SECTION 15901 – INTEGRAL VARIABLE SPEED PUMPS

PART 1 - GENERAL

1.1 SCOPE

A. Furnish and install variable speed pump control systems as required to provide a complete and satisfactory installation.

1.2 SECTION INCLUDES

A. Variable Speed Pump Package
   1. Vertical Inline pump
   2. Variable Frequency Drives
   3. TEFC motor
   4. Integral Controls Platform

1.3 REFERENCES

A. HI – The Hydraulic Institute ANSI – American National Standards Institute

B. NEMA – National Electrical Manufacturers Association

C. UL – Underwriters Laboratories, Inc.

D. ETL – Electrical Testing Laboratories

E. CSA – Canadian Standards Association

F. NEC – National Electrical Code

G. ISO – International Standards Organization

H. IEC – International Electrochemical Commission

I. IEEE – Institute of Electrical and Electronic Engineers

1.4 SUBMITTALS

A. Submittals shall include the following:

   1. System summary sheet
      a) Sequence of operation
      b) Shop drawing indicating dimensions, required clearances and location and size of each field connection.

c) Power and control wiring diagrams
d) System profile analysis including variable speed pump curves and system curve. The analysis shall also include job specific load profile and staging points.

B. Submittals must be specific to this project. Generic submittals will not be accepted.

1.5 QUALITY ASSURANCE

A. The pump control package shall be fully assembled by the manufacturer. The manufacturer shall be responsible for the complete pump control package, including system interface with pumps and VFDs, as well as the successful operation of all components supplied by the pump control system manufacturer.

B. All functions of the variable speed pump control system shall be thoroughly field tested prior to actual start-up. This test shall be conducted with motors connected to AFD output and it shall test all inputs, outputs and program execution specific to this application.

C. Pump control package shall be listed by Underwriter's Laboratories and bear the UL label.

1.6 DELIVERY STORAGE AND HANDLING

A. Delivery and Requirements:

1. Deliver material in accordance with Section 01 61 00 Common Product Requirements.
   a) Deliver materials and components in manufacturer's original packaging with identification labels intact and in sizes to suit project.
   b) Include manufacturer's name, job number, pump location, and pump model and series numbers on identification labels.

B. Storage and Handling Requirements: Store materials off ground and protected from exposure to harmful weather conditions and at temperature conditions recommended by manufacturer. Storage must be weather tight, rain proof, and dust proof.

1. Exercise care to avoid damage during unloading and storing.
2. Leave pump port protection plates in place until pumps are ready to connect to piping.
3. Do not place cable slings around pump shaft or integrated control enclosure.
4. Once installed the contractor must keep a dust proof cover over the drive, motor, and integral controller.

1.7 WARRANTY

A. Manufacturer's warranty: The entire package shall carry a 18 month parts warranty. The drive will carry a parts and labor warranty. The motor will carry a 12 month parts and labor warranty but must be delivered to a local authorized motor warranty shop by the installing contractor. Manufacturer's warranty is in addition to and not intended to limit other rights Owner may have under Contract Conditions.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with these specifications, the following manufacturers shall be acceptable:

1. Taco, Inc. – SKV/SKS Self-Sensing Series with ProBalance.
2. Pre-Approved Equal.

B. The above manufacturers are approved for this project. This approval does not relieve the manufacturer from strict compliance with this specification regardless of the manufacturer's own standards. Other manufacturers and or models seeking prior approval must send a detailed Engineering proposal with drawings to the Engineer ten days prior to the bid. Prior approval will be written; no verbal approvals will be given.

2.2 MANUFACTURED UNITS

A. The self-sensing product shall consist of a factory prepackaged and preprogrammed pump, drive, motor, and integral controls package.

B. The drive shall be mounted and integral to the motor. It shall be mounted with rubber vibration mounts. The mounting and packing of the drive shall be done in a manner that transmitted acceleration levels will be three times below the allowable limits published by the drive manufacturer. These limits will apply to a frequency range of 0-10,000 HZ.

C. The performance speed of this package shall 1750 RPM nominal as standard. Exceptions for 3600 RPM will be noted in the schedules. 3600 RPM shall NOT be an allowable substitution for a specified 1750 PRM package. 3600 RPM products might be considered as a substitution for 1750 RPM only if that manufacturer provides a spare motor, drive, and seal for each pumping unit.

