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PART 1  GENERAL

1.1  Scope

.1 This specification section is provided on behalf of the University of Alberta (U of A) for the purpose of defining the minimum acceptable requirements of Variable Frequency Drives (VFDs), and all associated components, to be provided in University maintained facilities.

.2 This section includes the supply, installation, start-up, testing and commissioning for Variable Frequency Drive (VFD) controllers, including but not limited to: associated enclosures, bypass components, input and output filters, warranty, start-up requirements, local and remote control requirements, testing and commissioning requirements as identified and detailed in this specification the drawings and/or in the motor schedule for the work of this project.

.3 The VFD and all specified components, including internal wiring between all the components must be installed and integrated into one common enclosure, supplied, factory tested, and commissioned by the VFD supplier. The integrated VFD assembly shall be ready for field installation and require only the connection of the incoming power cables, the motor load cables and the building management system control wiring for startup and operation.

.4 VFD supplier must coordinate with the installation contractor with respect to delivery dates, technical support for the installation, equipment start-up and commissioning of the VFDs.

.5 All VFDs and ancillary components must be procured by one supplier in order to assure an integrated system and one point of contact for service.

.6 Design of the VFD assembly is to utilize modularized components to allow for easy field maintenance and replacement of components.

.7 The VFD installer shall be responsible to arrange for a dedicated electrical permit for the VFD being installed per the requirements of the University Electrical Inspection Authority. Installation is to be carried out by a qualified installer.

.8 A standardized configuration for the VFD assembly is to be provided based on the supplier's products. Each supplier is to provide a VFD assembly configuration based on horsepower ranges of the products available. The design configuration is to be consistent for all future VFD assemblies having the same horsepower range.
1.2 Compliance with Specifications

.1 Compliance with all portions / clauses of this specification is required.

.2 If any supplier takes exception to any of the requirements of this specification, the deviations from the specification requirements shall be clearly explained on the submittal documents. Performance equivalence is to be demonstrated where compliance concerns exist. An explanation and demonstration of the proposed alternate compliance method is to be provided for evaluation and acceptance.

.3 The equipment build-up details (i.e. VFD, cabinet configuration, fan sizes and types, ventilation openings, filter arrangements, filter types, soft starter, etc.) shall not be changed from that submitted in the prequalification without written variance from the University of Alberta indicating the University’s acceptance.

1.3 Related Requirements

.1 Coordinate the requirements of this specification section with all applicable specification sections provided with the individual project’s contract documents.

.2 VFD installations at the University of Alberta shall be in compliance with the corresponding project specification sections for the items below and as identified elsewhere in the project documentation:

   a) General Conditions
   b) Submittals
   c) Operation and Maintenance Data
   d) Basic Electrical Materials and Methods
   e) Electrical Spare Parts and Maintenance Materials
   f) Grounding
   g) Distribution Wiring Systems
   h) Wiring and Cabling (1000V and less)
   i) Transformers
   j) Motors and Control Systems
   k) Electrical Testing and Commissioning
1.4 References

1.4.1 The most current version available, enforced, or adopted regarding codes, standards, and recommended guidelines are to be employed for the production of the complete VFD assembly. The minimum compliance standards and references are as follows:

a) Canadian Standards Association:
   i) CSA C22.2 No. 14-M91 – Industrial control Equipment

b) Institute of Electrical and Electronic Engineers:
   ii) IEEE C62.41.2 - Recommended Practice on Characterization of Surges in Low-Voltage (1000V and Less) AC Power Circuits.

c) National Electrical Manufacturers Association:
   i) NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum).
   ii) NEMA ICS 1 – Standard for Industrial Control and Systems General Requirements.
   iii) NEMA ICS 3.1 - Industrial Control and Systems: Handling, Storage, and Installation Guide for AC General Purpose Medium Voltage Contractors and Class E Controllers, 50 and 60 Hertz.
   iv) NEMA ICS 7 - Industrial Control and Systems: Adjustable Speed Drives.
   vi) NEMA FU1 - Low Voltage Cartridge Fuses.
d) Underwriters’ Laboratory

i) UL 508 – UL Standard for Safety Industrial Control Equipment

ii) UL 508C – UL Standard for Safety Power Conversion Equipment

1.5 Standards

.1 The VFD shall be designed to operate standard squirrel cage induction motor with a 1.15 motor Service Factor (SF) at a maximum continuous load of 1.0 SF. Harmonic loading will not exceed the maximums acceptable for a motor service factor of 1.0.

.2 The VFD and options shall be tested to ANSI/UL Standard 508.

.3 VFD shall be ULC listed and CSA (cUL) certified.

.4 Complete integrated VFD assembly shall be ULC listed and CSA (cUL) certified (or equivalent).

.5 The VFD assembly and associated options and peripherals shall comply with the applicable requirements of the latest standards of ANSI, IEEE, NEMA, and the Canadian Electrical Code.

1.6 Coordinating Responsible Party

.1 The contractor that supplies the Variable Frequency Drive (VFD) will be the responsible party for the coordination and installation of the drive.

.2 The contractor will be responsible for all of the VFD implementation requirements associated with the installation.

.3 The contractor shall engage the appropriate trade for the work to be performed if outside of the supplying contractor’s standard installation requirements.

.4 The responsible party is to ensure that all requirements of the installation have been satisfactory provided even if not specifically indicated in other contractor’s scope of work.
1.7 Warranty

.1 The VFD supplier shall provide warranty coverage for a minimum period of twelve (12) months upon the date of the contractor being granted final acceptance by the University of Alberta and with the warranty period having then officially commenced. *Note: An extended warranty may be required based on individual project requirements. Refer to applicable specification sections and conditions therein as part of the contract documents where required.*

.2 The warranty shall include parts, labor, travel costs, and living expenses incurred by the supplier to provide factory authorized service.

.3 Contractor shall be responsible to bring the supplier factory representative to site to reset, repair, and re-commission the VFD if problems arise with the normal operation of the VFD during the warranty period.

.4 Response requirements due to issues related to any part of the VFD assembly during the warranty period are listed under the maintenance requirements in item 1.10 below.

.5 Items repaired or replaced shall be warranted for an additional period of at least twelve (12) months from the date that the VFD becomes functional again.

.6 All existing motors as listed on the motor schedule will be tested for motor insulation integrity. All motors which do not meet the minimum standards for motor insulation integrity would not be included as part of the warranty program with respect to motor failure. The contractor will be responsible for the testing of the motor.

.7 The VFD supplier shall be responsible to coordinate all warranty works with the University of Alberta forces during the warranty period. No warranty work is to be performed on the VFD assembly without the approval of the University.

1.8 Submittals

.1 Submit complete shop drawings of all equipment for review by the Consultant and the University of Alberta prior to manufacturing.

.2 Incorporate all review comments into the documentation requirements of the submission and revise shop drawings for insertion into the Operation and Maintenance Manuals as directed.

.3 The submission package is to be provided as one submission for the complete VFD assembly including all referenced materials.
.4 Submission of the VFD assembly and associated components will be subject to potential re-submission at contractor expense for non-compliance with the requirements of this section and the overall contract document requirements.

.5 The shop drawings for each type / size of VFD must be specific to that unit. Separate diagrams are required for each VFD and motor. Generic diagrams are not acceptable.

.6 Provide the following information in the shop drawing submission package:

a) Catalog and technical data.

b) Include supplier, dimensions, ratings, listings, elementary power and control wiring diagrams and data on features and components.

c) Outline overall VFD assembly dimensions, shipping section dimensions, weights, and foundation requirements.

i) Replacement Drives: Unless permitted by the U of A in writing, replacement drives and / or drive enclosures shall be sized and constructed for installation within the space previously occupied by the original equipment. This includes for the drive, bypass, enclosure, and any associated peripheral equipment.

d) Internal and external connection diagrams showing the function and identification of all terminals requiring field connections and all programmable contacts.

e) Control schematics.

i) Show circuits and device elements for each replaceable module.

f) Installation instructions including all supplier notes and recommendations based on equipments provided.

g) Confirmation that the motor that is to be connected to the drive is compatible with variable speed drive configuration.

h) Component fabrication drawings consisting of detailed circuit schematics, printed circuit board drawings, and chassis layouts for all electrical and electronic components.
i) Supplier's certification that VFD assembly can withstand the short circuit fault current available from the building's electrical distribution system. The minimum interrupting capacity of VFD assemblies is to be provided per clause 2.12.1c) below. Obtained the actual assembly requirements from the electrical system designer associated with the project where higher levels of protection may be required.

j) Supplier's certification that VFD assembly can withstand the environmental conditions specified in this section or elsewhere in the project documents. (Note: Refer specifically to clauses 1.12.1e), 2.8, and 3.3 of this specification for environmental and execution criteria requirements. Additional conditions may also be noted elsewhere within this specification.)

k) Bolt and lug torque schedule for all power and control wiring termination points.

l) Supplier start up sheets for the drive.

.7 Provide certified copies of all production test results required by CSA, NEMA and this specification.

.8 Submit a sample copy of the expected input current waveforms to be seen by the VFD assembly. Include samples from previous installations with similar integrated harmonic mitigating equipment VFD packages.

.9 Upon the award of the Contract, provide a VFD check-list that is to be completed and submitted with the VFD shop drawings. The checklist is to outline all specification requirements and to reference where in the documentation the specific functionality clause is indicated.

.10 Provide VFD programming / troubleshooting software, as well as any connection cables required, to Owner. Separate software is to be provided for each drive type and size provided if different versions of the program exist.

.11 Provide a parameter list, “as programmed during commissioning,” for each VFD.

.12 All brochures, drawings (schematic and wiring), manuals, specifications, and test reports pertinent to the equipment provided are to be included with the Operation and Maintenance Manuals (O&MMs).

.13 Provide as-built shop drawings for each unit upon completion of installation. A copy of the as-built shop drawings shall be provided for each drive in addition to one set of drawings for each copy of the Operation and Maintenance Manual (O&MM). Refer to project specifications and drawings for quantities in addition to that indicated herein; the quantities shall be the maximum indicated plus one (1) copy for each drive.
1.9 Operation and Maintenance Manual Submittals

Supply a minimum of four (4) hard copies and one (1) electronic copy of Operation and Maintenance manual / data for each VFD (unless more are called for elsewhere) which shall include, but not limited to the following: (Note: Additional copies of the O&MM may be required based on project requirements. Coordinate with other specification sections included the contract documents.)

a) Troubleshooting charts for all device faults.

b) An instruction manual for: programming and the hardware provided with the equipment at time of shipment.

c) Supplier’s VFD start up check sheet(s) with list(s) that outlines all of the completed tasks. Check sheets are to contain final data from the drive start-up including all settings and parameters from the final state if installation. Any changes made to the drive parameters and setting musts be updated and provided as as-built information.

d) VFD field test measurement results: Copies of the most current field testing data is to be provided with the drive. All previous data is to be maintained for record purposes. If original testing has been redone then the new data shall be added to the original data as a supplement. Original test information is to be maintained and must then be marked for information only. All test data shall be dated and signed.

e) Setting sheets to record all VFD configuration options or selections for VFD setup. All settings and parameters are to be those present in the drive unit from its current condition. Any changes made to the drive parameters and settings must be updated and provided as as-built information. All setting revision data sheets are to identify the modifications be dated and signed.

f) Include a list of all authorized service depots, spare parts lists and recommended spare parts (i.e. cooling fans, filters, fuses, etc.) for each VFD assembly type supplied.

g) Provide copies of software for drive operation and integration for each size of drive. The number of copies shall match the number of Operation and Maintenance Manuals (O&MM) called for and will provide a minimum of one copy of software for each drive size in each O&MM.
1.10 Maintenance

.1 VFD supplier is to include a Preventative Maintenance Program (PMP) for a one (1) year period. The PMP is to be broken down to monthly and annual service periods, as applicable.

.2 Information for each service period is to include the entire supplier’s recommended maintenance tasks which should be completed in each period (ie: Monthly/Yearly).

.3 A maintenance checklist is to be provided structured to correlate the maintenance tasks with the service period.

.4 On-call maintenance services to be provided by the Contractor during the warranty period based on the following minimum conditions:
   a) Service shall be on a per-call basis with a four (4) hour response.
   b) Contractor shall support the maintenance of all hardware and software.
   c) Personnel to be provided to site for the maintenance of the equipment as required based on the call provided.
   d) Costs shall include travel, local transpiration, living expenses, and labour rates of the service personnel while responding to the service request.
   e) Provisions of this section are not in lieu of, nor relieve the Contractor of, warranty responsibilities covered in this specification.
   f) All costs associated with a system defect shall be borne by the Contractor.

1.11 Training

.1 Provide on-site half-day training seminar(s) for maintenance and service personnel.

.2 Training session is to be provided for a minimum of four (4) staff as selected by the University of Alberta Facilities Management department.

.3 Training personnel shall be fully conversant with the parameters and features of the VFD, along with the conditions associated with the installation.

.4 The instructors are to be thoroughly familiar with the subject matter to which they are to teach.
.5 Provide training aids, texts, and support material for each person in attendance. One additional copy is to be provided for inclusion in each copy of the Operation and Maintenance Manuals.

