SECTION XXXXX

VARIABLE FREQUENCY DRIVES

PART 1. GENERAL

1.01 SECTION INCLUDES

A. AS7 & AS100 Low Voltage Variable Frequency Drive (VFD)

1.02 RELATED SECTIONS

A. Sections XXXXX

1.03 REFERENCES

A. NEMA ICS 3.1 - Safety Standards for Construction and Guide for Selection, Installation and Operation of Variable Frequency Drive Systems

B. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum)

C. UL and cUL approved

D. IEEE Standard 519

E. UL 508C (Power Conversion)

F. UL 508A (Industrial Control Panel)

G. CSA 22.2 No. 14-95 (Industrial Control Equipment)

H. EN 61800-5-1 (LVD)

I. EN 61800-3 First Environment Restricted

J. CE mark 2006/95/EC LVD

K. CE mark 2004/108/EC

L. RoHS

M. IBC 2006 Seismic – referencing ASC 7-05 and ICC AC-156

N. IEEE 519-2022 - IEEE Standard for Harmonic Control in Electric Power Systems

1.04 SUBMITTALS

A. Submit under provisions of Section XXXXX.

B. Shop Drawings shall include: Wiring diagrams, electrical schematics, front and side views of enclosures, overall dimensions, conduit entrance locations and requirements, nameplate legends, physical layout and enclosure details.

C. Product Data: Provide data sheets showing; voltage, ratings of customer use switching and over-current protective devices, short circuit ratings, and weights.

D. Manufacturer's Installation Instructions and Technical Manuals: Indicate application conditions and limitations of use stipulated by product testing agency specified under regulatory requirements. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of adjustable speed drive. Document the sequence of operation, cautions and warnings, troubleshooting procedures, spare parts lists and programming guidance.

1.05 QUALITY ASSURANCE

A. VFD shall have a minimum design life of 10 years.

1.06 OPERATION AND MAINTENANCE DATA

A. Submit under provisions of Section XXXXX.

B. Include instructions for starting and operating VFD, and describe operating limits, which may result in hazardous or unsafe conditions.

1.07 QUALIFICATIONS

A. Manufacturer must have a minimum of 20 years of documented experience, specializing in variable frequency drives.

B. Manufacturer must have a certified quality management system in accordance with ISO 9001.

1.08 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, protect and handle products to site, under provisions of Section XXXXX.

B. Accept VFD on site in original packing. Inspect for damage.

C. Store in a clean, dry space. Maintain factory wrapping, or provide an additional heavy canvas or heavy plastic cover, to protect units from dirt, water, construction debris, and traffic.

D. Handle carefully, in accordance with manufacturer's written instructions, to avoid damage to components, enclosure, and finish.

1.09 WARRANTY

A. Provide VFD parts warranty, for three years from date of startup, not to exceed 42 months from date of shipment.

PART 2. PRODUCTS

2.01 MANUFACTURERS

A. FSE AS7 Series VFD - VFD shall be manufactured by LSIS (LG Industrial Systems)
B. Or Engineer Approved Equal in writing 21 days before bid date

2.02 DESCRIPTION

A. Provide a 480VAC enclosed NEMA type (1, 12, 3R, 4X SS) variable frequency drive suitable for operation at the current, voltage, and horsepower indicated on the plans.

2.03 RATINGS

A. VFD must be Constant Torque rated and readily optimized for pump & fan applications as well as pump jack or other constant torque applications.

B. VFD must operate, without fault or failure, when voltage varies plus 10% or minus 15% from rating, and frequency varies plus or minus 5% from rating.

