Product Application Note

Comparison of Higher Performance AC Drives
and
AC Servo Controllers

Applicable Product: General AC Drives

Yaskawa Electric America
2121 Norman Drive South
Waukegan, IL 60085
1-800-927-5292

Contents

Introduction

The gap between basic AC drives and servo control is bridged by vector control drives. The vector control technology advancements continue to make strides into applications primarily dominated by servo products or applications that were controlled previously with servo controllers. The fundamental guidelines used in previous generation vector control products, which defined whether the application was suited for vector control or servo control, was speed control versus position control. Applications requiring high precision speed regulation can be served by vector control and servo drives, and high performance position control applications can be served by servo drives. However, there are servo applications that can be categorized as “low performance” as opposed to “high performance”. This market is starting to see an influx of vector control drives used on these “low performance” servo applications.

Basic Differences

Guidelines

A few of the basic issues to consider when determining whether a positioning application can be controlled by a vector control drive or a servo drive are the following: acceleration and deceleration rates, drive rating, system inertia, and position accuracy. A starting point to determine whether vector control is suitable for a given positioning application is the calculation of the acceleration torque requirements.
Given the system inertia and speed requirements, the acceleration torque can be calculated based on the desired acceleration rate. Basically, the faster the acceleration rates, the higher the acceleration torque requirements. Yaskawa Sigma Series servos can handle 200-300% torque compared with 150-200% torque with a vector control drive.

Position Control and Repeatability

When comparing vector control to servo control capabilities with respect to positioning applications, the following control parameters need to be reviewed: speed range, system inertia, speed and torque control bandwidth, analog input scan times, and encoder resolution. Typical vector control speed ranges are 1000:1, whereas servo control is 5000:1. The system inertia for a vector control should be close to a 1:1 ratio (matching motor inertia to load inertia). This ratio is also ideal for servo applications; however, there are applications that can be greater than 5:1. In these applications, the bandwidth of the servo system can be adjusted or tuned, whereas the vector control drive maybe limited in its speed and torque bandwidth.

Many vector control drives do not include a position control loop. In a positioning application such as the rotary knife, a position controller would be required as an interface to the vector drive. The position controller would provide a torque reference to the vector control drive. The position controller's torque reference scan rate is usually 1ms or greater. Older type vector control analog input scan rates were around 5ms, but new generation vector controls have scan times faster than 2ms with some below 1ms. Servos, on the other hand, have analog input scan times of 125 microseconds.

Encoder resolution is another important characteristic of a positioning system. Typical resolution used on vector controls is 1024 ppr with an encoder frequency response of 300KHz, whereas in machine tool applications, the encoder resolution is typically 8192 ppr with an encoder frequency response of 500KHz. With these characteristics in mind, the position control repeatability issue between vector and servo control is usually not a concern. The vector control and encoder resolutions are such that the settling times for repeatability are very close. The position accuracy capabilities of a vector control drive, however, still lag behind the servo control. A vector control can achieve an accuracy of approximately 0.1mm compared to an accuracy of 0.001mm with a servo controller.

Sizing – Relative Cost

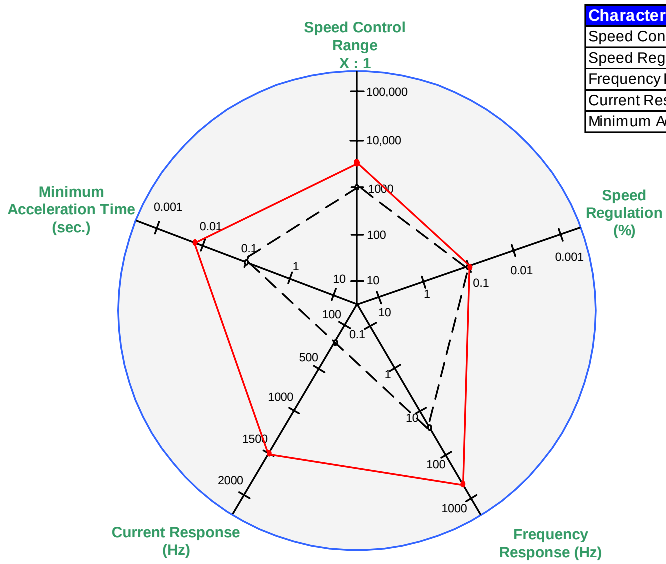
When vector controls and servo controls compete for the same applications, previous experience has shown that servo controls are very low cost compared to vector control drives below 3HP. Ratings of vector drives below 10HP can be very competitive with servo control drives if all of the system data can be provided, such as weights, motor inertia, load inertia, gear ratio's, etc. In many cases, this type of information is not available, and to ensure servo performance as the system dynamics change over time, the servo may be oversized, which results in the servo system becoming more expensive than a vector control system. Above 10HP, the servo control typically becomes more expensive than a vector control package. A system is defined as a motor/drive combination with an outer position loop. The smallest, closed-loop vector control drive available from Yaskawa is 0.5HP.