.6 A power point presentation is to be developed that identifies the items to be discussed. Photographs and diagrams of drive information to be presented as part of the presentation for information and demonstration purposes.

.7 Demonstration equipment to be provided for the training session if pertinent to explain the material presented.

.8 Field demonstration of the installed equipment is to be provided if appropriate to the seminar material.

.9 Provide for the following requirements:

   a) The VFD supplier is to provide a detailed agenda for the training to be provided and to present it to the Consultant and the University for review and adjustment.

   b) The Supplier shall comply with requests for modification to the content to suit University’s needs within the 4.0 hrs time allowance.

   c) Provide more than one seminar if the amount of material to be covered cannot be adequately addressed within a single training session.

   d) The training agenda shall be provided four (4) weeks prior to the drive start-up and the VFD Supplier shall schedule the timing and location of the seminar at a time and location suitable to the University.

.10 Training to address the following minimum requirements:

   a) System overview

   b) General theory of operation

   c) System operation

   d) System configuration

   e) Alarm formats

   f) Failure recovery procedures

   g) Troubleshooting and repair

   h) Maintenance and calibration
i) System programming and configuration

.11 Training sessions may be video recorded at the discretion of the University for the purpose of future review and archiving.

1.12 Testing

Factory Testing:

a) VFD assemblies are to be tested prior to shipment. Testing is to be performed at the factory or at the VFD OEM or integrator facility. Provide confirmation of actual tests completed and results.

b) All testing of the VFD assembly is to be provided utilizing a full load heat run test of the complete system.

c) Testing is to be provided for duration sufficient to fully prove out VFD and all local/remote control functions and bypass elements/functions.

d) Successful test results are required for a minimum testing period of 24 hours for all new drive assembly frame types not previously provided to the University prior to acceptance of the assembly. The 24 hour testing of the VFD assembly is to be provided to confirm all operating parameters of the drive assembly. The output variation of the VFD assembly is to be recorded at step increments of 100%, 90%, 75%, 50%, 25%, 10%, and 5% of full rated output of the VFD assembly. Sustained operation at the various output rates is to be maintained to obtain an accurate non-fluctuating baseline result for a minimum period of 30 minutes. Following the baseline testing of the VFD assembly is to be provided at continually varying output speeds of the motor to simulate potential extreme operating conditions.

e) Testing information is to be recorded on 30 minute intervals for each drive assembly type and later for any alterations to the prototypical drive assemblies.

f) Testing is to be provided for a minimum period of 4 hours by the VFD assembly supplier/integrator on all previously University accepted installation models. (Note: Insert requirement of 4 hours, 8 hours, 12 hours, or 24 hours as applicable based on project requirements. Smaller drives may require only a 4 hour time window for testing purposes.) Specific testing requirements of VFD assembly to be noted on the VFD schedule where required.
g) Filter media to be at 50% loading restriction for testing purposes. (Note: the filter media is to be blocked for 50% of all assembly openings to simulate potential filter media restriction for actual installation conditions.)

h) Phase loss protection for the both line and terminal outputs for each of the 3 phases of the VFD shall be proven as part of factory testing. A fault signal is to be produced upon phase loss identifying the source of the error and the drive is to shutdown. The fault signal and drive operational status is to be provided to the building automation system control.

i) All VFD and integration features shall be functionally tested at the factory for proper operation.

j) The VFD shall be heat run tested at an ambient external temperature of 40 degrees Celsius with the enclosure door closed to approximate the potential operating conditions of the VFD assembly.

k) Testing temperature sensors to be provided at multiple locations within the enclosure to confirm operating temperature is relatively consistent and the appropriate amount of air flow is provided within the assembly for cooling purposes. Internal temperature is to be measured at a minimum of four (4) locations within the enclosure.

l) Internal temperature of the VFD is to be monitored to confirm satisfactory operating conditions for all internal assembly equipment and components. Sensing mechanism is to provide a fault notification of over temperature condition of the VFD. VFD assembly is to be capable of causing/forcing VFD / bypass shutdown due to over temperature condition at the discretion of the University.

m) A mechanical review of the enclosure, relative to the air flow and cooling requirements is to be provided.

n) Where the internal operating temperature exceeds acceptable operation conditions of the equipment or components supplemental cooling fans are to be added to the enclosure per the requirements listed in item 2.11.10 below. Heat run tests are to be performed on the modified enclosure per the requirements listed in this specification.

o) Provide certified copies of production test results required by CSA and EEMAC, prior to acceptance of the equipment. Test results are to be provided to the Consultant and the University prior to shipment of the equipment. A copy of all factory production tests shall also be shipped with the drives.

.2 Field Testing
a) Allow for all costs for materials and labour, including traveling and living expenses, as necessary to complete all requirements herein.

b) The VFD supplier shall provide on-site startup, fine-tuning, field support during U of A commissioning, provision of final setup information prior to turnover and operator training and instruction.

c) The VFD supplier shall provide site functionality test reports indicating loading / current levels during testing as well as control point proving results.

d) The VFD supplier shall ensure shaft-to-ground voltage does not exceed 1.5 volts at any speed or load requirement.

e) The VFD installer shall prove that all field installed safeties and limits function properly together with the University of Alberta forces. Refer to commissioning procedures for supplemental background information.

f) The system is to be operated at varying rates for not less than 120 consecutive hours, at an average effectiveness level of 0.95, to demonstrate proper functioning of the complete process control system. VFD output to be modified continuously to ensure proper control function ability.

.3 Harmonics Testing

a) New Buildings or Buildings with Major Renovations: Complete harmonics testing and analysis compliance with IEEE 519 is required after complete VFD startup. (Refer to electrical project specifications listed elsewhere in the contract documents for detailed testing requirements.)

.4 Fine tune VFD with signal from controls, inspect, verify motor load RPM at 25%, 50%, 75%, 90% and 100%. Motor RPM should match the percentage indicated. If not motors/fans shall be re-sheaved. Record all measured values (minimum of RPM, frequency, current and voltage input/output).

.5 Calibrate VFD display values with Building Controls System display output. Verify motor RPM values with a calibrated tachometer. Motor RPM shall match the percentage indicated. If not motors/fans shall be re-sheaved. Conduct a minimum of four (4) samples. (Testing to be provided to 25%, 50%, 75%, 90% and 100% of motor output RPM.)

.6 Contractor is to submit a signed copy of the completed test results, certifying proper system operation demonstrating compliance with the specification requirements.
1.13 **Spare Components**

.1 Provide a complete inventory of all spare components associated with the VFDs. Inventory list to be included with the Operation and Maintenance Manuals.

.2 Provide one (1) complete set of all spare components associated with the drive and associated components. Spare components to allow a full replacement of all materials.

.3 The quantity of spare components is to be as listed in the project specifications.

.4 Items to be included with the spare components include, but are not limited to, the following items:
   
a) Cooling Fans.

   b) Filters – each size and type.

   c) Fuses – each size and type.

   d) Lamps.
PART 2 PRODUCTS

2.1 Approved Suppliers and Model Types

.1 The list of currently applicable suppliers and associated product lines are as follows:

a) ABB:
   i) VFD ACS800 Series
   ii) RVMS PST/PSTB Series

b) Schneider Electric (Telemecanique):
   i) VFD Altivar ATV61/71 Series
   ii) RVMS Altistart 48 Series

c) Siemens:
   i) VFD Masterdrive Series or
   ii) VFD Sinamics (G120/G150/S150) Series
   iii) RVMS 3RW44 Series

2.2 Supplier Requirements

.1 Supplier Service and Support

a) The drive supplier must provide a factory trained sales force locally available for applications assistance and to answer maintenance questions.

b) The Supplier is to provide a 24 hour, seven (7) day a week, assistance call line for maintenance and troubleshooting requirements with the VFD operation.

c) Supplier is to be capable of providing on-site technical support of the VFD system within a four (4) hour time period from notification.

.2 Supplier Spare Parts Availability

a) The supplier is to have a distributor organization, which locally stocks standard drives, modification kits, and spare parts.
b) Components not regularly stocked are to be capable of being provided to the site in less than 24 hours.

.3 Supplier Organization

a) The supplier must have factory trained service representatives within the local Edmonton area. The factory representatives must be trained in the maintenance and troubleshooting of the equipment as specified herein.

b) The factory representative is to be conversant in the requirements of the specific VFD provided for the installation.

.4 Supplier Maintenance and Training Schools

a) Supplier must provide regularly scheduled maintenance and training schools in North America on the equipment supplied.

b) Training programs are to be offered by the supplier on a yearly cycle (minimum).

2.3 VFD Application Types

.1 The VFD type employed is to be suitable for the control application required.

.2 The type of VFD to be employed is to match one or more of the following conditions:

a) Constant Torque Loads:

b) Constant Horsepower Loads:

c) Variable Torque Loads:

.3 Refer to VFD Schedule contained in the project document for drive type(s) to be utilized.

(Note: A sample schedule is included for reference purposes under item 3.14 below.)

2.4 General VFD Requirements

.1 Furnish complete variable speed drive(s) as specified herein. All standard and optional features requested shall be included within the VFD enclosure unless otherwise specified.

.2 Drives shall be configured for constant or variable torque loads as indicated.
.3 Variable speed controller shall be electronic adjustable frequency and voltage output unit. All units shall be CSA approved and manufactured to CSA Z299.3. (Note: ISO9002 standards may be used in lieu of CSA Z299.3 where the requirements are more complete and more stringent.)

.4 Unless otherwise noted, all horsepower / Kilowatt drive ratings are to be based on a variable torque load.

.5 The drive shall be rated for continuous duty while operating a NEMA design induction motor of the sizes and operating voltages as shown in applicable project specifications, schedules, and indicated on the drawings.

.6 The VFD shall have a current rating at least 10% in excess of the motor full load amp rating. When subject to the range of ambient conditions, the VFD to be capable of delivering;

a) 135% of rated output current for up to one (1) minute for variable torque applications.

b) 150% of rated output current for up to one (1) minute for constant torque applications.

.7 The output waveform shall closely approximate a sine wave. The VFD shall be a PWM output design utilizing current Insulated Gate Bipolar Transistor (IGBT) inverter technology and voltage vector control of the output PWM waveform.

.8 The VFD shall include a full-wave diode bridge rectifier and maintain a displacement power factor of near unity regardless of speed and load.

.9 The VFD is to be sized to the maximum current requirements under peak torque demands (minimum), in lieu of horsepower ratings, and the duty cycle requirements of the motor.

.10 VFD is to be provided with load synchronization for active rotating motor loads (i.e. load is spinning or coasting when the VFD is initially activated). VFD is to synchronize with the rotational speed of the respective motor and adjust the output activation frequency. To minimize equipment failure the VFD is not to activate until synchronization has been achieved with the respective active rotating motor load.

.11 Electrical and electromechanical components of the VFD shall not cause electromagnetic interference to adjacent electrical or electromechanical equipment while in operation.

.12 All VFD installations require a harmonic analysis which will look at both the location of installation and the magnitude of harmonic impact.
2.5 Harmonic Distortion Requirements

.1 The characteristics of the VFD assembly are to be as such that it does not adversely affect the overall electrical system performance. Installation of the VFD must not cause the building to exceed IEEE 519. The drive supplier must provide components within the drive to ensure that this requirement is met. The University can provide specific preliminary information relative to their existing facilities.

.2 Harmonic filters (passive or active), phase multiplication devices, or any other components required to mitigate harmonic voltage THD to 5% (insert requirement of 3% to 5% based on project requirements) and current THD to 8% (insert requirements of 3% to 20% based on project requirements) maximum level shall be an integral part of the VFD system.

.3 Compliance measurement shall be based on (insert one of the following)

a) THD added (during VFD full load operation compared to across-the-line operation) at the VFD circuit breaker terminals

or

b) actual THD measurements at the VFD circuit breaker terminals during full load VFD operation.

.4 Designs which employ shunt tuned filters must be designed to prevent the importation of outside harmonics which could cause system resonance or filter failure. Calculations supporting the design, including a system harmonic flow analysis, must be provided as part of the submittal process for shunt tuned filters.

.5 Any filter designs which cause voltage rises at the VFD terminals must include documentation in compliance with the total system voltage variation of plus or minus 10%.

.6 Documentation of power quality measurements testing shall be conducted at full load and provided for insertion in the operation and maintenance manuals.

.7 Conduct and document harmonic distortion compliance testing.

.8 Filters utilizing capacitors are to be avoided due to their potentially high failure rates as identified at the University. Alternate means are to be provided where available.

2.6 VFD Sizing Requirements

.1 The VFD employed is to match the requirements of the connected motor loads
.2 The VFD is to be sized for the following requirements:

a) Breakaway Torque: Torque required starting the load in motion (typically greater than torque required to maintain motion)

b) Accelerating Torque: Torque required to bring the load to operating speed within a given time

c) Running Torque: Torque required keeping the load moving at all speeds

d) Peak Torque: Occasional peak load due to momentary load imbalance (i.e. weight being added to a conveyer)

e) Holding Torque: Torque required to hold a motor when operating as a brake (i.e. high inertia machines)

2.7 Sound Level

.1 Maximum acceptable audible noise level is 80 dBA at 1 m from the VFD assembly under normal operating conditions with the drive at full rated load.

