

## SECTION 230901 - VARIABLE FREQUENCY DRIVES

## PART 1 - GENERAL

## 1.1 RELATED DOCUMENTS

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

## 1.2 SUMMARY

- A. This Section includes solid-state, PWM, VFDs for speed control of three-phase, squirrel-cage induction motors.
- B. Related Sections include the following:
  - 1. Division 23 Section "Common Work Results for Mechanical"
  - 2. Division 26

## 1.3 SUBMITTALS

- A. Product Data: For each type of VFD. Include dimensions, mounting arrangements, location for conduit entries, shipping and operating weights, and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes.
- B. Shop Drawings: For each VFD.
  - 1. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings. Include the following:
    - a. Each installed unit's type and details.
    - b. Nameplate legends.
    - c. Short-circuit current rating of integrated unit.
    - d. Listed and labeled for series rating of overcurrent protective devices in combination controllers by an NRTL acceptable to authorities having jurisdiction.
    - e. Features, characteristics, ratings, and factory settings of each motor-control center unit.
  - 2. Wiring Diagrams: Power, signal, and control wiring for VFDs. Provide schematic wiring diagram for each type of VFD.
- C. Operation and Maintenance Data: For VFDs, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 1 Section "Operation and Maintenance Data," include the following:
  - 1. Routine maintenance requirements for VFDs and all installed components.
  - 2. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
- D. Load-Current and Overload-Relay Heater List: Compile after motors have been installed and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.

- E. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that dip switch settings for motor running overload protection suit actual motor to be protected.

#### 1.4 QUALITY ASSURANCE

- A. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 100 miles of Project site, a service center capable of providing training, parts, and emergency maintenance and repairs.
- B. Source Limitations: Obtain VFDs of a single type through one source from a single manufacturer.
- C. Electrical Components, Devices, and Accessories: Comply with NFPA 70. Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

#### 1.5 DELIVERY, STORAGE, AND HANDLING

- A. Store VFDs indoors in clean, dry space with uniform temperature to prevent condensation. Protect VFDs from exposure to dirt, fumes, water, corrosive substances, and physical damage.

#### 1.6 COORDINATION

- A. Coordinate power wiring to VFD with Division 26.
- B. Coordinate layout and installation of VFDs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
- C. Coordinate features of VFDs, installed units, and accessory devices with pilot devices and control circuits to which they connect.
- D. Coordinate features, accessories, and functions of each VFD and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

### PART 2 - PRODUCTS

#### 2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Honeywell NXS
  - 2. Eaton Corporation; Cutler-Hammer Products HVX9000
  - 3. ABB ACH550
  - 4. Cerus Industrial P Series : Fan and Pump Optimized Control VFD
  - 5. Danfoss VLT
  - 6. GE AF-300 P11
  - 7. Allen-Bradley PowerFlex
  - 8. Square D E-Flex
  - 9. Toshiba FS1
  - 10. Yaskawa E7 Series

