
230509 VARIABLE FREQUENCY DRIVES

Part 1 – GENERAL

1.1 Description

A. This section details the guidelines and expectations for the design, install and programming of variable frequency drives (VFD) on Johns Hopkins University Homewood Campus. Project conditions and requirements vary, thus precluding the absolute adherence to the items identified herein in all cases. However, unless there is adequate written justification and approval from the JHFRE Engineering and Energy Department, it is expected that these guidelines will govern the design and specifications.

1.2 Submittals

A. Submittals shall include the following information:

1. Outline dimensions, conduit entry locations and weight.
2. Customer connection and power wiring diagrams.
3. Complete technical product description include a complete list of options provided. Any portions of this specification not met must be clearly indicated or the supplier and contractor shall be liable to provide all additional components required to meet this specification.

1.3 Quality Assurance

A. The drive manufacturer shall supply the drive and all necessary options as specified here. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of ten years. All VFDs installed on a project shall be from the same manufacturer.

B. VFDs and options shall be UL508 listed as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR without the need for external input fuses.

C. The entire VFD assembly, including the bypass, shall be seismically certified and labeled as such in accordance with the International Building Code.

D. Factory authorized start up and owner training shall be provided.

E. Warranty shall be 36 months from the date of factory shipment. The warranty shall include all parts, labor, travel time and expenses. A toll free 24/365 technical support line shall be available.

1.4 Delivery and storage

A. Material deliveries and storage areas to be approved by Owner.

B. Material storage to comply with manufacturer's recommendations.

Part 2 – PRODUCTS

2.1 Variable Frequency Drives

A. Acceptable Manufacturers

1. ABB
2. Allen Bradley
3. Eaton
4. Yaskawa

B. The VFD package as specified herein and defined on the VFD schedule shall be enclosed in a UL Type enclosure (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer in an ISO9001 facility.

C. The VFD package shall include options for a bypass and line reactors.

D. VFDs are required to be compatible with JHU BAS/DDC systems.

E. The VFD shall provide full rated output from a line of $\pm 10\%$ of nominal voltage. The VFD shall continue to operate without faulting from a line of $+30\%$ to -35% of nominal voltage.

1. VFDs shall be capable of continuous full load operation under the following environmental operating conditions:

a. 5 to 105° F ambient temperature. Operation to 122° F shall be allowed with a 10% reduction from VFD full load current.

b. Altitude 0 to 3300 feet above sea level.

c. Humidity less than 95%, non-condensing.

F. All VFDs shall have the following standard features:

1. All circuit boards shall be coated to protect against corrosion.

2. All VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.

3. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate “bumpless transfer” of speed reference when switching between “Hand” and “Auto” modes. There shall be fault reset and “Help” buttons on the keypad. The Help button shall include “on-line” assistance for programming and troubleshooting.

4. There shall be a built-in time clock in the VFD keypad. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault.

5. The VFD's shall utilize pre-programmed application macros specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.

6. The VFD shall have cooling fans that are designed for easy replacement. The VFD cooling fans shall operate only when required, based on the temperature of and run command to the drive. VFD protection shall be based on thermal sensing and not cooling fan operation.

7. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to set point without tripping or component damage (flying start).

8. The VFD shall have the ability to automatically restart after an over-current, over voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.

9. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds every minute. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.

10. VFDs through 200 HP shall have internal swinging (non-linear) chokes providing impedance equivalent to 5% to reduce the harmonics to the power line. Swinging choke shall be required resulting in superior partial load harmonic reduction. Linear chokes are not acceptable. 5% impedance may be from dual (positive and negative DC bus) chokes, or 5% swinging AC line chokes. VFD's with only one DC choke shall add an AC line choke.

11. The input current rating of the VFD shall not be greater than the output current rating. VFD's with higher input current ratings require the upstream wiring, protection devices, and source transformers to be oversized per NEC 430.122. Input and output current ratings must be shown on the VFD nameplate.

