Basis of Design

This section applies to the design and installation of motors and variable frequency drives for HVAC and plumbing systems.

Design Criteria

- The University wants motor driven systems that use “off the shelf” premium efficiency motors so if the motor fails, an appropriate replacement can be located in stock in Seattle. If the Consultant creates a need for an unusual motor (inverter rated, 900 RPM, metric, etc.) it may not be replaced in kind when it fails.

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase**: Provide a basis of design narrative describing HVAC and/or plumbing systems to be equipped with variable speed drives and any unusual motors.
- **Design Development Phase**: Provide preliminary motor schedule, motor service clearances, VFD locations and service clearances, and outline specifications.
- **Construction Document Phase**: Provide final motor and VFD schedule, motor service clearances, VFD locations and service clearances, and final specifications.

Construction Submittals

- Provide industry standard construction submittals.

Related Sections

- Facilities Services Design Guide – Mechanical - General Requirements
- Facilities Services Design Guide – Mechanical - Heating, Ventilating and Air Conditioning
  - Air Handlers and Ventilation Fans
- Facilities Services Design Guide – Mechanical - Pumps
- Facilities Services Design Guide – Mechanical - Nonstructural Component Seismic Design
- Facilities Services Design Guide – Mechanical - Identification
- Facilities Services Design Guide – Mechanical - Environmental Control Systems
- Facilities Services Design Guide – Mechanical - Testing, Adjusting and Balancing
- Facilities Services Design Guide – Mechanical - Commissioning
Electric Motors

- Endeavor to use NEMA rated 1800 RPM motors with Class F insulation when appropriately matched to the driven equipment. Do not select motor speeds requiring V-belt drive reduction ratios greater than 6 to 1.
- Identify the type of control for every motor within the scope of the project.
- Motor bearings shall be factory lubricated for motors less than 1/3 HP. Sleeve bearings will only be permitted for fractional HP motors and where specifically recommended by the equipment manufacturer as the better type of bearing for the application.
- Vertical shaft motors shall be equipped with suitable thrust bearings.
- Shaded pole-type motors ≥ 1/8 HP are not acceptable.
- Motors shall typically be open drip-proof construction. Totally enclosed or explosion proof types shall be provided where conditions dictate.
- Motors shall be sized to operate between 70% and 95% of full motor load when running at full 60 Hz speed. If a larger future load is anticipated, size the motor mounting pad to accommodate the larger anticipated motor frame size.

Variable Frequency Drives

- Most HVAC motors larger than 5 HP will use VFDs for modulation of flow and pressure. Compressors and vacuum pumps may be the only typical exception to this expectation. VFDs, motors and Environmental Controls are all within the Mechanical section to facilitate proper coordination. The Electrical section provides all electric supply equipment and wiring to the input of the VFD and the connecting wiring for the VFD, Environmental Control System and motor.
- By-pass starter: A manual by-pass starter is typically required when there is no redundancy. The use of a By-pass starter should be discussed with Campus Engineering. Critical-need applications require an automatic bypass feature. In some critical applications, a backup fan or pump and VFD is provided, in which case by-pass starters may not be necessary. The by-pass feature shall be fully isolated. All safeties shall operate in by-pass mode. Manual Start Operation shall operate VFD or bypass starter. A soft start is required for motor 50 hp and greater.
- Amperage interrupt capacity: Requirements can vary depending on the electrical system design. The nominal requirement is a 65,000 RMS symmetrical ampere interrupting capacity. Some electric services require less capacity, so the mechanical should coordinate with the electrical designer and comply with the protective device study to determine the appropriate specification.
- Radio frequency sensitive applications: A VFD may be installed in the vicinity of highly sensitive research or medical equipment. Radio microphones and sound reinforcement equipment may also be susceptible to RF generated by a VFD. An appropriate FCC rating may be necessary in these applications, and this requirement may result in the use of 6-step or 12-step technology VFDs. Review with Campus Engineering if control and interface requirements in the guide specification cannot be met.
• Interface with Environmental Control System: The guide specification requires both hardwire and digital connection to the environmental control system. These requirements should be carefully reviewed and coordinated with the environmental control system specifications.