C. VFD shall be 480 volts, 60 Hz, 3 Phase.

D. Displacement Power Factor: 0.97 over entire range of operating speed and load.

E. Service factor: 1.0

F. Operating Ambient Temperature: -10°C to 50°C (14°F to 122°F)

G. Ambient storage temperature: -20°C to 65°C (-4°F to 149°F).

H. Humidity: 0% to 90%, non-condensing.

I. Altitude: Up to 3,300 feet (1000m), higher altitudes achieved by derating.

J. Minimum Efficiency: 96% at half speed; 98% at full speed.

K. Starting Torque: 150% starting torque shall be available from 0.1 Hz to 60 Hz.

L. Overload capability: 150% of rating for 1 minute.

M. Controlled speed range: 100:1.

N. Total Harmonic Distortion (THD) compliance: Given the information provided by the customer's electric power single line diagram and distribution transformer data, the VFD manufacturer shall carry out an analysis of the system. The analysis reviews the potential for the proposed equipment, and any existing equipment, to meet IEEE 519.1992 (tables 10.2 and 10.3) and IEEE 519.2022 (tables 1 and 2) recommendations at the Point of Common Coupling (PCC). The result of the analysis shall determine if additional power quality improvement measures should be included in the proposal to meet the THD recommendations of IEEE 519.1992 and 2022. The PCC shall be at the primary side of the main distribution transformer. If required, a passive Harmonic Filter meeting the requirements of section 2.06 of this specification shall be integrated within the VFD enclosure to comply with this requirement.

O. VFD Output Sinusoidal Waveform compliance: Should it be required to have a sinusoidal VFD output waveform for long cable lead lengths or to minimize the potential for resonance and ringing of the secondary/load circuit versus a PWM waveform, the output Vthd conformance shall follow IEEE 519.2022 Table 1 Vthd limits. See Section 2.06 Note 16 and Section 2.08 for specification. Transient and Common Mode attenuation options are detailed within the specification section.

2.04 DESIGN

A. VFD shall employ microprocessor based inverter logic, isolated from all power circuits.

B. VFD shall include surface mount technology with protective coating.

C. VFD shall employ a PWM (Pulse Width Modulated) power electronic system, consisting of:

1. Converter Section:
    a. VFD input power stage shall convert three-phase AC line power into a fixed DC voltage via a solid-state full wave diode rectifier, with MOV (Metal Oxide Varistor) surge protection.
    b. Provide a minimum of a 3% DC bus choke to minimize reflected current and reduce harmonics.

2. DC Bus Section:
    a. DC bus as a supply to the VFD output Section shall maintain a fixed voltage with filtering and short circuit protection.
    b. DC bus shall be interfaced with the VFD diagnostic logic circuit, for continuous monitoring and protection of the power components.

3. Inverter Section
    a. Insulated Gate Bipolar Transistors (IGBTs) shall convert DC bus voltage to variable frequency and voltage.
    b. The VFD shall employ PWM sine coded output technology to power the motor.

D. VFD shall offer adjustable carrier frequency settings for low noise motor operation.

E. VFD shall have embedded RS-485 Modbus RTU communication with optional Modbus TCP/Ethernet IP, Profibus, DeviceNet, and LonWorks protocols available.

F. VFD shall include two independent analog inputs frequency references, one rated 0-10 or -10 to +10 VDC and one rated 0-20 mA. Each input shall have a programmable bias and gain.

G. VFD shall include eight independent multi-function digital input terminals that can be set for sinking/sourcing and internal/external power supplies. The inputs shall be individually programmed for, but not limited to:
    1. PID Enable/Disable
    2. Preset Speeds
    3. Fault Reset
    4. Emergency Override
    5. Forward / Reverse
    6. External Trip
    7. 3-Wire Control
    8. Jog

9. Multi-level Acceleration & Deceleration
10. Second Motor
11. Run Enable
12. 2nd Source

H. VFD shall include two analog outputs, one rated 0-10 VDC and one rated 0-20 mA. The outputs shall be individually programmed for, but not limited to:
   1. Output Frequency
   2. Output Current
   3. Output Power
   4. DC Bus Voltage
   5. PID Feedback
   6. PID Reference

I. VFD shall include one programmable form "C" contact, one programmable form "A" contact, and one programmable form open collector output. The output relay contacts shall be rated for 5A at 250 VAC. The outputs shall be individually programmed for, but not limited to:
   1. Fault
   2. Zero Speed
   3. Drive Ready
   4. Drive Running
   5. Drive Stop
   6. Frequency Detection
   7. Ready

J. VFD shall include a Kinetic Energy System algorithm to sustain drive control voltage during a power interruption by maintaining the drive DC bus voltage using regeneration energy from the motor.

