SECTION 26 29 23 – VARIABLE FREQUENCY DRIVE

1.01 SUMMARY:

A. **Basic Function**: This specification shall apply to gates operating motor mechanism and any other systems that the Contractor's design requires a Variable Frequency Drive (VFD).

B. **Scope of Work**: Variable [A17]frequency drives [A17] shall be installed whenever the operation of motors required variable speed applications. This specification covers the complete labor, materials, and equipment required to place into operation a VFD system, and covers all components of the engineered system. For the gates particular application, it may be required that two VFD's work in parallel in order to equalize load sharing and match the speed, and increase reliability.

1.02 [A16]REFERENCES:[A16]

A. **American National Standards Institute (ANSI) Standards**:

958 –03	Guide for the Application of AC Adjustable-speed Drives on 2,400 and 13,800V Auxiliary Systems in Electric Power Generating Stations
C57.110 – 04	Recommended Practice for Establishing Transformer Capability when Supplying Non-sinusoidal Load Currents
C57.16 – 01	Standard requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors
18 – 02	Standard for Shunt Power Capacitors
P1036 – 06	Guide for Application of Shunt Power Capacitors

B. **Institute of Electrical and Electronics Engineer (IEEE) Standard**:

519 – 04	Recommended Practice and Requirements for Harmonic Control in Electrical Systems

C. **National Fire Protection Association (NFPA) Publications**:

70 – 08	National Electrical Code

D. **National Electrical Manufacturers Association (NEMA) Publications**:

ICS 61800-4 - 04	Adjustable Speed Electrical Power Drive Systems Part 4: General Requirements Rating Specifications for AC Power Drive Systems Above 1,000VAC and not exceeding 35kV

ICS 6 – 06	Industrial Control and Systems Enclosures
ICS 7 – 06	Industrial Control and Systems: Adjustable-Speed Drives
250 – 03	Enclosures for Electrical Equipment (1000 volts maximum)

E. **Underwriters Laboratories Inc. (UL) Standards for Safety**:

1283 – 2005	UL Standard for Safety for Electromagnetic Interference Filters

1.03 [A7]REQUIREMENTS:[A7]

A. The drivers will be installed in an air conditioned room, but they shall be able to perform in the normal ambient conditions of Panama. VFD system shall be capable of continuous operation without derating in an average ambient temperature of 40°C at sea level and a humidity environment of 95% non-condensing.

B. [A7]**Performance**:[A7]

1. **Torque**: VFD shall meet the following speed and torque requirements:
   a. Continuous system operation output over a speed range as required for the application.
   b. Operating any standard AC motor over the specified speed range.
   c. Momentary overload of 120% of rated motor current for one minute out of any ten minutes.
   d. Produce full rated torque at any speed in the operating range (constant torque capability).
   e. Transient over-torque of 130% of nominal motor torque for one minute of any ten minutes.
   f. Breaking torque capacity to be determined by gate operation requirements, but in no case shall be less than 30% of motor torque.
   g. No speed sensor shall be required
   h. Continuous operation with 30% voltage sag or power loss of 3 cycles or less on the input power line.
   i. The VFD converter section shall be 18 or 12 pulse as required in paragraph 1.04 D.

2. **Input Harmonics**: VFD's shall comply with the latest edition of IEEE 519 for total harmonic voltage and current distortion calculation and measurement and meet the following distortion limits:

a. Voltage Harmonics: Individual or simultaneous operation of the VFD's shall not add more than 3% total harmonic voltage distortion while operating from the utility source and measured at the point of common coupling at any motor load and speed.

b. Current Harmonics: Maximum allowable total harmonic current distortion limits for each VFD shall not exceed 5% as calculated and measured at the point of common coupling at any motor load and speed.

c. [A17]The existing network source data is available as an Aspen data base, made available by the Employer to all Tenderers, to be used in all required studies and for determining the harmonic response of the existing network. [A17]

C. **Serviceability / Maintainability**

1. **Access**: VFD system should be designed for easy access. All maintenance, part replacement and/or installation shall be able to be done from access doors.

2. **Modularity**: Modular designed components for rack-out accessibility for ease of maintenance and to minimize repair downtime.

D. **Capacities**: Capacities of equipment and material shall be not less than those indicated on these specifications.

E. **Modularity**: VFD System shall be modular type system with easy access or replacement of the different modules or elements.

