

SECTION 26 29 23

VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS

04/06

Article I.

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- IEEE 519** (1992; R 1993; Errata 2004) Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- IEEE C62.41.1** (2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
- IEEE C62.41.2** (2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- NEMA 250** (2008) Enclosures for Electrical Equipment (1000 Volts Maximum)
- NEMA ICS 1** (2000; R 2005; R 2008) Standard for Industrial Control and Systems: General Requirements
- NEMA ICS 3.1** (2009) Guide for the Application, Handling, Storage, Installation and Maintenance of Medium-Voltage AC Contactors, Controllers and Control Centers
- NEMA ICS 6** (1993; R 2006) Enclosures
- NEMA ICS 7** (2006) Adjustable-Speed Drives

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 70** (2011; TIA 11-1; Errata 2011) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-461

(2007; Rev F) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

47 CFR 15

Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 489

(2009) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

UL 508C

(2002; Reprint Nov 2010) Power Conversion Equipment

## *Section 1.01 1.2 PROJECT DESCRIPTION AND RELATED REQUIREMENTS*

### 1.2.1 PROJECT SCOPE

Provide complete design and construction for the replacement of existing variable speed drive units as defined by this specification and applicable contract documents. Provide all services, skills expertise, labor, equipment, tools, and materials, needed to design, construct, and test as defined in this contract.

- 1.2.1.1 The schedule for the design portion of the project will start on Option 2 award date and will be 100% complete within 160 days. The installation of the replacement VFDs will follow the project phasing plan for the overall project as shown on 79K38825, Sheet V-04.
- 1.2.1.2 Perform site inspections during the course of the design and construction to ensure all existing conditions are addressed and verified.
- 1.2.1.3 Perform required engineering to develop design documents including shop drawings, design data, work plan, schedule, and product data submittals.
  - A. Submit shop drawings, design data, work plans, schedule, and product data to the government for review. Participate in a table-top meeting(s) at KSC to disposition all design comments and issues. The submittals will be approved and notice to proceed with construction will be given after all issues raised at the review meeting(s) are successfully resolved
  - B. Submit Ten (10) complete hard-copy sets of all design products for each review meeting (project) to the COTR. Review meeting drawings shall be half-size. Also provide .pdf format files on a compact disc for all drawings and data to be reviewed.

C. Submittal shall be a complete design ready for construction and shall be signed and sealed by the Florida Registered Engineer in responsible charge of their preparation.

D. Adhere to the following design drawing requirements:

- i. Format in AutoCAD™, MicroStation™, or DXF format. Format on KSC "F" size sheets using black ink on paper media or vellum. Drawings shall be fully readable when reduced to B-size (11-inches by 17-inches).
- ii. All sheets shall include a graphic scale for each scale used on that sheet.
- iii. Work point locations shall be vertically and horizontally tied to basic points of reference for proper installation.
- iv. Include the following drawings: Cover Sheet including index and symbol list; scaled electrical plans (floor plan); detail sheets – include installation, electrical power connections, control connections, and grounding details.

1.2.1.4 The government shall schedule the review meeting(s) within 21 calendar days of receipt of the submittal(s).

1.2.1.5 Procure all materials, equipment, and services required once notice to proceed has been given.

1.2.1.6 Perform all project work including demolition, installation, and testing to provide complete and usable facilities. Work shall be as indicated on the approved submittal drawings, work plans and product data.

1.2.1.7 Submit certified as-built drawings, design data, product data, and test report data. Include digital media with all source files and .pdf files.

## 1.2.2 RELATED REQUIREMENTS

Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL apply to this section with additions and modifications specified herein.

## Section 1.02 1.3 SYSTEM DESCRIPTION

A. This is a design-build VFD replacement project identified as Option 2 in the bid package. The overall scope of this project is to remove and replace the eight (8) 100 Horsepower, 480VAC 3-phase VFDs that are driving the secondary chilled water distribution pumps at the Industrial Area Chiller Plant (IACP). The VFD replacement shall be designed by a Professional Engineer register in the state of Florida. Three design reviews, held at KSC,

will be required prior to procurement and installation of the new VFDs. The first design review will be a kickoff meeting and will include a walk down of the IACP to assemble design and installation data. The second design review will be a 75% review and will include a table top review of the shop drawings and product data. The third design review will be a 100% review and will include a table top review of the shop drawings, the product data and a construction implementation plan.