2.8 Environmental Capabilities

.1 The drive shall operate without mechanical or electrical damage under any combination of conditions as follows:

a) Ambient temperature: 0° to 40°C

b) Humidity: 5% to 95% (non condensing)

c) Vibration: up to 0.5G

d) Altitude of City of Edmonton, Alberta, Canada

2.9 Input Power

.1 Input voltage for nominally rated VFDs shall be as indicated on the drawings, specifications and/or in mechanical motor schedules. Confirm voltage before ordering VFDs.

.2 The VFD assembly must be capable of operating under the following conditions without high or low line tripping: 3 phase, 60 Hz AC grounded power supply, line voltage 600V ± 15%. (For 208V VFDs the supply voltage operational limits would similarly be ± 15% outside of the nominal voltage.)
.3 If the drive trips on under voltage less than 85% of nominal voltage, then the drive will activate the Automatic Restart after the voltage returns to normal voltage operation range.

.4 All VFD drive and soft start component assemblies must be rated for 690V operation, but operated on a 600V nominally rated power system.

.5 Permit variations of 45 to 65 Hz of line frequency without the VFD shutting down on a fault.

.6 Permit power line interruptions for high inertia loads such as fans and centrifuges for at least 2.0 seconds without the VFD shutting down on a fault providing an extended power loss ride-through. If the drive trips on under voltage, the drive must activate an automatic restart mode. (The intent is that should any momentary power loss occur the drive would recover operation without intervention.)

.7 The VFD shall present a displacement power factor of 98% or better to the AC line over 10% to 100% speed range. Full load effective power factor shall be 96% or better.

.8 Efficiency of VFD controller shall be not less than 97.5% at 60-hertz output at 100% rated load.

.9 The VFD must 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 per microseconds.

.10 Isolation Transformers:
   a) Input isolation transformers to be provided where required coordinating with the drive provided. Transformers to be part of the VFD submission compliant with other sections of the specifications where required as part of the VFD assembly.
   b) Isolation transformers are to be installed in a separate enclosure mounted at a location near the applicable VFD to which they are provided for.
   c) Supply and installation of the isolation transformer to be included as part of the VFD assembly requirements if necessary for the VFD assembly.
   d) Isolation transformers are to be provided with the VFD assembly shop drawings where required.
e) Transformer minimum requirements are to be indoor, dry type, copper wound with Class H (220 degree Celsius) insulation. Size and voltage of the transformer to correspond with the inrush requirements associated with the motor control under full load bypass operation.

f) Isolation transformers are to be indicated on the single line diagram of the electrical distribution system and provided dedicated to the respective VFD assembly and associated load.

g) (Note: Coordinate the requirements of the transformer with the appropriate contract document specifications.)

.11 The VFD must not be sensitive to supplied power that has one phase grounded (Delta) or referenced to earth ground (Wye).

.12 The VFD must not be sensitive to incoming phase sequence.

.13 Power Line Surge Protection

a) The control panel shall have surge protection, included within the panel to protect the assembly from damaging transient voltage surges. Surge arrestor shall be mounted near the incoming power source and properly wired to all three phases and ground. Fuses shall not be used for surge protection.

b) The VFD must include a discrete Transient Voltage Surge Suppression (TVSS) filter with replaceable Metal-Oxide Varistors (MOVs) to allow reliable operation encountered in an industrial or commercial power distribution system for transients up to 3000 V, 200 Joules (minimum), phase to phase and phase to ground.

.14 Sensor and Control Wiring Surge Protection

a) Input and Output (I/O) functions as specified shall be protected against surges induced on control and sensor wiring installed outdoors and as shown. The inputs and outputs shall be tested in both normal mode and common mode using the following two waveforms:

   i) A 10 microsecond by 1000 microsecond waveform with a peak voltage of 1500 volts and a peak current of 60 amperes.

   ii) An 8 microsecond by 20 microsecond waveform with a peak voltage of 1000 volts and a peak current of 500 amperes.

.15 The VFD must include, at minimum, a 5% input AC line reactor filter. Do not use a DC bus choke as a substitute to this requirement.
2.10 Output Power

.1 The VFD to produce a 3-phase output for the motor loads.

.2 VFDs sized less than 100 HP to be of the 6-pulse Pulse-Width Modulated (PWM) type and consist of a full wave diode bridge converter to convert incoming fixed voltage/frequency to a fixed DC voltage. The PWM 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.

.3 VFDs sized from 100 HP to 199 HP to be of the 12-pulse Pulse-Width Modulated (PWM) type and consist of a full wave diode bridge converter to convert incoming fixed voltage/frequency to a fixed DC voltage. The PWM 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. Input isolation transformers with a 30 degree phase shift complete with appropriate filtering to be provided where required.

.4 VFDs sized at 200 HP and up shall be custom engineered units and the requirements of this specification shall be modified to suit the application. This specification shall not be used without approval for fabrication of custom engineered drives. The approved suppliers will be required to provide submissions tailored to the engineering requirements for larger drives/applications.

.5 Alternate supplier suggested VFD pulse ratings to be approved by the University where those listed above are deemed inappropriate for the connected load. Written approval is to be provided by the University prior to acceptance.

.6 The use of 18-pulse Pulse-Width Modulation (PWM) type VFD drives with phase shift transformer is permitted where the requirements of harmonic distortion reduction cannot be achieved with the drive parameters listed above.

.7 The use of Active Rectifier or integrated Active Filters is permitted where the requirements of harmonic distortion reduction cannot be achieved with the drive parameters listed above.

.8 VFD must generate the inverter output by IGBT power transistors.

.9 Unless otherwise specified, the standard VFD output frequency must be programmable from 0 to 66 Hz.

.10 When specified, frequencies of up to 120 Hz to be obtainable.

.11 Unless otherwise specified, the VFD output voltage to be adjustable from 0 to full voltage reaching full voltage at 60 Hz.
.12 Unless otherwise specified, the VFD to produce a constant volts-per-hertz (V/Hz) ratio in the 60 Hz range and below or use Vector Control.

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

.14 The volts-per-hertz output of the VFD must not be affected or require readjustment when other drive adjustments (such as maximum speed) are changed.

.15 Provide selectable constant V/Hz ratio PWM or Vector Control algorithm.

.16 When subject to the range of ambient conditions, the VFD to be capable of maintaining 100% of rated output current continuously.

.17 The VFD output waveform to be the PWM or Vector type waveform producing smooth torque at low frequencies and low motor current harmonics.

.18 Programmable PWM carrier frequency.

.19 The VFD to be capable of operating with the VFD output open circuited (no motor connected), with no fault or damage for startup and testing purposes.

.20 Radio Frequency Interference (RFI) must be limited to levels specified in applicable standards. Equipment must be designed that use of radio communication equipment adjacent to VFD assembly is permissible. In addition, the VFD must not be susceptible to interference from radio equipment operated adjacent to it.

.21 Include provision for adequate grounding within the equipment in addition to that provided to safeguard against electrostatic discharge damage.

.22 The VFD is to be provided with AC (dV/dT) motor protecting KLC output filter rated to operate in a 40°C ambient temperature. Do not mount the KLC filter near the top of the VFD chassis.

.23 Provide NEMA rated output contactors, based on motor and drive full-load amps. (Note: IEC Rated Contactors are not acceptable.)
2.11 Integrated VFD Equipment Enclosure

.1 The integrated VFD assembly, including all components shall be provided within a single ventilated CSA (NEMA) Type 1 - enclosure (fabricated from 12 gauge metal) with a hinged gasketed door and a drip-shield constructed to project over the door and sized to protect all ventilation openings (if present) in the top of the enclosure from dripping water. It shall be suitable for wall or free standing installation. All VFD assembly openings are to be provided with filtering.

.2 Drives rated above 100 HP shall be constructed per clause 2.11.1 above but shall be housed in CSA (NEMA) Type 12 enclosures with forced air cooling.

.3 Supply full length painted 100 mm steel channels for floor mounted VFD enclosures. If housekeeping pads are provided, the channel bases are not required. Base construction shall be such that VFD Door bottom will not drag on the house keeping pad if drive is placed on top of a housekeeping pad.

.4 Enclosures to be provided with a defeatable handle to allow the unit to remain in operation while the door is in the open condition.

.5 U of A standard colors for primary system voltage identification shall apply for the VFD enclosure assembly:

a) Exterior Enclosure Finishes:
   i) 120/208V VFD: Standard Electrical Grey (Universal ASA-61)
   ii) 347/600V VFD: Sand Beige (Endura Coatings CLR-33918)

b) Interior Enclosure Finishes:
   i) Semi-Gloss White (Endura Coatings CLR-11438)

c) Interior Back Pan
   i) Bare non-painted galvanized metal finish

.6 The back-pan to be galvanized metal, non-painted, 16 gauge for EMC bonding requirements. Provide a minimum of two (2) lugs for bonding conductors (sized per CEC). Lugs are to be bolted to the galvanized metal back-pan.

.7 Door must be grounded with multi-conductor or braided ground strap connecting the door to the grounding system in the enclosure interior.

.8 Supply a Control Power Transformer sized as recommended by the VFD supplier with, at minimum, two (2) primary fuses and one (1) secondary fuse for control power transformer protection.
.9 Filter:
   a) Filter media is to be chemical treated (tackifier) type (Air Guard P-Series Filter Media, dual denier polyester, with 85% particle arrestance or better).
   b) Filter media to be provided for all intakes and exhaust (passive or forced) ventilation openings associated with the enclosure to assist in the protection of the internal components of the drives.
   c) All air flow must pass through, and not around, the filter media.
   d) All filter media is to be provided within a framed housing for easy maintenance and removal. Loose filter media provided behind a screen, hold down clip, or other media is not acceptable.
   e) Filter media removal and replacement to be provided in a fashion that the drive will not need to be shut down for its replacement.
   f) Enclosure air flow requirements to address the restrictions resulting from the installation the filter media or other restrictions for both passive and forced air VFD assembly system designs.
   g) Air flow and resulting ventilation opening requirements associated with the enclosure to be evaluated with the filter media at 50% restriction due to loading. Cooling capacity of the VFD assembly is not be compromised due to the air flow restrictions identified.

.10 Cooling Fans:
   a) Provide enclosure cooling fans where required to augment the natural passive convection cooling parameters of the VFD assembly to ensure adequate heat dissipation. Cooling fans are to be installed in such a manner that they will not degrade the enclosure rating. Provide alarm status and shutdown for VFD on fan loss either by tachometric sensing or through excessive temperature rise in the enclosure for VFDs that utilize forced air fans for enclosure cooling.
   b) Supplied Cooling Fans for VFD or VFD Enclosure Systems (where installed) shall be high quality, long life, ball bearing fans.
   c) Operation of the VFD cooling fan is to be monitored by the VFD. Failure of the cooling fan is to instigate a trouble signal for the unit to identify an abnormal operating condition.
   d) Fans are to be provided with insulation to limit vibration of the enclosure.
e) Minimum standard of acceptance for enclosure fans would be tube axial fans as manufactured by EBM-PABST Inc. 4000 Series, Puck Type Cooling Fans or approved alternate.

f) Fans shall be warranted by the supplier for a minimum of one (1) year.

g) Enclosure ventilation openings for the cooling fan are to be provided such that the maximum displacement of air can be provided from the VFD assembly. Restrictions in the ventilation openings are to be minimized.

h) Ventilation air flow within the VFD to be provided to ensure that the cooling air is provided throughout the entire VFD assembly and to all components (i.e. circuit board assemblies, soft start, etc.) and not simply circulated near to the door area or the exterior edges of the drive enclosure. Provide designed air deflection fins within the enclosure as required to ensure appropriate air flow for all internal components for heat dissipation.

i) Supplier is to provide information on cooling fan assembly provided for the VFD assembly.

.11 Enclosure Heat Run Test

 a) Provide heat run test results for the internal temperature of the complete built-up VFD assembly identifying the temperature and air flow data operating conditions inside the assembly when in operation at multiple locations within the enclosure.

 b) Heat Run testing of the VFD enclosure and internal components to be provided per the requirements listed in “Testing” item 1.12 above.

.12 Cabinet Construction Configuration:

 a) The configuration of the VFD assembly will be based on the overall assembly configuration, internal components required and their accessibility and satisfactory test results.

 b) Once the enclosure configuration has been validated to satisfactorily meet all necessary operational and testing requirements the VFD assembly shall not be altered without the approval of the University.

