USask Master Specification Directions: The master specifications are intended to be incorporated into the Consultant's final, project specific specification package. The project specific specifications are expected to include any and all sections or portions of sections (Part 1, Part 2, Part 3) that are required to create a fully executable project specification. USask Master Specs only provide information that USask **requires** be a part of the final specification package. Components or sections not included in the Master USask Specifications may still be required for a complete, well-designed project. **It is the consultant's responsibility to ensure all specifications match USask requirements. Any deviations or revisions to any section included in the master specifications requires written consent from the USask Engineering department. The consultant is liable for any omissions, errors, or incorrect equipment or components supplied to site.**
The Master Specifications shall be used in conjunction with USask's Design Guidelines. Any conflicts shall be brought to the attention of USask Engineering staff for clarification.

Part 1 General

Part 2 Products

.1 General

.1 VFD's for motors less than 15 hp shall be permissible to be mounted in motor control centres and shall be of the same manufacture. VFD's shall be located in cells three and four and shall not be installed in the lower or upper portions of an MCC section.
.2 VFD's for motors 15 hp and larger shall be loose mounted and shall be of one manufacturer.
.3 Acceptable Manufacturers: Eaton/Cutler-Hammer, Schneider. Other manufacturers shall be approved by the U of S Engineering Department. VFD Manufacturer to Provide a BACNET MS/TP Controller Card for connection to the U of S BAS Controller NET2 Port

.2 Equipment Ratings

.1 The VFD shall be rated as indicated, 575/3/60, sized to the motor service factor rating.
.2 Unless otherwise indicated, contactor, relays, switches to be NEMA rated.

.3 Ambient

.1 The VFD to be suitable for use in normal indoor non-hazardous industrial environments subject to the following conditions:
  .1 For enclosed units, an ambient temperature range of 0º to 40º C.
  .2 For open units, an ambient temperature range of 0º to 50º C.
  .3 For all units, a humidity range from 5 to 95%, non-condensing.
  .4 For all units, an altitude range up to 1,000 metres without derating the VFD's output power capability.

.4 Construction

.1 Design the VFD to provide for ease of maintenance.
.2 The VFD shall consist of the following major components:
  .1 Input rectifier section to supply fixed DC bus voltage.
  .2 Phase-to phase and phase-to-ground MOV protection.

.3 Smoothing reactor for each incoming phase. Input line reactors to be sized to reduce the harmonics generated back to the power supply system to less than 10% T.D.D.
.4 DC bus capacitors.
.5 Sine weighted PWM generating inverter section with IGBT switching devices
.6 Suitable snubber circuitry to control output voltage spikes and to control rise times of the output pulses.
.7 Built in ground fault protection.
.8 Microprocessor to control PWM pulse generation, microprocessor specifically dedicated to PWM pulse generation.
.9 RLC output network to limit dv/dt to motors. This requirement may be waived if the VFD vendor submits data showing that output filtering is not required for protection of the motor driven with the VFD.
.10 Include control and transformer for energizing field devices.
.11 Provide a BACNET MS/TP Controller Card for connection to the U of S BAS Controller NET2 Port

.3 Each VFD, as standard, shall have a full digital display which will display programming, operation, and fault code diagnostic information. The display shall be visible through the enclosure door.
.4 Separate the VFD power terminal blocks physically from control signal terminal blocks. Provide the control terminations in a separate control box as indicated on the drawings. Submit a CSA control box control manufactured shop drawings showing the separate control enclosure details. See drawings.
.5 The VFD shall be modularly constructed. Provide printed circuit boards with plug-in connections and easily removable from the drive. Provide power components readily accessible with “fast-on” or screw terminal connections for easy removal.
.6 Shop assemble and pre-wire the equipment including:
.1 Circuit breakers.
.2 Variable frequency drive controller complete with accessories.
.3 Input line reactors.
.4 Output line RLC filters.

.5 Equipment Enclosure

.1 Enclosures to be NEMA 1. See also requirement for a separate control box by the VFD enclosure.
.2 Cable connections or bus bars for connecting of all power components.
.3 Provide forced air ventilation for cooling if required. Filters shall be cleanable.

.6 System Requirements

.1 Unless otherwise noted, NEMA Type B premium efficiency inverter rated AC induction motors having a 1.15 service factor will be used to operate a variable or constant torque load over a 30 to 110% speed range reaching rated nameplate horsepower (hp) at 60 Hz. Determine final VFD selection by load type, full load motor current and special requirements (if any) listed.