• Interface with the Fire/Lifesafety Systems: Ensure the Fire/Life Safety system operation sequence is met in Manual, Off, Auto, and Bypass Modes. Verify the correct speed is maintained in all Modes.

• Sheaves and impellers: Motor Speed should be used as the adjustment mechanism for balancing critical paths in air and water systems. After testing and balancing is complete, adjust sheaves, impellers and motor sizes as necessary so that the motor operates above 55 Hz and between 70% and 95% of full load amperage when the maximum desired system pressures and flows are produced. When the motor operates in VFD bypass at 60 Hz, system pressures and flows shall not cause problems and the motor current shall not exceed full load amperage. It may be necessary to install pressure protection switches and/or duct blowout panels to protect variable air volume systems from over-pressure. Coordinate these requirements with the Testing and Balancing requirements.

• Line reactance: Provide a minimum of 3% input line reactance. This may be provided in the form of separate line reactors at the input of the VFD, reactors included as part of the DC bus or a combination of the two totaling 3% to 5%.

• Total Harmonic Distortion (THD): Specify in the documents that the THD at the point of common coupling for all VFDs connected, shall be less than 5% and to provide required filtering equipment in conjunction with line reactors.

• Output rate of rise, peak output voltage and wire length: A primary purpose of the guide specification is to purchase and install VFDs that will not damage typical premium efficiency motors. Implementing the following three requirements will essentially eliminate motor insulation and bearing failures associated with VFD use.
  1) Use output filtering to keep the rate of rise, for each pulse in the output, below 1,000 volts/microsecond.
  2) Use output circuitry, which prevents the peak output voltage from reaching 1,000 volts to ground at the motor.
  3) Limit wire length to less than 50 feet between the motor and VFD. Demonstrate the 50 foot distance in the contract documents.

• Provide damper control accessory.

Installation, Fabrication and Construction

Electric Motors

• Do not expose motors to the weather. Install motors within the building or in suitable enclosures. If motors are not housed within the building structure, specify totally enclosed type motors, even though a weatherproof enclosure is provided. Provide motor heaters in outdoor enclosures.

Variable Frequency Drives

• Mount the VFD close enough to the motor to keep the wire length below 50 feet (shorter is better). Coordinate with the electrical designer to ensure that this requirement is met. It is also necessary that the VFD be solidly mounted to structural members.
1) Unistrut type structures can be used in most mounting circumstances.

2) Do not mount VFDs directly to the flexible sides of air handling units, plenums or ductwork.

3) Avoid mounting VFDs outdoors, inside plenums, or adjacent to piping that could spray a leak onto the VFD housing. Discuss VFD location with Campus Engineering.

- Verify working clearances within air handling unit service areas. Special manufacturing may be required.

END OF DESIGN GUIDE SECTION
GUIDE SPECIFICATION

The following specification is intended as a guide only. The Consultant shall write the specifications to meet the project needs in consultation with the Owner.

MECHANICAL – ELECTRIC MOTORS IN HVAC AND PLUMBING APPLICATIONS

PART 1 - GENERAL

1.01 SCOPE

A. These standards apply to the selection and installation of electric motors used in HVAC applications. Coordinate all requirements and references with other divisions.

1.02 RELATED DOCUMENTS

A. Division 15: Variable Frequency Drives
B. Division 16: Motor Controls (including disconnects) Power Factor Correction, Identification and Power System Studies.

1.03 CODES, REGULATIONS, AND STANDARDS

A. Motors shall conform to N.E.M.A. standards for each specific purpose and application.
B. Motors shall meet or exceed Seattle Energy Code.
C. Motor shall be listed and labeled by a recognized laboratory such as UL or ETL.