D. Pump logic controller, variable frequency drives, sensor/transmitters and related equipment shall be installed by the mechanical contractor as shown on the plans.

2.3 COMPONENTS

A. Pump Logic Controller.

1. The controller operation shall operate the system using a tested and proven program that safeguards against undesirable or damaging conditions including:

a) Motor overload
b) Pump flow surges
c) Hydraulic cycling (hunting).
d) End of curve unstable operation: The pump logic controller, through a factory pre-programmed algorithm, shall be capable of protecting the pumps from hydraulic damage due to operation beyond their published end-of-curve. This feature requires a flow meter for activation. The operator interface shall include an owner adjustable flow setpoint to set the parameters for this routine.

2. The pump logic controller shall be capable of starting, unloading, and stopping pumps based on a system performance program that will minimize energy consumption , provide reliable performance and bumpless transitions.

3. The integrated logic controller shall be capable of running four different hydronic optimization sub-routines

   a) Setup one: This subroutine shall allow the pump package to track a quadratic system curve and will optimize a secondary distribution loop. It shall use a technology that allows the pump, drive, and motor package to translate the hydronic data from both a pump and system curve and translate it to electrical data. This allows the drive to know exactly where it is in the hydronic world.
      i. Setup two: This subroutine shall allow two pumps to run as backup for each other and shall alternate the pumps based on a real time clock.
      ii. Setup three: This subroutine shall allow the package to run in a customer defined flow rate. The package will always seek to run at the user defined flow even with fouling causing system changes. It shall use a technology that allows the pump, drive, and motor package to translate the hydronic data from both a pump and system curve and translate it to electrical data. This allows the drive to know exactly where it is in the hydronic world.
      iii. Setup four: This subroutine shall incorporate a traditional external sensing and control platform. It shall allow the option of controlling the pumps with three zones of differential pressure or central plant differential temperature. This optional setup shall allow the owner the option of external sensing without adding an external controller. This feature shall be equal to Taco System Logic (TSL) or equal.

4. The control platform shall include a subroutine equal to the Taco Self-Sensing Series with ProBalance™. This subroutine shall allow for the automatic balancing of secondary system distribution pumps. The package shall automatically run system distribution pumps to a user defined duty point and will recognize that duty point and hold the pumps at a speed that matches the actual installed system quadratic system curve. The package will then use this data to set up a new duty point as the max point for the quadratic control curve. Use of external balancing devices or contractors will not be needed.

5. The package shall serve as a flow metering device and will display pump flow at the user interface.

6. Shall have optional ProView controller that automates pump balancing.

B. PUMPS (See pump schedule on plans for exact model, type, and duty points.)

1. Vertical Close Coupled Pumps.
   a) Pumps shall be Taco Model KV or approved equal. The pumps shall be single stage vertical inline design. The seal shall be serviceable without disturbing the piping connections. The capacities and characteristics shall be as called for in the plans/schedules.

i. Pump casing shall be constructed of ASTM A48 class 30 cast iron. The pump casing/volute shall be rated for 250 psi working pressure for all jobs. The pump flanges shall be matched to suit the working pressure of the piping components on the job, with either ANSI Class 125 flanges or ANSI class 250 flanges. The pump casing shall be drilled and tapped for gauge ports on both the suction and discharge connections and for a drain port at the bottom of the casing. The casing shall have an additional tapping on the discharge connection to allow for the installation of a seal flush line. The pump cover shall be drilled and tapped to accommodate a seal flush line which can be connected to the corresponding tapping on the discharge connection, or to an external source to facilitate cooling and flushing of the seal faces.
ii. All casings shall be flanged. Threaded casings not allowed unless extra unions and fittings are provided to allow servicing.
iii. The pump shall have a factory installed vent/flush line to insure removal of trapped air from the casing and mechanical seal cooling. The vent/flush line shall run from the seal chamber to the pump discharge.
iv. The impeller shall be ASTM B584-836/875 bronze and hydraulically balanced. The impeller shall be dynamically balanced to ANSI Grade G6.3 and shall be fitted to the shaft with a key. The impeller shall be cast by the hydraulically efficient lost foam technique to ensure repeatability of high quality.
v. The pump shall incorporate a dry shaft design to prevent the circulating fluid from contacting the shaft. The pump shaft shall be AISI 1045 carbon steel with field replaceable bronze SAE 660 shaft sleeve. In order to improve serviceability and reduce the cost of ownership the shaft sleeve must be slip on (press on not allowable) and must be easily replaced in the field.
vi. The pump shall be fitted with a single mechanical seal, with EPT elastomers and Carbon/Ceramic faces, rated up to 250ºF. The mechanical seal shall be an inside type seal . This seal must be capable of being flushed externally via a tapping in the pump cover adjacent to the seal cavity. The entire pump line shall use no more than three different sizes of seals.
vii. Outside mechanical seals are NOT acceptable.
viii. The pump shall be close coupled to a JM Frame, TEFC, inverter rated motor with class F insulation and shaft grounding ring.
ix. In order to both simplify and reduce the total cost of ownership, the manufacturer shall standardize on no more than three sizes of mechanical seals throughout the entire range of the family of pumps. The manufacturer shall not use multiple part numbers for the same part.

