Vector drive:

A standard VFD (lets call it a Scalar Drive) puts out a PWM pattern designed to maintain a constant V/Hz pattern to the motor under ideal conditions. How the motor reacts to that PWM pattern is very dependent upon the load conditions. The Scalar drive knows nothing about that, it only tells the motor what to do. If for example it provides 43Hz to the motor, and the motor spins at a speed equivalent to 40Hz, the Scalar Drive doesn't know. You can't do true torque control with a scalar drive because it has no way of knowing what the motor output torque is (beyond an educated guess).

A Vector Drive uses feedback of various real world information (more on that later) to further modify the PWM pattern to maintain more precise control of the desired operating parameter, be it speed or torque. Using a more powerful and faster microprocessor, it uses the feedback information to calculate the exact vector sum of voltage and frequency to attain the goal. In a true closed loop fashion, it goes on to constantly update that vector to maintain it. It tells the motor what to do, then checks to see if it did it, then changes its command to correct for any error. Vector drives come in 2 types, Open Loop and Closed Loop, based upon the way they get their feedback information.

A true Closed Loop Vector Drive uses a shaft encoder on the motor to give positive shaft position indication back to the microprocessor (mP). So when the mP says move x radians, the encoder says "it only moved x-2 radians". The mP then alters the PWM signature on the fly to make up for the error. For torque control, the feedback allows the mP to adjust the pattern so that a constant level of torque can be maintained regardless of speed, i.e. a winder application where diameters are constantly changing. If the shaft moves one way or the other too much, the torque requirement is wrong and the error is corrected. A true closed Loop Vector Drive can also make an AC motor develop continuous full torque at zero speed, something that previously only DC drives were capable of. That makes them suitable for crane and hoist applications where the motor must produce full torque before the brake is released or else the load begins dropping and it can't be stopped. Closed Loop is also so close to being a servo drive that some people use them as such. The shaft encoder can be used to provide precise travel feedback by counting pulses.

Open Loop is actually a misnomer becuase it is actually a closed loop system, but the feedback loop comes from within the VFD itself instead of an external encoder. For this reason there is a trend to refer to them as "Sensorless Vector" drives. The mP creates a mathematical "model" of the motor operating parameters and keeps it in memory. As the motor operates, the mP monitors the output current (mainly), compares it to the model and determines from experience what the different current effects mean in terms of the motor performance. Then the mP executes the necessary error corrections just as the closed Loop Vector Drive does. The only drawback is that as the motor gets slower, the ability of the mP to detect the subtle changes in magnetics becomes more difficult. At zero speed it is generally accepted that an Open loop Vector Drive is not reliable enough to use on cranes and hoists. For most other applications though it is just fine.

This is all done at very high speeds, that is why you did not see Vector Drives as available earlier on. The cost of the high speed mP technology has now come down to every day availability.

The types:

Three basic types of variable frequency drives offer certain advantages as well as disadvantages depending on your motor application. The new flux vector drive is also discussed.

While all variable frequency drives (VFDs) control the speed of an AC induction motor by varying the motor's supplied voltage and frequency of power, they all do not use the same designs in doing so. There are three major VFD designs commonly used today: pulse width modulation (PWM), current source inverter (CSI), and voltage source inverter (VSI). Recently, the flux vector drive also has become popular.

Let's compare these technologies.

PWM design

The PWM drive has become the most commonly used drive controller because it works well with motors ranging in size from about 1/2 hp to 500 hp. A significant reason for its popularity is that it's highly reliable, affordable and reflects the least amount of harmonics back into its power source. Most units are rated either 230V or 460V, 3-phase, and provide output frequencies from about 2 Hz to 400 Hz. Nearly 100 manufacturers market the PWM controller. A typical controller is shown in the photo.

As shown in Fig. 1, an AC line supply voltage is brought into the input section. From here, the AC voltage passes into a converter section that uses a diode bridge converter and large DC capacitors to create and maintain a stable, fixed DC bus voltage. The DC voltage passes into the inverter section usually furnished with insulated gate bipolar transistors (IGBTs), which regulate both voltage and frequency to the motor to produce a near sine wave like output.

The term "pulse width modulation" explains how each transition of the alternating voltage output is actually a series of short pulses of varying widths. By varying the width of the pulses in each half cycle, the average power produced has a sine-like output. The number of transitions from positive to negative per second determines the actual frequency to the motor.