.7 Electrical Design Characteristics

.1 Input Power

.1 Unless otherwise specified, the VFD to accept nominal supply voltage of 600 volts ± 10%, 3-phase 60 Hz, artificially grounded power supply.

.2 Permit variations of up to ± 2 Hz of line frequency without the VFD shutting down on a fault.

.3 Permit power line interruptions of up to 2.0 seconds without the VFD shutting down on a fault providing an extended power loss ride-through. If the drive trips on undervoltage, the drive will activate the Automatic Restart/Reset for undervoltage trips and the rotating start functions to allow the drive to restart immediately when the power returns and match the motor rotating speed and take control.

.4 The VFD not to exceed notch depth of 20%, total harmonic distortion factor (THD) of 5%, total demand distortion of 10% and the notch area of the line-to-line voltage to be maximum 28,500 volt-microseconds at rated voltage and current, as specified in IEEE 519 latest edition.

.5 The VFD shall present a displacement power factor of 0.98 or better to the AC line at any speed or load. Full load power factor shall be 95% or better.

.6 Efficiency of VFD controller shall be not less than 97% at 60 hertz output when driving the specified maximum load.

.7 The variable frequency control shall operate satisfactorily when connected to a bus supplying other solid state power conversion equipment which may be causing up to 5% total harmonic voltage distortion and communication notches up to 36,500 volt microseconds.

.8 The VFD shall not require an input isolation transformer.

.9 The VFD shall include transient voltage suppression to allow reliable operation encountered in an industrial/commercial power distribution system for transients up to 3000V, 50 joules.

.2 Output Power

.1 The VFD shall produce a three-phase output for the load.

.2 The VFD shall be of the Pulse-Width Modulated type and to consist of a full wave diode bridge converter to convert incoming fixed voltage/frequency to a fixed DC voltage. The Pulse Width Modulation strategy shall incorporate a microprocessor to handle all Logic functions as well as the complex, sine coded PWM generating algorithms that control output stage switching. Generate the inverter output by IGBT power transistors or gate turn off thyristors only.

.3 Unless otherwise specified, the standard VFD output frequency shall be adjustable from 0 to 72 Hz.

.4 When specified, frequencies of up to 90 Hz shall be obtainable.

.5 Unless otherwise specified, the VFD output voltage shall be adjustable from 0 to full voltage reaching full voltage at 60 Hz.

.6 Unless otherwise specified, the VFD shall produce a constant volts-per-hertz (V/Hz) ratio in the 60 Hz range and below.

.7 Unless otherwise specified, the VFD shall supply a constant full voltage output when operating above 60 Hz.

.8 The volts-per-hertz output of the VFD shall not be affected or required re-adjustment when other drive adjustments (such as maximum speed) are changed.

.9 Provide selectable constant V/Hz ratio or configurable V/Hz ratio. Specific V/Hz patterns shall be available for both constant torque and variable torque applications.

.10 When subject to the range of ambient conditions stated in Paragraph 2.3 the VFD

shall be capable of maintaining 100% of rated output current continuously.

.11 When subject to the range of ambient conditions stated in Paragraph 2.3 the VFD shall be capable of delivering 115% of rated output current for up to one minute for variable torque loads. (For constant torque application 150% of rated output current).

.12 The VFD output waveform shall be the PWM waveform producing smooth torque at low frequencies and low current harmonics.

.13 The VFD shall have a programmable PWM carrier frequency.

.14 The VFD shall be capable of operating output open circuited with no fault or damage for startup and testing purposes.

.15 The short circuit current at point of common coupling under utility operation will be available from the Consultant. A preliminary harmonic analysis must be submitted by the VFD manufacturer at time of tender in accordance with IEEE 519, latest edition. Compliance to be verified by the VFD manufacturer with field measurements of the harmonic distortion difference at the point of common coupling with and without VFD's operating.

.16 Manufacturer to indicate, at time of tender, the anticipated levels of electrical noise and heat generated. These levels to be warranted and supported by actual test data. Audible noise levels to be less than 85 dbA at 1 m out from any point on the VFD cabinet under normal operating condition.

.17 Electrical noise, (radio interference and AC line harmonics) limited to levels specified in applicable standards. Equipment to be so designed that use of radio communication equipment adjacent to VFD units is possible. In addition, the variable speed equipment not to be susceptible to interference from radio equipment operating adjacent to it. Harmonics generated by the variable speed equipment to be guaranteed not to exceed a level indicated by manufacturer at the time of tender and in no case to be greater than 5 percent total harmonic distortion for voltage and 10 percent for current based on the equipment rating, per IEEE 519, 1992.