- B. The existing VFDs are located on the IACP mezzanine and they are connected to the 8 secondary pumps located on the IACP floor (see appendix A for existing system photos and 70K38825 sheet I-49 for equipment locations). The replacement design shall utilize the existing conduit and wiring to the greatest extent possible so the new VFDs shall be installed within the same foot print area as the existing ones. If the existing conduit and wiring are not sufficient length to connect to the new VFDs, wire splices are allowed but they must be clearly identified on the shop drawings and approved by the government prior to construction. VFD input/output wiring is copper THHN/THWN. Input conductors are (3) 2/0, #4 ground in 1-1/2" conduit for VFD's No. 1 through 6 and (3) 4/0, #2 ground in 2" conduit for VFD's 7 and 8. Output conductors are (3) 2/0, #4 ground in 1-1/2" conduit for VFD's No. 1 through 6 and (3) 3/0, #4 ground in 2" conduit for VFD's 7 and 8.
- C. The base contract includes modifications to the existing VFDs that will not be required for the VFDs if FPO-2 is exercised (reference 79K38825 sheet I-49 note P). The replacement VFD design shall identify all construction interfaces that will be affected as a result of exercising FPO-2.
- D. The new VFDs shall be provided with two (2) removable control panels. One control panel shall be mounted on the new IACP manual control panel and the other control panel shall remain in the drive enclosure for local use as required. Reference 79K38825 sheet I-70 for the manual control panel mounting details. The replacement VFD design shall include conduit, wiring, and installation details required to install the VFD control panel in the IACP manual control panel.
- E. The new VFDs shall provide monitor and control capability via the new control system being installed as a part of the base contract. Reference 79K38825 sheets I-55 through I-58 for the I/O connection requirements. Note that new cabling and conduit to the VFDs is already included in the base contract.

### (a) 1.3.1 Performance Requirements

#### (i) 1.3.1.1 Electromagnetic Interference Suppression

Computing devices, as defined by [47 CFR 15](#), [MIL-STD-461](#) rules and regulations, shall be certified to comply with the requirements for class A computing devices and labeled as set forth in part 15.

(ii) 1.3.1.2 Electromechanical and Electrical Components

Electrical and electromechanical components of the Variable Frequency Drive (VFD) shall not cause electromagnetic interference to adjacent electrical or electromechanical equipment while in operation.

(b) 1.3.2 Electrical Requirements

(i) 1.3.2.1 Power Line Surge Protection

IEEE C62.41.1 and IEEE C62.41.2, IEEE 519 Control panel shall have surge protection, included within the panel to protect the unit from damaging transient voltage surges. Surge arrester shall be mounted near the incoming power source and properly wired to all three phases and ground. Fuses shall not be used for surge protection.

(ii) 1.3.2.2 Sensor and Control Wiring Surge Protection

I/O functions as specified shall be protected against surges induced on control and sensor wiring installed outdoors and as shown. The inputs and outputs shall be tested in both normal mode and common mode using the following two waveforms:

- a. A 10 microsecond by 1000 microsecond waveform with a peak voltage of 1500 volts and a peak current of 60 amperes.
- b. An 8 microsecond by 20 microsecond waveform with a peak voltage of 1000 volts and a peak current of 500 amperes.

*Section 1.03 1.4 SUBMITTALS*

Government approval is required for submittals with a "G" designation. The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

*SD-02 Shop Drawings*

*Design Drawings; G*

*Schematic diagrams; G*

*Interconnecting diagrams; G*

Installation drawings; G

Manual panel installation drawings; G

Submit drawings for government approval prior to equipment construction or integration. Modifications to original drawings made during installation shall be immediately recorded for inclusion into the as-built drawings.

SD-03 Product Data – Submit with design drawings.

Variable frequency drives; G

Wires and cables; G

Power conductor splice and insulation kits; G

Equipment schedule; G

Include data indicating compatibility with motors being driven.

SD-06 Test Reports

VFD Test; G

Performance Verification Tests; G

Endurance Test; G

SD-07 Certificates

Design Engineer Florida PE registration; G

SD-08 Manufacturer's Instructions

Installation instructions; G

SD-09 Manufacturer's Field Reports

VFD Factory Test Plan; G

Factory test results; G

SD-10 Operation and Maintenance Data

Variable frequency drives, Data Package 4

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Provide service and maintenance information including preventive maintenance, assembly, and disassembly procedures. Include electrical drawings from electrical general sections. Submit additional information necessary to provide complete operation, repair, and maintenance information, detailed to the smallest replaceable unit. Include copies of as-built submittals. Provide routine preventative maintenance instructions, and equipment required. Provide instructions on how to modify program settings, and modify the control program. Provide instructions on drive adjustment, trouble-shooting, and configuration. Provide instructions on process tuning and system calibration.