Applications

Applications where vector control has penetrated the servo market are "low performance" cut-to-length applications, rotary knife, printing press, machine tool change, machine tool spindle, rough pipe cutting. The applications that are still well suited for servos are the high technical performance applications like metal cutting, die bonding, "high performance" cut-to-length, "high performance" rotary knife, contouring, and welding.

Comparison of Controller Performance

Radar Chart



Characteristics	Vector Control	Servo Drive
Speed Control Range	1 : 1000	1 : 5000
Speed Regulation	± 0.01%	± 0.01%
Frequency Response	40Hz	400Hz
Current Response	360Hz	1500Hz
Minimum Acceleration Time (sec)	0.1 sec.	0.03 sec.

Speed Control Range

The speed range is defined as the minimum speed the motor can operate from a given base speed and still generate 100% torque. A speed range defined as 1000:1 for an 1800 rpm motor means the motor can operate between 1.8 to 1800 rpm at full load and maintain the specifications for that motor. The frequency control range is defined as the minimum frequency the controller can operate and still generate 150% torque. The 150% torque may be defined for a limited time period. The frequency control range is different than the speed control range by the factor of motor controller slip frequency. Speed control range usually pertains to motor speed in revolutions per minute (rpm); whereas, frequency control range is associated with output frequency applied to the motor in Hertz (Hz). Example of a frequency controlled range of 100:1 equals 0.6Hz minimum frequency (60Hz/100).

Speed Regulation

The speed regulation is defined as the % change in speed between no-load (synchronous) and full load applied to the motor. The speed point referenced is at the base speed of the motor (i.e. 1800 rpm for a 4 pole motor), not the set speed of the motor. An example, a 1% speed regulation refers to a motor speed change of 18 rpm between no-load and full load at 1800 rpm operating speed (synchronous speed). The 18 rpm speed change would also apply to a set speed of 50% or 900 rpm operating speed. The speed regulation of AC Drives with respect to AC Servo is equal due to the advancement in closed loop flux vector control methods.

Frequency Response

The frequency response of the controller relates to the automatic speed regulator (ASR) capabilities. The frequency response of the controller is defined by the frequency range applied to the frequency command input reference and the ability of the output frequency to track this reference. The performance of the controller is usually tested by applying a sinewave to the frequency command input reference and measuring the output frequency. If the controlled specification for frequency response is 100Hz, this indicates the output will also produce a frequency output of a 100Hz sinewave with a frequency input signal of a 100Hz applied.

The frequency response of the controller and the speed response of the system usually are different due to the mechanical constraints within the system configuration. Mechanical constraints will reduce the response of the system, even though; the controller's response is very high.

Current Response

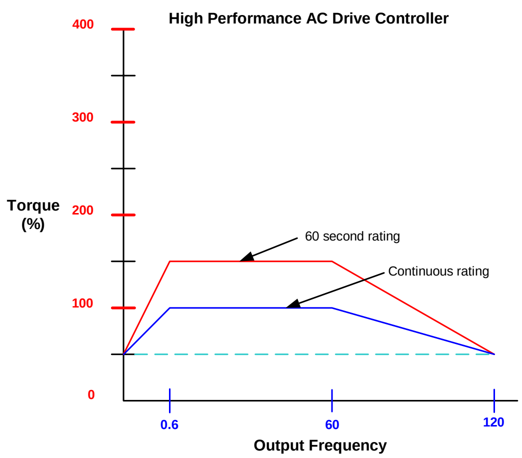
The current response of the controller relates to the automatic current regulator (ACR) capabilities. The current response of the controller is defined by the frequency range applied to the current command input reference and the ability of the output current to track this reference. The performance of the controller is usually tested by applying a sinewave to the current command input reference and measuring the output current. If the controlled specification for current response is 200Hz, this indicates the output will also produce a current output of 200Hz with a current input signal of 200Hz applied.