.18 Provision of adequate grounding within the equipment in addition to protection means for electrostatic discharge.

.8 Protective Features

.1 Incorporate the following protective features with each VFD:

.1 Disconnect switch with fuses.

.2 Short Circuit protection; Instantaneous overcurrent protection, including short circuit phase-phase or phase-ground by high-speed fuses with 100,000 ampere fault capacity rating.

.3 Fully protect the VFD against load faults. Bolted faults, phase to phase or phase to ground shall not damage the unit. Design VFD to withstand the short circuit.

.2 Adjustable current limit from 50-150 percent (50-125 percent for variable torque loads) rated current of unit. The VFD to avoid nuisance current trips caused by short acceleration or deceleration settings by temporarily increasing the acceleration or deceleration times.

.3 Phase Protection

.1 Each output phase to be monitored. If a short circuit conditions occurs, a circuit shall guard against further damage by turning off the entire output section experiencing the shorted condition.

.2 The VFD to shut down and annunciate the fault and display the appropriate fault code on the digital display panel.

.4 Overvoltage Sensing
- .1 Should either the input line rise above 15% of rated input voltage, or the internal DC bus rise above allowable levels due to load regeneration, the VFD shall sense an overvoltage condition and annunciate it on the digital display panel and alarm contact.
- .2 The VFD to trip if the DC voltage exceeds 125% of rated voltage. The VFD shall compensate for overvoltages caused by short deceleration settings by automatically increasing the decelerating time in order to avoid nuisance overvoltage trippings.

.5 Undervoltage Sensing
- .1 Should the input line fall below 85% of rated input voltage, the VFD shall sense an undervoltage condition and annunciate it on the digital display panel.

.6 Motor Overload Protection
- .1 Provide the VFD with motor overload protection.
- .2 The overload protection to be adjustable from 80 to 115% of the full load current rating.
- .3 The overload to provide the protection required by the CEC for motor overload protection and to be tested in accordance with CSA.

.7 Heat Sink Temperature
- .1 The VFD shall monitor the temperature of the heat sink. If the heat sink temperature exceeds design/limits the VFD shall shut down and annunciate the condition on the digital display panel.

.8 Ground Fault Detection
- .1 Should an output phase short to earth ground occur, the VFD shall guard against excessive currents. This condition to be monitored and annunciated on the digital display panel.

.9 Bus Charged Led
- .1 When power is applied to the VFD and hazardous potentials exist on the DC bus, the VFD shall provide indication at the front of the VFD.

.10 Bus Discharge Protection
- .1 The VFD to contain circuits which discharge the DC bus after input power is from the VFD.

.9 Control Features

.1 Provide two (2) analog inputs which are both capable of operating from 0 to 20 mA.
.2 A linear or S curve suitable for drives requiring controlled acceleration/deceleration.
.3 Provide offset and gain programmable functions to set operating range.
.4 Provide two (2) analog outputs which can be programmed proportional to:
- .1 Output frequency
- .2 Motor speed
- .3 Motor torque
- .4 Motor power
- .5 Output current
- .6 DC bus voltage
- .7 Motor voltage

.5 All VFD set-up operations and adjustments shall be digital and stored in nonvolatile memory (EEPROM). No analog or potentiometer adjustments to be allowed.

.6 VFD operation shall be fully digital with microprocessor control of frequency, voltage and current.

.7 The VFD shall be capable of communicating with a communication device over the remote I/O serial link, multi-drop, typically RS485, using industry standard communication protocol. Provide software for personal computer use to upload and download parameters.

.8 A speed drop feature which reduces the speed of the drive on transient overloads. The drive is to return to set speed after transient is removed. If the acceleration or deceleration rates are too rapid for the moment of inertia of the load, the drive is to automatically compensate to prevent drive trip.

.9 Speed Profile: Individual adjustable settings for start, stop, slope and minimum and maximum speed points.

.10 Process Signal Inverter: Software selectable to allow speed of drive to vary inversely with input signal.

.11 Digital Interface: Provide a local interface to upload, download and read drive parameter settings through the use of a personal computer or a similar portable device.