2.12 Equipment Protection

 .1 Protective devices to be incorporated are:
a) Three pole fused disconnect switch to provide over current protection with fuses rated at not more than 150% of drive input current rating, except if the VFD is specifically marked with a recommended rating for its over current protection, then the VFD marking shall take precedence.

b) The operation of the disconnect switch shall be interlocked with the VFD enclosure door. It shall not be possible to open the door without the disconnect being in the open position. A manual means to defeat this interlock for maintenance purposes shall be included and the external operator handle for the switch must have lock-out capability.

c) The withstand Symmetrical Short-Circuit Interrupting Rating (SSCIR) fusing shall be verified for every installation, and be coordinated with the VFD’s electronic protection circuits. The minimum acceptable VFD assembly rating for the drive and all internal components is to be 65kA IC symmetrical rating coordinated with the drive’s electronic protection circuits. VFD supplier is responsible to obtain SSCIR information from the designer / design documents for VFDs being constructed for the project.

d) High-speed semi-conductor type fuses are to be used for equipment overcurrent protection.

e) Discrete TVSS filter (MOV) on the drive input to protect electronic components from transient voltage conditions. MOV’s are not to be part of the bridge circuit.

f) Integral electronic motor overload protection is to be adjustable up to 150% of motor rating for 60 seconds.

g) Overcurrent instantaneous trip 250%.

h) Short-circuit protection.

i) Ground fault protection.

j) Overvoltage DC bus monitor/protection.

k) Undervoltage protection, 85% of rated input voltage.

l) Loss of phase and phase unbalance protection.

m) Inverter over-temperature protection.

n) Output filter package (dV/dT) to limit motor voltage to <1000 V/ms maximum, at 208V rated motor terminals.
o) Output filter package (dV/dT) to limit motor voltage to <1200 V/ms maximum, at 600V rated motor terminals.

p) Motor overload protection, adjustable for a minimum range of 80% to 115% of FLA of motor.

q) External motor overload protection relays shall be electronic dial adjustable units with inherent single phase protection. The current range of the overload block shall be selected to place the Full Load Current of the Motor at approximately the centre of the dial scale for the supplied overload relay.

**Note:** - Motor full load current shall be confirmed prior to shipment. Incorrectly sized motor overload relays must be replaced before VFD start-up will be permitted. No extra costs will be allowed for replacement of overload relays being improperly supplied.

2.13 Control and Operational Features

.1 Keypad with multi-line LCD readout display.

.2 Fault shutdown and keypad identification of fault cause.

.3 Automatic restart following power outage and under voltage trip.

.4 Ability to disconnect motor load for setup or trouble - capable of running without motor.

.5 Manual raise and lower speed control pushbuttons.

Programmable maximum and minimum speed limits.

.6 Programmable acceleration and deceleration time adjustment from 0 to 300 seconds (minimum).

.7 Controller "coast to stop" interlock from dry contract opening.

.8 Provide Hand/Off/Auto selector switch.

.9 Provide second Hand/Off/Auto selector switch for bypass where bypass operation required for VFD assembly.

.10 Provide one (1) analog individual optically isolated input which is capable of operating from 4-20 mA or 0-10 VDC.
.11 Provide two (2) analog 0-10 VDC or 4-20 mA individual optically isolated outputs that can be programmed to be proportional to any two of the following:

a) Output frequency
b) Motor speed
c) Motor torque
d) Motor power
e) Output current
f) DC bus voltage
g) Motor voltage

.12 The VFD to be capable of communicating with the communication network over the remote I/O serial link, multi-drop, typically RS-485, using BacNet MSTP, or LonWorks communication protocol. (Note: Clarify communication protocol required for individual project based on existing facility protocol or new building integration requirements.)

.13 Include one (1) communication protocol card for each VFD.

.14 Provide offset and gain programmable functions to set operating range.

.15 A programmable linear or S-curve suitable for all drives requiring controlled acceleration/deceleration.

.16 All VFD assemblies are to be provided with dynamic braking. Dynamic braking is to be used to provide the stopping and slow down rate for motor assemblies.

.17 All VFD set-up operations and adjustments are to be digital and stored in a nonvolatile memory (EEPROM).

.18 VFD operation is to be fully digital with microprocessor control of frequency, voltage, and current.

.19 Speed Droop: Provide a speed droop feature that reduces the speed of the drive on transient overloads. The drive is to return to set speed after transient overload 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.

.20 Speed Profile: Provide individual adjustable settings for start, stop, slope, and minimum and maximum speed points.
.21 Process Signal Inverter: Provide programmable control to allow speed of drive to vary inversely with input analog signal.

.22 Pick up a Spinning Load (Rotating Start): The VFD shall be programmable for load synchronization rotating start (i.e. load is spinning or coasting when the VFD is initially activated), enabling the VFD to start into a rotating motor, regardless of direction, without tripping offline and without setting the motor to zero speed. VFD is to synchronize with the rotational speed of the respective motor and adjust the output activation frequency to start at the speed the motor is rotating and then accelerates the motor according to the speed reference signal. To minimize potential equipment failure the VFD is not to activate until synchronization has been achieved with the respective active rotating motor load.

.23 Bumpless speed transfer: Provide a bump-less speed transfer from remote control to local control and vise-versa, without setting the motor to zero speed.

.24 Automatic Reset/Restart: Provide programmable automatic reset/restart after any individual trip condition resulting from either over current, over voltage, under voltage, or an over temperature.

.25 Automatic Reset: 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.

.26 IR Compensation: Complete set of parameters (programmable range) which allows for extra torque to be applied at speeds between 0.1 Hz and the set field weakening point, 140% rated torque shall be produced with 150% rated current.

.27 Torque Compensation: The automatic boost in torque to handle impulse loads or demands for fast acceleration by momentarily increasing the output volt/hertz ratio. When selected, the function to be operative at all speeds even under overload conditions, and eliminates the motor speed droop that would otherwise occur.

.28 Provide output damper interface control card and/or programming, which permits the VFD to ramp up to 10% speed prior to the supply air and or return air dampers opening. Dampers must then open to 100% and be proven open before building control system permits the VFD to ramp to the desired speed output.
.29 Provide external control interface capability in variable frequency drive assemblies to provide the functionality prescribed in Attachment #4 and other clauses of this specification. This would include the provision of an output interface (card) and/or programming, which permits the VFD to ramp up to 10% speed prior to the supply air and or return air dampers opening. Dampers must then open to 100%, and be proven open, before building control system permits the VFD to ramp to the desired speed output. (Note: - Data in 2.14, 2.15, 2.17, 2.18, 2.22, 2.23, and 2.26, etc. further develop the VFD Assembly integration functionality required by Attachment #4). (Note: Alternate means of integration and control may be proposed by the manufacturer where the intent of control remains consistent with the information depicted.)

.30 Local communications port:

a) Provide a local interface to upload, download, and read drive parameter settings, through the use of a notebook computer. Include Windows based software for computer on CD-ROM(s) with all associated operating instructions.

b) Software information shall be provided with the shop drawings.

c) Compatibility software to be provided for each drive type provided with the project.

d) Provide local interface and communication cable for connection to the VFD.

e) The local interface connection is to be provided on the outside cover of the enclosure and be provided with a weather resistance cover.

f) One communication cable is to be provided for each VFD assembly.

2.14 Drive Control (Local Operation)

.1 Provide an operator station on the drive door complete with the following features as a minimum. The following applies to a VFD with Bypass capability. Adjust requirements as applicable for VFDs without a Bypass starter.

a) Control Switches/Pushbuttons

i) Selector switch No. 1: “LOCAL-OFF-AUTO” operation.

iii) “LOCAL RUN” for local control of VFD or Bypass starter to be provided via the VFD keypad interface.

iv) Pushbutton: “STOP” for local control. Active in every mode.

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

b) Individual RED cluster LED pilot lights are to be mounted on the door to indicate the following fault status VFD assembly functions:

i) “VFD” – Variable Frequency Drive internal fault

ii) “EXT” – External input/output fault

iii) “MOTOR O/L” – Motor overload condition fault

.2 Control Method

a) Selector switch No. 1: “LOCAL-OFF-AUTO” operation:

i) Selector switch in “LOCAL” position: VFD operated by panel mounted keypad, speed controlled by the keypad or potentiometer.

ii) Selector switch in “OFF” position: Motor cannot be started.

iii) Selector switch in “AUTO” position: VFD operates by remote start/stop command, the speed controlled by the isolated 4 – 20 mA signal.

b) Selector switch No. 2: “BYPASS ENABLED – OFF - VFD ENABLED” operation (where provided):

i) Selector switch in “BYPASS ENABLED” position: Position starts bypass manually.

ii) Selector switch in “OFF” position: Motor cannot be started.

iii) Selector switch in “VFD ENABLED” position: Enables Selector Switch No. 1 to perform operational functions.

.3 Keypad with LCD display on front of enclosure door.

.4 All VFD control and safety interlocks in the circuit are to function for all modes of operation.
2.15 Drive Controls (Remote Operation)

1. The VFD is to accept an isolated output signal via the Building Management System to stop and start the drive. Signal to be provided via a digital input device located on the drive.

2. The VFD to have the capability to interlock of up to three (3) N/C external alarm interlocks to shut down the VFD and provide status of the trip.

3. The VFD is to provide a digital output signal to identify a drive fault condition (general fault). Output signal is to indicate specifically the fault condition on the drive.

4. The VFD is to provide a minimum of three (3) programmable Form C dry contact status outputs. Status of contacts to indicate:
   a) Run
   b) Ready
   c) Fault

5. VFD to provide digital output signal of conditions identified in clause 2.15.4 above.

6. In addition, the three (3) output contacts shall be programmable for any combination of the following:
   a) Stopped
   b) Over speed
   c) At speed
   d) Under speed
   e) Forward/Reverse
   f) Low reference
   g) Manual/Auto Mode
   h) Local/Remote Mode

7. Controller “stop” interlock from a NC dry contact.

8. Motor selected to "Auto" ("Remote") enables the motor to be started and stopped remotely, and the speed to be adjusted via the field analog signal.
.9 Motor selected to "Manual" ("Local") enable motor to be started, stopped and speed to be adjusted via the front panel pushbuttons and selector switches of the panel operator station.

.10 The VFD to accept an isolated analog input speed reference of 0 to 10 Vdc or 4-20 mA from the field device. The 4-20 mA analog input speed reference signals shall be optically isolated. An electrical test jack is to be used for the signal requirements. Calibration adjustments shall be provided for settings within the speed ranges specified.

2.16 **Provision for Electrical Test Jacks**

.1 Electrical test jacks are to be provided by the University Facilities and Maintenance staff for field monitoring and testing of VFD functions.

.2 Test jacks are to be installed on the front surface of the VFD enclosure and be electrically isolated from the build-out door.

.3 Test jacks opening is to be provided with a weather proof 2-gang blank plate to prevent transmission of moisture or particulate into the jack or drive assembly.

.4 Provide a standard 2-gang junction box hole opening in the front cover of the VFD assembly along with applicable mounting screws for the mounting of a 2-gang blank plate. Space is to be provided for the mounting of a deep 2-1/8 inch (54mm) junction box within the VFD assembly such that it does not interfere with the internal components of the VFD assembly. The junction box is to be mounted within the enclosure on the door behind the cover hole opening.

.5 Provide an insulated 2-gang blank cover plate for the hole opening in the door enclosure as identified in item 2.16.4 above.

.6 Test jacks and all wiring from the isolator terminal blocks to the jacks will be provided by U of A selected forces following installation of VFD assembly. Test jacks are to apply a 0-10 V or 4-20 mA reference signal to the drive. Test jacks are for set-up, controls calibration, operation and troubleshooting purposes. Refer to clauses 2.13.10, 2.15.1, and 2.15.10 for additional information.

2.17 **End Switches for VFDs Controlling Fans**

.1 End switches are provided on some of the dampers associated with ventilation fans provided in the facility.

.2 End switches are to be monitored by the VFD to ensure that they are in the correct operating configuration prior to allowing the VFD to function the fan unit.
.3 Bypass functionality of the VFD to ensure that the dampers are in the correct operating configuration prior to allowing the fans to activate.

.4 Smart relays are not to be employed for this purpose.

2.18 Isolated Bypass Operation

.1 Provide motor bypass based on unit operation and redundant motor conditions as outlined in the motor schedule.

.2 Bypass starters to be solid-state reduced voltage type for motors rated at 25HP and larger.

.3 Provide NEMA rated motor starter contactors for Bypass and VFD operation for motors rated less than 25HP which require bypass operation unless otherwise identified.

.4 Coordinate over current protection rating for the drive and bypass starter to protect both devices in either mode of operation (i.e. standard operation versus bypass mode).

.5 Provide primary (2) and secondary (1) fusing for 120 VAC control power transformer. Transformer load rating as required with 50 VA spare capacity.

.6 Provide an electronic adjustable thermal overload relay sized to protect the motor for either mode of operation. The overload relays (as indicated previously in this specification) shall be correctly sized and correctly adjusted for the installed motor. The supplier is responsible to ensure that the motor matches the provided overload relay. If overload(s) are incorrectly sized they must be replaced by the VFD Supplier before start-up will be allowed.

.7 Provide a three position “LOCAL-OFF-AUTO” selector switch and an interposing relay to select the run/stop operation in conjunction with “VFD - VFD TEST - BYPASS” switch as follows:

a) VFD MODE:

i) Selector switch in “LOCAL” position: VFD operated by panel mounted start and stop pushbuttons, speed controlled by the keypad or potentiometer.

ii) Selector switch in “OFF” position: Motor cannot be started.

iii) Selector switch in “AUTO” position: VFD operates by remote start/stop command, the speed controlled by the isolated 4 - 20 mA signal.
b) BYPASS MODE:
   i) Selector switch “LOCAL” position: Bypass starter operated by panel mounted start and stop pushbuttons
   ii) Selector switch “OFF” position prevents motor from operating.
   iii) Selector switch “AUTO” position allows motor to start by remote start/stop command.
   iv) All Interlocks are in the circuit for all modes of operation.

