SECTION 15172

VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.01 SECTION INCLUDES

1. Variable Frequency Drive (VFD).

1.02 RELATED SECTIONS

1. Section 16195 - Electrical Identification: Engraved nameplates.

1.04 SUBMITTALS

1. Submit under provisions of Section 01340.
2. Vendor is required to submit shop drawing for approval. 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.
3. Product Data: Provide data sheets showing; voltage, short circuit ratings, and weights.
4. 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 variable frequency drive. Document the sequence of operation, cautions and warnings, spare parts lists and programming guidance.

1.05 QUALITY ASSURANCE

1. VFD shall have a minimum MTBF (mean time between failures) rating of 28 years (245,280 Hours).
2. The drive manufacturing facility shall be ISO 9001 and 14001 certified
3. The drive shall be UL listed, or Canadian UL listed, or CSA listed and comply with EMC Directive 89/336 EEC, Low Voltage Directive 73/23 EEC in accordance with the European Union’s CE directive.
4. The drive shall utilize efficient “bidirectional switch” technology throughout the entire drive manufacturer’s power and voltage range.
5. The drive shall utilize the same communications architecture, utilizing plug-in communications cards, for high-speed noise immune connectivity throughout the entire drive manufacturer’s power range.
6. The drive manufacturer shall have an analysis laboratory to evaluate the failure of any component. The failure analysis lab shall allow the manufacturer to perform complete electrical testing, x-ray components, and decap or delaminate components and analyze failures within the component.
7. The drive shall utilize surface mount technology in the manufacturing of internal printed circuit boards and electronics, for maximum reliability.

1.06 OPERATION AND MAINTENANCE DATA

1. Submit under provisions of Section 01700.
2. Include instructions for starting and operating VFD, and describe operating limits, which may result in hazardous or unsafe conditions.

1.07 QUALIFICATIONS

1. Manufacturer must have a minimum of 25 years of documented experience,
specializing in variable frequency drives.

1.08 DELIVERY, STORAGE, AND HANDLING

1. Deliver, store, protect and handle products to site, under provisions of

 Section 01610

1. Accept VFD on site in original packing. Inspect for damage.
2. 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.
3. Handle carefully, in accordance with manufacturer's written instructions, to avoid damage to components, enclosure, and finish.

1.09 WARRANTY

1. Provide VFD warranty, for one year from date of startup, not to exceed 18 months from date of shipment. VFD vendor’s standard published warranty shall apply.

PART 2 PRODUCTS

2.01 MANUFACTURERS

1. VFD shall be U1000 Industrial Matrix type, manufactured by Yaskawa America, Inc.
2. Motors should be inverter duty rated, per NEMA MG1 parts 30 and 31, for motor-drive compatibility.

2.02 DESCRIPTION

1. Provide enclosed variable frequency drives suitable for operation at the current,
voltage, and horsepower indicated on the schedule. Conform to requirements of NEMA ICS 3.1.

2.03 RATINGS

1. 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.
2. VFD shall be \_\_\_\_\_\_\_\_\_\_ volts, \_\_\_\_\_\_\_ Hz, 3 Phase
3. True Power Factor: Greater than or equal to 0.98 at rated load.
4. Service factor: 1.0
5. Operating Ambient Temperature:
NEMA 1 (IP20): -10°C to 40°C (14°F to 104°F)
6. Ambient storage temperature: -20°C to 60°C (-4°F to 140°F)
7. Humidity: 0% to 95% non-condensing.
8. Altitude: to 3,300 feet (1000m), higher altitudes achieved by derating.
9. Vibration: 9.81m/s2 (1 G) maximum at 10 to 20 Hz, 2.0 m/s2 (0.2 G) at 20 Hz to 55 Hz.
10. Minimum Efficiency: 96% at half speed; 98% at full speed.
11. Starting Torque: 150% starting torque shall be available from 3 Hz to 60 Hz without derating. Drive shall be able to run at 100% current at 0.0 Hz continuously.
12. Overload capability: Normal Duty, 120% of rated FLA (Full Load Amps) for 60 seconds; Heavy Duty 150% of rated FLA for 60 seconds.
13. Controlled speed range of 40:1
14. Total Harmonic Distortion (THD) compliance to IEEE 519:

The Drive Manufacturer shall provide calculations showing total harmonic current distortion and total harmonic voltage distortion is less than 5%, both with no individual harmonic greater than 3%, at the drive input terminals. Calculations at the transformer are not acceptable. This requirement may be met by VFD’s that use Matrix conversion technology. 18-Pulse input VFD’s will be accepted in lieu of Matrix conversion technology. VFD’s employing the use of 6-Pulse, Passive Filters, 12-Pulse, or “LCL” filter schemes will be rejected. Additional equipment required to meet this performance will be the responsibility of the contractor with no additional cost to the owner.

1. VFDs must be suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical amperes, without additional branch circuit protection devices.

2.04 DESIGN

1. VFD shall employ microprocessor based inverter logic, isolated from all power circuits.
2. VFD shall include surface mount technology with protective coating.
3. VFD shall employ use of matrix conversion technology for direct conversion of AC to AC. Active AC to DC rectifier schemes are not acceptable and will be rejected. 6 pulse, passive filters, and 12-pulse rectifiers are not acceptable and will also be rejected.
4. Input / Output Section:

VFD input power stage shall convert three-phase AC line power directly into variable AC output. The main circuit shall consist of a compact input filter and bidirectional switches. The bidirectional switches are power devices that carry the full current of the drive. VFD’s without direct AC to AC conversion will require integral 18-Pulse Transformer input.