F. **Corrosion Resistance**: All interior and exterior ferrous metal shall be cleaned and painted with corrosion protective coating system as per ANSI C57.12.29 and Section 09 96 00 (*Corrosion Control Coatings*).

G. **Installation**: VFD Systems shall be installed as per manufacturer's recommendation.

H. **Standard Products**: Materials and equipment submitted for approval shall be standard cataloged products of concerns regularly engaged in the commercial production of these products and shall be the latest standard design that conforms to the specifications.

I. **Marking**: Internal equipment wiring marking shall be as per Section 26 05 53 (*Identification for Electrical Systems*).

1.04 [A7]DESIGN CRITERIA/SYSTEM DESCRIPTION AND PERFORMANCE:[A7]

A. Each VFD system shall consist of all system components required to meet the performance, protection, safety, testing, and certification criteria of this specification. These components shall be part of an integral motor control system: VFD, motor, harmonic filter and power factor correction unit, isolation transformer, VFD converter/DC-link/inverter, and output filter.

B. The Contractor will be allowed to design the gate control system in medium voltage (12kV). This will requires a medium voltage VFD and a medium voltage motor. If

Contractor decides to use medium voltage system, IEEE 958 standard shall be followed in addition to the requirements of these specifications.

C. The VFD system as defined above shall be completely factory pre-wired, assembled and tested (with the motor) as complete packages by the VFD manufacturer, to assure a properly coordinated and fully integrated drive system.

D. The VFD converter section shall be of at least eighteen pulse type for motors sized above 200 HP, and twelve pulse type for motors sized 200 HP or less. Harmonic filters shall be tuned to avoid resonance problems.

E. **Metering**: Power quality metering system shall be permanent installed in the VFD system to continuously monitor the quality of the input and output electrical power. The power quality meter data shall include the following:

1. Input and output voltage, current, (per phase and average rms value)
2. Input and output frequency, Power factor
3. Input and output kW, kVAR; input kWh and kVARh
4. Input and output harmonic demand distortion in current and voltage
5. THD (average of three phases) for current and voltage
6. Drive efficiency
7. **Motor**: Speed (in RPM and/or %), flux (%), torque (%)
8. Elapse time meter

F. **Standard Motor Compatibility**:

1. VFD system shall provide an output waveform that will allow utilization of standard squirrel cage motors with 1.15 service factor, without need of any special insulation or de-rating. Motor life expectancy should not be compromised in any way by operation with the VFD system. The VFD must provide motor overload protection in any operating condition.

2. To avoid motor heating, VFD output current waveform, as measured at the motor, shall be inherently sinusoidal at all speeds, with a total harmonic current distortion not exceeding 3% referenced to the output current fundamental at any operating point in the range between 10% and 100% speed at any motor load.

3. VFD shall inherently protect existing motors from high-voltage, resonance wave and $\delta v/\delta t$ stress; independent of cable length to motor. The VFD system shall be designed to produce no standing waves or over-voltage conditions based on a cable length of at least 1000 ft (~300 m). If the VFD requires an output filter or isolation transformers or any other device in order to meet the requirement of the IEEE 519, it shall be an integral part of the VFD system and included within the enclosure.

4. All internal firing signals and other communications (which link operational controls with power components such as status and diagnostic signals) must meet noise immunity and safety requirements as defined by standard UL 1283.

5. VFD system shall maintain a 0.90 minimum true power factor at any speed. Power factor correction and/or harmonic filter shall never have leading power factor. Power factor correction unit shall include short circuit protection, power factor correction capacitors, and series harmonic de-coupling reactors, all integrated into VFD system and mounted within the same enclosure.

6. Sleeve type wire marker tags or other acceptable means of permanent identification shall be applied to power and control wiring. Individual labels shall be provided for all major components of the VFD system

7. Redundant cooling system shall be provided with automatic switchover in the event of a failure, for enhanced reliability. Drive must have ability to detect failed operation of the cooling system. During normal operation, the system must periodically cycle between the two systems (main & stand-by) to "exercise" them. Contractor shall coordinate VFD's heat dissipation with the design of the HVAC system.

