

Variable Speed Drives

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Applying Variable Speed Drives

Howard G. Murphy P.E.

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During the past 40 years, the variable speed drive market has changed drastically. Mechanical and electrical speed drives, ie fixed speed motors with adjustable pulleys and gear changers, eddy current clutches, etc. These, in turn were replaced by electronic or solid state drives. From 1950 to 1970, the success of the dc motor drives as the only dependable electronic variable speed drive method created the desire for improved motor control and the start of an ever growing variable speed motor market.

During the 1970s, the ac drive, which controlled a standard 3 phase, ac motor began to replace the dc drive as the only electronic method for obtaining variable speed. In less than 10 years, the PWM (Pulse Width Modulated) ac drive became the most common and widely use method for controlling the speed of an 3 phase ac motor. With the interest in reducing energy consumption and improving the efficiency of motor operated equipment and processes, the demand and utilization of the ac drives resulted in more than 30% of the fixed speed motor market being converted with the application of variable speed ac motor drives.

Significant improvements resulted from these changes, including energy saving, increased efficiency, and improved process control. Global awareness of these improvement, has increased interest so that it is estimated that by the year 2008, more than 70% of the today's fixed speed market will convert to variable speed control using ac drives.

These changes have not been without problems. As the use of variable speed drive increases, the knowledge of how to apply these drives will determine how the success of these applications. There still exists much confusion about ac drives and their impact on motors, distribution systems and how best to operate these drives for a specific application. There are a number of different terms used to describe the ac drive. AFD, VSD, VFD and Inverters all are used but have the same meaning. The main purpose for the all ac drives is to control the operation of the ac motor with regard to speed and torque. Much is still misunderstood about the use and performance of the ac motor. Because of the use of fixed speed ac motors, many types of motors exist. NEMA A, B, C, C and E were designed to modify the starting characteristics of the motor. Synchronous ac motors were design to improve the speed regulation of the ac motor. Most applications have operated with fixed speed ac motors with limited problems. Most problems were mechanical in nature and most solutions were limited to replacing the motor with a larger motor or larger fuses when problems occurred.

Today, a lot of "BUZZWORD" are used by suppliers in any attempt to convince the user that their products are better suited to an application. For the most part there are only subtle differences that exist between the suppliers products. Most applications depend only on the characteristic of the applied motor and the current rating of the ac drive. Accurate speed regulation still depends on some type of feedback where the actual speed is detected. Fortunately, most applications do not required precise speed control and as such can use most of the ac drive product that are on the market. There are differences in the quality of the product and differences in the ability of the

supplier to support and service their products, but in most cases, the user has many choices for supplier and products which will result in the successful use of an ac drive and improvement for the process.

When it comes to applying ac drives, it is important that the user does not get caught up in the "MAGIC" image that some drive supplier attempt to create for their products. When it comes to controlling motors, it is still volts and amps that determine how the motor will perform. AC Drives can control the applied voltage to the motor with a greater degree of accuracy that exists when the motor is direct on line. Although ac drives are design with many control parameters, ie programmable memory, there are very few parameters that must be selected and programmed to operate the ac drive at it in its most effective operating mode. The most important parameters are voltage. Since the speed will vary from low to high speed, the voltages at each of these operating point should be adjusted for optimum performance. At the highest or nameplate rated speed, the voltage should be set to either the nameplate voltage value or to a lower value if the motor is not fully loaded. The exact value for a lightly loaded motor will depend on the motor and the characteristic of the load. Most drive supplier can make a recommendation concerning this point. At low speed, the voltage should be set to a value which allows the motor to develop sufficient torque to overcome the load. Too little voltage will result in not enough torque or too much current. Too much voltage will result in the motor overheating if operation at this low speed continue for a period of time. Fancy names for features of the ac drive like vector control can not ensure proper performance under all operating conditions. Most application can use the ac drive "right out of the box" and experience successful operation. However, some applications may require the ac drive to be "adjusted" using the drive parameters to achieve successful operation.

There are five key points that should be considered when attempting to apply variable speed drives. Since the most common variable speed drive today is the ac drive, this paper will discuss those points as applied to ac motors and ac drives.

The first point is optimizing electrical performance. Since performance depends almost entirely on the characteristic of the ac motor, understanding the ac motor will determine how successful the application will be when the motor is used with an ac drive. The principal reasons for using an ac motor is to convert electrical energy into mechanical energy to do some form of work.

With the use of ac motors, there are two components within the electrical energy used. The most important is the real current the motor converts to mechanical energy. The least important and undesirable is reactive current which turns into heat. Until the PWM ac drive can into existence, little could be done to eliminate or reduce the reactive current component. With the introduction of the PWM ac drive, reactive current, which must exist in the motor, can be eliminated or greater reduced as a burden for the distribution system. PWM drives transfer real current from the ac line to the ac motor and provide an electrical path for the reactive currents which must flow in the motor. No longer does the distribution system have to carry the extra current load. Since more than 20% of the current that flows in most distribution system is reactive, reduction or elimination of the reactive current increases the amount of real current, and resulting real work, that can be transferred by a given distribution system. Applying PWM ac drives where fixed motor had be used will decrease the demand on the distribution system.