1. VFD shall have an adjustable carrier frequency, from 4 kHz to 10 kHz.
2. VFD must include an adjustable dynamic noise control for quiet motor operation.
3. VFD must have a Harmonic Suppression Priority setting.
4. VFD shall have embedded protocol for network communications Modbus/RTU which shall be accessible via a RS-422/485 communication port.
5. VFD shall include three independent analog inputs. Selectable for either 0-10 VDC or 4-20 mA. Either input shall respond to a programmable bias and gain.
6. VFD shall include three independent multi-function analog inputs, individually selectable for 0-10 VDC, -10 to +10 VDC, 0-20 mA or 4-20 mA. Each input shall have a programmable bias and gain. The inputs shall be individually programmed for, but not limited to:
7. PID Set Point
8. PID Feedback
9. Pressure Level
10. Flow Level
11. Depth Level
12. 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:
13. Hand – Off – Auto operation Selection
14. Detection of External Fault Condition
15. Remote Reset
16. Multi-step Speed Commands
17. Run Permissive
18. Floating Control
19. Check Valve input alarm/fault
20. High or low level Alarm/fault
21. High or Low input pressure Alarm/fault
22. High pressure alarm/fault
23. Pump pre-charge
24. VFD shall include one multi-function 32 kHz pulse train input that shall be programmed for, but not limited to:
25. PID Set Point
26. PID Feedback
27. VFD shall include two individually selectable 0-10 VDC, -10 to +10 VDC, or 4-20 mA analog outputs. The outputs shall be individually programmed for, but not limited to:
28. Output Frequency
29. Output Current
30. Output Power
31. PID Feedback
32. VFD shall include one fixed form "C" fault contact, two programmable multi-function form "A" contacts, and one programmable form “C” contact. These output relay contacts shall all be rated for 1A at 250 VAC and shall be programmed for, but not limited to:
33. Pump Fault
34. Low and High Pressure Detection
35. Pump Over Cycling Detection
36. Loss of Prime Detection.
37. Drive Fault
38. Over/Under Torque Detection
39. Not Maintaining Set Point Detection
40. No Flow Detection
41. Thrust Bearing Start
42. Low Input Pressure
43. Low/high Flow Level
44. Anti-Jam Protection
45. De-scale Operation
46. VFD shall provide terminals for remote input contact closure, to allow starting in the automatic mode.
47. VFD shall provide 24 VDC, 150ma transmitter power supply for powering transducer feedback devices.
48. VFD shall include an external fault input function to be programmed a digital input, which shall be programmable for a normally open or normally closed contact. These terminals can be used for the connection of firestats, freezestats, or similar safety devices.
49. VFD shall include a control power loss ride through capable of 2 seconds.
50. VFD shall have DC injection braking capability that is adjustable and current limited.
51. VFD shall have a bidirectional speed search function to catch a spinning motor, regardless of its direction.
52. VFD unit shall include the following meters to estimate use of energy:
53. Elapsed Time Meter
54. Kilowatt Meter
55. Kilowatt Hour Meter
56. VFD shall have a fault trace function to capture relevant monitor values at the time of the most recent fault. This is includes a time/date stamp of when the fault occurred.
57. VFD shall have a motor preheat function to prevent moisture accumulation in an idle motor.
58. VFD shall have a motor auto-tuning function capable of automatically determining the motor's electrical characteristics for maximum torque production and minimum energy usage.
59. VFD shall include diagnostic fault history with the last 10 fault indications in the selected keypad language and time/date stamp as well as heatsink cooling fan operation hours.
60. VFD shall have preventative maintenance monitors for predicting the remaining life of the IGBTs, cooling fans, and pre-charge relay.
61. VFD shall turn off its cooling fans when not running to increase fan life.
62. VFD shall have the following minimum protective functions: Overheat, motor overload, VFD overload, short circuit, overvoltage, undervoltage, input phase loss, output phase loss, output ground fault and overcurrent.
63. VFD shall have a USB port for easy connection to a computer (PC) for startup and troubleshooting.
64. VFD manufacture shall provide free PC software that includes online and offline parameter management, application wizards, oscilloscope function, network configurator for Ethernet, parameter conversion tool and diagnostic functions.
65. VFD shall have an eight-language removable HOA Keypad with an illuminated LCD display. The operator shall have program copy and storage functions to simplify the set up of multiple drives. The HOA Keypad shall be interchangeable for all drive ratings. The operator will provide complete programming, operating, monitoring, and diagnostic capabilities.