## 11. Siemens

## 2.2 VARIABLE FREQUENCY DRIVES

- A. The VFDs shall be rated for voltage as scheduled. The VFD shall provide microprocessor based control for three-phase induction motors. The controller's full load output current rating shall be based on Variable Torque application at 40° C ambient and 1-16 kHz switching frequency below 50 HP and 1-10 kHz 50 HP and above to reduce motor noise and avoid increased motor losses.
- B. The VFD shall be of the Pulse Width Modulated (PWM) design converting the utility input voltage and frequency to a variable voltage and frequency output via a two-step operation. Adjustable Current Source VFD are not accepted. Insulated Gate Bipolar Transistors (IGBT's) shall be used in the inverter section. Bipolar Junction Transistors, GTO's or SCR's are not accepted. The VFD shall run at the above listed switching frequencies.
- C. The VFD shall have an efficiency at full load and speed that exceeds 95% for VFD below 15 HP and 97% for drives 15 HP and above. The efficiency shall exceed 90% at 50% speed and load.
- D. The VFD shall maintain a minimum line side displacement power factor of 0.96, regardless of speed and load. The VFD shall have a one (1) minute overload current rating of 110% for variable torque applications.
- E. The VFD shall be capable of operating any NEMA design B squirrel cage induction motor, regardless of manufacturer, with a horsepower and current rating within the capacity of the VFD.
- F. The VFD shall have an integral EMI/RFI filter as standard.
- G. The VFD shall limit harmonic distortion reflected onto the utility system to voltage and current levels as defined by IEEE 519-1992 for general systems applications, by utilizing the standard 3% nominal impedance integral AC three-phase line reactor. DC link chokes are not accepted.
- H. Any harmonic calculations shall be done based on the kVA capacity, X/R ratio and the impedance of the utility transformer feeding the installation, as noted on the drawings, and the total system load. The calculations shall be made with the point of common coupling (PCC) being the point where the utility feeds multiple customers.
- I. Total harmonic distortion shall be calculated under worst case conditions in accordance with the procedure outlined in IEEE 519-1992. Copies of these calculations are to be made available upon request. The contractor shall provide any needed information to the VFD supplier three (3) weeks prior to requiring harmonic calculations.
- J. The system containing the VFD shall comply with the 5% level of total harmonic distortion of line voltage and the line current limits as defined in IEEE 519-1992. If the system cannot meet the harmonic levels with the VFD provided with the standard input line reactor or optional input isolation transformer, the VFD manufacturer shall supply an eighteen pulse, multiple bridge rectifier, AC to DC conversion section with phase shifting transformer for all drives above 75 HP. This eighteen pulse rectifier converter shall result in a multiple pulse current waveform that will more nearly approximate a true sine wave to reduce voltage harmonic content on the utility line. The phase shifting transformer shall be of a single winding type to optimize its KVA rating and harmonic cancellation capability. Harmonic filters are not accepted above 75 HP.
- K. The VFD shall be able to start into a spinning motor. The VFD shall be able to determine the motor speed in any direction and resume operation without tripping. If the motor is spinning in the reverse direction,

the VFD shall start into the motor in the reverse direction, bring the motor to a controlled stop, and then accelerate the motor to the preset speed.

L. Standard operating conditions shall be:

1. Incoming Power: Three-phase, VAC as scheduled (+10% to -15%) and 50/60 Hz (+/-5 Hz) power to a fixed potential DC bus level.
2. Frequency stability of +/-0.05% for 24 hours with voltage regulation of +/-1% of maximum rated output voltage.
3. Speed regulation of +/- 0.5% of base speed.
4. Load inertia dependant carryover (ride-through) during utility loss.
5. Insensitive to input line rotation.
6. Humidity: 0 to 95% (non-condensing and non-corrosive).
7. Altitude: 0 to 3,300 feet (1000 meters) above sea level.
8. Ambient Temperature: -10 to 40 °C (VT).
9. Storage Temperature: -40 to 70 °C.

M. Control Functions

1. Frequently accessed VFD programmable parameters shall be adjustable from a digital operator keypad located on the front of the VFD. The VFD shall have a 3 line alphanumeric programmable display with status indicators. Keypads must use plain English words for parameters, status, and diagnostic messages. Keypads that are difficult to read or understand are not accepted, and particularly those that use alphanumeric code and tables. Keypads shall be adjustable for contrast with large characters easily visible in normal ambient light.
2. The keypad shall include a Hand-Off-Auto membrane selection and an Inverter/Bypass membrane selection. When in “Hand” the VFD will be started and the speed will be controlled from the up/down arrows. When in “Off”, the VFD will be stopped. In “Auto”, the VFD will start via an external contact closure or a communication network and the VFD speed will be controlled via an external speed reference.
3. The keypad shall have copy / paste capability.
4. Upon initial power up of the VFD, the keypad shall display a start up guide that will sequence all the necessary parameter adjustments for general start up.
5. Standard advanced programming and trouble-shooting functions shall be available by using a personal computer’s RS-232 port and Windows™ based software. In addition the software shall permit control and monitoring via the VFD’ RS232 port. The manufacturer shall supply a diskette with the required software. An easily understood instruction manual and software help screens shall also be provided. The computer software shall be used for modifying the drive setup and reviewing diagnostic and trend information as outlined in this section through Section 18.
6. The operator shall be able to scroll through the keypad menu to choose between the following:
  - a. Parameter Menu
  - b. Keypad Control
  - c. System Menu
  - d. Expander Boards
  - e. Monitoring Menu
  - f. Operate Menu
7. The following setups and adjustments, at a minimum, are to be available:
  - a. Start command from keypad, remote or communications port
  - b. Speed command from keypad, remote or communications port
  - c. Motor direction selection
  - d. Maximum and minimum speed limits
  - e. Acceleration and deceleration times, two settable ranges