K. VFD shall provide 24 VDC, 150ma transmitter power supply.

L. VFD shall have a bidirectional speed search function to catch a spinning motor, regardless of its direction.

M. Keypad shall be able to simultaneously display 3 programmable meters to include, but not limited to:
   1. Output Frequency
   2. Output Speed
   3. Output Current
   4. Output Voltage
   5. Output Power

6. Watt-hours
7. DC Bus Voltage
8. DI & DO Status
9. PID Output, Reference, & Feedback
10. Temperature

N. VFD shall have a fault trace function to capture relevant monitor values at the time of the most recent fault.

O. VFD shall include diagnostic fault history for the last 5 faults.

P. VFD shall have the following minimum protective functions: Overheat, motor overload, VFD overload, short circuit, overvoltage, under voltage, input phase loss, output phase loss, output ground fault and overcurrent.

Q. VFD shall have a five language removable digital operator with an illuminated LCD display. The operator shall have program copy and storage functions to simplify the set-up of multiple drives. The digital operator shall be interchangeable for all drive ratings. The operator will provide complete programming, operating, monitoring, and diagnostic capabilities.

R. VFD shall have selectable and user-customizable engineering units for easy configuration of keypad displays to match process and feedback labels in units.

S. VFD shall include a user selectable PID control loop, to provide closed loop set point control capability, from a feedback signal, eliminating the need for closed loop output signals from a building automation system. The PID controller shall have a differential feedback capability for closed loop control of fans and pumps for pressure, flow or temperature regulation in response to dual feedback signals.

T. An energy saving sleep function shall be available in both open loop (follower mode) and closed-loop (PID) control, providing significant energy savings while minimizing operating hours on driven equipment. When the sleep function senses a minimal deviation of a feedback signal from set point, or low demand in open loop control, the system reacts by stopping the driven equipment. Upon receiving an increase in speed command signal deviation, the drive and equipment resume normal operation.

U. VFD shall include loss of input signal protection, with a selectable response strategy including running at a preset speed.

V. VFD shall have an underload detection function that monitors the load and will stop the system in the event of a fan belt or pump shaft failure.

W. VFD shall include electronic thermal overload protection for both the drive and motor.

X. VFD shall have a removable control wiring terminal board that stores the drive's parameter settings. The terminal board can be installed into a new drive and transfer all settings to the new drive. The control wiring shall not need to be removed.

Y. VFD shall use 24 VDC cooling fans for all ratings. Fans shall be mounted at the top of the drive for easier access. No tools shall be required to replace the fans.

Z. VFD shall include the following additional program functions:

1. Capability to reset all parameters back to the factory settings.
2. Capability to reset all parameters back to a user-defined set of parameters.
3. Capability to see only the parameters that have been modified.
4. Ability to set the motor speed in Hertz or RPM.
5. Critical frequency rejection capability: 3 selectable, adjustable dead bands.
6. Auto restart capability with adjustable delay between attempts.
7. Ability to close fault contact after the completion of all fault restart attempts.
8. Kinetic Energy Braking (KEB) function for stopping at power loss.
9. Overvoltage suppression function for cyclic regenerative loads.
10. Stall prevention capability.
11. "S" curve soft start / soft stop capability with four programmable corners.
12. Seven sets of acceleration/deceleration times, selectable via digital input.
13. Acceleration/deceleration adjustment from 0.01 to 600 seconds while running.
14. Four preset volts per hertz patterns.
15. Programmable security code to prevent parameter setting changes.
16. Motor thermistor input.
17. Reverse direction lockout.
18. Current limit adjustment from 30% to 250% of rated current of the motor.
19. Input signal or serial communication loss detection and response strategy.
20. Automatic energy saving function.
21. Under torque/Over torque Detection.
22. Over excitation braking function to quickly stop the motor.
23. Cooling fan failure detection and selectable drive action.
24. Select any of fifteen preset speeds while running.
25. Ability to remove of digital operator during VFD operation.