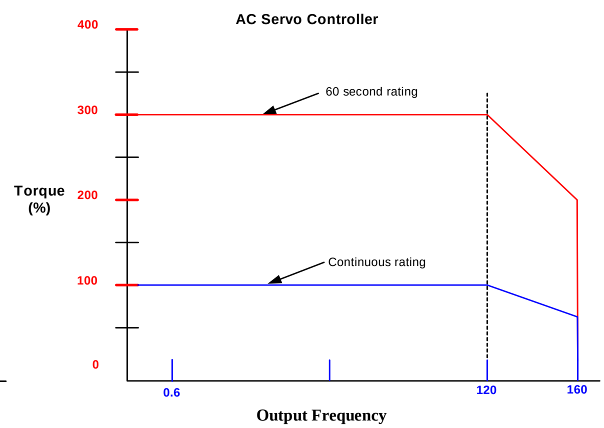
The current response of the controller and the torque response of the system usually are different due to the mechanical constraints within the system configuration. Mechanical constraints will reduce the response of the system, even though; the controller's response is very high.

Minimum Acceleration Time (seconds)

The minimum acceleration time is defined by the time required to accelerate to rated speed using the maximum motor torque and without a load (motor inertia only). The mechanical system and system inertia can limit or extend the acceleration time required to reach top motor speed.

Torque Characteristics





Maximum Torque

The typical maximum current is 150% to 200% for an AC Drives and 200% to 300% for an AC Servo controller.

Low Speed Torque

In an AC Servo controller, constant torque can be maintained from 0 rpm up to the rated speed. As for AC Drives, the maximum torque declines at low speeds, and the continuous operating range also declines. Because of this, operation at low speeds should be carefully considered.