PART 2 - PRODUCTS

2.01 SPECIFICATIONS

A. Motor efficiency shall exceed values listed in NEMA Table 12.6C when tested in accordance with IEEE Standard 112 Method B as defined by NEMA Standard MG 1-12.6C.
B. Motors shall be rated for "continuous duty," with Class F insulation.
C. The service factor shall be 1.15 for 3 phase motors and 1.35 for single-phase motors.
D. NEMA MG-1 Part 31 for applications where motor drops below 60 to 90% speed range.
E. Every motor shall have its unique serial number clearly engraved or stamped on a non-corrosive metal nameplate at the factory. This nameplate shall be permanently attached to the motor with metal fasteners.
F. Motors over 5 HP shall be provided with power factor correction capacitors. Power factor shall be corrected to 97%. Coordinate with Electrical and refer to Electrical – Motor Control Centers.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Install materials in accordance with drawings, approved shop drawings and manufacturer’s recommendations.

END OF GUIDE SPECIFICATION:
ELECTRIC MOTORS IN HVAC AND PLUMBING APPLICATIONS
GUIDE SPECIFICATION

The following guide specification is intended to be modified and included in the construction contract documents. Items to be modified will be decided by consultation involving the Project Manager, the A/E, and Campus Engineering. The A/E is expected to modify this and other specifications as necessary to accurately reflect VFD requirements based upon specific conditions of the project.

MECHANICAL – VARIABLE FREQUENCY DRIVES (VFD) IN HVAC AND PLUMBING APPLICATIONS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Included are VFDs in variable torque applications for Division 15 work.

B. Related documents

1. Motors and VFDs - Electric Motors in HVAC Applications
2. Environmental Control Systems
3. Testing, Adjusting and Balancing
4. Electrical - Motor Equipment
5. Electrical - Equipment Identification
6. Electrical - Variable Frequency Drive Installation
7. Electrical – Protective Device Study

C. Submittals

1. Submit product manuals and drawings including wiring diagrams, dimensions and catalog information indicating all electrical and mechanical characteristics.
2. Submit one set of operating, troubleshooting, repair and maintenance manuals.

D. Shop drawings

1. Provide wiring diagrams to external devices including Environmental and Fire Alarm Controls.

E. Regulations

1. All provided products shall be listed as a package with Underwriters Laboratories (UL).

PART 2 - PRODUCTS

2.01 REQUIREMENTS

A. Approved Manufacturers: Provide VFDs that meet all specifications and are manufactured by Allen Bradley Powerflex 70, Danfoss VLT 6000, or Yaskawa GPD 506. No substitutions will be accepted.
B. Construction: The adjustable speed drive and all associated equipment shall be mounted in a NEMA 1 enclosure(s). This entire package will be referred to as the VFD.

1. Provide the VFD enclosure with an electric disconnect switch which can be locked in the OFF position with a padlock.

2. Provide the VFD enclosure with door interlocks that prevent the door from opening when the operating handle is in the ON position. This feature must be defeatable through a simple but not obvious means.

3. Provide between 3% and 5% input reactance in the form of line and DC bus reactors.

4. Provide output devices as necessary to limit peak output voltage to less than 1,000 volts to ground, at the motor when connected to the VFD by less than 50 feet of wire, and to reduce the VFD output rise time to less than 1,000 volts per microsecond. These output filter devices shall be designed for constant duty with the VFD operating at full rated load.

5. Provide a bypass contactor as a means to manually connect the motor “across the line” to the input power source while electrically isolating the VFD from both the input power source and the motor. Provide a full voltage, non-reversing contactor for line operation of the motor and a manual “VFD/Bypass” switch mounted to the VFD enclosure door. For motors above 50HP use reduced voltage starters.

6. The VFD shall have at least 65,000 RMS symmetrical ampere interrupting capacity.

7. Provide auxiliary contact that will allow damper control to operate in bypass.

C. Interface

1. All VFDs shall use one common type of operator interface.

2. Provide complete programming software for use in a laptop PC so that changes to the VFD program can be made by directly connecting the laptop to the VFD.

3. Primary control of ON/OFF, speed and failure annunciation shall be through a hardwired connection to the Environmental Control system. Provide the following:
   a. A dry contact output enunciating VFD failure,
   b. An ON/OFF input which responds to a remote dry contact closure,
   c. A speed control input which responds to remote 4-20 mA and 0-10 VDC signals.