## *Section 1.04 1.5 QUALITY ASSURANCE*

### *(a) 1.5.1 Schematic Diagrams*

Show circuits and device elements for each replaceable module. Schematic diagrams of printed circuit boards are permitted to group functional assemblies as devices, provided that sufficient information is provided for government maintenance personnel to verify proper operation of the functional assemblies.

### *(b) 1.5.2 Interconnecting Diagrams*

Show interconnections between equipment assemblies, and external interfaces, including power and signal conductors. Include for enclosures and external devices. Also include interconnection of the VFD control panel to the IACP manual control panel.

### *(c) 1.5.3 Installation Drawings*

Show floor plan of each site, with V.F.D.'s and motors indicated. Indicate ventilation requirements, adequate clearances, and cable routes. Also include installation details for installing the VFD control panel to the IACP manual control panel.

### *(d) 1.5.4 Equipment Schedule*

Provide schedule of equipment supplied. Schedule shall provide a cross reference between manufacturer data and identifiers indicated in shop drawings. Schedule shall include the total quantity of each item of equipment supplied. For complete assemblies, such as VFD's, provide the serial numbers of each assembly, and a sub-schedule of components within the assembly. Provide recommended spare parts listing for each assembly or component. Provide final parameter values for all drive parameter settings.

(e) 1.5.5 Installation instructions

Provide installation instructions issued by the manufacturer of the equipment, including notes and recommendations, prior to shipment to the site. Provide operation instructions prior to acceptance testing.

(f) 1.5.6 Factory Test Results

Document test results and submit to government within 7 working days after completion of test.

*Section 1.05 1.6 DELIVERY AND STORAGE*

Equipment delivered and placed in storage shall be stored with protection from the weather, humidity and temperature variations, dirt and dust, or other contaminants.

*Section 1.06 1.7 WARRANTY*

The complete system shall be warranted by the manufacturer for a period of one year, or the contracted period of any extended warrantee agreed upon by the contractor and the Government, after successful completion of the acceptance test. Any component failing to perform its function as specified and documented shall be repaired or replaced by the contractor at no additional cost to the Government. Items repaired or replaced shall be warranted for an additional period of at least one year from the date that it becomes functional again, as specified in the FAR CLAUSE 52.246-21.

*Section 1.07 1.8 MAINTENANCE*

(a) 1.8.1 Spare Parts

Manufacturers provide spare parts in accordance with recommended spare parts list.

(b) 1.8.2 Maintenance Support

During the warranty period, the Contractor shall provide on-site, on-call maintenance services by Contractor's personnel on the following basis: The service shall be on a per-call basis with 36 hour response. Contractor shall support the maintenance of all hardware and software of the system. Various personnel of different expertise shall be sent on-site depending on the nature of the maintenance service required. Costs shall include travel, local transportation, living expenses, and labor rates of the service personnel while responding to the service

request. The provisions of this Section are not in lieu of, nor relieve the Contractor of, warranty responsibilities covered in this specification. Should the result of the service request be the uncovering of a system defect covered under the warranty provisions, all costs for the call, including the labor necessary to identify the defect, shall be borne by the Contractor.

*Article II.*            **PART 2 PRODUCTS**

**Section 2.01 2.1 VARIABLE FREQUENCY DRIVES (VFD)**

Provide frequency drive to control the speed of induction motor(s). The VFD shall include the following minimum functions, features and ratings.

- A. Input circuit breaker per **UL 489** with a minimum of 10,000 amps symmetrical interrupting capacity and door interlocked external operator.
- B. A converter stage per **UL 508C** shall change fixed voltage, fixed frequency, ac line power to a fixed dc voltage. The converter shall utilize a full wave bridge design incorporating diode rectifiers. Silicon Controlled Rectifiers (SCR) are not acceptable. The converter shall be insensitive to three phase rotation of the ac line and shall not cause displacement power factor of less than .95 lagging under any speed and load condition.
- C. An inverter stage shall change fixed dc voltage to variable frequency, variable voltage, ac for application to a standard NEMA design B squirrel cage motor. The inverter shall be switched in a manner to produce a sine coded pulse width modulated (PWM) output waveform.
- D. The VFD shall be capable of supplying 120 percent of rated full load current for one minute at maximum ambient temperature.
- E. The VFD shall be designed to operate from a 480 volt, plus or minus 10 percent, three phase, 60 Hz supply, and control motors with a corresponding voltage rating.
- F. Acceleration and deceleration time shall be independently adjustable from one second to 60 seconds.
- G. Adjustable full-time current limiting shall limit the current to a preset value which shall not exceed 120 percent of the controller rated current. The current limiting action shall maintain the V/Hz ratio constant so that variable torque can be maintained. Short time starting override shall allow starting current to reach 175 percent of controller rated current to maximum starting torque.
- H. The controllers shall be capable of producing an output frequency over the range of 3 Hz to 60 Hz (20 to one speed range), without low speed cogging. Over frequency protection shall be included such that a failure in the controller electronic circuitry shall not cause frequency to exceed 110 percent of the maximum controller output frequency selected.