66. VFD shall have a keypad with dedicated Hand-Off-Auto keys. The keys shall include industry standard commands for Hand, Off, and Auto functions.
67. VFD shall have an internal real time clock. The internal time clock shall include a back up via battery. The time clock will be used to date and time stamp faults and record operating parameters at the time of fault. The internal time clock can be programmable to control start/stop functions, running speeds, PID parameter sets and digital output relays.
68. VFD keypad shall provide plain language display readouts of output frequency in hertz, PI feedback in percent, pump speed in RPM, set point and feedback level in programmable engineering units (PSI, GPM, etc.), output voltage in volts, output current in amps, output power in kilowatts, control terminal status, heatsink temperature in degrees and fault conditions in the selected keypad language.
69. VFD parameter settings shall be stored in non-volatile memory that does not require a battery backup.
70. VFD shall be designed to allow all parameter adjustments to be made with the door closed.
71. VFD shall have selectable and user-customizable engineering units for easy configuration of keypad displays to match process and feedback labels in units such as PSI, GPM, and Feet.
72. 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 pumps for pressure, flow or temperature regulation in response to dual feedback signals.
73. VFD shall have an independent, PID loop that can be used with an analog input that will vary a VFD analog output and maintain a set point of an independent process (valves, dampers….).
74. VFD shall include pump-specific application presets. The parameter presets can be used to help facilitate start-up. The presets will program all parameters and customer interfaces for a particular application (Pump Down Level, Geothermal, Vertical Turbine) to reduce programming time.
75. VFD shall include an energy saving “sleep” function shall be available, providing significant energy savings while minimizing operating hours on driven equipment. When the sleep function senses minimal deviation of a feedback signal from set point or low demand, the system reacts by stopping the driven equipment. Upon receiving an increase in speed command signal deviation, the drive and equipment resume normal operation.
76. VFD shall include loss of input signal protection, with a selectable response strategy including running at a preset speed or a percentage of the most recent speed.
77. VFD shall have an underload detection function that monitors the load and will stop the system in the event of a pump shaft failure.
78. VFD shall include electronic thermal overload protection for both the drive and motor. The electronic thermal motor overload shall be approved by UL.
79. VFD shall have a quick disconnect, 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.
80. 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.
81. VFD shall include the following additional program functions:
82. Capability to reset all parameters back to the factory settings.
83. Capability to reset all parameters back to a user-defined set of parameters.
84. Capability to see only the parameters that have been modified.
85. Ability to set the motor speed (PI set point) in Hertz, RPM, percent or custom units with units label.
86. Critical frequency rejection capability: 3 selectable, adjustable dead bands to lock out continuous operation at frequencies that may product mechanical resonance.
87. Auto restart capability: 0 to 10 attempts with adjustable delay between attempts.
88. Ability to close fault contact after the completion of all fault restart attempts.
89. Kinetic Energy Braking (KEB) function for stopping at power loss.
90. Overvoltage suppression function for cyclic regenerative loads.
91. Stall prevention capability.
92. "S" curve soft start / soft stop capability with four programmable corners.
93. Four sets of acceleration/deceleration times, selectable via digital input.
94. Acceleration/deceleration adjustment from 0.00 to 6000 seconds while running.
95. Fourteen preset and 1 custom volts per hertz patterns.
96. Programmable security code to prevent parameter setting changes.
97. Heatsink over temperature speed fold back capability.
98. Control I/O Terminal status indication.
99. Motor thermistor input.
100. Reverse direction lockout.
101. Current limit adjustment from 30% to 200% of rated current of the motor.
102. Input signal or serial communication loss detection and response strategy.
103. Automatic energy saving function.
104. Undertorque/Overtorque Detection.
105. Overexcitation braking function to quickly stop the motor.
106. Cooling fan failure detection and selectable drive action.
107. Select any of four preset speeds while running.
108. Ability to remove of HOA Keypad during VFD operation.
	1. SOFTWARE FEATURES