2. Vertical Split Coupled Pumps. above 10 HP to a max of 700 HP shall be split coupled.
   a) Pumps shall be Taco Model KS or approved equal. The pumps shall be single stage vertical inline design. The seal shall be serviceable without disturbing the piping connections. The capacities and characteristics shall be as called for in the plans/schedules.

i. Pump casing shall be constructed of ASTM A48 class 30 cast iron. The pump casing/volute shall be rated for 250 psi working pressure for all jobs. The pump flanges shall be matched to suit the working pressure of the piping components on the job, with either ANSI Class 125 flanges or ANSI class 250 flanges. The pump casing shall be drilled and tapped for gauge ports on both the suction and discharge connections and for a drain port at the bottom of the casing. The casing shall have an additional tapping on the discharge connection to allow for the installation of a seal flush line. The pump cover shall be drilled and tapped to accommodate a seal flush line which can be connected to the corresponding tapping on the discharge connection, or to an external source to facilitate cooling and flushing of the seal faces.

ii. All casings shall be flanged. Threaded casings not allowed unless extra unions and fittings are provided to allow servicing.

iii. The pump shall have a factory installed vent/flush line to insure removal of trapped air from the casing and mechanical seal cooling. The vent/flush line shall run from the seal chamber to the pump discharge.

iv. The impeller shall be ASTM B584-836/875 bronze and hydraulically balanced. The impeller shall be dynamically balanced to ANSI Grade G6.3 and shall be fitted to the shaft with a key. The impeller shall be cast by the hydraulically efficient lost foam technique to ensure repeatability of high quality.

v. The pump shall be manufactured with AISI 416 Stainless Steel shaft.

vi. The pump shall be fitted with a single mechanical seal, with EPT elastomers and Carbon/Ceramic faces, rated up to 250ºF. The mechanical seal shall be an inside type seal yet engineered and applied in a manner that is as or more accessible than a specialty outside seal. This seal must be capable of being flushed externally via a tapping in the pump cover adjacent to the seal cavity. The entire pump line shall use no more than three different sizes of seals. Outside mechanical seals are NOT acceptable.

vii. The pump shall be coupled via a high tensile aluminum split style coupling. The design must permit easy replacement of the mechanical shaft seal without removal of the motor. The motor mount must be designed to accept several different motor frame standards; CZ and HP. The motor shall be a TEFC, inverter rated motor with class F insulation and shaft grounding ring.

viii. In order to both simplify and reduce the total cost of ownership, the manufacturer shall standardize on no more than three sizes of mechanical seals throughout the entire range of the family of pumps. The manufacturer shall not use multiple part numbers for the same part.