Switching speeds of the IGBTs in a PWM drive can range from 2 KHz to 15 KHz. Today's newer PWM designs use power IGBTs, which operate at these higher frequencies. By having more pulses in every half cycle, the motor whine associated with VFD applications is reduced because the motor windings are now oscillating at a frequency beyond the spectrum of human hearing. Also, the current wave shape to the motor is smoothed out as current spikes are removed. Fig. 2 (on page 56) shows the voltage and current waveform outputs from a PWM drive.

PWMs have the following advantages.

\* Excellent input power factor due to fixed DC bus voltage.

\* No motor cogging normally found with six-step inverters.

\* Highest efficiencies: 92% to 96%.

\* Compatibility with multimotor applications.

\* Ability to ride through a 3 to 5 Hz power loss.

\* Lower initial cost.

The following are disadvantages, however, that you should also consider.

\* Motor heating and insulation breakdown in some applications due to high frequency switching of transistors.

\* Non-regenerative operation.

\* Line-side power harmonics (depending on the application and size of the drive).

CSI design

As shown in Fig. 3, the incoming power source to the CSI design is converted to DC voltage in an SCR converter section, which regulates the incoming power and produces a variable DC bus voltage. This voltage is regulated by the firing of the SCRs as needed to maintain the proper volt/hertz ratio. SCRs are also used in the inverter section to produce the variable frequency output to the motor. CSI drives are inherently current regulating and require a large internal inductor to operate, as well as a motor load.

CSIs have the following advantages.

\* Reliability due to inherent current limiting operation.

\* Regenerative power capability.

\* Simple circuitry.

The following are disadvantages, however, in the use of CSI technology.

\* Large power harmonic generation back into power source.

\* Cogging below 6 Hz due to square wave output.

\* Use of large and costly inductor.

\* HV spikes to motor windings.

\* Load dependent; poor for multimotor applications.

\* Poor input power factor due to SCR converter section.

VSI design

As shown in Fig. 4, the VSI drive is very similar to a CSI drive in that it also uses an SCR converter section to regulate DC bus voltage. Its inverter section produces a six-step output, but is not a current regulator like the CSI drive. This drive is considered a voltage regulator and uses transistors, SCRs or gate turn off thyristors (GTOs) to generate an adjustable frequency output to the motor.

VSIs have the following advantages.

TERMS TO KNOW

Cogging: Pulsating symptom of a motor while operating at a very low frequency, usually 2 to 6 Hz. Shaft of motor jerks in a rotational manner. The term "cogging" comes from gear cogs.

Non-regenerative: The inability of a drive to regenerate, or reverse, the power flow back from the motor through the drive.

\* Basic simplicity in design.

\* Applicable to multimotor operations.

\* Operation not load dependent.

As with the other types of drives, there are disadvantages.

\* Large power harmonic generation back into the power source.

\* Poor input power factor due to SCR converter section.

\* Cogging below 6 Hz due to square wave output.

\* Non-regenerative operation.

Flux vector PWM drives

PWM drive technology is still considered new and is continuously being refined with new power switching devices and smart 32-bit microprocessors. AC drives have always been limited to "normal torque" applications while high torque, low rpm applications have been the domain of DC drives. This has changed recently with the introduction of a new breed of PWM drive, the flux vector drive.

Flux vector drives use a method of controlling torque similar to that of DC drive systems, including wide speed control range with quick response. Flux vector drives have the same power section as all PWM drives, but use a sophisticated closed loop control from the motor to the drive's microprocessor. The motor's rotor position and speed is monitored in real time via a resolver or digital encoder to determine and control the motor's actual speed, torque, and power produced.

By controlling the inverter section in response to actual load conditions at the motor in a real time mode, superior torque control can be obtained. The personality of the motor must be programmed into or learned by the drive in order for it to run the vector control algorithms. In most cases, special motors are required due to the torque demands expected of the motor.

The following are advantages of this new drive technology.

\* Excellent control of motor speed, torque, and power.

\* Quick response to changes in load, speed, and torque commands.

\* Ability to provide 100% rated torque at 0 speed.

\* Lower maintenance cost as compared to DC motors and drives.

As usual, there are disadvantages.

\* Higher initial cost as compared to standard PWM drives.

\* Requires special motor in most cases.

\* Drive setup parameters are complex.

While flux vector technology offers superior performance for certain special applications, it would be considered "over-kill" for most applications well served by standard PWM drives.