.8 All drive safety features are to be engaged regardless of the operation condition of the VFD.

2.19 Drive 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:
   a) Motor frequency
   b) Number of poles
   c) Full load speed
   d) Motor volts
   e) Motor full load amps
   f) Motor HP

.3 VFD limits:
   a) Independent acceleration and deceleration rates
   b) No load boost
   c) Vmin, Vmax, V/Hz
   d) Full load boost
   e) Overload trip
   f) Minimum speed (0 to 60Hz)
Variable Frequency Drives

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- Maximum speed (40 to 90Hz)
- Auto reset for load or voltage trip select
- Slip compensation
- Rotating Start select
- Overload trip setting

Controller adjustments:

- Minimum frequency 0 - 60 Hz
- Maximum frequency 40 -- 90 Hz
- Acceleration time 0.3 - 300s
- Deceleration time 0.3 - 300s
- Output current from 50 - 150% of nominal current for constant torque and output current of 50 - 135% for variable torque applications as a minimum.
- Start of motor by: Normal acceleration or automatic start boost or rotating start.
- Stop by: Coasting or ramp deceleration or DC braking
- Slip compensation
- Electronic over load adjustment setting
- Automatic restart after voltage trip
- IR compensation boost between 15 - 45V depending on size
- Linear or tapered V/Hz ratio
- Selection of field weakening point (V/Hz ratio)
- Automatic start boost, programmable, active only at start until output frequency reaches 20 Hz or set speed reference less than 20 Hz
- Provide an adjustable skip frequency with programmable bandwidth to avoid operation in a resonant speed area
2.20 Keypad Operation and Features

.1 The digital keypad must allow 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.

.2 The VFD is 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:

a) Overcurrent
b) Short Circuit/Ground Fault
c) Under voltage
d) Over voltage
e) Over temperature
f) Power Supply Fault
g) Motor stalled

.3 Fault codes to provide direction as to board level and input-output level to aid in trouble shooting.

.4 The fault log record shall be accessible via a RS485 serial link as well as readout on the keypad display on the panel door.

.5 Self-diagnostic check to indicate faulty internal components.

.6 Provide a trace buffer to store actual values of up to eight different programmable signals at the time of a fault trip. The information to be stored in memory is to be retrieved by a PC or a recorder.

.7 Diagnostic and indicating features:

a) Power ON indication
b) All set points
2.21 Drives Connected To Emergency Power System

1. The VFD may be supplied from an emergency power distribution system, which is subjected to short power interruptions during test of the emergency generator system. The VFD shall be designed to continuously operate through this test mode. Minimum time requirement of two (2) seconds of ride through is to be provided.

2. VFD supplier shall confirm that this condition will not cause damage to their equipment and that they will be able to ride-through this disturbance without any operational shutdowns.

3. VFDs rated 50 hp or higher shall be capable of defaulting to half-power state upon failure of normal power source. Provide input point capable of receiving signal (i.e. contact state change) from the Building Management System to communicate to the VFD to operate at reduced speed until normal power is restored. This feature shall be used only where called for in the mechanical design.
2.22 Internal Wiring and Identification

.1 Control wiring shall be stranded TEW 105°C (220°F) rise.

.2 Terminal blocks for remote interface shall be Weidmueller SAK6N or approved equivalent.

.3 Provide wire markers at both ends of all control wires, Electrovert Type Z or approved equivalent.

.4 Provide lamicoid tag warning that more than one voltage source is present, provide caution label regarding regenerative voltage that may be present on the load side of output contactor.

.5 Ensure arc flash labeling has been installed as required by standards in effect (ie: CEC, NFPA-70E, CSA Standard Z462).

2.23 External Control Wiring

.1 Provide isolation and voltage surge suppression for contacts used for external monitoring to limit inductive switching surges to less than 200 V peak.

.2 Provide DC coils with freewheeling diodes to limit inductive surges to 28V peak.

.3 Use Shielded Twisted Pair (STP) wiring for control and signal wiring that connects external to the VFD.

.4 Control wiring is to be provided in a separate pathway from power carrying conductors.

.5 Provide separate conduits for each of the following: VFD control wiring, input power wiring and output power wiring. The required separation is intended to prevent voltage and / or current harmonics inherent to inverter from being impressed onto signal wiring.

2.24 Standard Variable Speed Drive Cable

.1 Acceptable suppliers:
   a) Nexans DriveRx Variable Speed Drive Cable
   b) or approved alternate

.2 Variable Speed Drive Cable to meet the following minimum requirements:
a) Phase Conductor: Three (3) Class “B” Compact Copper (for thicker 1000-volt rated XLPE insulation to better withstand high voltage spikes and reflected voltage)

b) Bonding Conductor: Three (3) Class “B” soft bare copper bonding conductors (for balanced low resistance path to ground to minimize common mode currents and motor frame standing voltage)

c) Insulation Rating: RA90 (CSA rating)

d) Fire Rating: FT4 Rated

e) Voltage Rating: 1000 volt RW90 Cross-Linked Polyethylene (XLPE) Insulation

f) Aluminum Sheath: Welded Impervious and Continuously Corrugated (for full 360 degree connection to sheath and high frequency shielding to help reduce cross talk from adjacent conductors)

g) Black, sunlight resistant, low acid gas emission, PVC jacket (for protection from contact to ground other than at the connection locations)

h) Corrugated Polyester tape binder

2.25 2-Hour Fire-Rated Variable Speed Drive Cable

.1 Provide 2 hour Fire-Rated cabling for VFD wiring systems consisting of wiring cable, components and accessories, where called for specifically in the contract documents.

.2 Supplier of the cable is to be a company that specializes in providing products of this type.

.3 Cable to conform to all applicable standards:


b) Furnish products listed by ULC as suitable for the purpose outlined.

.4 Description: Type MC Cable

.5 Conductor: Annealed copper, Class “B” strand per ASTM B-3 and B-8

.6 Insulation Rating: 600 volts

.7 Cable Temperature Rating: 90 degrees Celsius wet or dry
.8 Termination Temperature Rating: 90 degrees Celsius

.9 Insulation Material: Silicone Rubber

.10 Insulation Characteristics: High dielectric strength, withstand reflective wave voltages spikes characteristic of AC Drive control systems.

.11 Armour: Continuously welded corrugated copper
   a) To be used as an Equipment Grounding Conductor (CEC Table 16)
   b) Highest level of mechanical protection available
   c) Highest level of EMI / EMF screening

.12 Over-jacket: Flame retardant Low Smoke Zero Halogen (LSZH)

.13 Fire Rating: Cable shall have a 2-hour fire rating

.14 Wet location approval

.15 Connectors: Brass or nickel-plated brass and suitable for use with copper armoured MC cable.

2.26 Reduced Voltage Motor Starters (RVMS or Soft Starters)

.1 Coordination Requirements with VFD assembly and mechanical design requirements
   a) RVMS are to have similar electrical characteristics as the VFD.
   b) All voltage and current operational restrictions associated with the VFD are to be applied to the RVMS.
   c) Environmental conditions required by the VFD are to be maintained for the RVMS.
   d) Enclosure requirements of the VFD assembly are to be applied to the RVMS.

.2 General Requirements
   a) The RVMS shall be an integrated unit with power SCRs, heat sink, logic control board, paralleling by pass contractor, and electronic overload relay enclosed within a single moulded housing.
b) The SCR power section is to consist of a minimum of six (6) SCRs and rated for a minimum peak inverse voltage rating of 1600 volts PIV.

c) The starter is to be a three phase unit rated for motor horsepower, current, and voltage as outlined in the contract documents.

d) Starter is to be provided with an integral heat sink device and over temperature monitoring device.

e) Provide an integral cooling fan assembly to maintain the operational cooling requirements of the unit as required.

f) Starter is to be provided with built-in electronic solid-state overload protection.

g) Provide programmable overload settings of the rated FLA current (minimum of 40 - 100%) for the unit.

h) Overload protection to be capable of being disabled during ramp start for long acceleration loads.

i) All RVMS control functions to be accessible via the device keypad. Door mounted Digital Interface Module (DIM) for access to soft start control features

j) RVMS is to be capable of electronic or mechanical reset after a fault condition.

k) Interface provided via communication network

l) Internal run bypass contractors

m) Silicon Controlled Rectifiers (SCRs) to reduce the voltage output to the motor.

n) Maximum continuous operation is to be for 100% of the motor continuous amp rating.

o) All testing, start up testing and commissioning requirements associated with the VFD shall also be applied to the RVMS.

.3 RVMS Protection Features

a) RVMS to have protection for the following conditions:

i) Over temperature
ii) Phase reversal

iii) Phase loss

iv) Motor stall during start ramp

v) Motor jam

vi) Overload

b) A fault condition of any of the functions listed above to be identified by an LED display on the device keypad and via the communication network.

c) A minimum of one normally open (NO) and one normally closed (NC) form C dry contact is to be provided to identify any of the fault conditions identified above.

.4 Keypad Operation Features

a) Door mounted Digital Interface Module (DIM) for access to soft start control features.

b) Keypad interface control function adjustment to be provided for the following features (minimum):

c) Selectable Torque Ramp Start or Current Limit Start

i) Adjustable Initial Torque: 0 – 95% of locked rotor torque

ii) Adjustable Kick Start Time: 0 – 2 seconds

iii) Adjustable Kick Start Torque: 0 – 85% (for high friction loads)

iv) Adjustable Ramp Start Time: 0 – 120 seconds

v) Adjustable Initial Starting Ramp torque: 0 – 85%

vi) Adjustable Smooth Stop Ramp Time: 0 – 30 seconds (Stopping control of the motor to allow for a longer stopping period of the motor in lieu of a coast to stop condition)
PART 3 EXECUTION

3.1 General

.1 All information for the motor that is to be connected to the VFD drive is to be provided for confirmation and integration purposes.

.2 Shop drawing information for all new motors is to be provided outlining the specific requirement of the motor.

.3 Existing motor parameters are to be confirmed with the actual unit installed on site.

.4 The Contractor will provide the VFD supplier the actual specific motor information prior to final connection.

.5 Motor application data will include the following:
  a) Motor Supplier / Manufacturer
  b) Motor class
  c) Motor Model #
  d) Motor Serial #
  e) Motor Frame
  f) Motor kW
  g) Motor HP
  h) Motor F.L.A.
  i) Motor Service Factor
  j) Size of VFD Supply
  k) Ground Conductor Size
  l) Length of Conductors from VFD to Motor
  m) Size and Material of Conductors from VFD to Motor
  n) Motor Overload
3.2 General Construction and Installation Requirements

.1 The VFD system and associated harmonic mitigating equipment shall be supplied as a complete, pre-integrated, stand-alone package produced by a single supplier regularly engaged in the production of same and maintains full system support responsibility.

.2 The VFD system supplier shall integrate all components and equipment required to meet the specifications, features, and functions as a single system.

.3 Supplier providing non-integrated equipment that requires contractor mounting or wiring of separate system components is not permitted.

.4 Supplier providing equipment that is not warranted by the manufacture is not permitted.

.5 Only one (1) motor may be connected to any single VFD unless specifically called for otherwise in the contract documents. Contractor / Supplier to notify the Consultant and the University of any concerns associated with this requirement.

.6 Contractor is to provide installation information to supplier, including length and size of conductors from VFD to motor for all VFD. Contractor is to provide a long-lead (motor feeder) filter package if required based on this information.

.7 For renovation and replacement installations, remove all obsolete wiring, electrical equipment (contactors, starters, overloads, etc.), conduits, and cabling to the source location.

.8 Install VFD in locations as shown and provide all interconnection wiring to the associated motor load. All VFDs are to be mounted as close to the motor as practical based on site conditions to minimize load feeder lengths.

.9 VFD supplier to provide adequate cooling devices for VFD equipment integral with the equipment provided.

.10 VFD cabinets shall be mounted such that there is adequate room for ventilation and no build-up of heat.

.11 The minimum allowable distance between VFDs is 300 mm. The minimum clearance in front of VFDs is 1 m.

.12 Follow supplier’s recommendations for maximum distance between the VFD and the motor.

.13 Provide remote keypad for VFD located inside air handling system plenum. Cable shall be booster type or type acceptable for length between VFD and keypad.
14. Provide a wire terminal location for both input and output wiring in each VFD build-up enclosure.

15. Safety interlocks for Freeze Control, Fire Alarm functions, and Fan Damper Controls are to be provided via hard wired connections to the appropriate module.

3.3 VFD Assembly Installation Locations

1. VFD assemblies are to be provided in noncorrosive environments where possible with an ambient humidity ranging between 0 to 95 percent non-condensing. Alternate protection means are to be provided for the VFD assembly where the ambient conditions are not deemed as standard acceptable locations for their installation.

2. Prohibited locations for VFD assemblies are locations where there are greater than normal dust build-ups and where higher than normal ambient temperatures or poor ventilation exists. (Some examples are near steam stations, steam converters, condensate tanks, generators, or where passive or forced ventilation systems will bring dust into the space from the exterior, from parkades, etc.)