.12 Pick Up a Spinning Load (Rotating Start): The VFD shall be programmable for rotating start, enabling the VFD to start into a rotating motor, regardless of direction, without tripping and without setting the motor to zero speed. The VFD to start at the speed the motor is rotating and then accelerate the motor according to the speed reference signal.

.13 Bumpless Speed Transfer: Provide a bumpless speed transfer from remote control to local control, without setting the motor to zero speed.

.14 Automatic Reset/Restart: Provide software programmable automatic reset/restart after any individual trip condition resulting from either overcurrent, overvoltage, undervoltage or over temperature. For safety, the drive shall shut down and require manual reset if the automatic reset function is not successful within a maximum of three attempts within a short time period.

.10 External Control and Monitoring

.1 General

.1 Provide isolation and voltage surge suppression for contacts used for external monitoring to limit inductive switching surges to less than 200V peak. Provide DC coils with free-wheeling diodes to limit inductive surges.

.2 Wiring

.1 Use twisted pairs for control and signal wiring that connects external to the VFD. Separate signal and power wiring that may contain voltage and/or current harmonics inherent to inverter.

.11 Digital Display Operator Station (Front Panel)

.1 Provide an operator station on the drive door complete with the following features as a minimum:

.1 START pushbutton for local control.

.2 STOP pushbutton for local control.

.3 HOA Selector Switch or LOCAL/REMOTE pushbutton.

.4 Potentiometer or speed raise/power pushbuttons with digital frequency display for local speed adjustment.

.2 The digital operator station to be capable of being mounted on the drive and/or display for

local speed adjustment.

.12 Speed Control

.1 The VFD shall contain an independent parameter which will provide an adjustable minimum speed setting from 0 to 60 Hz.

.2 The VFD shall contain an independent parameter which will provide an adjustable maximum speed setting from 40 to 90 Hz.

.3 The VFD shall accept an isolated analog input speed reference of 4-20 mA and be adjustable via the digital operator station.

.4 The 4-20 mA analog input speed reference signal shall be galvanically isolated. Calibration adjustments shall be provided within the speed ranges specified.

.5 Selectable stopping modes of coast, ramp to stop of DC brake to stop shall be available.

.13 Drive Controls

.1 Provide control transformer fuses, terminal blocks and control relay(s) interconnected in accordance with the project requirements.

.2 The VFD shall accept an isolated output signal via DCS to stop and start the drive.

.3 The VFD shall have provision for an external stop interlock circuit that inhibits running in “Auto” and “Manual” modes.

.4 The VFD shall provide 3 programmable contact outputs. Status of contacts to indicate:
- .1 Run
- .2 Ready
- .3 Fault

.5 The drive shall be wired to achieve the following functionality:
- .1 Motor selected to “Auto” (“Remote”) enables motor to be started, stopped and speed to be adjusted via DCS.
- .2 Motor selected to “Manual” (“Local”) enables motor to be started, stopped and speed to be adjusted via the front panel pushbuttons.

.6 Drive Protection/Fault Annunciation
- .1 The VFD shall be capable of monitoring the following conditions or sensing the following faults. Where indicated in the following text, the condition or fault shall be annunciated on the diagnostic display panel. The panel shall be mounted on the front of the VFD and visible through the door of the enclosure. The VFD shall instantaneously shutdown when a fault condition occurs.
  - .1 Short circuit problem.
  - .2 DC bus undervoltage protection.
  - .3 DC bus overvoltage protection.
  - .4 Overtemperature protection.
  - .5 Power semiconductor protection.
  - .6 Ground fault protection.

.14 Parameter Settings

.1 Provide the following system configuring settings, field adjustable through the keypad/display unit or via the serial communication port.

.2 Motor configuration data:
- .1 Motor frequency
- .2 Number of poles

.3 Full load speed.
.4 Motor volts
.5 Motor full load amps
.6 Motor HP

.3 VFD limits:
.1 Independent acceleration/deceleration rates.
.2 No load boost.
.3 Maximum voltage, minimum voltage, volts/Hertz.
.4 Full load boost.
.5 Overload trip.
.6 Min/Max. Speed (frequency).
.7 Auto reset for load or voltage trip select.
.8 Slip compensation.
.9 Rotating start select.
.10 Overload trip time.