- I. Minimum and maximum output frequency shall be adjustable over the following ranges:
  - 1) Minimum frequency 3 Hz to 50 percent of maximum selected frequency;
  - 2) Maximum frequency 40 Hz to 60 Hz.
  
- J. The controller efficiency at any speed shall not be less than 96 percent.
  
- K. The controllers shall be capable of being restarted into a motor coasting in the forward direction without tripping.
  
- L. Protection of power semiconductor components shall be accomplished without the use of fast acting semiconductor output fuses. Subjecting the controllers to any of the following conditions shall not result in component failure or the need for fuse replacement:
  - 1. Short circuit at controller output
  - 2. Ground fault at controller output
  - 3. Open circuit at controller output
  - 4. Input undervoltage
  - 5. Input overvoltage
  - 6. Loss of input phase
  - 7. AC line switching transients
  - 8. Instantaneous overload
  - 9. Sustained overload exceeding 115 percent of controller rated current
  - 10. Over temperature
  - 11. Phase reversal
  
- M. Solid state motor overload protection shall be included such that current exceeding an adjustable threshold shall activate a 60 second timing circuit. Should current remain above the threshold continuously for the timing period, the controller will automatically shut down.
  
- N. Provide load reactors between the VFD and the motor to reduce the peak voltage at the motor terminals. Coordinate reactor size with the motor and VFD manufactures. Install the reactors in the VFD enclosure.
  
- O. A slip compensation circuit shall be included which will sense changing motor load conditions and adjust output frequency to provide speed regulation of NEMA B motors to

within plus or minus 0.5 percent of maximum speed without the necessity of a tachometer generator.

- P. The VFD shall be factory set for manual restart after the first protective circuit trip for malfunction (overcurrent, undervoltage, overvoltage or overtemperature) or an interruption of power. The VFD shall be capable of being set for automatic restart after a selected time delay. If the drive faults again within a specified time period (adjustable 0-60 seconds), a manual restart will be required.
- Q. The VFD shall include external fault reset capability. All the necessary logic to accept an external fault reset contact shall be included.
- R. Provide critical speed lockout circuitry to prevent operating at frequencies with critical harmonics that cause resonant vibrations. The VFD shall have a minimum of three user selectable bandwidths.
- S. Provide the following operator control and monitoring devices mounted on the front panel of the VFD:
  - 1. Main breaker ON/OFF disconnect handle.
  - 2. Drive-OFF-Bypass switch.
  - 3. Power on light.
  - 4. Drive run power light.
  - 5. Fault light.
  - 6. Bypass light.
  - 7. Local display (stored in VFD enclosure).
- T. Provide properly sized NEMA rated by-pass and isolation contactors to enable operation of motor in the event of VFD failure. Mechanical and electrical interlocks shall be installed between the by-pass and isolation contactors. Provide a selector switch and transfer delay timer.
- U. The VFD shall be capable of operating continuously in a 122°F ambient environment at no less than 90% of its rated output current in a 104°F ambient environment.

## *Section 2.02 2.2 ENCLOSURES*

Provide equipment enclosures conforming to [NEMA 250](#), [NEMA ICS 7](#), [NEMA ICS 6](#).

### Section 2.03 2.3 WIRES AND CABLES

All wires and cables shall conform to NEMA 250, NEMA ICS 7, NFPA 70. Electrical splices for power conductors shall be inline copper compression type and insulation shall be cold shrink type.

### Section 2.04 2.4 NAMEPLATES

Nameplates external to NEMA enclosures shall conform with the requirements of Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL. Nameplates internal to enclosures shall be manufacturer's standard, with the exception that they must be permanent.

### Section 2.05 2.5 SOURCE QUALITY CONTROL

#### (a) 2.5.1 VFD Factory Test Plan

To ensure quality, each VFD shall be subject to a series of in-plant quality control inspections before approval for shipment from the manufacturer's facilities. Provide test plans and test reports.