3. Confirm installation location of VFD assembly complies with outlined requirements. Where the installation is in conflict with these requirements identify the condition to the Consultant and the University for a potential resolution.

4. VFD assemblies shall be suitable for mounting in a typical building mechanical room or mixed air plenum and shall operate under these conditions with no special cleaning requirements.

5. Ensure appropriate distances between VFD assemblies to avoid mutual heating effects. A minimum spacing of 300 mm is to be provided between adjacent enclosures.

3.4 Mounting Requirements

1. Install VFDs with the assistance of supplier’s authorized field personnel and in accordance with the supplier’s recommendations.

2. Set and secure VFD assembly in place on channel bases, rigid, plumb and square to building floor and wall. VFD to be placed on housekeeping pad where permitted elsewhere following the same requirements.

3. Provide a minimum of one hold down bolt in the front and rear of the VFD assembly for every 1 m linear length or portion thereof. Secure VFD to channel supports with a minimum of four (4) bolts.
3.5 VFD Installation Protection

.1 Protect against dust and damage during entire construction period. If filters have been soiled replace filter media at the end of the construction period. The VFD supplier shall provide one additional set of all filter media types with each drive equipped with filter systems for maintenance purposes. Filter media to be provided to the U of A facility management division for future maintenance replacements purposes.

.2 After all internal connections have been completed, vacuum clean the interior and close the assembly to prevent dirt migration into the interior of the unit. Hand-clean exterior and touch-up any damaged paint.

3.6 Field Quality Control

.1 Seal the VFD against contamination from construction dust and debris. If the VFD becomes contaminated, the contractor is responsible for providing a factory representative to completely tear down, clean, test, reassemble and re-commission affected VFD.

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

3.7 VFD Calibration

.1 The Contractor supplying the drive shall allow for the drive supplier’s Factory Technical Agent to completely calibrate all drive circuits after installation on site. Final drive settings (the final “as left” state) shall be as-built and changes from earlier configurations shall be dated and signed. Copies of the data shall be provided both in the drives and the operation and maintenance manuals for the project.

3.8 Conduit, Cabling, and Grounding by Electrical Contractor

.1 The following requirements are to be included in the VFD installation contract requirements regardless if not specified elsewhere in the contract documents.

.2 Provide wiring per the supplier’s installation instructions.
.3 The installer is to take all necessary precautions to prevent accidental damage to the cable from contact with any foreign objects.

.4 Conduit and cable entries into VFDs shall be made through either the bottom or the side of the unit. Top entry into VFDs by conduits or cables is not permitted. Confirm preferred installation location with VFD supplier so as to coordinate with internal wiring requirements.

.5 Provide separate conduits and or cables for VFD input and output power.

.6 Network communication and control wiring are to be provided in a separate conduit from VFD supply and motor feeder conduits.

.7 Extend cables for: analog input signal, analog speed indicating output, shutdown contact and drive fault contact from the drive to the Motor Relay Interface Panel (MRIP) or to an alternate location as indicated on the drawings or as directed by the project designer and approved by the University. (The MRIP normally houses the freeze and fire relays.)

.8 If the VFD is not pre-installed and pre-wired as a part of a packaged equipment assembly / unit, provide and connect Variable Speed Drive Cable (or approved alternate) from VFD to designated motor load for motors separated by more than 10 meters of cable length from the VFD.

a) For motors installed at 10 meters or less from the unit, the use of standard building wire inside of steel conduit and terminal sections of seal tight flex is deemed acceptable.

.9 Inspect wiring / cable for physical damage and proper connection.

.10 Measure tightness of any bolted connections and where applicable compare torque measurements with supplier’s recommended values.

.11 Verify continuity of each conductor.

.12 Prior to energizing cables, measure the insulation resistance of each cable. Tabulate and submit for approval.

.13 Provide feeders with adequately sized grounding / bonding conductors in conduit (or cable) as indicated on the project drawings or in the specifications from distribution source (i.e. motor control centre, distribution centre, etc.) to the VFD.

.14 Provide a ground conductor in each control conduit with the signal and data control cables from Building Management System to each VFD.
.15 Provide a grounding conductor from the motor to the VFD’s internal grounding terminal. Grounding conductor is required to minimize interference and for proper operation of the ground-fault protection function of the equipment.

.16 No conductors (supply or motor feeders) are to be taped or otherwise bundled within conduits.

.17 2-hour Fire-Rated cable is to be employed where required due to installation conditions.

.18 The supplier’s wiring instructions shall incorporate a means of preventing smoke from entering the electrical equipment. Duct seal or other approved means of preventing transfer of smoke to the enclosure is to be provided.

.19 Reference other related project specification sections for wiring, cabling, and grounding requirements.

.20 Torque all conductors with calibrated torque wrench, (Terminations to be checked include, but are not limited to, power, line, load, ground, and control.) Terminations shall be torqued to the supplier’s recommendation.

3.9 Local Motor Disconnect with VFD Installation Application

.1 If a local disconnect is required (by either the engineered design or by Canadian Electrical Code) near the motor, the operating mechanism of the disconnecting means shall be so constructed that an auxiliary NO/NC contact will change state when the switch is operated. Control wiring shall be installed between the disconnect switch and the VFD to enable the VFD to determine if the disconnect switch is open or closed. VFD safeties will be enabled when the motor is disconnected on the load side of the VFD to ensure that the drive does not activate. When disconnect is in the closed position, a permissive run signal allows for the restart of the VFD at low voltage and frequency.

.2 Local motor disconnects or isolating switches for motors driven by VFDs shall be identified with a separate laminoid nameplate located as close as practicable to the operating handle of the field (local) disconnecting means. Tag color shall be orange face and white core. The tag shall contain the following wording:

WARNING
3.10 Motor Thermal Protection

.1 Where thermal sensing of the motor windings is provided per the project requirements an interlock with the VFD control circuit is to be provided.

.2 The thermal sensor is to monitor the motor operating temperature to disengage the VFD for over temperature conditions. (For motors that operate at low speeds for extended periods that will have reduced cooling capacity due to slower operation speeds.)

.3 The temperature of the motor windings is to be maintained below that specified for its insulation class.

3.11 Labelling

.1 Place a mechanically fastened lamicoid, with orange face and white core, 12mm high lettering, that reads “VFD SUPPLY” for all VFD supply sources.

3.12 VFD Assembly Startup

.1 Each drive assembly will be subject to a start-up process that will involve the Mechanical Contractor, Electrical Contractor, and the VFD Supplier. The Owner’s start-up and Commissioning Team shall be notified of VFD start-ups and may elect to witness the start-up.

.2 The Mechanical Contractor will be responsible to coordinate the installation, testing and start-up (prior to commissioning commencement) with all other parties participating in the start-up activities.

.3 Start-up to be provided in compliance with the requirements outlined in specification Attachment #1 titled VFD Start-up Procedures. This document shall be considered the minimum requirements for start-up procedures.
.4 Additional start-up requirements as recommended by the supplier to ensure satisfactory operation of the equipment are to be performed per the supplier's recommendations.

.5 Demonstrate operation of the VFD and all associated peripherals in automatic and manual modes.

.6 Where there is any issue or dispute with the outlined start-up requirements it shall be indicated at the time of tender. If the installer, supplier, integrator, or assigned start-up agency believes any requirement could be harmful to the drive or would invalidate warranty the disputed item(s) shall be identified in writing specific to the clause or condition in dispute to the attention of the Consultant and the University.

.7 Alternate start-up procedures are to be presented for approval by the University regarding any disputed items associated with the start-up requirements.

3.13 Commissioning

.1 The mechanical contractor (or contractor supplying the VFD) shall be responsible for complete commissioning of each VFD to the satisfaction of Consultant and Owners Commissioning Forces. Requirements will be based upon the completion of the commissioning requirements outlined herein.

.2 Each drive will be subject to a commissioning process that will involve the Control System Representative, the Mechanical and Electrical Contractors, the drive supplier’s Factory Technical Agent and the Owner’s Project Commissioning Team.

.3 The Contractor (or drive supplier for a standalone application) is responsible to schedule commissioning in coordination with all appropriate divisions. Scheduling of commissioning activities to include a minimum five (5) working days notice to U of A Commissioning Team Members prior to each separated commissioning activity.

.4 Allow for factory representative to completely calibrate all drive circuits after installation on site.

.5 Commissioning requirements to be provided in accordance with the specification Attachments #2 and #3 titled VFD Commissioning Procedures and VFD Commissioning Sheets respectively. These documents shall be considered the minimum requirements for commissioning procedures. (Note: Outline any additional commissioning requirements to be provided based on contract requirements. Reference applicable sections and documentation as part of the contract documents where applicable.)
.6 Additional commissioning requirements as recommended by the supplier to ensure satisfactory operation of the equipment are to be performed per the supplier’s recommendations.

.7 A step-by-step procedure is to be documented for the testing of the VFD and all associated components.

.8 Where there is any issue or dispute with the outlined commissioning requirements it shall be indicated at the time of tender. If the installer, supplier, integrator, or assigned commissioning agency believes any requirement could be harmful to the drive or would invalidate warranty the disputed item(s) shall be identified in writing specific to the clause or condition in dispute to the attention of the Consultant and the University.

.9 Alternate commissioning procedures are to be presented for approval by the University regarding any disputed items associated with the commissioning requirements.

3.14 VFD Schedule

.1 The following sample represents the minimum information requirements associated with the VFD assembly.

.2 Provide VFD assemblies compliant with the following parameters:

a) (The following is a sample VFD schedule template. Modify as required for project requirements.)

<table>
<thead>
<tr>
<th>Sample #1 – Information Only</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Frequency Drive</td>
<td>VFD-1</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>600 V, 3-phase, 60 Hz</td>
</tr>
<tr>
<td>Motor Voltage</td>
<td>600 V, 3-phase, 60 Hz</td>
</tr>
<tr>
<td>Motor Horsepower</td>
<td>30 hp</td>
</tr>
<tr>
<td>Motor FLA</td>
<td>40.0 A</td>
</tr>
<tr>
<td>Motor Service</td>
<td>Pump, Hot Water</td>
</tr>
<tr>
<td>Isolation Transformer</td>
<td>No</td>
</tr>
<tr>
<td>VFD Isolation Bypass (Y/N)</td>
<td>Yes</td>
</tr>
<tr>
<td>VFD Type</td>
<td>Variable Torque Load</td>
</tr>
<tr>
<td>VFD Bypass Starter (Soft Start / Contactor)</td>
<td>Soft Start</td>
</tr>
<tr>
<td>Note: - Provide additional information as required. (i.e. 2-hour rated VFD cable)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample #2 – Information Only</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Variable Frequency Drive</td>
<td>VFD-2</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>208 V, 3-phase, 60 Hz</td>
</tr>
</tbody>
</table>
Sample #2 – Information Only

<table>
<thead>
<tr>
<th>Variable Frequency Drive</th>
<th>VFD-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Voltage</td>
<td>208 V, 3-phase, 60 Hz</td>
</tr>
<tr>
<td>Motor Horsepower</td>
<td>10 hp</td>
</tr>
<tr>
<td>Motor FLA</td>
<td>40.0 A</td>
</tr>
<tr>
<td>Motor Service</td>
<td>Pump, Condenser</td>
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<td>Isolation Transformer</td>
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</tr>
<tr>
<td>VFD Isolation Bypass (Y/N)</td>
<td>No</td>
</tr>
<tr>
<td>VFD Type</td>
<td>Variable Torque Load</td>
</tr>
<tr>
<td>VFD Bypass Starter (Soft Start / Contactor)</td>
<td>Contactor</td>
</tr>
</tbody>
</table>

Note: - Provide additional information as required. (i.e. 2-hour rated VFD cable)
PART 4 SPECIFICATION INFORMATION AND GUIDELINES

4.1 Instructions to Project Designers and Specifiers

.1 The use of this VFD specification and its contained terms and conditions is to be evaluated as an overall determination of the project requirements.

.2 Various aspects of this specification may be duplicated with respect to the overall project. To assist in removing ambiguity and potential conflicts related to the overall project documents, redundant information is to be removed from the appropriate section of the documentation.

.3 Coordination with other specification sections is to be provided to ensure a complete workable system is achieved as a final product.

.4 Revise specification cross reference information to suit the project requirements. Provide specification cross references to the appropriate sections forming the complete contract documents.

.5 This specification can be adapted for use with project specifications as required to comply with the format being used.

4.2 VFD Specification Application Parameters

.1 The use of this section is to be applied to motors that will require significant periods of reduced speed operation in response to external parameters such as temperature and pressure.

.2 Where loads fluctuations are expected, the use of this section is to be employed.

.3 Where load applications vary only occasionally, or not at all, the use of a soft start or standard motor starter may be applicable.

.4 Confirm with the mechanical consultant for the intended operation of the motor and mechanical system prior to providing a VFD for the selected motor.

.5 For information purposes, refer to the U of A Mechanical Design and Construction Guidelines which contain requirements that include direction regarding the application of VFDs in mechanical system designs.
4.3 **Voltage Utilization Operational Requirements**

.1 Confirm with the electrical consultant the input operational voltage available for use with the VFD assembly at time of system design.