.4 Controller adjustments:
.1 Minimum frequency 0 – 60 Hz.
.2 Maximum frequency 40 – 90 Hz.
.3 Acceleration time 0.3– 255 seconds.
.4 Deceleration time 0.3 – 255 seconds.
.5 Output current 50 – 150% of nominal current for constant torque. Output current 50 – 125% for variable torque application minimum.
.6 Speed range 0 – 120%.
.7 Start by: Normal acceleration or, automatic start boost or rotating start.
.8 Stop by: Coasting or, normal deceleration or, braking.
.9 Slip compensation.
.10 Electronic o/l adjustment.
.11 Automatic restart after overvoltage.
.12 Automatic restart after undervoltage.
.13 Linear or tapered V/Hz ratio.
.14 Selection of field weakening point (V/Hz ratio).
.15 Automatic start boost, programmable active only at start until output frequency reaches 20 Hz or set speed reference less than 20 Hz.

.15 Diagnostic Features and Fault Handling

.1 Provide a microprocessor based digital diagnostic system which monitors its own control functions and displays faults and operating conditions. Microprocessor systems must be product of the same manufacturer as the VFD to assure single source responsibility, availability of service and access to spare parts.

.2 The digital keyboard allows the operator to enter exact numerical settings. A plain English user menu shall be provided in software as a guide to parameter setting, (rather than codes). Drive parameters shall be factory set in EEPROM and be resettable in the field through the keypad. Multi levels of password security shall be available to protect drive parameters from unauthorized personnel. The EEPROM stored drive variables must be able to be transferred to new boards to reprogram spare boards.

.3 The VFD to execute, on initial power-up, a self diagnostic check. The integral programming display panel shall provide first fault indication of VFD protection functions. Fault indication to be retained if input power is lost. The following faults to be displayed on the local programming panel:

.1 Overcurrent.
.2 Short Circuit/Ground Fault.
.3 Undervoltage
.4 Overvoltage
.5 Overtemperature.
.6 Power Supply Fault
.7 Motor stalled.

.4 Fault codes to provide direction as to board level and input/output level to aid in troubleshooting.

.5 The fault log record shall be accessible via a RS485 serial link as well as line by line on the keypad display.

.6 Self diagnostic check to indicate faulty internal components.

.16 Factory Testing

.1 Provide certification that the following tests have been successfully completed.

.2 Factory tests include but are not limited to:

.1 Testing of power transistors, diodes and other solid state components to ensure correct function and highest reliability.
.2 All control printed circuit boards shall be dynamically tested while heat cycled.
.3 Power semiconductors must be fully tested for proper electrical characteristics (dc/dt, di/dt, etc.)
.4 Functional testing of chips (CMOS, TTL, LINEAR, etc.).
.5 Functional testing of power capacitors and active components.
.6 Inspection of sub-assemblies and/or testing for conformance to manufacturer's engineering and quality assurance specifications.
.7 All power components shall be run under "worst case" conditions for at least 2 hours.
.8 All VFD's shall be burned-in under full load a minimum of 8 hours, in 40ºC heat chamber.
.9 The VFD shall be functionally tested with a motor for 8 hours before shipment to assure proper operation per specification to applicable CSA and IEEE standards.

.3 Tests

.1 Factory tests shall be done by manufacturer to ensure proper system operation, freedom from grounds and open and short circuits.
.2 Conduct visual equipment inspection and functional test of assembled VFD units.

Part 3 Execution

.1 Installation

.1 Install variable speed drives with the assistance of factory-trained representatives in accordance with the manufacturer' specifications.
.2 Group VFD's where not constrained by distance limitations.
.3 Set and secure VFD assembly in place, rigid, plumb, and square to building floor and wall.
.4 Fasten to mounting surface as per manufacturer's recommendations.
.5 Protect against dust and damage during entire construction period.
.6 After connections have been made, vacuum-clean interior. Hand-clean and touch-up damaged paint.

.7 Loose mounted VFD's shall be fed from a breaker in an adjacent central distribution panel.

.2 Field Test

.1 Provide manufacture representatives to test and calibrate each VFD. Allow for ½ day per system. All testing shall be witnessed by Facilities Management, University of Saskatchewan. Witnessing should preferably be by CCMS in order to ensure complete system (not just VFD) operates as intended. Also, service mechanics to witness motor operation, electrician, etc.

.2 Provide written report of commissioning test including all parameter settings.

.3 Training

.1 Provide operator training on maintenance and servicing seminar for ½ day.

.2 The on-the-job training to cover the following topics as a minimum:

.1 Theory
.2 Configuration/models
.3 Setup
.4 Maintenance
.5 Troubleshooting

END OF SECTION