12. The VFD shall include a coordinated AC transient surge protection system consisting of 4 MOVs (phase to phase and phase to ground), a capacitor clamp, 1600 PIV Diode Bridge and internal chokes. The MOV's shall have a minimum 125 joule rating per phase across the diode bridge. VFDs that do not include coordinated AC transient surge protection shall include an external TVSS (Transient Voltage Surge Suppressor).

13. The VFD shall provide a programmable loss-of-load (broken belt/broken coupling) Form-C relay output. The drive shall be programmable to signal the loss-of-load condition via a keypad warning, Form-C relay output, and/or over the serial communications bus.

14. The VFD shall include multiple "two zone" PID algorithms that allow the VFD to maintain PID control from two separate feedback signals (4-20mA, 0-10V, and / or serial communications). The two-zone control PID algorithm will control motor speed based on a minimum, maximum, or average of the two feedback signals.

15. If the input reference is lost, the VFD shall give the user the option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued, as selected by the user.

16. The VFD shall have programmable “Sleep” and “Wake up” functions to allow the drive to be started and stopped from the level of a process feedback signal.

G. All VFDs to have the following adjustments:

1. Three programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed. The lockout range must be fully adjustable, from 0 to full speed.

2. Two PID Set point controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed loop control. The VFD shall have 250ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID set point shall be adjustable from the VFD keypad, analog inputs, or over the communications bus. There shall be two independent parameter sets for the PID controller and the capability to switch between the parameter sets via a digital input, serial communications or from the keypad. The independent parameter sets are typically used for night setback, switching between summer and winter set points, etc.

3. There shall be an independent, second PID loop that can utilize the second analog input and modulate one of the analog outputs to maintain the set point of an independent process (i.e. valves, dampers, etc.). All set points, process variables, etc. to be accessible from the serial communication network.

4. Two programmable analog inputs shall accept current or voltage signals.

5. Two programmable analog outputs (0-20ma or 4-20ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, Active Feedback, and other data.

6. Six programmable digital inputs for maximum flexibility in interfacing with external devices. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC.

7. Three programmable, digital Form-C relay outputs. The relay outputs shall include programmable on and off delay times and adjustable hysteresis. The relays shall be rated for maximum switching current 8 amps at 24VDC and 0.4A at 250VAC; Maximum voltage 300VDC and 250VAC; continuous current rating of 2 amps RMS. Outputs shall be true Form-C type contacts; open collector outputs are not acceptable. Drives that have only two relay outputs must provide an option card that provides additional relay outputs.

8. Run permissive circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications), the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a VFD digital input and allows VFD motor

operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop and the damper shall be commanded to close. The safety input status shall also be transmitted over the serial communications bus.

9. The VFD control shall include a programmable time delay for VFD start and a keypad indication that this time delay is active. A Form-C relay output provides a contact closure to signal the VAV boxes open. The time delay shall be field programmable from 0 – 120 seconds. Start delay shall be active regardless of the start command source (keypad command, input contact closure, time-clock control, or serial communications), and when switching from drive to bypass.

10. Seven programmable preset speeds.

11. Two independently adjustable acceleration and deceleration ramps with 1 – 1800 seconds adjustable time ramps.

12. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise. The VFD shall have selectable software for optimization of motor noise, energy consumption, and motor speed control.

13. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows higher carrier frequency settings without derating the VFD.