2.05 PRODUCT ACCESSORIES

A. VFD shall be provided with following accessories:
   1. NEMA type (1, 12, 3R, 4X SS) enclosure rated for (indoor, outdoor duty)
   2. 35 KAIC rated main circuit breaker (higher KAIC ratings available, please specify)
   3. Remote Operator Mounting Kit: VFD's operator shall be mounted on the front of the enclosure

2.06 OPTIONAL ACCESSORIES

A. VFD shall be provided with following optional accessories (please specify):
   1. NEMA type (12, 4, 4X) enclosure
   2. Cabinet Space Heater
   3. Motor Space Heater
   4. Isolation Amplifier for Analog Inputs
   5. Isolation Amplifier for Analog Outputs
   6. E-Stop Push Button
   7. Input Surge Protection Device
   8. Pilot Devices (VFD Ready, VFD Run, VFD Fault)
   9. Full Voltage Manual Bypass (2 contactor bypass with VFD input fusing)
   10. Output Reactor
   11. Output dV/dT Filter
   12. Output Sinusoidal Filter
   13. Motor Protection Relay (Multilin 369)
   14. RTD Monitor
   15. PLC or HMI
   16. Output Sinewave Filter (See Section 2.08 Integrated and Separately Mounted)

2.07 PASSIVE HARMONIC FILTER

A. If required by section 2.03.N of this specification, the Variable Frequency Drives shall be equipped with harmonic mitigation equipment to prevent power system problems resulting from high levels of harmonic distortion.

B. Requirements:

   1. The harmonic mitigation equipment shall treat all of the characteristic low frequency harmonics generated by a 3-phase, diode bridge rectifier load (5th, 7th, 11th, 13th, etc.). The characteristic harmonics shall be suppressed without the need for individual tuning or the requirement to phase shift against other harmonic sources.

2. Harmonic mitigation shall be by passive inductor/capacitor network. To prevent possibility of switching frequency resonance, active electronic components shall not be used.
3. Total Power factor shall be > 0.95 in operating range from 25% to full load.
4. To ensure compatibility with engine generators, the harmonic mitigation equipment must never introduce a capacitive reactive power (kVAR) which is greater than 15% of its kW rating for sizes ≥ 100HP and 20% for sizes ≤ 75HP.
5. Maximum voltage boost at no load must be < 3% of nominal line voltage without the need for a capacitor contactor.
6. The harmonic mitigation equipment shall not resonate with system impedances or attract harmonic currents from other harmonic sources.
7. The harmonic mitigation equipment in combination with the Variable Frequency Drive shall meet all requirements as outlined in IEEE std 519 (both 1992 and 2022 editions) for individual and total harmonic voltage and current distortion. The Point of Common Coupling (PCC) for all voltage and current harmonic calculations and measurements shall be at the input terminals to the harmonic mitigation equipment.
8. Voltage Total Harmonic Distortion (VTHD) shall meet the requirements of IEEE std 519 (Table 10.2 in 1992 or Table 1 in 2014) by not exceeding 5% and by limiting the individual harmonic voltage distortion to less than 3%, while operating on either utility supply or generator supply. The harmonic mitigation equipment vendor shall not be responsible for pre-existing voltage distortion caused by other harmonic sources.
9. Current Total Demand Distortion (ITDD) at the input terminals of the harmonic mitigation equipment shall meet the limits as defined in IEEE Std. 519 (Table 10.3 in 1992 and Table 2 in 2022) but shall not exceed 8% [OPTION: 5%]. ITDD to include harmonics up to 100th. The full load efficiency of the harmonic mitigation equipment / VFD combination shall be greater than 96%. The harmonic mitigation equipment itself shall have efficiency no less than 99%.
10. Performance Guarantee: ITDD must be <8% with background voltage distortion up to 5% and voltage imbalance up to 3%. [OPTION: Additionally, ITDD must be <5% with background voltage distortion up to 2% and voltage imbalance up to 2%]. Must be capable of operating in voltage distortion environments up to 8% without derating.
11. [OPTIONAL] Provide coordinated surge protection factory integrated into the harmonic filter to provide additional protection against voltage transients, spikes, and surges. Inclusion of the coordinated surge protection must extend the warranty of the harmonic filter to 5 years. Surge protection must include:

I. Low impedance internal circuitry with very low let through levels coordinated below most harmonic filtered drive circuit withstand limits.
II. LED status lights installed on the filter enclosure exterior. Two types of fusing: component level thermal fusing and phase level fault current fusing.
III. Metal oxide varistor (MOV) design with fast reaction time (<1ns).
IV. Compatibility with systems with SCCR rating up to [120kAIC] [200kAIC].

12. The harmonic mitigation equipment and all of its components shall be manufactured and tested in accordance with the latest applicable standards of UL, CSA and NEMA.
13. Demonstration of compatibility between the harmonic mitigation equipment and the VFD must be available upon request.
14. Harmonic mitigation equipment shall be warranted to be free of defects in materials and workmanship for a period of 3 years from the date of shipment.
15. Subject to compliance with all of the contract documents and specifications, the acceptable product and manufacturer is: LINEATOR™ AUHF, by MIRUS International Inc. or as approved prior to bid.

C. Basic Requirements:
1. All wiring shall be copper.
2. 50°C Ambient Rated Maximum [Option] Extreme Duty Model 55°C Maximum
3. Insulation class: 220°C system. Temperature rise: 130°C over Ambient

D. Acceptance
1. Harmonic compliance shall be verified with onsite field measurements of both the voltage and current harmonic distortion at the input terminals of the harmonic mitigating equipment with and without the equipment operating. A recording type AEMC 8336 or equivalent harmonics analyzer displaying individual and total harmonic currents and voltages must be utilized.

2.08 INTEGRATED OR SEPARATE MOUNTED OUTPUT SINEWAVE FILTER

A. If required by section 2.03.O of this specification, the Variable Frequency Drives shall be equipped with an Output Sinewave Filter to load system differential mode noise and secondary circuit high levels of harmonic distortion being feed to the motor load. [Option] Output Sinewave filter shall incorporate a Common Mode Choke (CMC) – see 2.08. E.1

B. General:

1. The Sinewave Filter and all of its components shall be manufactured and tested in accordance with the latest applicable standards of UL, CSA and NEMA.
2. The Sinewave Filter shall be warranted to be free of defects in materials and workmanship for a period of 3 years from the date of shipment.
3. Factory Performance Testing: Manufacturer must be capable of factory testing for Sinewave Filter performance and energy efficiency under actual variable frequency drive operation.
4. Subject to compliance with all of the contract documents and specifications, the acceptable product and manufacturer is the INVERSINE™ Advanced Universal Sinewave Filter, by MIRUS International Inc. or as approved prior to bid.

