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## **Inverter Duty Motors**



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# INVERTER DUTY MOTORS

## Overview

This short course provides general but pertinent information on inverter duty motor. This course is intended for engineers in general and can be helpful for electrical engineers as well. It provides general information about inverter duty motor and related aspects. This information may be most suitable for engineers who want to become familiar with or intend to make use of variable frequency drive or inverter duty motor.

The information gained from this course will help an engineer apply the right approach and avoid equipment mismatch. The information is presented in concise and general terms that most engineers are expected to be familiar with. Technical details or mathematical formulas are avoided so that the ideas are covered in a simple manner. This course is not to be considered as comprehensive and is intended to be a refresher or introductory course.

## Definitions

**Horsepower:** Measure of power or rate of work done. Work done at the rate of 33,000 foot pounds per minute is defined as one horse power or HP. One HP = 746 watts.

**Voltage:** Volt, short for voltage is the unit measure of electric pressure. The pressure that will cause a current flow of one ampere through a one-ohm resistor is called one Volt.

**Frequency:** The number of periods or cycles an event is repeated in a particular time period is defined as Frequency, such as in the flow of electricity. For alternating current the number of complete cycles in a second, from zero to positive maximum then to zero and then negative maximum and then to zero, is called frequency per second. Example: Utility Power Frequency is 60 Hertz or 60 cycles per second in US.

**Harmonics:** Utility Power has sine wave power at 60 Hertz in US. Power generated from DC using inverters creates square waves due to switching. This square wave power inherently has harmonics of the fundamental frequency. Normally present are 3, 5 and 7th harmonics in good strength. Higher harmonics are very weak.

## What is inverter duty motor?

Standard AC induction motors, because of their simple design and construction, are more reliable and cheaper than DC motors. For this reason they are very popular. But with standard on line starter their use is limited to fixed speed application even though the process can be run over a speed range. This is a trade off that is made for low cost.

There are applications where, at times, the process can be run at lower speeds. In doing so, peak demand can be reduced and electric bills reduced by the energy savings. For such variable speed applications, a VFD or Variable Frequency Drive, also known as Variable Speed Drive, is needed. Their cost is more than standard direct online starters. But energy savings over time can eventually pay off the higher initial capital cost.

Now comes the question of using the standard speed motor with the VFD. Most regular AC induction motors are designed for use at one speed. A standard induction motor when run at reduced speeds may have inadequate cooling by the motor fan. Over longer time periods, the motor may get overheated and ultimately fail. Also VFD output power to the motor inherently has power frequency harmonics. These harmonics are likely to present higher voltages at the motor winding for which they are not designed to withstand with the result being failure of the motor winding.

An AC induction motor that is specially designed for use with variable frequency drives is commonly known as an inverter duty motor. This motor has windings that can withstand harmonics and higher voltages and is also designed with proper cooling to run at lower speeds.

Different VFD manufacturers have different VFD designs. It may be prudent to buy the inverter duty motor along with the VFD as a package for the application and install them per vendor recommendations.

### **Why an inverter duty motor is needed.**

A regular AC induction motor can be used with a variable frequency drive. It is not uncommon for a user to couple a VFD to an existing regular AC induction motor. The variable frequency drive imposes the characteristics of its output power onto the motor. The existing regular motor is designed for common sine wave utility power. When the motor is subjected to the harmonics present in the variable frequency drive output, its life is shortened due to premature insulation failure.

There are specific applications that can run at varying speeds. A cooling tower fan is a good example. In winter when less cooling is needed, the fan can be run at a lower speed. Consider the two options below:

Option 1: We can use a standard induction motor with direct online starter, but the fan will run at one fixed speed only.

Option 2: A variable frequency drive combined with an inverter duty AC induction motor can be used very effectively and efficiently. Such installations can save energy at lower speeds. Energy savings over a period of time can pay back the extra cost of the variable frequency drive and inverter duty motor relative to the standard motor and motor starter.

Additionally, a properly selected inverter duty motor and variable frequency drive is likely to provide many years of reliable operation.

In applications where the aim is to reduce energy consumption, the use of an inverter duty motor and variable frequency drive combination is called for. In installations where the energy costs are particularly high, there is more incentive to make use of an inverter duty motor and variable frequency drive combination. Many industrial plants already have started to make use of such combinations for their cooling tower fans and other applications.

## **Inverter duty motor types**

A particular variable frequency drive is designed to match the specific load requirements such as speed range, speed accuracy, horsepower, and speed-torque. Hence, several types of variable frequency drives are commercially available.