14. The VFD shall include password protection against parameter changes.

H. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable) with all VFD faults displayed in English words. The keypad shall include:

1. Start-up assistant
2. Parameter assistants
3. Maintenance assistant
4. Troubleshooting assistant
5. Drive optimizer assistants

I. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):

1. Output Frequency
2. Motor Speed (RPM, %, or Engineering units)
3. Motor Current
4. Motor Torque

5. Motor Power (kW)

6. DC Bus Voltage

7. Output Voltage

J. The VFD shall include a fireman's override input. Upon receipt of a contact closure from the fire/smoke control station, the VFD shall operate in one of two modes: 1) Operate at a programmed predetermined fixed speed ranging from -500Hz (reverse) to 500Hz (forward). 2) Operate in a specific fireman's override PID algorithm that automatically adjusts motor speed based on override set point and feedback. The mode shall override all other inputs (analog/digital, serial communication, and all keypad commands), except customer defined safety run interlocks, and force the motor to run in one of the two modes above. Upon removal of the override signal, the VFD shall resume normal operation, without the need to cycle the normal digital input run command.

K. Serial Communications

1. The VFD shall have an EIA-485 port as standard. The standard protocols shall be Johnson Controls N2, Siemens Building Technologies FLN, and BACnet. Each individual drive shall have the protocol in the base VFD. The use of third-party gateways and multiplexers is not acceptable. All protocols shall be "certified" by the governing authority (i.e. BTL Listing for BACnet). Use of non-certified protocols is not allowed.

2. The BACnet connection shall be an EIA-485, MS/TP interface operating at 9.6, 19.2, 38.4, or 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:

- a. Data Sharing – Read Property – B.
- b. Data Sharing – Write Property – B.
- c. Device Management – Dynamic Device Binding (Who-Is; I-Am).
- d. Device Management – Dynamic Object Binding (Who-Has; I-Have).
- e. Device Management – Communication Control – B.

3. Serial communication capabilities shall include, but not be limited to; run-stop controls, speed set adjustment, and lock and unlock the keypad. The drive shall have the capability of allowing the BAS to monitor feedback such as process variable feedback, output speed/frequency, current (in amps), % torque, power (kW), kilowatt & operating hours (resettable), and drive temperature. The BAS shall also be capable of monitoring the VFD relay output status, digital input status, and all analog input and output values. Remote VFD fault reset shall be possible.

4. Serial communication in bypass (if bypass is specified) shall include, but not be limited to; bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the BAS to monitor feedback such as, current (in

amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The BAS shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible.

5. The VFD/bypass shall allow the BAS to control the drive and bypass digital and analog outputs via the serial interface. This control shall be independent of any VFD function. The analog outputs may be used for modulating chilled water valves or cooling tower bypass valves. The drive and bypass' digital (Form-C relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the drive and bypass' digital inputs shall be capable of being monitored by the BAS system. This allows for remote monitoring of which (of up to 4) safeties are open.

6. The VFD shall include an independent PID loop for customer use. The independent PID loop may be used for cooling tower bypass value control, chilled water value / hot water valve control, etc. Both the VFD PID control loop and the independent PID control loop shall continue functioning even if the serial communications connection is lost.

L. All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level (Category C2) with up to 100 feet of motor cable. Second environment (Category C3, C4) is not acceptable, no Exceptions. Certified test reports shall be provided with the submittals confirming compliance to EN 61800-3, First Environment (C2).

M. DRIVE OPTIONS – Options shall be furnished and mounted by the drive manufacturer as defined on the VFD schedule. All optional features shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

N. BYPASS – Bypasses shall be furnished and mounted by the drive manufacturer as defined on the VFD schedule. All VFD with bypass configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

1. A complete factory wired and tested bypass system consisting of a door interlocked, padlocked circuit breaker, output contactor, bypass contactor and fast acting VFD input fuses. UL Listed motor overload protection shall be provided in both drive and bypass modes.

2. The bypass enclosure door and VFD enclosure must be mechanically interlocked such that the disconnecting device must be in the "Off" position before either enclosure may be accessed.

3. The VFD and bypass package shall have a UL listed short circuit current rating (SCCR) of 100,000 Amps and this rating shall be indicated on the UL data label.