8. **Enclosure**: Provide enclosures conforming to NEMA 250, NEMA ICS 7 and NEMA ICS 6. All VFD system components including transformer shall be mounted and wired by the VFD system manufacturer in a grounded enclosure meeting the following requirements without exception:

    a. VFD system shall be NEMA-1. Units shall have washable filter media covering all air inlets. Inlet air filters shall be corrosion-free media. Filters shall be easy replaceable while the equipment is in operation without exposing maintenance personnel to any of the power components. Cabinet color shall be ANSI 61 Gray. Paint procedures and materials shall be manufacturer's system designed and proven for resistance to chemical attack in industrial powerhouse environment.

    b. Cabinets and doors shall be fabricated using heavy gauge steel conforming to NEMA ICS 6, for sturdy construction and dimensional integrity to assure long-term fit and function. All doors shall be gasketed to provide environmental protection and secure fits.

    c. Enclosures must be designed to avoid harmonic and inductive heating effects. The enclosure must be designed to protect the equipment from any outside interference; and enclosed, and shielded to eliminate any radio frequency interference.

    d. Main grounding consisting of copper bus bars in the enclosure base. Corrosion resistant grounding pads shall be provided on two locations, one at each end of the enclosure. A copper ground bus shall be provided for grounding of control circuits.

    e. All control wiring shall be physically separated from the power wiring. All wiring shall be tagged with permanent labels at each termination, junction box, and device. Labels shall correspond to the schematic and wiring diagrams.

9. **Power Component Protection**:

   a. VFD system shall include distribution class surge arrestors to protect the system against voltage surges.

   b. The VFD system shall include short circuit protection on the input to the converter rectifier devices to protect the system from any potentially harmful fault currents.

   c. Protective Features and Circuits:

      1) The controller shall include the following alarms and protective features:

         a) Instantaneous over-current and over-voltage

         b) Under-voltage, reverse phase, and power loss

         c) Volts/Hertz

         d) Over-temperature

         e) Motor inverse time overload

         f) Provisions for 6 motor stator windings RTD's for motor temperature monitoring to provide trip and alarm.

      2) The VFD system shall be protected from damage due to the following:

         a) Single-phase fault or three-phase short circuit on VFD system output terminals

         b) Failure to commutate inverter electronic switching device due to severe overload or other conditions

         c) Loss of input power due to opening of VFD input disconnect device or utility power failure during VFD operation

         d) Loss of one (1) phase of input power

         e) Motor regeneration due to backspin or loss of VFD input power

      3) The VFD shall be able to withstand the following fault conditions without damage to the power circuit components:

         a) Failure to connect a motor to the VFD output.

         b) VFD output open circuit that may occur during operation.

10. **Data Displays**: As a minimum, the following door mounted digital display indications shall be supplied:

   a. Speed demand in percent

   b. Input and output current in amperes

c. Input and output Frequency in hertz

d. Input and output voltage

e. Total 3-phase kW output

f. Peak and Average demand of following, peak values shall be kept until manually reset: Kilowatts, kVA, Volts, Amperes, Power Factor.

g. Kilowatt hour accumulated

h. Elapsed time running meter

11. **Diagnostics & Fault Recording**:

a. The control logic section shall be fully digital and may not require analog adjustment pots or fixed selector resistors.

b. Fault log data storage memory shall be stored in non-volatile memory.

c. Shall include a comprehensive microprocessor based digital diagnostic system, which monitors its own control functions and displays faults and operating conditions.

d. A "EVENT LOG" shall record and store, the last three fault events. Each event record shall include the following control variables at an adjustable time rate of 5 samples per cycle; for the 125msec immediately preceding a fault trip and 250msec following such trip:

1) VFD mode (manual/auto/inhibited/tripped/etc.)

2) Speed demand

3) VFD output frequency

4) Demand (output) Amps

5) Feedback (motor) Amps

6) VFD output volts

7) Type of fault:

8) Drive inhibit (On/Off)

9) The fault log record shall be accessible via a communication link. If special software is required to download and display data, it shall be included in the proposal.

G. [A7]**Protection Characteristics**:[A7]

1. In the event of a ground fault, the VFD shall be capable of annunciating a ground fault condition, and continue safely operating due to the condition of working in an ungrounded system. There shall not be risk of fire or electric shock because of the ground fault.

2. The failure of any power-switching device (SCR, GTO, diode, IGBT, IGCT, etc.) shall not prevent continued VFD operation. In the event of a device failure, the

VFD shall annunciate and identify the specific location of the failed device and trip the unit.