C. VARIABLE FREQUENCY DRIVES

1. The VFD shall convert incoming fixed frequency three-phase ac power into an adjustable frequency and voltage for controlling the speed of three-phase ac motors. The motor current shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current suitable for the driven load and to eliminate the need for motor derating. When properly sized, the VFD shall allow the motor to produce full rated power at rated motor voltage, current, and speed without using the motor's service factor. VFDs utilizing sine weighted/coded modulation (with or without 3rd harmonic injection) must provide data verifying that the motors will not draw more than full load current during full load and full speed operation.
2. The VFD shall include an input full-wave bridge rectifier and maintain a fundamental (displacement) power factor near unity regardless of speed or load.
3. The VFD shall have a dual 5% impedance DC link reactor on the positive and negative rails of the dc bus to minimize power line harmonics and protect the VFD from power line transients. The chokes shall be non-saturating. Swinging chokes that do not provide full harmonic filtering throughout the entire load range are not acceptable. VFDs with saturating (non-linear) dc link reactors shall require an additional 3% AC line reactor to provide acceptable harmonic performance at full load, where harmonic performance is most critical.
4. The VFD’s full load output current rating shall meet or exceed nec table 430-150. The VFD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and 120% of rated torque for up to 0.5 second while starting.
5. The VFD shall provide full motor torque at any selected frequency from 20 hz to base speed while providing a variable torque v/hz output at reduced speed. This is to allow driving direct drive fans without high speed derating or low speed excessive magnetization, as would occur if a constant torque v/hz curve was used at reduced speeds. Breakaway current of 160% shall be available.
6. A programmable automatic energy optimization selection feature shall be provided standard in the VFD. This feature shall automatically and continuously monitor the motor’s speed and load to adjust the applied voltage to maximize energy savings.
7. The VFD must be able to produce full torque at low speed to operate direct drive fans.
8. Output power circuit switching shall be able to be accomplished without interlocks or damage to the VFD.
9. An automatic motor adaptation algorithm shall measure motor stator resistance and reactance to optimize performance and efficiency. It shall not be necessary to run the motor or de-couple the motor from the load to perform the test.
10. Galvanic isolation shall be provided between the VFD’s power circuitry and control circuitry to ensure operator safety and to protect connected electronic control equipment from damage caused by voltage spikes, current surges, and ground loop currents. VFDs not including either galvanic or optical isolation on both analog i/o and discrete digital i/o shall include additional isolation modules.
11. VFD shall minimize the audible motor noise through the use of an adjustable carrier frequency. The carrier frequency shall be automatically adjusted to optimize motor and VFD operation while reducing motor noise. VFDs with fixed carrier frequency are not acceptable.
12. All VFDs shall contain integral EMI filters to attenuate radio frequency interference conducted to the ac power line.
13. The drive enclosure shall be standard as NEMA 12 (IP 55) and optional shall be NEMA 4X (IP 66). See schedules for project requirements.
14. Protective features

a) A minimum of class 20 i2t electronic motor overload protection for single motor applications shall be provided. Overload protection shall automatically compensate for changes in motor speed.

i. Protection against input transients, loss of AC line phase, output short circuit, output ground fault, over voltage, under voltage, VFD over temperature and motor over temperature. The VFD shall display all faults in plain language. Codes are not acceptable.

ii. Protect VFD from input phase loss. The VFD should be able to protect itself from damage and indicate the phase loss condition. During an input phase loss condition, the VFD shall be able to be programmed to either trip off while displaying an alarm, issue a warning while running at reduced output capacity, or issue a warning while running at full commanded speed. This function is independent of which input power phase is lost.

iii. Protect from under voltage. The VFD shall provide full rated output with an input voltage as low as 90% of the nominal. The VFD will continue to operate with reduced output, without faulting, with an input voltage as low as 70% of the nominal voltage.

iv. Protect from over voltage. The VFD shall continue to operate without faulting with a momentary input voltage as high as 130% of the nominal voltage.

v. The VFD shall incorporate a programmable motor preheat feature to keep the motor warm and prevent condensation build up in the motor when it is stopped in a damp environment by providing the motor stator with a controlled level of current.

vi. VFD shall include a “signal loss detection” algorithm with adjustable time delay to sense the loss of an analog input signal. It shall also include a programmable time delay to eliminate nuisance signal loss indications. The functions after detection shall be programmable.

vii. VFD shall function normally when the keypad is removed while the VFD is running. No warnings or alarms shall be issued as a result of removing the keypad.

viii. VFD shall catch a rotating motor operating forward or reverse up to full speed without VFD fault or component damage.

ix. Selectable over-voltage control shall be provided to protect the drive from power regenerated by the motor while maintaining control of the driven load.

x. VFD shall include current sensors on all three output phases to accurately measure motor current, protect the VFD from output short circuits, output ground faults, and act as a motor overload. If an output phase loss is detected, the VFD will trip off and identify which of the output phases is low or lost.

xi. If the temperature of the VFD’s heat sink rises to 80°c, the VFD shall automatically reduce its carrier frequency to reduce the heat sink temperature. It shall also be possible to program the VFD so that it reduces its output current limit value if the VFD’s temperature becomes too high.