4.4 **Related Specification Requirements**

.1 *Refer to item 1.3 of this specification.*

.2 The related requirements section of the specification is to be closely evaluated based on the project requirements. All applicable sections are to be identified for coordination purposes with the appropriate cross referenced section number.

4.5 **Approved Suppliers and Model Types**

.1 *Refer to item 2.1 of this specification.*

.2 The University of Alberta has reviewed the acceptability of various VFD manufacturers through the process of a prequalification document and associated evaluation criteria. The purpose of the previously issued prequalify documentation was to determine an appropriate selection of firms able to provide the VFD assembly systems per the complete information contained with this document.

.3 Selection of the VFD assembly was based on a number of factors such as, but not limited to, technical compliance, product representation, warranty, and technical response capabilities.

.4 Further details of the previously issued RFQB Request for Qualification which covers this specification document can be obtained from the University of Alberta.

4.6 **VFD Application Types**

.1 *Refer to item 2.3 of this specification.*
The VFD type employed is to be suitable for the control application required. Depending on the operational conditions and the connected motor load a different VFD operational configuration would be recommended. The types of VFD and the typical connected loads are listed in the following:

a) Constant Torque Loads:
   i) To be used for general industrial machine loads (other than pumps and fans) such as hoist, conveyors, positive displacement pumps, reciprocating and rotary compressors.

b) Constant Horsepower Loads:
   i) To be used generally for machine tool applications such as wheel grinders, large driller machines, lathes, planers, boring machines, core-driven reels, etc.
   ii) The use of DC drives or High Performance Flux Vector VFD’s are recommended for the control of these loads. Consult with the U of A Facilities Management for the recommended control of these drives.

c) Variable Torque Loads:
   i) To be used for variable flow applications such as fans and pumps.

Proper selection of the appropriate drive should be considered for all drive applications. The type of VFD control should be identified in the VFD Schedule for drive requirements for each project.

4.7 Output Power

Refer to item 2.10 of this specification.

The type of pulse width modulation (PWM) used will be dependent on the connected motor application. Control of the motor may require a higher pulse rate to minimize harmonic distortion on the electrical system. A cost benefit analysis of the appropriate motor may deem a modification to the general requirements indicated.

The specifier is to review the individual requirements of the motor drive control related to the electrical system to determine the appropriate PWM to be used.
4.8 Integration Drawings

.1 Refer to item 2.13.29 of this specification

.2 The integration control of the VFD assembly can be provided via the means depicted in the document attachment.

.3 Alternate means of control (i.e. via smart relay control logic) can also be provided where deemed appropriate based on the application being employed.

4.9 Provision for Electrical Test Jacks

.1 Refer to item 2.16 of this specification.

.2 The University of Alberta will provide test jacks interconnected to the VFD assembly for testing and maintenance purposes.

.3 The provisions for the test jacks are to be provided in the VFD enclosure to standardize where the service can be located.

4.10 Isolated Bypass Operation

.1 Refer to item 2.18 of this specification.

.2 Selection of motor bypass is to be based on the driven equipment's individual motor operational requirements and mechanical system configuration rather than applied universally for all VFDs.

.3 Bypass is to be provided where the operation of a single motor is to be maintained for the selected system per the mechanical and control system design requirements.

.4 Where a dual redundant motor system configuration is used the application of a bypass on the VFD assembly may not be required.

.5 The application of reduced voltage soft start bypass for smaller motors may not be cost efficient. A size restriction has been decided based on motor horsepower. Where motors are less than 25HP a contactor bypass may be used in lieu of a RVMS (soft starter).

.6 Provide isolation bypass for VFDs where required by project design.

.7 Adjust recommended operational conditions as necessary to suit project requirements.
4.11 Installation Location

.1 Refer to item 3.3 of this specification.

.2 The installation location for the VFD assembly is to be maintained in an environment that is advantageous for its continued optimal operation.

.3 Where possible, the location for the VFD assembly installation is to be provided adjacent to the controlled motor and in a conditioned space with controlled ambient conditions.

.4 If the VFD assembly cannot be provided in the same area a local isolation disconnect is to be provided and the appropriate cabling is to be provided through the building classification areas.

.5 Specific labeling is to be provided when a local isolation disconnect is employed to ensure the safe operation of the VFD is maintained.

4.12 Electrical Distribution and VFD Drive Cable

.1 Refer to items 2.24 and 2.25 of this specification.

.2 An evaluation of the electrical distribution system upstream from the VFD should be reviewed. The use of 2 hour rated VFD supply feeder cables from the electrical distribution should be considered depending on the motor system being supplied.

.3 A VFD drive cable is recommended for all VFD load applications to help mitigate any harmonic influences and improve system performance.

.4 Where the location of the VFD assembly is not provided with the motor, but across a building boundary, it is recommended that a 2 hour fire rated VFD drive cable is used to maintain service to the selected motor.

.5 Where the motor is used for essential building systems to maintain life safety equipment (i.e. dual purpose smoke evaluation fans) 2 hour fire rated VFD drive cable is recommended to maintain service to the selected motor.

4.13 Reduced Voltage Motor Starters (RVMS or Soft Starters)

.1 Refer to item 2.26 of this specification.
.2 A separate specification section may be warranted for this section of the document pending project requirements. Remove the information from this section if provided elsewhere in the contract documents. Commissioning should address the requirements of the RVMS if not included within this section as listed in Attachment #2.

.3 Soft starts are recommended for all larger motor loads due to the inertia requirements necessary in starting most high horsepower loads.

.4 Soft starting control of motor loads will help minimize the mechanical component shock of providing across the line starting to the load. Some mechanical advantages of soft starts are prevention of shaft damage, rotor and winding failures, and drive belt squeal and possible breakage. Electrically, the current in-rush is reduced on the electrical distribution system thereby increasing component life and help eliminating nuisance breaker tripping.

.5 Utilization of the soft start control helps eliminate sudden starting or stopping of the connected load and can improve system performance of the entire building systems.

.6 The University of Alberta Mechanical Design and Construction Guidelines have established a threshold of 25HP as the smallest motor size where VFD bypass RVMS are to be employed. Motor sizes that are smaller than 25HP may employ contactor controls if deemed acceptable based on installation design considerations.

4.14 Matching VFDs to Motors

.1 The following guidelines may assist in the selection of a properly sized VFD to an associated motor:

a) Define the operating profile that the VFD is to be applied. Include any or all torques required as listed in item 2.6 above. Obtain the highest “peak” current readings under the worst conditions. Confirm if the motor is working in an overload condition relative to its FLA. Overloaded motors operating at reduced speeds may not operate at the increased temperature range and will have decreased life.

b) Determine why the load output speed needs to be changed. VFDs should only be applied where the load output speed needs to be modified otherwise a soft start may be sufficient.

c) Size VFD to the motor based on the maximum current under peak torque demands and not horsepower ratings. The maximum demands on the motor by the load must be met by the VFD.
d) Evaluate the possibility of over sizing the VFD to accommodate motor performance requirements (i.e. breakaway torque) to not impede motor operation. VFD over sizing may be required to accommodate the type of load and the duty cycle expected.

4.15 Important VFD Parameters

.1 The three main factors in VFD specifications are:

a) Continuous run current rating: The maximum RMS current the VFD can safely handle under all operating conditions. The motor full load sine wave currents must be equal or less than this rating.

b) Overload current rating: Inverse time / current range is the maximum current the VFD can produce for a given time frame. Value is important for VFD sizing necessary to produce the required motor breakaway torque.

c) Line voltage: The operational voltage of the VFD with the allowable voltage variation before the unit goes into a protective trip scenario. Motor starters typically have a wider operational range than VFDs.
Attachment #1 - VFD Start-up Procedures

The Start-up process is to ensure that all of the necessary components have been provided for the VFD assembly installation. Through this process all features of the VFD assembly are to be confirmed with the design parameters to which the unit is being applied to.

Prior to start-up ensure that the following requirements have been provided and adhered to:

- Static Verification Sheets have been completed in their entirety.
- Factory Test Reports has been received and accepted by the University of Alberta (U of A).
- The Building Automation System is operational.
- Ensure that specific electrical permits have been obtained for the drives and copies supplied to the U of A for the Project Safety Codes Files.

Initial start up of the VFD will require the following personnel are in attendance:

- VFD Manufacturer’s Representative.
- Owner’s Assigned Commissioning Team Member(s).

Start up of the VFD is to be performed by the VFD Supplier’s Representative who will perform the pre-start up checks and program the drive with all relevant parameters and enter these parameters on the start up sheet. Copies of all parameters and updates must be documented.

Ensure setting of the Bypass over loads are correctly sized and have been set for the Full Load Amperes (FLA) of the motor accounting for the Motor Service Factor.
Attachment #2 - VFD Commissioning Procedures

The Commissioning process is to ensure the correct operation of the complete VFD assembly, through the Building Automation System and in Local Control Mode, in both Inverter and Bypass modes and to confirm that all VFD, Building Control System and safety systems interlocks are functioning properly.

Required documentation to be provided prior to instigation of VFD commissioning:

- Static Verification Check Sheets - Completed.
- Start-up Sheets - Completed.
- Parameter Sheets - Completed.
- Copy of the intended control strategy for the VFD and associated equipment provided to the U of A with written acceptance of same - Completed.

Attendees (minimum):

- VFD Manufacturer’s Representative.
- Owner’s Assigned Commissioning Team Member(s).
- U of A Electrical and Controls Divisions.

Tools:

- Digital Multi Meter rated 600 V or higher.
- Current Probe.
- Tachometer.
- 4-20 ma Test Jack Probe.
- Hand Tools.
- Can of Freeze Spray.

PPE:

- Hard Hat.
- Safety Glasses.
- Safety Boots.
- Arc Flash Gear (Face Shield, Gloves) Level 2 (minimum).
  - Level 3 protection (minimum) to be provided for 600 V applications.
Arc Flash Report may indicate higher values. Consult report and review equipment specific labelling before deciding on final PPE equipment selection.

**General Installation Requirements**

- Perform a physical inspection of all installed VFD equipment:
  - Remove any moisture or debris from inside the equipment.
  - Repair any damage to the enclosure, damaged or loose components and wiring, and disconnected terminal connectors.
  - Remove any restrictions to airflow cooling fans or heat sinks.
  - Remove any shipping blocks and any other associated equipment.
- Review entire motor to VFD installation conditions:
  - Ensure wiring connections have been properly installed and labelled.
  - Review connected load connections.
  - Review circuit breaker feeder connections.
  - Review control wiring interconnections to all associated equipment.
- Review installation parameters:
  - Review all connections between equipment (i.e. line, load, and grounding).
  - Confirm motor parameters (i.e. Voltage, Horsepower Full Load Amperes, Rotation, etc.).
  - Confirm corresponding VFD output parameters with connected motor.
  - Ensure operating condition of all protective devices are functions as required (i.e. circuit breakers, fuses, overloads, thermal devices).
  - Local disconnects are installed and in the correct operating configuration.
  - Monitor incoming line power voltage measurements to the VFD (A-B phase, B-C phase, and C-A phase).
  - Confirm all electrical and mechanical components are set to their proper operating conditions. Equipment includes valves, dampers, limit switches, etc.

➢ **BEFORE ENERGIZING THE DRIVE SYSTEM ENSURE:**

- All external control wiring has been connected and tagged (Freeze and Fire shutdown, Damper end switches, Volume control, etc.).
- The INVERTER/OFF/BYPASS switch is in the OFF position.
- The LOCAL/OFF/REMOTE switch is in the OFF position.
**Energize VFD:**

- Check Voltage. (Use appropriate safety equipment).
- VFD to be operated at full load.
- Allow the system to operate for minimum period of two (2) hours before taking test readings for future comparison.

**Inverter Mode / (Local Control):**

- Turn the INVERTER/OFF/BYPASS switch to the INVERTER position.
- Turn the LOCAL/OFF/REMOTE switch to the LOCAL position.
- Using the Key Pad or Potentiometer attempt to bring motor to 10% speed.
- Where interlocked with end switches the system should not ramp to 10% speed.
- Check dampers have opened. Damper motor end switch shall prevent increase in speed if dampers do not open.
- Check for correct rotation.
- With dampers open, run drive through 25%, 50%, 75% and 100% Speed. Verify speed with tachometer and record all % and RPM values.
- Take amperage reading at 100% and verify same with U of A Control Centre and re-calibrate if necessary. Log values.
- Spray Freeze Switch with Freeze Spray and ensure inverter shuts down giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch.
- Restart Fan.
- Open Fire Shutdown Relay and ensure inverter shuts down or reacts as required by strategy giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch. Final test shall repeat this step with the fire alarm system causing the drive to shut off. Fire alarm technician shall command the relay to open.
- Verify that the U of A Control Centre is monitoring all changes (i.e. Freeze Alarm, Fire Shutdown Alarm).
- Any additional control devices shall be checked to ensure they operate as required.
- Bring VFD speed to zero.
- Turn off drive via local Control.