- f. Critical (skip) frequency avoidance
- g. Torque limit
- h. Multiple attempt restart function
- i. Multiple preset speeds adjustment
- j. Catch a spinning motor start or normal start selection
- k. Programmable analog output

N. The VFD shall have the following system interfaces:

1. Inputs – A minimum of six (6) programmable digital inputs, two (2) analog inputs and serial communications interface shall be provided with the following available as a minimum:
  - a. Remote manual/auto
  - b. Remote start/stop
  - c. Remote forward/reverse
  - d. Remote preset speeds
  - e. Remote external trip
  - f. Remote fault reset
  - g. Process control speed reference interface, 4-20mA DC
  - h. Potentiometer or process control speed reference interface, 0 -10VDC
  - i. RS-232 programming and operation interface port
2. Outputs – A minimum of two (2) discrete programmable digital outputs, one (1) programmable open collector output, and one (1) programmable analog output shall be provided, with the following available at minimum.
  - a. Programmable relay outputs with one (1) set of Form C contacts for each, selectable with the following available at minimum:
    - 1) Fault
    - 2) Run
    - 3) Ready
    - 4) Reversing
    - 5) Jogging
    - 6) At speed
    - 7) In torque limit
    - 8) Motor rotation direction opposite of commanded
    - 9) Over-temperature
  - b. Programmable open collector output with available 24 Vdc power supply and selectable with the following available at minimum:
    - 1) Fault
    - 2) Run
    - 3) Ready
    - 4) Reversing
    - 5) Jogging
    - 6) At speed
    - 7) In torque limit
    - 8) Motor rotation direction opposite of commanded
    - 9) Overtemperature
  - c. Programmable analog output signal, selectable with the following available at minimum:
    - 1) Output frequency

- 2) Frequency reference
  - 3) Motor speed
  - 4) Output current
  - 5) Motor torque
  - 6) Motor power
  - 7) Motor voltage
  - 8) DC link voltage
  - 9) PID controller reference value
  - 10) PID controller actual value 1
  - 11) PID controller actual value 2
  - 12) PID controller error value
  - 13) PID controller output
3. Capability of two additional expandable I/O interface cards. Upon installation, software shall automatically identify the interface card and activate the appropriate parameters. This should be done without adding any new software.

O. Monitoring and Displays

1. The VFD display shall be a LCD type capable of displaying three (3) lines of text and the following thirteen (13) status indicators:
  - a. Run
  - b. Forward
  - c. Reverse
  - d. Stop
  - e. Ready
  - f. Alarm
  - g. Fault
  - h. Input/Output (I/O) Terminal
  - i. Keypad
  - j. Bus/communication
  - k. Hand
  - l. Auto
  - m. Off
2. The VFD keypad shall be capable of displaying the following monitoring functions at a minimum:
  - a. Motor Speed (RPM and %)
  - b. Frequency reference
  - c. Output frequency
  - d. Motor current
  - e. Motor torque
  - f. Motor power
  - g. Motor voltage
  - h. DC-link voltage
  - i. Heat sink temperature
  - j. Motor run time (resettable)
  - k. Total operating days counter
  - l. Operating hours (resettable)
  - m. Total megawatt hours
  - n. Megawatt hours (resettable)
  - o. Voltage level of analog input
  - p. Current level of analog input
  - q. Digital inputs status
  - r. Digital and relay outputs status

- s. Motor temperature rise
- t. PID references

P. Protective Functions

1. The VFD shall include the following protective features at minimum:
  - a. Over-current
  - b. Over-voltage
  - c. System fault
  - d. Under-voltage
  - e. Input line supervision
  - f. Output phase supervision
  - g. Under-temperature
  - h. Over-temperature
  - i. Motor stalled
  - j. Motor over temperature
  - k. Motor under-load
  - l. Logic voltage failure
  - m. Microprocessor failure
  - n. Brake chopper supervision
  - o. DC Injection braking
2. The VFD shall provide ground fault protection during power-up, starting, and running. VFD with no ground fault protection during running are not accepted.

