modes. There shall be fault reset and “Help” buttons on the keypad. The Help button shall include “on-line” assistance for programming and troubleshooting.
				3. Provide a built-in time clock with battery back-up in the VFD keypad. The time clock shall be used to date and time stamp faults and record operating parameters at the time of fault. If the battery fails, the VFD shall automatically revert to hours of operation since initial power up. The time clock shall also be programmable to control start/stop functions, constant speeds, PID parameter sets and output relays. The VFD shall have a digital input that allows an override to the time clock (when in the off mode) for a programmable time frame. There shall be four (4) separate, independent timer functions that have both weekday and weekend settings.
			1. Serial Communication
				1. VFD shall have the capability of communicating with the building automation system (BAS) via an RS-485 serial port.
				2. VFD shall be provided with BacNET communication protocol information compatible with Johnson Control Metasys and shall be pre-configured at the factory to provide automatic communications without the need for field programming.
				3. VFD shall continue to provide serial communications regardless of how inverter is being controlled (“manual” mode via keypad, “automatic” mode via BAS, or “stopped” mode via either keypad or automatic BAS start/stop signal).
				4. Serial communications capabilities shall include, but not be limited to:

Enabled.

Run/stop control speed set adjustment.

Proportional/integral or PID control adjustments.

Current limit.

Accel/decel time adjustments.

* + - * 1. VFD shall have the capability of allowing the BAS to monitor the following feedback signals:

Process variable.

Output speed/frequency.

Current.

Torque.

Power (kW).

Operating hours.

Kilowatt hours (kWh).

Relay outputs.

Diagnostic warning and fault information.

* + - * 1. VFD shall allow the BAS to control the drive’s digital and analog outputs and monitor all drive digital and analog inputs via the serial interface.
				2. VFD shall be capable of providing the BAS with status signals for bypass operation and external safety trips via serial interface.
			1. System Operation
				1. Selector switch in the "off" position: controller run circuit shall be open and the system shall not operate.
				2. Selector switch in the "manual" position: motor speed shall be controlled by the manual speed potentiometer.
				3. Selector switch in the "auto" position: operation shall be via input 0 to 10 VDC or 4-20 mA signal with strategy output speed proportional to the input signal. If required into the controls strategy, VFD manufacturer shall furnish a pressure transducer mounted in the drive enclosure to convert a 3 to 15 psi pressure signal to a 0 to 10 VDC signal or 4-20 mA signal.
1. EXECUTION
	* + 1. preparation
				1. Verify that surfaces are ready to receive Work.
				2. Verify that field measurements are as shown on Shop Drawings and as instructed by manufacturer.
				3. Verify that required utilities are available, in the proper location, and ready for use.
			2. INSTALLATION
				1. Installation shall meet or exceed all applicable federal, state and local requirements, referenced standards and conform to codes and ordinances of authorities having jurisdiction.
				2. All installation shall be in accordance with manufacturer’s published recommendations.
				3. Power wiring shall be completed by the Electrical Contractor in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
			3. TESTING
				1. Manufacturer shall provide a factory trained technician to inspect, test and start-up the VFD and associated equipment and place the VFD into operation. This shall include any coordination with the BAS Provider to properly address the VFD in the BAS system.
				2. A harmonic test verifying the distortion level shall be included as part of Start-up and forwarded to the Owner. Any additional equipment, installation and equipment floor space required to meet the distortion level as set forth in the Specification, shall be borne by the VFD manufacturer.
			4. TRAINING
				1. Manufacturer shall provide for and present to the Owner, at no cost to the Owner, a training and troubleshooting course at the Owner’s location. **[Note to Engineer: Select one of the following training levels per Project requirements.]**

Provide one (1) hour orientation/start-up operation training for a minimum of two (2) people.

Provide minimum two-day training, four (4) hours per day for up to twelve (12) people. The course shall be classroom instruction complete with visual aids, documentation, circuit diagrams and hands-on training. This course shall not be construed as a sales meeting, but rather as a school to familiarize the Owner with the care, troubleshooting, and servicing of the VFD.

END OF SECTION 23 05 13