Pump-specificfirmware shall be embedded within the ***U1000 iQpump*** controller. These pump-specific software functions and settings shall be standard as minimum. All control features, Alarms, and Faults shall be displayed in intuitive system pump terminology on the HOA Keypad. Parameter codes with abbreviations are not acceptable.

* 1. Hand/Off/Auto Run operation from HOA Keypad without stopping (bumpless transfer). HOA Keypad to display current operational mode. Example: Off Mode, Hand Mode, Hand Mode Reference, and Automatic Mode.
	2. HOA Keypad can be configured to lock out “Hand” with only off and auto run enabled.
	3. Application Presets that automatically set all critical drive settings. Applications include Water Level Control, Geothermal Well Control, Vertical Turbine Control, and General Purpose Mode.
	4. Full use of Real Time clock to time/date stamp faults and alarms and to provide for time/date based on/off control.
	5. Auto Restart on complete power loss. If in Auto Mode without external run control for start/stop, the pump system will automatically restart to maintain set point and cycle through all safety & restart conditions.
	6. Programmable Engineering units (PSI, GPM, LPH) for set point, feedback, and parameter scaling. It is not acceptable to use percent of VFD parameters for pump level settings.
	7. Programmable start levels, sleep levels, stop levels with engineering units specific to pump application. Example: PSI, GPM, LPH, etc.
	8. Programmable scaling for feedback levels with feedback transducer loss protection based on level and delay time. Both of these functions shall be independent.
	9. Pump Quick Setup Menu for pump settings and startup.
	10. System Pre-Charge: Programmable settings in pump engineering units that allows for charging of the pump system prior to automatic mode. Dedicated pre-charge system level settings with programmable timers. PI control is turned off and will enable automatically once operation is completed.
	11. Thrust Bearing: Programmable operation that will allow the pump motor to rapidly accelerate to a fixed speed with independent timers. PI control is turned off and will enable automatically once operation is completed.
	12. Programmable Low and High Pressure feedback settings with timers.
	13. Programmable pump over-cycling timer.
	14. Programmable Anti-Jam feature with cycle count and timer.
	15. Programmable Low City Pressure switch that will prohibit the drive from running when low incoming pressure is indicated by a pressure switch.
	16. Programmable Output Current Limit to protect the motor-pump system.
	17. Programmable parameter lockout feature to prevent parameter and set point changes.
	18. Programmable drive input Single Phase protection feature.
	19. Programmable Remote Drive Disable function that can put the system to sleep via a remote contact closure.
	20. Programmable Stop with Timer function to prevent starting into a back-spinning pump.
	21. Programmable alarms and faults for High and Low Water Level switches.
	22. Programmable Geothermal mode. A geothermal well facilitates heat transfer between the earth and a known system, such as space heating, electric power generation and food processing. The geothermal function has the ability to regulate the speed of the U1000 iQpump Controller based on an external temperature signal following a preset temperature-speed curve.
	23. Programmable Suction Pressure Control that will deviate from output pressure control when the pump inlet suction pressure drops beyond a settable point and control suction pressure.
	24. Programmable Vacuum Pressure Control that will deviate from output pressure control when the pump inlet vacuum increases beyond a settable point and regulate the vacuum pressure.
	25. Programmable Water Level Control Pressure Control that will deviate from output pressure control when the well level drops below a settable point and regulate the well level.
	26. Programmable Feedback Wire Break detection function with selectable response.
	27. Programmable Lube Pump control to enable pre-lubricating the pump seals prior to starting.
	28. Programmable Pre-Charge function to fill piping or storage tank before turning on the PI controller.
	29. Programmable Thrust Bearing function to protect the bearings of submersible motors.
	30. Programmable Flow Meter Control that can measure flow over time and store the data in non-volatile memory put the drive to sleep, control the drive to a flow set point, and check for high/low flow faults and alarms.
	31. Programmable Utility Start function to prevent all drives in a system from starting at the same time to reduce peak currents.
	32. Programmable low water & high water input settings.
	33. Programmable Minimum Pump Speed to prevent pump damage caused by cavitation.
	34. Programmable Alarm and Fault specifically for a thermostat placed on the pump housing (volute) or inside of the pump motor.
	35. Programmable Pump Motor heating level when stopped to control motor condensation.
	36. Programmable No Flow or Dead Head Pump Curve protection allowing for either settings in Hz, Engineering units (PSI, GPM, etc) or motor RPM.
	37. Embedded Pump Controller Capability: In addition to the ability to follow an analog input for speed control, the drive shall be able to operate in the following control modes:
1. Simplex controller: The drive shall accept an input proportional to the process variable (flow, pressure, etc.). The drive shall accept direct keypad entry or analog input entry of the desired set point. The Drive shall utilize PI set point control to continuously modulate the output speed to maintain set point.
2. Multiplex controller: The drive shall be capable of being operated as a multiplex master controller operating as in simplex mode with same system inputs but provide lead-lag control of up to five (5) pumps such that the set point is controlled via operation of one or more pumps while alternating pumps to evenly distribute operation time. System master controller to have independent control settings in engineering units for pump system to turn on and off.
	1. Dedicated English Pump Alarms & Messages: Flashing LED or abbreviated codes are not acceptable:
3. Low Feedback
4. High Feedback
5. Low Water
6. Pump Over Cycling Detection
7. No Flow Detection
8. Loss of Prime Detection
9. Pump Fault
10. Motor Thermostat Fault
11. Pre-Charge Mode Active
12. Thrust Bearing Active
13. Start Mode Active
14. Sleep Mode Active
15. Anti-Jam Active
16. Feedback Loss Detection
	1. ***U1000 iQpump*** as standard is supplied with a pump controller SCADA PC program that allows the users to program pump parameter settings, drive commissioning, and diagnose system conditions. As standard, the PC program should have the following functions:
17. Online PID turner with graphical representation
18. System trending recorder (Oscilloscope) that allows a minimum of 6 signals to be graphed with a playback mode.
19. Run Status Page with pump visual graphics allowing for all pump functions such as, set points, feedback levels, faults, alarms, and Multiplex operation to be displayed with actual running data.
20. Programming parameter page for all pump specific parameters allowing for pre-setup, online changes, and complete upload/download of settings.
21. Pump Setup Wizard to be a graphical interface configured to ask questions to the operator for pump parameter settings based on pump application.
22. Pump Simulator with graphical interface allowing for training of engineers, service and start up technicians that will emulate the actual pump running conditions based on pump parameters settings, set point and feedback levels.
23. Program shall be able to communicate to pump controller via RS232/485, and Ethernet TCP/IP.
24. PC tool shall be automatically updated via the Internet.
	1. PRODUCT OPTIONS