xii. In order to ensure operation during periods of overload, it must be possible to program the VFD to automatically reduce its output

current to a programmed value during periods of excessive load. This allows the VFD to continue to run the load without tripping.

xiii. The VFD shall have temperature controlled cooling fan(s) for quiet operation, minimized losses, and increased fan life. At low loads or low ambient temperatures, the fan(s) may be off even when the VFD is running.

xiv. The VFD shall store in memory the last 10 alarms. A description of the alarm, and the date and time of the alarm shall be recorded.

xv. When used with a pumping system, the VFD shall be able to detect no-flow situations, dry pump conditions, and operation off the end of the pump curve. It shall be programmable to take appropriate protective action when one of the above situations is detected.

15. Internal Control Algorithm

a) This is a standard HVAC drive that has been upgraded and modified by pump experts for Hydronic applications. It is set up with a closed loop internal control sequence that will optimize life cycle, system comfort, and minimize energy consumption.

16. Interface Features

a) Hand, off and auto keys shall be provided to start and stop the VFD and determine the source of the speed reference. It shall be possible to either disable these keys or password protect them from undesired operation.

i. There shall be an “info” key on the keypad. The info key shall include “on-line” context sensitive assistance for programming and troubleshooting.

ii. The VFD shall be programmable to provide a digital output signal to indicate whether the VFD is in hand or auto mode. This is to alert the building automation system whether the VFD is being controlled locally or by the building automation system.

iii. Password protected keypad with alphanumeric, graphical, backlit display can be remotely mounted. Two levels of password protection shall be provided to guard against unauthorized parameter changes.

iv. All VFDs shall have the same customer interface. The keypad and display shall be identical and interchangeable for all sizes of VFDs.

v. To set up multiple VFDs, it shall be possible to upload all setup parameters to the VFD’s keypad, place that keypad on all other VFDs in turn and download the setup parameters to each VFD. To facilitate setting up VFDs of various sizes, it shall be possible to download from the keypad only size independent parameters. Keypad shall provide visual indication of copy status.

vi. Display shall be programmable to communicate in multiple languages including English, Spanish and French.

vii. A red fault light, a yellow warning light and a green power-on light shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.

viii. A quick setup menu with factory preset typical HVAC parameters shall be provided on the VFD. The VFD shall also have individual fan, pump, and compressor menus specifically designed to facilitate start-up of these applications.

ix. A four-feedback PID controller to control the speed of the VFD shall be standard. This controller shall accept up to four feedback signals. It shall be programmable to compare the feedback signals to a common setpoint or to individual setpoints and to automatically select either the maximum or the feedback signal as the controlling signal. It shall also be possible to calculate the controlling feedback signal as the average of all feedback signals or the difference between a pair of feedback signals.

x. The VFD shall be able to apply individual scaling to each feedback signal.

xi. For fan flow tracking applications, the VFD shall be able to calculate the square root of any or all individual feedback signals so that a pressure sensor can be used to measure air flow.

xii. The VFD's PID controller shall be able to actively adjust its setpoint based on flow. This allows the VFD to compensate for a pressure feedback sensor which is located near the output of the pump rather than out in the controlled system.

xiii. The VFD shall have three additional PID controllers which can be used to control damper and valve positioners in the system and to provide setpoint reset.

xiv. Floating point control interface shall be provided to increase/decrease speed in response to contact closures.

xv. Five simultaneous meter displays shall be available. They shall include at a minimum, frequency, motor current, motor voltage, VFD output power, VFD output energy, VFD temperature in degrees, among others.

xvi. Programmable sleep mode shall be able to stop the VFD. When its output frequency drops below set "sleep" level for a specified time, when an external contact commands that the VFD go into sleep mode, or when the VFD detects a no-flow situation, the VFD may be programmed to stop. When the VFD's speed is being controlled by its PID controller, it shall be possible to program a "wake-up" feedback value that will cause the VFD to start. To avoid excessive starting and stopping of the driven equipment, it shall be possible to program a minimum run time before sleep mode can be initiated and a minimum sleep time for the VFD.

xvii. A run permissive circuit shall be provided to accept a "system ready" signal to ensure that the VFD does not start until dampers or other auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of initiating an output "run request" signal to indicate to the external equipment that the VFD has received a request to run.

xviii. VFD shall be programmable to display feedback signals in appropriate units, such as inches of water column (in-wg), pressure per square inch (psi) or temperature (°f).

xix. VFD shall be programmable to sense the loss of load and signal this condition via a keypad warning, relay output and/or over the serial communications bus. To ensure against nuisance indications, this feature must be based on motor torque, not current, and must include a proof timer to keep brief periods of no load from falsely triggering this indication.

