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Overspeed Motors

Introduction

Historically in the United States, with our 60 Hertz (Hz) alternating current electrical (AC) frequency, motors operate between minimum rotational speed (as low as 0 Hz/0 Rotations Per Minute (RPM)) and 60 Hz (maximum motor RPM). With the use of Variable Frequency Drives (VFD), motors can be run at higher than 60 Hz, known as an overspeed condition, typically as direct drive fan wall/plenum fans (per NIH DRM 6.2.4.2, the maximum operating speed is 90 Hz). Multiple important factors must be considered before allowing a motor to operate at this overspeed condition, whether it happens by design or to meet field conditions that are outside design intent.

Requirements for Air Barrier

The first important factor is the torque produced by the motor when operating at overspeed conditions. As motor speeds extend beyond 60 Hz, motor torque reduces. This torque reduction occurs because motor impedance increases as frequency does. Since a VFD cannot increase the voltage above its supply voltage, the current decreases as frequency increases, decreasing the available torque. Motor torque is calculated as:

$$\text{Torque} = (\text{Line Frequency}/\text{Extended Frequency})^2$$

or

$$\text{Torque} = (\text{Base Frequency}/\text{Extended Frequency})^2$$

As can be seen by the graph below, motor speed can potentially be increased to 120 Hz, but the torque output of the motor at that speed would only be 50% of the output at 60 Hz. Other factors such as bearing efficiency can reduce the torque output even further. Without careful design consideration, this could result in underpowered output for the application.

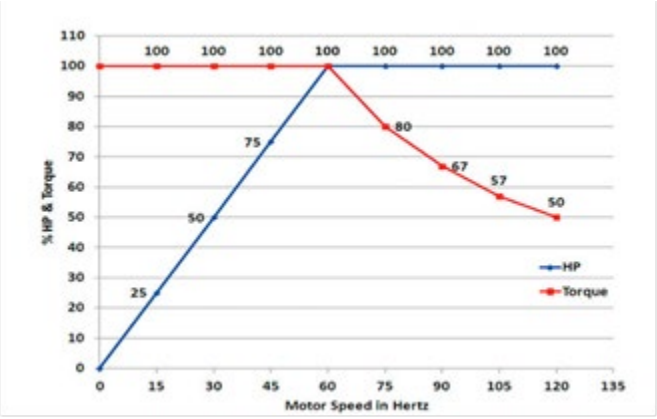

Figure 1: Motor Speed vs. Torque

The second important factor is confirmation that the motor can run at the overspeed frequency without being damaged. Operating motors at an overspeed frequency they are not capable of sustaining can result in a shortened life expectancy, or even motor break up. Among the motor features that must be considered when running at overspeed:

- Motor rating:
  - Many general duty motors are not rated to handle overspeed operation. At minimum, a motor should be rated for VFD operation and be equipped with shaft grounding such as an Aegis grounding ring. Even with this rating, the manufacturer should be consulted to confirm the motor can operate at the anticipated overspeed condition. Motor imbalance tolerance will be amplified at higher speed and will exacerbate vibrations, reducing the motor's useful life.
  - Motors rated as "Inverter Duty," which meet National Electrical Manufacturers Association (NEMA) Standard MG-1 Part 31, are designed to handle the voltage spikes associated with VFDs and can therefore be operated at overspeed without potential damage to the motor. It should be noted that inverter duty motors can also be operated at very low speeds without overheating.
- Bearing speed rating:
  - Bearing manufacturers provide tables for speed ratings where bearings can be operated without overheating. When confirming that a motor can operate at an overspeed condition, the motor manufacturer should provide tables and confirmation from the bearing manufacturer that their bearings can safely operate at the anticipated speed without heat buildup that could reduce operational life.

The third important factor to consider when evaluating a motor at overspeed conditions is the operation of the connected system when the VFD is set to bypass mode (frequency at 60 Hz). For motors on critical systems, such as fans handling pressure control for hospital or laboratory directional airflow, the motor speed is potentially critical to maintaining infection and containment control. For these types of applications, maintenance personnel may be required to operate the fans in bypass mode to keep a space in operation while addressing immediate maintenance or repair issues. In cases where motors are operating at an overspeed condition, this change in mode of operation could result in serious consequences, such as airflow reversals and impact to room air change rates.

The motor-driven machinery must also be carefully evaluated for operation. Fan wheels, pump impellers, drive belts, and other rotating devices have rotational / speed limitations that must be considered. Design engineers must analyze the operation of the systems when the VFD is operating in bypass mode to confirm all failure mode control sequences have been accounted for in order to prevent any serious consequences.

Conclusion

While it is possible for some types of motors to operate well over their nameplate frequency, there are critical factors that need to be carefully considered by the design engineer before allowing a motor to operate at these conditions. Failing to review these factors can result in significant consequences for both the motors and the spaces they operate in.