Thus, it is important that the inverter duty motor and variable frequency drive should match with each other to meet the application and load requirements. Such a system is likely to provide a nice package for the application and prove to be a reliable system. Inverter duty motors are available in various designs just like standard motors. Following are some examples of inverter duty motor designs. Please note motor selection for the areas where hazardous gases may be present, is normally dependent on the hazard area classification for the area, application and evaluation of available vendor recommended motor design.

- TEFC: Totally enclosed fan cooled. This type of inverter duty motor is normally used in chemical plants where corrosive or moderately hazardous gases may occasionally be present.
- ODP: Open drip proof type of inverter duty motor is normally used outdoors in non-hazardous environment.
- TEBC: Totally enclosed blower cooled inverter duty motors are specially designed motors for wide speed range applications. In this design separate blower is utilized to provide adequate motor cooling at lower speed range.
- TENV: Totally enclosed non-ventilated design inverter duty motor is commonly used in moderately hazardous areas.
- Explosion proof motor. This type of motor is normally used in the areas where hazardous gases are expected to be present.
- Gear motor: Inverter duty motor with gear is applied for loads that run at speeds far different than achievable directly with a motor.
- Vector duty: Vector duty inverter motor is applied for applications requiring precise motor speed control.
- Wash-down duty: The wash-down inverter duty motors are designed for production areas that routinely require wash-downs. This is very common in the food industry.

## **Comparison of Inverter duty motor with Standard AC Induction Motor**

A regular AC induction motor is designed for a fixed nominal speed.

An Inverter Duty Motor is designed to run at varying speed within a speed range. This speed range can be 10% to 100% of the standard nominal speed. At lower speeds the fan of a regular AC induction motor will run slower and not provide adequate cooling. An inverter duty motor is designed with special cooling to run at lower speeds without overheating.

The variable frequency drive converts AC power to DC then provides AC power by converting DC to AC using switching and pulse wave modulation methods. The switching and modulation conversion method introduces harmonic frequencies in the AC power output to the cable and to the motor. In such cases, a reflected and an incident pulse can meet at the motor terminals, effectively doubling the voltage at the motor terminals. This is similar to a wave striking a beach, its height increases as it reflects back and crosses other incoming waves. Thus the reflected wave can contribute to doubling the voltage at the motor terminals, which can over time lead to motor winding failure.

Besides other design features, the Inverter Duty Motor has its winding designed to withstand more than twice the nominal voltage. Other features specific to the design of the inverter duty motor include:

- Extra heavy insulation in the slots
- Extra end turn bracing
- Double dip and bake polyester varnish

### **Special considerations in specifying inverter duty motors**

While specifying induction motors for use with variable frequency drives, the following items should be taken into consideration. Where practical these may be included in the specification as requirements for the motor vendor:

- Driven load
- Driven load speed and torque requirements
- Speed range for motor
- Gear or coupling type between the motor and load.
- Conditions where the motor will be installed
- Hazard area classification of the area where the motor will be installed.
- Nominal voltage, frequency and phases for the motor.
- Motor HP and service factor. This may be provided by the vendor supplying the driven load (pump, blower etc.). This vendor may also be required to supply speed-torque curve for the load.

- It is a good practice to include the above information in the specification for the motor as well as for the variable frequency drive.
- In critical applications it is good idea to buy the motor and variable frequency drive as a package from a single vendor.
- The specifications should require the vendor to ensure that the motor and the variable frequency drive match with each other and are suitable for the driven load.
- The above items are in addition to the general requirements, like bearing, space heater, temperature sensors, etc., included in the specification for a motor depending upon motor size, application and other needs.

### **Other design criteria for inverter duty motors**

In addition to the general requirements and code considerations, the following items may help to ensure a good installation.

- Special attention is to be given when sizing the cable for the inverter duty motor. Minimum motor data from the motor vendor is required for cable sizing.
- Sometimes the motor supplied may be a larger motor de-rated to lower size for a particular load application. For this reason, use of the motor nameplate data for sizing the cable is helpful.
- Variable frequency drive vendors, depending on the application, use different methods for reducing the harmonic components in the power output to the motor. Thus, it is important to make use of their recommendations regarding the cable for supplying power to the motor.
- Also, to minimize the induced voltage effect in the nearby cables, it is prudent to use a shielded cable, armored cable or cable in conduit.
- In general, the Variable frequency drive and motor installation shall be completed as per the Variable frequency drive and motor vendor requirements.

### **Sources for additional information**

Inverter Duty Motor manufacturers, their web-sites and their literature.

Trade publications.

Variable Frequency Drive manufacturers, their web-sites and their literature.