17. Standard Control And Monitoring Inputs And Outputs
    a) Six dedicated, programmable digital inputs shall be provided for interfacing with the systems control and safety interlock circuitry.
        i. Two terminals shall be programmable to act as either as digital outputs or additional digital inputs.
        ii. Two programmable relay outputs, Form C 240 V AC, 2 A, shall be provided for remote indication of VFD status.
        iii. Each relay shall have an adjustable on delay / off delay time.
        iv. Two programmable analog inputs shall be provided that can be either direct-or-reverse acting.
        v. Each shall be independently selectable to be used with either an analog voltage or current signal.
        vi. The maximum and minimum range of each shall be able to be independently scalable from 0 to 10 V dc and 0 to 20 mA.
        vii. A programmable low-pass filter for either or both of the analog inputs must be included to compensate for noise.
        viii. The VFD shall provide front panel meter displays programmable to show the value of each analog input signal for system set-up and troubleshooting,
        ix. One programmable analog current output (0/4 to 20 mA) shall be provided for indication of VFD status. This output shall be programmable to show the reference or feedback signal supplied to the VFD and for VFD output frequency, current and power. It shall be possible to scale the minimum and maximum values of this output.
        x. It shall be possible through serial bus communications to read the status of all analog and digital inputs of the VFD.
        xi. It shall be possible to command all digital and analog output through the serial communication bus.

18. Optional Control And Monitoring Inputs And Outputs
    a) It shall be possible to add optional modules to the VFD in the field to expand its analog and digital inputs and outputs.
        i. These modules shall use rigid connectors to plug into the VFD's control card.
        ii. The VFD shall automatically recognize the option module after it is powered up. There shall be no need to manually configure the module.
        iii. Modules may include such items as:
        iv. Additional digital outputs, including relay outputs
        v. Additional digital inputs
        vi. Additional analog outputs
        vii. Additional analog inputs, including Ni or Pt temperature sensor inputs
        viii. It shall be possible through serial bus communications to control the status of all optional analog and digital outputs of the VFD.

19. Standard programmable firefighter's override mode allows a digital input to control the VFD and override all other local or remote commands. It shall be possible to program the VFD so that it will ignore most normal VFD safety circuits including motor overload. The VFD shall display firemode whenever in firefighter's override mode. Firemode shall

allow selection of forward or reverse operation and the selection of a speed source or preset speed, as required to accommodate local fire codes, standards and conditions.

20. A real-time clock shall be an integral part of the VFD.
    a) It shall be possible to use this to display the current date and time on the VFD's display.
        i. Ten programmable time periods, with individually selectable ON and OFF functions shall be available. The clock shall also be programmable to control start/stop functions, constant speeds, PID parameter setpoints and output relays. Is shall be possible to program unique events that occur only during normal work days, others that occur only on non-work days, and others that occur on specific days or dates. The manufacturer shall provide free PC-based software to set up the calendar for this schedule.
        ii. All VFD faults shall be time stamped to aid troubleshooting.
        iii. It shall be possible to program maintenance reminders based on date and time, VFD running hours, or VFD operating hours.
        iv. The real-time clock shall be able to time and date stamp all faults recorded in the VFD fault log.

21. The VFD shall be able to store load profile data to assist in analyzing the system demand and energy consumption over time.

22. The VFD shall include a sequential logic controller to provide advanced control interface capabilities. This shall include:
    a) Comparators for comparing VFD analog values to programmed trigger values
        i. Logic operators to combine up to three logic expressions using Boolean algebra
        ii. Delay timers
        iii. A 20-step programmable structure

23. The VFD shall include a cascade controller which allows the VFD to operate in closed loop setpoint (PID) control mode one motor at a controlled speed and control the operation of 3 additional constant speed motor starters.