A recent trend has been the change from standard efficiency motor to energy efficient motors. Although this transition resulting in an improvement in energy consumption, some unique and somewhat unexpected characteristics were uncovered. Applying an energy efficient motor is an existing fan application in many cases resulted in an increase in energy consumption. This was due to the fact the energy efficient motors run slightly faster than standard efficient motors. Due to the characteristic of a fan power curve, a slight increase in fan speed results in a greater consumption of energy and higher electrical costs. When the same energy efficient motor is used with an ac drive, the speed of the motor can be controlled resulting in a decrease in energy consumption and lower energy costs.

Understanding the nature of motor and the differences between standard and energy efficient motors will aid in knowing how to correctly apply ac drives. The most important aspects when comparing motors is their demand for current. The energy efficient motor demands more current when starting across the line than the standard efficient motor. However, when used with an ac drive, that disadvantage is eliminated. Inrush current when starting a motor using an ac drive is less than full load amps. Another factor is a slightly higher line voltage will result in a very hot energy efficient motor. With an ac drive, the motor voltage can be adjusted to the correct value to eliminate unnecessary heating in the motor. Of the many types of ac drives, only the PWM drives offers a distinct advantage regarding eliminating or reducing high current demands from the distribution system. Besides the near unity power factor of the PWM ac drive, the reduction in reactive current yields a much more effective means of controlling an ac motor. For example, a 460v, 100 HP motor would require about 124 amps from the distribution system if operated direct on line. That same motor doing exactly the same work would only require about 100 amps from the distribution system. This translates into lower energy upstream losses in wires, transformer, etc. and may result in lower utility charges for poor power factor.

The next point is the opportunity to reduce energy costs by eliminating unnecessary losses in the application. In a variable volume fan application where inlet dampers or output vanes are used to control the airflow, substantial energy costs can be obtained with the application of ac drives. By controlling the speed of the fan directly, flow can be controlled and pressure losses across the fan blades can be reduced. In many applications, as much as a 50% reduction in energy costs have been obtained by using ac drives to control the air flow.

To control the flow by restricting the amount of air that can flow results in pressure build up in the system. Removing the restrictive device, such as a outlet damper or inlet vane and applying an ac drive to directly control the speed of the motor and thus the fan results in reducing system pressures contributing to substantial energy savings.

The same principles can be used in the control of pumps in many applications. Replacing the throttling valves with ac drives, can reduce the pressure losses that exist on the impeller blades of the pump. In both cases, eliminating the high inrush current associated with starting a motor across the line are part of the advantages that are obtained when using an ac drive to control the ac motor that runs the fan or pump.

Another factor is eliminating high starting current losses. With standard efficient motors, the lock rotor current is 6 to 8 times full load amps. With energy efficient motors, the lock rotor current is 8 to 10 times full load amps. With an PWM ac drive, the starting current is never more than full loads amps and generally much less.

In many cases where an on-off method is used to control flow, merely selecting a slightly lower operating speed and operating at that lower speed for a slightly longer period of time will result in significant energy savings.

When applying ac drives, the response time compared to other means of flow control is much faster. Short term high energy demands are eliminated thus reducing short high energy costs. Regardless of the type of ac motor, standard or energy efficient, the application of the ac drive improves performance of the process while maximizing the efficiency of the system. The use of energy efficient motor will further increase efficiency.

There are motor considerations to apply when using PWM ac drives. In most cases, no concerns exist relative to heating insulation and torque capability of the motor. In some applications, these factors must be considered. Most supplier can advise the type of drive adjustment (parameter settings) that will be useful in those applications. Generally, adjusting the voltage at various

operating speeds and adjusting the acceleration and deceleration parameters are all that is required.

Addressing ac drive system concerns include a number of issues where many unfamiliar terms are used. Harmonics, reflected waves, EMI, etc. For most applications, these factors need not be considered. Most drive supplier provide information and guidelines covering these topics. Installation practices are most important and may have undesirable results if recommendations are not followed. Power feeds should include a 4th wire to provide a path for high frequency leakage currents that exist in all ac drive installations. Although it is likely that a 3 wire power feed will appear to work, currents circulating in undefined ground path may result in electrical noise which could affect other electronic signal type equipment such as sensors and metering.

Signal and power wires should never use the same conduit. Multiple motor circuits should be kept to less than 5. Grounding should be based on high frequency grounds for low ground to neutral voltages, not 60 Hz methods. All PWM ac drives should have at least 3% series impedance between the voltage supply and the drive. Branch circuit protection can use same methods as used for fixed speed motor, however ac drives will sense current malfunction faster and indicate those conditions but turning off and displaying the condition which cause the shutdown.

During operation, the ac motor should always be started using the ac drive. Motor starters should never be used to stop or start the motor. Time should be allowed for the field in the motor to build so that full torque capability is available. During running, acceleration and deceleration rates or times should be selected so that the drive stays within its current rating. Too rapid an acceleration will force an overcurrent condition and may cause the drive to shut down. Use the drive to stop the motor, do not remove input. The drive must have rated input voltage in order to maintain control over the motor. Any energy stored in the motor must be absorbed if the motor is to be brought to a rapid stop. This energy can cause drive to trip on overvoltage conditions if the energy is not absorbed.

In general, most applications can use a standard or energy efficient motor with an ac drive and improve energy saving and performance. Some applications need a "little extra attention." Applying ac drives can be made simple if care is taken regarding voltage from the source and current demanded by the motor. Some thought about subtle changes to a process can yield large results.