#### Article III. PART 3 EXECUTION

### Section 3.01 3.1 INSTALLATION

Per NEMA ICS 3.1, install equipment in accordance with the approved manufacturer's printed installation drawings, instructions, wiring diagrams, and as indicated on project drawings and the approved shop drawings. A field representative of the drive manufacturer shall supervise the installation of all equipment, and wiring and shall be on site to perform the initial inspection and start up of the drive. The contractor shall inform the government 7 calendar days prior to the date of initial VFD start up.

### Section 3.02 3.2 FIELD QUALITY CONTROL

Specified products shall be tested as a system for conformance to specification requirements prior to scheduling the acceptance tests. Contractor shall conduct performance verification tests in the presence of Government representative, observing and documenting complete compliance of the system to the specifications. Contractor shall submit a signed copy of the test results, certifying proper system operation before scheduling tests.

#### (a) 3.2.1 VFD Test

A proposed test plan shall be submitted to the contracting officer at least 28 calendar days prior to proposed testing for approval. The tests shall conform to NEMA ICS 1, NEMA ICS 7, and all manufacturer's safety regulations. The Government reserves the right to witness all tests and review any documentation. The contractor shall inform the Government at least 14 working days prior to the dates of testing. Contractor shall provide video tapes, if available, of all training provided to the Government for subsequent use in training new personnel. All training aids, texts, and expendable support material for a self-sufficient presentation shall be provided, the amount of which to be determined by the contracting officer.

#### (b) 3.2.2 Performance Verification Tests

"Performance Verification Test" plan shall provide the step by step procedure required to establish formal verification of the performance of the VFD including the operation of the VFD control panel. Compliance with the specification requirements shall be verified by inspections, review of critical data, demonstrations, and tests. The Government reserves the right to witness all tests, review data, and request other such additional inspections and repeat tests as necessary to ensure that the system and provided services conform to the stated requirements. The contractor shall inform the Government 14 calendar days prior to the date the test is to be conducted.

#### (c) 3.2.3 Endurance Test

Immediately upon completion of the performance verification test, the endurance test shall commence. The system shall be operated at varying rates for not less than 192 consecutive hours, at an average effectiveness level of .9998, to demonstrate proper functioning of the complete PCS. Continue the test on a day-to-day basis until performance standard is met. During the endurance test, the contractor shall not be allowed in the building. The system shall respond as designed.

### Section 3.03 3.3 DEMONSTRATION

#### (a) 3.3.1 Training

Coordinate training requirements with the Contracting Officer.

##### (i) 3.3.1.1 Instructions to Government Personnel

Provide the services of competent instructors who will give full instruction to designated personnel in operation, maintenance, calibration, configuration, and programming of the

complete control system. Orient the training specifically to the system installed. Instructors shall be thoroughly familiar with the subject matter they are to teach. The Government personnel designated to attend the training will have a high school education or equivalent. The number of training days of instruction furnished shall be as specified. A training day is defined as eight hours of instruction, including two 15-minute breaks and excluding lunch time; Monday through Friday. Provide a training manual for each student at each training phase which describes in detail the material included in each training program. Provide one additional copy for archiving. Provide equipment and materials required for classroom training. Provide a list of additional related courses, and offers, noting any courses recommended. List each training course individually by name, including duration, approximate cost per person, and location of course. Unused copies of training manuals shall be turned over to the Government at the end of last training session.

#### (ii) 3.3.1.2 Operating Personnel Training Program

Provide two 2 hour training session at the site at a time and place mutually agreeable between the Contractor and the Government. Provide session to train 4 operation personnel in the functional operations of the system and the procedures that personnel will follow in system operation. This training shall include:

- a. System overview
- b. General theory of operation
- c. System operation
- d. Alarm formats
- e. Failure recovery procedures
- f. Troubleshooting
- g. A comprehensive review of all the drive parameters setup in the VFD including hands on demonstration of how to review and change each parameter.

#### (iii) 3.3.1.3 Engineering/Maintenance Personnel Training

Accomplish the training program as specified. Training shall be conducted on site at a location designated by the Government. Provide a one day training session to train 4 engineering personnel in the functional operations of the system. This training shall include:

- a. System overview
- b. General theory of operation

- c. System operation
- d. System configuration
- e. Alarm formats
- f. Failure recovery procedures
- g. Troubleshooting and repair
- h. Maintenance and calibration
- i. System programming and configuration

**Appendix A**



VFDs 7&8



VFD 1-6