4. The Environmental Control system will be used to diagnose VFD conditions and to reconfigure resident VFD software. Provide all hardware, software and connecting cable as necessary to digitally communicate and exchange information with the Environmental Control system using Johnson N2 bus, Siemens P1 LAN or equal interface appropriate for use with the installed DDC equipment.
   a. The exchanged information shall include motor speed, electric load in kW, Volts, Amps, VFD fault description, Hand/Off/Auto/Bypass mode and network point address.
   b. It shall be possible to modify VFD settings including acceleration and deceleration times and skip frequency ranges using the environmental control system operator station.
5. Fire alarm interface
   a. Provide an override input so that opening dry contacts will absolutely stop the motor under any operating condition.
   b. Provide an override input so that closing dry contacts will cause the motor to operate at a speed predetermined by VFD programming.
   c. Provide a Summary Alarm dry contact for connection to the Fire Alarm system, indicating that the VFD is not operable.
   d. Provide auxiliary contact that will allow damper control to operate in bypass.

2.02 PERFORMANCE

A. The VFD shall not create a voltage rate of change greater than 1000 volts/microsecond nor a peak voltage greater than 1000 volts to ground at the motor when the motor is connected to the VFD by less than 50 feet of wire.

B. The carrier frequency of pulse width modulated VFDs shall be variable and adjusted so motor noise resulting from the VFD, measured at 3 feet from the motor, is less than 3 dB greater than the motor noise when operating across the line. Carrier frequency adjustment shall be available such that the average carrier frequency can be maintained at less than 9 kHz while meeting acoustical noise requirements.

C. Configure the VFD so, when turned ON, it will accommodate for motor rotation in either direction and drive the motor to control setpoint.

PART 3 - EXECUTION

3.01 INSTALLATION, START-UP, TESTING

A. The VFD shall be sized to continually operate at $\geq 105\%$ of nameplate load of the motor to which it is applied.

B. Installation and field wiring
   1. Mounting and Control wiring shall be by Division 15. VFD shall be mounted so power wires connecting the VFD to the motor are less than 50 feet in length.
   2. VFD shall be mounted to rigid Unistrut type and/or building structures.
   3. Power wiring shall be by Division 16.
   4. Submit Protective Device Study (Electrical) so total harmonic distortion (THD) adjustments can be determined.

C. Field start up and testing
   1. Start up and testing shall be provided at the installation site by the manufacturer or other agent deemed acceptable by the University. The University shall witness the final operational demonstration.
   2. Verify all installation connections and controls.
3. Field-adjust all safety controls.

4. Field-adjust VFD parameters as follows: Acceleration time - 60 seconds for fans and 10 seconds for pumps
   a. Deceleration time - 65 seconds for fans; 20 seconds for pumps
   b. Minimum fan speed - 15 Hz for supply fans; 6 Hz for return/exhaust fans
   c. Minimum pump speed – as stated by pump manufacturer or 450 RPM as default
   d. Program the VFD so that, upon reapplication of power after a power failure, the VFD shall automatically reapply power and drive the motor to control setpoint.
   e. Program the VFD so that there are an infinite number of restarts that will be made within one hour after shutdown due to input power problems.
   f. Adjust the carrier frequency to provide optimum efficiency while not increasing motor noise more than 3 dB measured at 3 feet from motor.

5. Demonstrate operation of the VFD including control, display of information and programming by the environmental control system and a laptop PC, return to operation after a power failure, and the by-pass contactor.

6. Record and place final setting at each VFD.

D. Training
   1. Provide on-site operation and maintenance training for two identical 4-hour sessions. Coordinate training times with the University.
   2. Provide 6 sets of operating, troubleshooting, repair and maintenance manuals. Provide final settings programmed into the VFD’s in the O&M manuals.

E. Service during the warranty period
   1. The VFD shall be serviced by an agency located within 50 miles of the installed location.
   2. Qualified technical support shall be available on site within 24 hours of request.

F. Repair parts
   1. During the warranty period, replacement parts shall be available on site within 48 hours of initial request for service.

END OF GUIDE SPECIFICATION:
VARIABLE FREQUENCY DRIVES (VFD) IN HVAC AND PLUMBING APPLICATIONS