3. The VFD system shall have the user selectable option of programming up to three speed avoidance bands. This gives the user the ability to block out and prevent operation at any undesirable speed, such as one that may be coincident with a mechanical resonance condition.

H. [A7]**Programming & Communications**:[A7]

1. **User Input/Keypad**: User shall be allowed to do all programming of the VFD through a local display interface. Monitoring and alarms shall be also available in this interface.

2. **Ethernet communications**:

   a. The VFD shall have network communication capability to allow remote control, programming and status monitoring. The supplier shall also provide the software that makes possible the remote control, programming and status monitoring of the system.

   b. Provisions for local computer connection must be provided.

   c. An Ethernet link shall be provided.

   d. At least Modbus communication protocol must be provided.

3. **Input Isolation Transformer**: If required, it could be dry-type or oil type. Transformer shall comply with the standards C57.110 and C57.16; in addition to Sections 26 12 19 (*Pad Mounted Liquid Filled Medium Voltage Transformer*) or 26 22 00 (Dry Type Transformers).

4. **DC Link Inductors**: DC link inductors if required shall be air core to prevent saturation. Maximum temperature rise shall not exceed 115°C with minimum 220°C insulation and over-temperature protection. The inductors shall be integral to the VFD system lineup. Inductors shall meet IEEE C57.16 requirements and be designed to prevent saturation under maximum fault current conditions.

5. **DC Link Capacitors**: Shall comply with the requirements specified on ANSI 18, ANSI P1036, and Section 26 60 00 (*Dynamic VAR Compensator*).

6. **Harmonic Filters**: If required they shall meet Section 26 60 00 (*Dynamic VAR Compensator)*.

1.05 [A7]SUBMITTALS:[A7]

A. **Before Manufacture**:

1. **Certification**: Electrical materials shall be new and listed by the Underwriters Laboratories, Inc., wherever standards have been established by that agency.

2. **Drawings and Descriptive Literature**: The Contractor shall submit to the Employer's Representative for review before manufacturing, copies of drawings and literature describing the equipment to be furnished and including, but not limited to, the following items:

   a. Preliminary [A17]dimensions and weights [A17]

   b. General performance information: Voltage, current, efficiency, speed range, torque range, over-current and overload allowances, THD of the system at every speed and load conditions.

3. **Proven Technology**: Proof of actual operation of a similar system for a minimum of three years in service.

B. **Before Shipment**:

1. **Final manufacturing Drawings**: After the VFD have been manufactured, and before installation, the Contractor shall submit copies of each final drawing, and shall include all authorized changes made during the course of manufacture.

2. [A16]**Reserved.** [A16]

3. **Factory Test Reports**: Submit certified factory test reports of all factory tests performed by the manufacturer, including tests required by the applicable standards. Results of factory tests performed shall be certified by the manufacturer, or an approved testing laboratory, and submitted following successful completion of the tests.

4. **Installation Manuals and Field Test Procedures**: Submit copies of installation manuals and field test procedures for the variable frequency driver and related subsystems. The manufacturer's pass/fail criteria for field tests shall be included.

5. **Field Test Plan**: Submit a proposed field test plan, prior to testing equipment and subsystems. No field test shall be performed until the test plan has been reviewed by the Employer's Representative. The test plan shall consist of complete field test procedures, including tests to be performed, qualifications of personnel performing the testing, test equipment required, and tolerance limits. After completion of field testing, submit Certified Field Test Reports.

C. **Before Taking Over**:

1. **Equipment List**: Shall provide an electronic database of all installed VFD with the following information:

   a. Unit Identification (name or number)

   b. Manufacturer & Serial Number

   c. Voltages primary/secondary

   d. kVA rating

   e. Location

   f. Enclosure type

2. **Final Documentation**: The following documentation shall be provided:

   a. Start-up and commissioning instructions data

   b. Complete set of "as-built" drawings

   c. Operation and maintenance manual

   d. [A16]**Reserved.**[A16]

   e. Equipment dimensions, including stub-up locations

1.06 [A7]QUALITY ASSURANCE:[A7]

A. Any third party certification, safety or protection requirements shall be applied to the VFD system as a whole. Certification of system elements or individual components by themselves is not acceptable.

B. VFD's shall be manufactured, assembled, tested and provided with a UL label.

C. Variable frequency drives shall be manufactured on a facility, which has a quality assurance program that is certified at least in conformance with ISO Standard 9001 and UL.