4. The drive and bypass package shall be seismic certified and labeled to the IBC.

5. Drive Isolation Fuses - To ensure maximum availability of bypass operation, fast acting fuses, exclusive to the VFD, shall be provided to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection. Third-party "isolation contactors" are not an acceptable alternative to fuses, as contactors are not an NEC-recognized disconnecting device.

6. The bypass shall maintain positive contactor control through the voltage tolerance window of nominal voltage +30%, -35%. This feature is designed to avoid contactor coil failure during brown out/low line conditions and allow for input single phase operation when in the VFD mode. Designs that will not allow input single phase operation in the VFD mode are not acceptable.

7. Motor protection from single phase power conditions - the bypass system must be able to detect a single-phase input power condition while running in bypass, disengage the motor in a controlled fashion, and give a single-phase input power indication.

8. The bypass system shall be designed for stand-alone operation and shall be completely functional in both Hand and Automatic modes even if the VFD has been removed from the system for repair/replacement. Serial communications shall remain functional even with the VFD removed. Bypass systems that do not maintain full functionality with the drive removed are not acceptable.

9. Serial communications – the bypass shall be capable of being monitored and/or controlled via serial communications. On-board communications protocols shall include Johnson Controls N2 and BACnet MS/TP.

a. Serial communication capabilities shall include, but not be limited to: bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the BAS to monitor feedback such as, current (Amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The BAS shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible. The BAS system shall also be able to monitor if the motor is running in the VFD mode or bypass mode over serial communications.

b. The bypass serial communications shall allow control of the drive/bypass (system) digital outputs via the serial interface. This control shall be independent of any bypass function or operating state. The system digital (relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. All system analog and digital I/O shall be capable of being monitored by the BAS system.

10. There shall be an adjustable motor current sensing circuit for the bypass and VFD modes to provide proof of flow (broken belt) indication. The condition shall be indicated on the keypad display, transmitted over the BAS and/or via a Form-C relay output contact closure. The broken belt indication shall be programmable to be a system (drive and bypass) indication.

11. The digital inputs for the system shall accept 24VDC. The bypass shall incorporate an internally sourced power supply and not require an external control power source. The bypass power board shall supply 250mA of 24VDC for use by others to power external devices.

12. There shall be a coordinated run permissive circuit for damper or valve control. Regardless of the source of a run command, the bypass shall provide a dry contact closure that will signal the damper to open before the motor can run. When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a bypass system input and allows

motor operation. Up to four separate safety interlock inputs shall be provided. When any safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. This feature will also operate in Fireman's override / smoke control mode.

13. The bypass control shall monitor the status of the VFD and bypass contactors and indicate when there is a welded contactor contact or open contactor coil. This failed contactor condition shall be indicated on the bypass LCD display, programmed to activate a Form-C relay output, and / or over the serial communications protocol.

14. The bypass control shall include a programmable time delay bypass start including keypad indication of the time delay. A Form C relay output commands the VAV boxes open. The time delay shall be field programmable from 0 – 120 seconds.

15. There shall be a keypad adjustment to select manual or automatic transfer to bypass. The user shall be able to select via keypad programming which drive faults will result in an automatic transfer to bypass mode and which faults require a manual transfer to bypass.

16. The bypass shall include the ability to select the operating mode of the system (VFD/Bypass) from either the bypass keypad or digital input.

17. The bypass shall include a two-line, 20-character LCD display. The display shall allow the user to access and view:

- a. Bypass motor amps
- b. Bypass input voltage– average and individual phase voltage
- c. Bypass power (kW)
- d. Bypass faults and fault logs
- e. Bypass warnings
- f. Bypass operating time (resettable)
- g. Bypass energy (kilowatt hours – resettable)
- h. I/O status
- i. Parameter settings/programming
- j. Printed circuit board temperature

18. The following indicating lights (LED type) or keypad display indications shall be provided. A test mode or push to test feature shall be provided.