Note to the Consulting Engineer; See Appendix One to Select Options to be Applied to a Specific Project

2.06 FABRICATION

1. All standard and optional features shall be included in a single NEMA 1 (uL Type 1), rated enclosure with a UL certification label.

2.07 SOURCE QUALITY CONTROL

1. In-circuit testing of all printed circuit boards shall be conducted, to insure the proper mounting and correct value of all components.
2. Final printed circuit board assemblies shall be functionally tested, via computerized test equipment. All tests and acceptance criteria shall be preprogrammed. All test results shall be stored as detailed quality assurance data.
3. All fully assembled controls shall be functionally tested, with loaded induction motors. The combined test data shall then be analyzed, to insure adherence to quality assurance specifications.

PART 3 EXECUTION

3.01 EXAMINATION

1. Verify that surface is suitable for VFD installation.
2. Do not install VFD until the building environment can be maintained, within the service conditions required by the manufacturer.

3.02 INSTALLATION

1. Install VFD where indicated, in accordance with manufacturer's written instructions and NEMA ICS 3.
2. Tighten accessible connections and mechanical fasteners after placing VFD.
3. Provide a nameplate label on each VFD with, full load amperes, model number, and voltage/phase rating.

3.03 FIELD QUALITY CONTROL

1. Field inspection and testing to be performed under provisions of Section 01400.
2. Inspect completed installation for physical damage, proper alignment, anchorage, and grounding.

3.04 MANUFACTURER'S FIELD SERVICES

1. Prepare and start systems under provisions of Section 01400.

3.05 ADJUSTING

1. Carry out adjusting work under provisions of Section 01700. Make final adjustments to installed VFD, to assure proper operation of industrial control system.

END OF SECTION

APPENDIX ONE

PRODUCT OPTIONS

Note to the Consulting Engineer; Select Options to be Applied to this Project, Insert in the Appropriate Specification Section

 VFD shall have the following optional accessories:

1. Network Communication: DeviceNet, EtherNet/IP, Modbus TCP/IP, Modbus RTU, Profibus DP, ProfiNet, EtherCAT, and Mechatrolink.
2. Auxiliary Control Power Unit: VFD control circuit can be powered using separate 24 VDC supply.
3. Remote Operator Mounting Kit: VFD’s operator can be mounted in the control cabinet behind a UL Type 4X membrane.
4. Outdoor Operator: VFD operator with special LCD capable of being seen outside in bright sun at high ambient temperatures.