24. Serial communications
    a) The VFD shall include a standard eia-485 communications port and capabilities to be connected to the following serial communication protocols at no additional cost and without a need to install any additional hardware or software in the VFD:
        i. Johnson Controls Metasys N2
        ii. Modbus RTU
        iii. Siemens FLN
        iv. BACnet MS/TP
        v. Optional communication shall include:
        vi. LonWorks Free Topology (FTP)
    b) VFD shall have standard USB port for direct connection of Personal Computer (PC) to the VFD. The manufacturer shall provide no-charge pc software to allow complete setup and access of the VFD and logs of VFD operation through the USB port. It shall be possible to communicate to the VFD through this USB port without interrupting VFD communications to the building management system.

c) The VFD shall have provisions for an optional 24 v DC back-up power interface to power the VFD's control card. This is to allow the VFD to continue to communicate to the building automation system even if power to the VFD is lost.

25. Adjustments
    a) The VFD shall have a manually adjustable carrier frequency that can be adjusted in 0.5 khz increments to allow the user to select the desired operating characteristics. The VFD shall also be programmable to automatically reduce its carrier frequency to avoid tripping due to thermal loading.
        i. Four independent setups shall be provided.
        ii. Four preset speeds per setup shall be provided for a total of 16.
        iii. Each setup shall have two programmable ramp up and ramp down times. Acceleration and deceleration ramp times shall be adjustable over the range from 1 to 3,600 seconds.
        iv. Each setup shall be programmable for a unique current limit value. If the output current from the VFD reaches this value, any further attempt to increase the current produced by the VFD will cause the VFD to reduce its output frequency to reduce the load on the VFD. If desired, it shall be possible to program a timer which will cause the VFD to trip off after a programmed time period.
        v. If the VFD trips on one of the following conditions, the VFD shall be programmable for automatic or manual reset: external interlock, under-voltage, over-voltage, current limit, over temperature, and VFD overload.
        vi. The number of restart attempts shall be selectable from 0 through 20 or infinitely and the time between attempts shall be adjustable from 0 through 600 seconds.
        vii. An automatic "start delay" may be selected from 0 to 120 seconds. During this delay time, the VFD shall be programmable to either apply no voltage to the motor or apply a DC braking current if desired.
        viii. Four programmable critical frequency lockout ranges to prevent the VFD from operating the load at a speed that causes vibration in the driven equipment shall be provided. Semi-automatic setting of lockout ranges shall simplify the set-up.

26. Optional features
    a) All optional features shall be built and mounted by VFD manufacturer. All optional features shall be UL listed by the VFD manufacturer as a complete assembly and carry a UL label.
        i. All panels shall be marked for their short circuit current rating in compliance with UL.

27. Service conditions
    a) Ambient temperature, continuous, full speed, full load operation:
        i. -10 to 45°C (14 to 113°F) through 125 HP @ 460 and 600 volt, through 60 HP @ 208 volt
        ii. -10 to 40°C (14 to 104°F) 150 HP and larger
        iii. 0 to 95% relative humidity, non-condensing.
        iv. Elevation to 3,300 feet without derating.
        v. AC line voltage variation, -10 to +10% of nominal with full output.

vi. No side clearance shall be required for cooling.
vii. All power and control wiring shall be done from the bottom.
viii. All VFDs shall be plenum rated.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install equipment in accordance with manufacturer's instructions and all applicable codes.
1. Ensure that pump is pipe-mounted and free to float with any movement, expansion and contraction of piping system.
a. Support pump using floor mounted saddle as required.
i. For vertical in-line pumps supported from structure, ensure no pipe strain is imposed on pump flanges.
2. Power wiring, as required, shall be the responsibility of the electrical contractor. All wiring shall be performed per manufacturer's instructions and all applicable codes.
3. Control wiring for remote mounted switches and sensor/transmitters shall be the responsibility of the controls contractor. All wiring shall be performed per manufacturer's instructions and all applicable codes.

3.2 DEMONSTRATION

A. The control package manufacturer's factory trained representative shall provide start-up of the packaged pumping system. This start-up shall include verification of proper installation, system initiation, adjustment and fine tuning. Start-up shall not be considered complete until the sequence of operation, including all alarms, has been sufficiently demonstrated to the Owner or Owner's designated representative. This jobsite visit shall occur only after all hook-ups, tie-ins, and terminations have been completed and signed-off on the manufacturer's start-up request form.

B. The pump control package manufacturer's factory trained representative shall provide on-site training for owner's personnel. This training shall fully cover maintenance and operation of all system components.

END OF SECTION 15901