- a. Power-on (Ready)
- b. Run enable
- c. Drive mode selected

- d. Bypass mode selected
- e. Drive running
- f. Bypass running
- g. Drive fault
- h. Bypass fault
- i. Bypass H-O-A mode
- j. Automatic transfer to bypass selected
- k. Safety open
- l. Damper opening
- m. Damper end-switch made

19. The Bypass controller shall have six programmable digital inputs, and five programmable Form-C relay outputs. The bypass I/O shall be available to the BAS system even with the VFD removed.

20. The on-board Form-C relay outputs in the bypass shall be programmable for any of the following indications.

- a. System started
- b. System running
- c. Bypass override enabled
- d. Drive fault
- e. Bypass fault
- f. Bypass H-O-A position
- g. Motor proof-of-flow (broken belt)
- h. Overload
- i. Bypass selected
- j. Bypass run
- k. System started (damper opening)
- l. Bypass alarm
- m. Over temperature

21. The bypass shall provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in VFD or Bypass mode. The remote start/stop contact shall operate in VFD and bypass modes. The terminal strip shall allow for independent connection of up to four unique safety inputs.

22. The bypass shall include a supervisory control mode. In this bypass mode, the bypass shall monitor the value of the VFD's analog input (feedback). This feedback value is used to control the bypass contactor on and off state. The supervisory mode shall allow the user to maintain control over applications such as cooling towers and booster pumps.

23. Smoke Control Override Mode (Override 1) – The bypass shall include a dedicated digital input that will transfer the motor from VFD mode to Bypass mode upon receipt of a dry contact closure from the Fire / Smoke Control System. The Smoke Control Override Mode action is not programmable and will always function as described in the bypass User's Manual documentation. In this mode, the system will ignore low priority safeties and acknowledge high priority safeties. All keypad control, serial communications control, and normal customer start / stop control inputs will be disregarded. This Smoke Control Mode shall be designed to meet the intent of UL864/UUKL.

24. Fireman's Override Mode (Override 2) – the bypass shall include a second, programmable override input which will allow the user to configure the unit to acknowledge some digital inputs, all digital inputs, ignore digital inputs or any combination of the above. This programmability allows the user to program the bypass unit to react in whatever manner the local Authority Having Jurisdiction (AHJ) requires. The Override 2 action may be programmed for "Run-to-Destruction". The user may also force the unit into Override 2 via the serial communications link.

O. Maintenance Material Requirement: Spares are to be turned over to JHFRE, but left on site of project with storage space determined during planning phase.

1. Power Fuses: Equal to 10% of quantity installed for each size and type, but no fewer than three of each size and type.

2. Control Power Fuses: Equal to 10% of quantity installed for each size and type, but no fewer than two of each size and type.

3. Indicating Lights: Two of each type and color installed.

4. Auxiliary Contact: Equal to 10% of quantity installed for each size and type, but no fewer than three of each size and type.

5. Power Contacts: Equal to 10% of quantity installed for each size and type, but no fewer than three of each size and type.

Part 3 – EXECUTION

3.1 Installation

A. Installation shall be the responsibility of the mechanical contractor. The contractor shall install the drive-in accordance with the recommendations of the VFD manufacturer as outlined in the VFD installation manual.

B. Power wiring shall be completed by the electrical contractor, to NEC code 430.122 wiring requirements based on the VFD input current. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

C. Indoor installation (mechanical room or penthouse) is strongly preferred by JHFRE for all VFDs, including those serving rooftop units.

3.2 Start-Up

A. Factory start-up shall be provided for each drive by a factory authorized service center. A startup form shall be filled out for each drive with a copy provided to the owner, and a copy kept on file at the manufacturer.

3.3 Product Support

A. Factory trained application engineering and service personnel that are thoroughly familiar with the VFD products offered shall be locally available at both the specifying and installation locations.

B. Training shall include installation, programming and operation of the VFD, bypass and serial communication. Factory authorized start up and owner training to be provided locally upon request.