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T.E.F.C. Motors Minimum Speed with Inverters

What is the minimum speed that an AC induction motor (T.E.F.C.) can operate at when using an inverter to control the speed?

This is a frequently ask question, and the answer varies with applications.

When using a volts/hertz PWM inverter with a standard T.E.F.C. (Totally Enclosed Fan Cooled) AC induction motor. The inverter can operate the motor as slow as 1.5Hz or 2.5% of 60Hz. This is approximately 45 RPM for an 1800 RPM, 4 – pole motor.

If the motor is run at this speed or lower for long periods of time the motor can overheat. This is due to the fact that the cooling fan on this type of motor is connected to the shaft of the motor. Therefore the slower the motor rotates; the slower the fan rotates and produces reduced airflow through the motor. The air is moved through the motor, to provide cooling to the windings of the motor.

One of the fan laws state mathematically:

$$\frac{CFM_2}{CFM_1} = \frac{RPM_2}{RPM_1}$$

CFM₁ = maximum Cubic Feet per/Minute.

CFM₂ = Cubic Feet per/minute at other than maximum.

RPM₁ = maximum Rotations Per Minute

RPM₂ = Rotations Per Minute at other than maximum.

Example:

An 1800-RPM motor fan develops 600 CFM at base speed (60Hz).

If that motor is operated at 45 RPM (1.5Hz) the fan will deliver about 15 CFM of air across the winding of the motor. If the motor is fully loaded then 15 CFM will not provide proper cooling to the motor.

This would be typical of a constant torque application, such as a conveyor, extruder or other types of motor loads where the load on the motor is constant regardless of the speed.

Examples of variable torque loads are fans and centrifugal pumps, where as the speed changes, so does the load on the motor. With fans the horsepower changes with the cube of the speed change. This is represented mathematically as:

$$\frac{HP_2}{HP_1} = \frac{RPM_2^{(3)}}{RPM_1^{(3)}}$$

HP₁ = maximum Horsepower.

HP₂ = Horsepower at other than maximum.

RPM₁⁽³⁾ = maximum Rotations Per Minute cubed

RPM₂⁽³⁾ = Rotations Per Minute at other than maximum cubed.

Example:

The same 1800-RPM motor is rated at 20HP and develops 20HP when connected to a fan load. When the speed of the motor is reduced to 45RPM the horsepower required is reduced to 0.0003 HP. This represents an insignificant amount of load current to the motor.

Due to the nature of motors there are two types of currents developed, one being torque producing current (load). The other is magnetizing current; this is the amount of current it takes to make the motor rotate under no load conditions.

Magnetizing current can be as much as 30% of a motor full load ampere rating.

This means that even though there may be a small torque producing load on the motor, there is always approximately 30% current flowing in motor that is operating. Current flowing through wire creates heat. Excessive heat can cause motor winding insulation to break down and fail.

Keep in mind that motor fans are designed to deliver maximum CFM at their base speed (60Hz). When they are operated at speeds less than design speed less CFM is being developed. Less CFM means more heat retained in the motor windings.

A general rule of thumb used within industry is, to limit the operation of a T.E.F.C. motor from an inverter below approximately 50% of the base speed of the motor or 30Hz without providing a cooling method. When in doubt, please consult the motor manufacture for application assistance. If operation over a large speed range is desired, an inverter duty motor should be used. These motors are designed with larger frame sizes or external cooling methods to dissipate the heat and protect the motor windings.