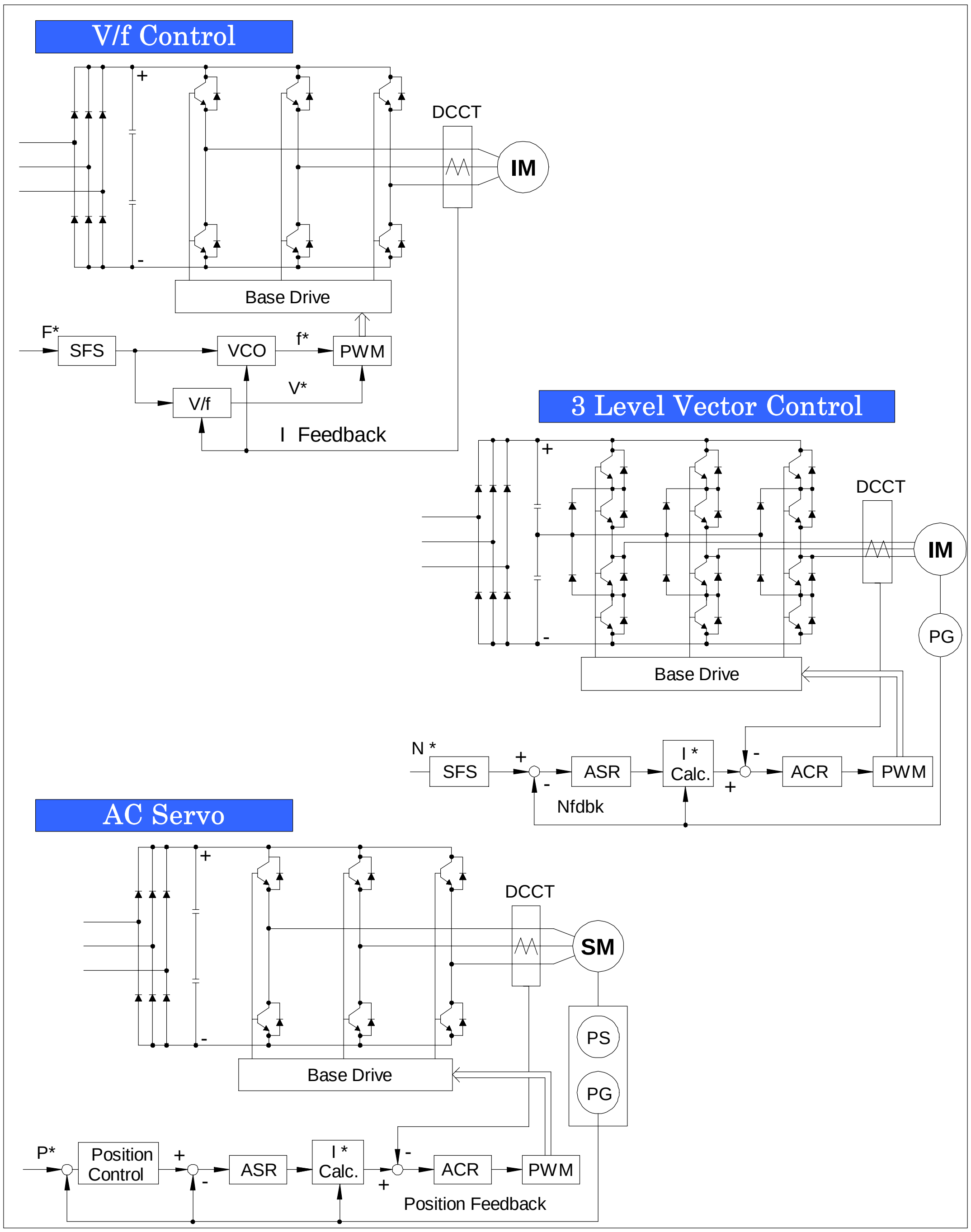
Locked Rotor

AC Drives cannot perform locked rotor operations. The AC Servo can, though only for a short time. Continuous operation can be performed when the torque is limited to 70% of the motor torque.

Stopping (Braking) Methods

An AC Servo motor becomes a generator when input power is lost. This is because the AC Servo motor employs a permanent magnet for the magnetic field. When a short circuit occurs at the motor terminals, a short circuit current flows between terminals, which produces a large braking torque. On the other hand, a general-purpose Drive cannot easily obtain braking torque as AC Drives use induction motors. A variety of Braking options should be considered for AC Drives when braking torque is required.

Comparison of Control Block Diagram Configuration



Appendix

Comparison of High Performance AC Drive and AC Servo Controllers

Item		AC Drive			Servo Drive
		V/f Control	**Open Loop Vector Control 2**	**Flux Vector Control**	**AC Servo**
Capacity		0.5HP ~ 400HP (0.4kW ~ 300kW)	0.5HP ~ 400HP (0.4kW ~ 300kW)	0.5HP ~ 400HP (0.4kW ~ 300kW)	3HP ~ 50HP (50% duty cycle) (0.3kW ~ 55kW)
Performance	Speed Control Range	1 : 40	1 : 200	1 : 1000	1 : 5000
	Speed Control Accuracy	+/- 2% ~ +/- 3% (+/- 0.5 ~ 1% with slip comp)	+/- 0.01%	+/- 0.01%	+/- 0.01% (eliminates temperature and voltage fluctuation)
	Frequency Response	5Hz	10Hz	30 ~ 40Hz	400Hz
	Peak Current (max. / continuous)	120% ~ 150%	150% ~ 200%	150% ~ 200%	200% ~ 300%
	Current Limit Current Control	Not Available	Torque Limit *1, Torque Control	Torque Limit *1, Torque Control	Torque Limit, Torque Control
	Torque Response	Not Available	200Hz	200Hz (360Hz)	1500Hz
	Torque Accuracy	Not Available	+/- 5%	+/- 5%	+/- 2%
Feedback Response		Not Available	Not Available	Line Driver, 300kHz	Serial, 500kHz
Positioning Control Accuracy *2		Not Available	Not Available	+/-1 Quadrature Count	+/-1 Quadrature Count
Application		Variable Speed (fan, pump, blower, conveyor)	High accuracy variable speed/torque (extruder, crane, paper, film lines, steel plants, elevator)	For large capacity servo (injection molding machine, gear pump, press feeder)	General Servo (X-Y table, IC bonder, plotter, form, fill, and seal)

*1 - Open Loop Vector 2 has additional torque control capabilities.
*2 - Mechanically and resolution (ppr) of encoder device dependent .