C: Requirements:

1. The Sinewave Filter shall be designed to attenuate the carrier component and its harmonics present in the output waveform of a typical PWM frequency converter (inverter) and produce sinusoidal output voltage waveform that has less than 5% THD(V) (voltage total harmonic distortion) measured to the 100^{th} harmonic.
2. Output voltage waveform dV/dt stress and voltage overshoots characteristic for PWM inverter must be completely eliminated and suppressed without the need for snubber resistors, or auxiliary power electronic circuits.
3. The Sinewave Filter shall eliminate the effects of reflected wave phenomenon. The need for VFD rated cables shall also be eliminated when common-mode option is included.
4. Application of the Sinewave Filter shall allow for the use of standard motors eliminating the need for NEMA MG-1, Part 31 compliance, when the common-mode option is required.
5. The general Sinewave Filter topology shall be LC low pass circuit.
6. The Sinewave Filter circuit input shall be of a three-phase inductor of sufficient impedance to control the capacitor charging below the PWM inverter peak current fault point.
7. The Sinewave Filter cut-off frequency shall be set approximately three (3) times the max allowed fundamental frequency of the PWM inverter to attenuate the carrier components at the rate of >40db per decade while minimizing the absorption of fundamental current by the filter.
8. The Sinewave Filter shall have efficiency of no less than 99%.

9. The capacitive reactance of the Sinewave Filter at the load shall compensate for motor inductive reactive power such that power factor at the PWM inverter output is improved to 0.97 or better. This shall lower overall filter insertion loss (i.e. voltage drop) to < 3%.
10. The Sinewave Filter shall be suitable for application with PWM inverters that have carrier frequencies between 1.5 kHz to 8 kHz and motor leads up to 15,000 feet.

D: Basic Requirements:

1. The three-phase inductor shall be designed for low pass filtering service and to attenuate voltage high-frequency components in the range of the PWM inverter switching frequency.
2. Construction shall be of copper wire or copper foil wound on magnetic core.
3. The design maximum operating temperature rise shall be 130 deg C above maximum ambient temperature of 40 deg C.
4. Inductors shall be air-gapped to control magnetic saturation. The inductance shall remain above 50% of its nominal value for any overload not exceeding 200% of rated current.
5. The Sinewave Filter shall not sustain any thermal damage from overloads of up to 150% of rated current for minimum periods of sixty (60) seconds every ten (10) minutes.
6. Capacitors shall be AC rated, polypropylene film material, and self-healing technology. They shall be connected in ungrounded neutral Y (wye) or delta configuration.

E: Options:

1. [OPTION] Include integral mounted common-mode choke option to reduce the effects of common-mode currents on motor bearings and cable insulation. Option Code CMC.
2. [OPTION] Provide integral mounted coordinated surge protection factory integrated into the harmonic filter to provide additional protection against voltage transients, spikes, and surges - Option Code CSP. Inclusion of the coordinated surge protection must extend the warranty of the Sinewave filter to 5 years. Surge protection must include:

    I. Low impedance internal circuitry with very low let through levels coordinated below most harmonic filtered drive circuit withstand limits.
    II. LED status lights installed on the filter enclosure exterior.

III. Two types of fusing: component level thermal fusing and phase level fault current fusing.
IV. Metal oxide varistor (MOV) design with fast reaction time (<1ns). Compatibility with systems with SCCR rating up to [120kAIC] [200kAIC].

2.09 SOURCE QUALITY CONTROL

A. Inspect and test, each completed VFD at the completion of production. All test results shall be stored as detailed quality assurance data.

PART 3. EXECUTION

3.01 EXAMINATION

B. Verify that surface is suitable for VFD installation.

C. Do not install VFD until the installation environment can be maintained, within the service conditions required by the manufacturer.

3.02 INSTALLATION

A. Install VFD where indicated, in accordance with manufacturer's written instructions.

B. Tighten accessible connections and mechanical fasteners after placing VFD.

3.03 FIELD QUALITY CONTROL

A. Field inspection and testing to be performed.

B. Inspect completed installation for physical damage, proper alignment, anchorage and grounding.

3.04 MANUFACTURER'S FIELD SERVICES

A. Field Services shall be provided by an authorized LSIS service center.

B. Harmonic testing shall be provided at time of Start-up.

3.05 ADJUSTING

A. Make final adjustments to installed VFD, to assure proper operation of the system.