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 (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.

Products, Material and Equipment

**Electric Motors**

- Endeavor to use NEMA rated 1800 RPM motors with Class F or H 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 \( \geq 1/8 \) 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.
- Motors that are controlled by VFDs shall have shaft grounding. Approved: AEGIS.

**Variable Frequency Drives**

- Specify VFD manufacturers limited to Allen Bradley, Danfoss, and Yaskawa.
- 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 or Dual VFD: A manual by-pass starter or dual VFD is typically required when there is no redundancy. The use of a By-pass starter or dual VFD should be discussed with Engineering Services. Critical-need applications without redundancy require an automatic bypass feature or dual VFD feature. In some critical applications, a backup fan or pump and VFD is provided, in which case by-pass starters or dual VFDs may not be necessary. The by-pass feature or dual VFD shall be fully isolated. All safeties shall operate in by-pass or dual VFD 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 amperes 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 Engineering Services 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/Life safety 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.
- Provide display and keypad for all drives, mounted either locally through enclosure door or remotely.

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

END OF DESIGN GUIDE SECTION