D. **Experience**: The equipment offered shall have the best performance available from currently proven technology.

E. A factory test shall be performed at the VFD manufacturer's facility certifying that efficiencies have been met. If efficiencies submitted are not achieved the equipment will not be accepted.

F. [A7]**Factory Testing**:[A7]

1. **Subassembly Tests**:

   a. Printed circuit boards shall be visually inspected and functionally tested. All boards must be tested individually prior to assembly to minimize any impact faulty boards may have on delivery schedules and system reliability. Each board shall be load and temperature cycled from no load to full load and from ambient to +60°C during a 24-hour burn-in test. Any boards that exhibit drift during the test must be replaced with boards that have successfully completed the burn-in without drift.

   b. Power assemblies shall be visually inspected and then HIPOT tested. Complete diagnostics and logic shall be tested. The complete power conversion circuit shall be thoroughly tested at 100% load for a minimum of 10 minutes and then tested for one minute at momentary overload rating.

2. **System Level Tests**:

   a. The system shall be given preliminary checks including verification of electrical connections and ground connections; power and control wiring

shall be resistance-checked point-to-point. E-prom and EE-prom shall be checked for correct revision level. Visual check shall be performed to verify: degree of protection for cabinets, input isolation is lockable in the off-position, marking of terminals and wiring, space availability for cable termination, accessibility of components and ease of maintenance and repair. The VFD system shall be fully checked against the approved drawings for compliance and correct physical dimensions.

b. Power circuit and all control circuits shall be HIPOT tested to ground.

c. All control voltage levels shall be checked and verified.

d. A no load test shall be performed on the system. Drive is to be connected to an unloaded motor. Output voltage shall be calibrated. All logic and interlocks including customer logic and instrumentation shall be tested.

e. Drive shall be given a full power test at rated current and rated voltage (simultaneously) for a minimum of four hours on a dynamometer or reactor load. This test shall be performed as an integrated system including all supplied: input switchgear, input transformer, input filter, power section and output filter. The VFD manufacturer shall perform the factory system test to verify that total system efficiency, power factor and harmonic distortion limits are met as specified. System shall not be shipped unless specified performance criteria are met. Certified test data of all tests conducted shall be provided with final documentation.

f. Employer reserves the right to witness factory tests at no extra cost. Employer will cover all travel expenses of their representatives. A projected test schedule and a copy of proposed test procedures shall be provided at least one month in advance of test date. Employer shall be given at least three-week notice or confirmation of actual test date(s).

G. [A7]**Start-Up**:[A7]

1. VFD system manufacturer shall provide the commissioning services of a factory technician as necessary to supervise/inspect installation, test and start-up all equipment [A17]provided. All [A17] equipment required for testing, start-up and performance verification shall be provided by the start-up technician.

2. Verification of VFD input harmonic voltage and current distortion limits specified must be verified as part of the final acceptance and it shall comply with the IEEE 519 for the all speed range regardless of the load.

H. **VFD System Efficiency**: Guaranteed minimum total VFD system efficiency (ηsys) shall be a minimum 95% at full load and minimum 93% at 50% load at any speed. Efficiency evaluation shall include input transformer, harmonic filter and power factor correction (if applicable), VFD converter, and output filter, as indicated below. Auxiliary controls, such as internal VFD control boards, cooling fans, shall be included in all loss and efficiency calculations.

The VFD efficiency is: ηsys = ηVFD x ηxfmr x ηpfc x ηharm x ηfilter x ηothers

Converter/Inverter (VFD)	ηVFD
[A17]Input transformer	ηxfmr
Power factor correction	ηpfc
Input harmonic filter [7]	ηharm
Output filter	ηfilter [A1]
Others (fans, control, auxiliary's equipments)	ηothers

Note: space heaters, lighting and other not operational loads shall not be included.

I. **Training**: VFD system supplier shall provide on site training for customer's operations, maintenance and service personnel (3 days training for 15 people). The training shall include classroom discussion on the theory of operation of the equipment, as well as maintenance and service methods for the purchased equipment. Topics covered shall include safety, hardware layout and functions, power & control wiring, diagnostic indicators, keypad/display interface, software mapping, programming, setup, configuration, control loop tuning, operational indicators, faults, diagnostic tools, troubleshooting, and preventive maintenance. Hands-on training shall be on the same equipment provided.

END OF SECTION