**Inverter Mode / [Remote Control]:**

- Turn the INVERTER/OFF/BYPASS switch to the INVERTER position.
• Turn the LOCAL/OFF/REMOTE switch to the REMOTE position.
• Verify that the volume control is at 4 ma (0 speed).
• Have U of A Control Centre turn drive on via the BMS.
• Drive shall ramp to minimum speed (typically ~6-7 mA equates to 15% speed).
• Ensure Dampers have opened. Damper motor end switch shall prevent increase in speed if dampers do not open.
• Have BMS system bring drive up to 25%, 50%, 75% and 100% Speed. Verify speed with tachometer and record values.
• Spray Freeze Switch with Freeze Spray and ensure inverter shuts down giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch.
• Restart Fan.
• Open Fire Alarm Relay and ensure inverter shuts down or reacts as required by strategy giving a fault (interlock) indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch. Final test shall repeat this step with the fire alarm system causing the drive to shut off. Fire alarm technician shall command the relay to open.
• Restart Fan.
• Verify that the U of A Control Centre is monitoring all changes (i.e. Freeze Alarm, Fire Shutdown Alarm, etc.).
• Any additional control devices shall be checked to ensure they operate as required.
• Bring VFD speed to zero.
• Turn off drive via BMS Remote Control.
• Turn LOCAL/OFF/REMOTE switch to the OFF position.
• Turn INVERTER/OFF/BYPASS switch to the OFF position.

➤ **WARNING :Before going to BYPASS MODE, ensure that the Fan can run at full speed without causing damage.** (Damage to duct work from full rpm motor operation or due to closed or partially closed dampers can occur. Ensure that these issues have been resolved prior to proceeding.).

**Bypass Mode / Local Control:**

- Turn the INVERTER/OFF/BYPASS switch to the BYPASS position.
- Turn the LOCAL/OFF/REMOTE switch to the LOCAL position.
- Turn on BYPASS with the ON switch.
• BYPASS shall not engage until Dampers have opened and End Switch has closed.
• Check for correct motor rotation.
• Spray Freeze Switch with Freeze Spray and ensure BYPASS shuts down giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch.
• Restart Fan.
• Open Fire Relay and ensure BYPASS shuts down giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch. Final test shall repeat this step with the fire alarm system causing the drive to shut off. Fire alarm technician shall command the relay to open.
• Verify that the U of A Control Centre is monitoring all changes. (i.e. Freeze Alarm, Fire Shutdown Alarm, etc.).
• Turn Fan off with STOP Switch.
• Turn INVERTER/OFF/BYPASS to OFF.

**Bypass Mode / Remote Control:**

• Turn the INVERTER/OFF/BYPASS switch to the BYPASS position.
• Turn the LOCAL/OFF/REMOTE switch to the REMOTE position.
• Turn on BYPASS with the BMS System.
• BYPASS shall not engage until Dampers have opened and End Switch has closed.
• Spray Freeze Switch with Freeze Spray and ensure BYPASS shuts down giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch.
• Restart Fan.
• Open Fire Alarm Relay and ensure BYPASS shuts down giving a fault indication. Fan shall remain OFF until the U of A Control Centre resets the System Switch. Final test shall repeat this step with the fire alarm system causing the drive to shut off. Fire alarm technician shall command the relay to open.
• Verify that the U of A Control Centre is monitoring all changes. (i.e. Freeze Alarm, Fire Shutdown Alarm).

**Reduced Voltage Motor Starters (RVMS or Soft Starters):**

• When Soft Starts are used, their programming parameters shall be documented on the appropriate sheets.
• All common operational features and functions of the RVMS as they relate to the VFD installation are to be confirmed with the same operational conditions as required from the VFD documentation identified above.

**Start-Up and Commissioning Documentation:**

• A copy of each of the following documents shall be left inside the VFD upon completion of commissioning shall include, but not be limited to:
  o Start-up check sheet
  o Factory test report
  o Parameter sheet
  o VFD commissioning sheet
  o Copy of the system strategy
  o Soft start parameters
  o Revisions to any original start-up data / settings & parameters

• All information is to be dated and signed.
### Attachment #3 - VFD Commissioning Checksheets

<table>
<thead>
<tr>
<th>Action</th>
<th>Requirement / Task / Check</th>
<th>Record Equip Data Here</th>
<th>Y/N - N/A</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Verification</strong></td>
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<tr>
<td>Confirm</td>
<td>VFD meets specifications / shop drawing</td>
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<tr>
<td>Confirm</td>
<td>Correct Voltage rating (Record Here Typical --&gt;)</td>
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<tr>
<td>Confirm</td>
<td>Correct HP rating</td>
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<tr>
<td>Confirm</td>
<td>Correct Conductor size</td>
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<tr>
<td>Confirm</td>
<td>Correct Grounding</td>
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<tr>
<td>Confirm</td>
<td>Per Spec: Drive Cable Used or Conduit</td>
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<tr>
<td>Confirm</td>
<td>VFD Acceptably Mounted</td>
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<td>Confirm</td>
<td>Secured to Housekeeping pad</td>
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<tr>
<td>Confirm</td>
<td>Enclosure Inspected for damage inside</td>
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<tr>
<td>Confirm</td>
<td>Enclosure Inspected for damage outside</td>
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<td>Confirm</td>
<td>Has enclosure been cleaned inside &amp; out</td>
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<tr>
<td>Confirm</td>
<td>Has filter medium been installed</td>
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<tr>
<td>Confirm</td>
<td>Has Control / Safety wiring been connected</td>
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<tr>
<td>Confirm</td>
<td>The test jacks have been installed</td>
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<tr>
<td>Confirm</td>
<td>Wire and Terminal Block Tagging installed</td>
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<tr>
<td>Confirm</td>
<td>Has VFD electronic O/L setting been made</td>
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<tr>
<td>Confirm</td>
<td>Has Bypass Electronic O/L setting been made</td>
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<tr>
<td><strong>Programming / Parameter Settings</strong></td>
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<tr>
<td>Confirm</td>
<td>Has motor nameplate data entered into VFD</td>
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</tr>
<tr>
<td>Record</td>
<td>Ramp up time</td>
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<tr>
<td>Record</td>
<td>Ramp down time</td>
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<tr>
<td>Ensure</td>
<td>Number of restarts</td>
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<tr>
<td>Ensure</td>
<td>Parameter Sheet has been filled out</td>
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<tr>
<td><strong>Startup Checks</strong></td>
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<tr>
<td>Confirm</td>
<td>Voltage (Record Measured Data Here Typical --&gt;)</td>
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<tr>
<td>Confirm</td>
<td>Amperage</td>
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<tr>
<td>Confirm</td>
<td>Correct Rotation in VFD Mode</td>
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<tr>
<td>Confirm</td>
<td>Correct Rotation in Bypass Mode</td>
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<tr>
<td><strong>Operational Checks</strong></td>
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<tr>
<td>Confirm</td>
<td>System Strategy Known (Copy Available)</td>
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<td>Confirm</td>
<td>Associated BMS points connected</td>
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<tr>
<td>Confirm</td>
<td>End to end checks completed</td>
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<tr>
<td>Confirm</td>
<td>Copy of strategy placed in the VFD</td>
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<tr>
<td>Confirm</td>
<td>Copy of Parameter sheet placed in the VFD</td>
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<tr>
<td><strong>VFD Local Control</strong></td>
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<tr>
<td>Confirm</td>
<td>VFD starts on local control</td>
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<tr>
<td>Confirm</td>
<td>Auxiliary control devices operate</td>
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<tr>
<td>Confirm</td>
<td>VFD shuts down on Fire control</td>
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<tr>
<td>Confirm</td>
<td>VFD shuts down on Freeze control</td>
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<tr>
<td>Confirm</td>
<td>System switch required to restart</td>
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<tr>
<td>Confirm</td>
<td>Speed controlled locally</td>
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<tr>
<td>Confirm</td>
<td>Control devices operate as designed</td>
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<tr>
<td>Confirm</td>
<td>Control Centre monitoring is functional</td>
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<tr>
<td><strong>VFD Remote Control</strong></td>
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<tr>
<td>Confirm</td>
<td>VFD starts on E-point (Digital Output)</td>
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<tr>
<td>Confirm</td>
<td>Auxiliary control devices operate</td>
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<td>Confirm</td>
<td>VFD shuts down on Fire control</td>
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<td>Confirm</td>
<td>VFD shuts down on Freeze control</td>
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<tr>
<td>Confirm</td>
<td>System switch to restart after fault</td>
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<tr>
<td>Confirm</td>
<td>Speed controlled by B-point (Analogue Output)</td>
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<td>Confirm</td>
<td>Control devices operate as designed</td>
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## Attachment #3 - VFD Commissioning Sheet

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<th>VFD #:</th>
<th>Descriptor:</th>
<th>Action</th>
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<th>Record Equip Data Here</th>
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<td>VFD starts on local control (Record Responses -&gt;)</td>
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<td></td>
<td>Confirm</td>
<td>Auxiliary control devices operate</td>
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<td>Confirm</td>
<td>VFD shuts down on Fire control</td>
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<td>Confirm</td>
<td>VFD shuts down on Freeze control</td>
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<td></td>
<td>Confirm</td>
<td>System switch to restart after fault</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Confirm</td>
<td>Control devices operate as designed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Confirm</td>
<td>Control Centre monitoring is functional</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Bypass Remote Control** | | | Confirm | Bypass operates by E-point control | | | |
| | | | Confirm | Auxiliary control devices operate | | | |
| | | | Confirm | Bypass shuts down on Fire control | | | |
| | | | Confirm | Bypass shuts down on Freeze control | | | |
| | | | Confirm | System switch to restart after fault | | | |
| | | | Confirm | Control devices operate as designed | | | |
| | | | Confirm | Control Centre monitoring is functional | | | |

### Notes:

- Bypass Local Control
- Bypass Remote Control

---

**Date:** __________________  
**Signed:** __________________
## Attachment #4 - VFD Integration - Drawing Legend

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>F1</td>
<td>Cabinet Fan Fuse</td>
</tr>
<tr>
<td>F2</td>
<td>Control Circuit Fuse</td>
</tr>
<tr>
<td>TB1</td>
<td>Customer Control interface Terminal Block</td>
</tr>
<tr>
<td>S1</td>
<td>VFD/Bypass Selector Switch</td>
</tr>
<tr>
<td>S2</td>
<td>Local / Remote Selector Switch</td>
</tr>
<tr>
<td>S3</td>
<td>Local Bypass Start Switch</td>
</tr>
<tr>
<td>S4</td>
<td>Local Bypass Stop Switch</td>
</tr>
<tr>
<td>S5</td>
<td>Cabinet Fan Temp Control Switch (Thermostat)</td>
</tr>
<tr>
<td>Fan(s) 1</td>
<td>Cabinet Cooling Fan- EDM-Pabst 4000 Series</td>
</tr>
<tr>
<td>R1</td>
<td>Safety Interlock Control Relay</td>
</tr>
<tr>
<td>R2</td>
<td>Remote Run Control Relay</td>
</tr>
<tr>
<td>R3</td>
<td>Local Run Control relay</td>
</tr>
<tr>
<td>IV</td>
<td>VFD Input Contactor</td>
</tr>
<tr>
<td>OV</td>
<td>VFD Output (Contactor/Aux Relay Contacts)</td>
</tr>
<tr>
<td>OB</td>
<td>Bypass Output (Contactor/Soft-Start/Aux Relay Contacts)</td>
</tr>
<tr>
<td></td>
<td>Field Wiring Connection Points (Shaded Areas)</td>
</tr>
</tbody>
</table>

### TB1 Customer Control interface Terminal Block

**Terminal Numbers**

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB1-1</td>
<td>Customer Remote Run command (Supply)</td>
</tr>
<tr>
<td>TB1-2</td>
<td>Customer Remote Run command (Return)</td>
</tr>
<tr>
<td>TB1-3</td>
<td>Optional Damper Control Connection</td>
</tr>
<tr>
<td>TB1-N</td>
<td>Optional Damper Control Neutral Connection</td>
</tr>
<tr>
<td>TB1-4</td>
<td>External Fault / Interlock (Supply)</td>
</tr>
<tr>
<td>TB1-5</td>
<td>External Fault / Interlock Series Connection Terminal)</td>
</tr>
<tr>
<td>TB1-6</td>
<td>External Fault / Interlock Series Connection Terminal)</td>
</tr>
<tr>
<td>TB1-7</td>
<td>External Fault / Interlock (Supply)</td>
</tr>
<tr>
<td>TB1-8</td>
<td>(Note Shown on Integration Diagram) Terminal for Isolator Analog Input 1 +</td>
</tr>
<tr>
<td>TB1-9</td>
<td>(Note Shown on Integration Diagram) Terminal for Isolator Analog Input 1 -</td>
</tr>
<tr>
<td>TB1-10</td>
<td>(Note Shown on Integration Diagram) Terminal for Isolator Analog Output 1 +</td>
</tr>
<tr>
<td>TB1-11</td>
<td>(Note Shown on Integration Diagram) Terminal for Isolator Analog Output 1 -</td>
</tr>
<tr>
<td>TB1-12</td>
<td>(Note Shown on Integration Diagram) Terminal for Isolator Analog Output 2 +</td>
</tr>
<tr>
<td>TB1-13</td>
<td>(Note Shown on Integration Diagram) Terminal for Isolator Analog Output 2 -</td>
</tr>
</tbody>
</table>