Q. Diagnostic Features

1. Active Faults
2. The last 10 faults shall be recorded and stored in sequential order
3. Fault code and description of fault shall be displayed on the keypad.
4. Fault or alarm LED shall blink
5. Display drive data at time of fault
6. In the event several faults occur simultaneously, the sequence of active faults shall be viewable.
7. During a fault, the drive must be able to identify the following:
  - a. Drive Speed
  - b. Running hours
  - c. Running Days
  - d. Amps during fault
  - e. Motor Power
  - f. Motor Torque
  - g. DC bus Voltage
  - h. Drive Temperature
8. Fault History
  - a. The last 30 faults shall be recorded and stored in sequential order.
  - b. Display drive data at time of fault

R. Additional features included in the VFD:

1. The following indicating lights shall be provided on the keypad.
  - a. Drive Ready

- b. Drive Run
  - c. Drive Fault
2. The current withstand rating of the drive shall be 100,000 AIC. The rating of the complete drive assembly shall be UL tested and listed at 65kAIC.
  3. Communication card for interface with BACnet or LonWorks control system.
  4. The VFD shall have a cooling fan that is field replaceable using non-screw accessibility.
- S. Enclosure
1. The VFD shall be designed in a NEMA enclosure suitable for mounting conditions. Packaging of the drive shall be designed and manufactured by the manufacturer of the drive for quality assurance.
  2. The VFD shall have complete front accessibility with easily removable assemblies.
  3. Cable entry shall be bottom entry.
- T. Disconnect Switch: allows a convenient means of disconnecting the drive from the line; operating mechanism can be padlocked in the OFF position; factory-mounted in the enclosure.
- U. The VFD manufacturer shall maintain, as part of a national network, engineering service facilities within 250 miles of project to provide start-up service, emergency service calls, repair work, service contracts, maintenance and training of customer personnel.

### PART 3 - EXECUTION

#### 3.1 EXAMINATION

- A. Examine areas, surfaces, and substrates to receive VFDs for compliance with requirements, installation tolerances, and other conditions affecting performance. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFD installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

#### 3.2 APPLICATIONS

- A. Select features of each VFD to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; and duty cycle of motor, controller, and load.
- B. Select horsepower rating of controllers to suit motor controlled.

#### 3.3 INSTALLATION

- A. Anchor each VFD assembly to steel-channel sills or unitstrut arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with mounting surface.
- B. Comply with mounting and anchoring requirements specified in Division 26.
- C. Controller Fuses: Install fuses in each fusible switch. Comply with requirements in Division 26.



### 3.4 IDENTIFICATION

- A. Identify VFDs, components, and control wiring according with labeling that indicates the controlled device.

### 3.5 CONTROL WIRING INSTALLATION

- A. Install wiring between VFDs and remote devices according to Division 26.
- B. Bundle, train, and support wiring in enclosures.
- C. Connect hand-off-automatic switch and other automatic-control devices where applicable.
  - 1. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
  - 2. Connect selector switches with control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

### 3.6 CONNECTIONS

- A. Conduit installation requirements are specified in other Division 26 Sections. Drawings indicate general arrangement of conduit, fittings, and specialties.
- B. Ground equipment according to Division 26 Section "Grounding and Bonding."

### 3.7 FIELD QUALITY CONTROL

- A. Provide the services of a qualified manufacturer's employed Field Service Engineer or authorized service representative to assist the Contractor in installation and start-up of the equipment specified under this section. Field Service personnel shall be factory trained with periodic updates and have experience with the same model of VFD's on the job site. Sales representatives will not be accepted to perform this work. The manufacturer's service representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, installation as specified in manufacturer's installation instructions, wiring, application dependant adjustments, and verification of proper VFD operation.
- B. The following minimum work shall be performed by the Contractor under the technical direction of the manufacturer's service representative.
  - 1. Inspection and final adjustments.
  - 2. Operational and functional checks of VFDs and spare parts.
  - 3. The contractor shall certify that he has read the drive manufacturer's installation instructions and has installed the VFD in accordance with those instructions.
- C. The Contractor shall provide three (3) copies of the manufacturer's field start-up report before final payment is made. Perform the following field tests and inspections and prepare test reports:
  - 1. Perform each electrical test and visual and mechanical inspection, except optional tests, stated in NETA ATS. Certify compliance with test parameters.
  - 2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

3.8 ADJUSTING

- A. Set field-adjustable switches and circuit-breaker trip ranges.

3.9 DEMONSTRATION

- A. The Contractor shall provide a training session for one normal workday with a maximum of one trip. Training and instruction time shall be in addition to that required for start-up service. The training shall be conducted by the manufacturer's qualified representative. The training program shall consist of the following:
  - 1. Instructions on the proper operation of the equipment.
  - 2. Instructions on the proper maintenance of the equipment.

END OF SECTION 230901