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Bridging customer needs

A movable bridge application arises out of embedded control programs in ABB low-voltage drives

MIKAEL HOLMBERG – Embedded control programs installed in ABB industrial drives provide a cost-efficient and application-specific solution for many of the most common drive applications. From ubiquitous pumps and fans, to more specialized applications like cranes and winches, the embedded control programs ensure that the drives not only speak the right language, but that they are delivered with the built-in functionality that is required to meet the most common customer requirements. These applications are designed and built using ABB's many years of experience of working with customers across a wide range of control applications. Sometimes, embedded control programs can themselves become the basis for new control solutions. This was the case when ABB was asked to provide a solution for a bridge control system.

Movable bridges share many common control requirements with materials handling applications like cranes and winches. Therefore, ABB's existing crane control program offered the ideal starting point.

Developed for the ACS800 ➔ 1 industrial drives, the crane control program provides step-less speed and torque control for the hoist, trolley and long-travel movements. This is used on:

- Industrial cranes, mainly electrical overhead travelling (EOT) cranes ➔ 2
- Harbor cranes ➔ 3
- Construction/tower cranes
- Marine and deck cranes

The drives with the crane control program can work in either standalone or master-follower mode. In standalone mode, the drive is used simply for independent control of the crane movements. In a master-follower arrangement, several drives are interlinked, with one of the drives operating as the master to the other drives. This allows coordination and load sharing for different types of motors connected to the same system. This configuration can be used in speed-speed, speed-torque or speed-synchro mode.

Title picture
A typical movable bridge which benefits from AC drives used with the bridge control system.

Embedded control programs installed in ABB industrial drives provide a cost-efficient and application-specific solution for many of the most common drive applications.

1 ABB's ACS800 low voltage industrial drives

The functional programming provides the capability to switch between master, follower or standby mode. This ensures that the master and follower are not fixed, but can be changed at will simply by providing each drive with a selection switch. This provides a high level of redundancy for the crane application.

Anti-sway control

Complementing the crane control program, the anti-sway control program for indoor cranes using ABB industrial drives provides a built-in solution to prevent load sway. This program estimates the time constant of the hoist by continually measuring its position and load properties, and factors in the swing velocity and angle to calculate the compensating speed reference for the long travel and trolley movements of the crane. Because the embedded anti-sway program calculates the sway, no external sensors are needed. Reducing the part count for an effective solution is an added customer benefit.

Using crane control as the basis for winch control

Marine winches have many similarities to cranes when it comes to their drive control requirements. ACS800 industrial drives with marine certification provided the ideal hardware platform, and the crane control program was the perfect starting point, for the creation of a winch control program. These incorporate all the functions usually required for winch applications. The control program is commonly used on anchor winches, mooring winches (auto-mooring), roll-on, roll-off gate ramp winches, towing winches and research winches ➔ 4.

The winch control program provides built-in features that replace traditional, costly hydraulic winch control systems. This eliminates high maintenance costs and performance inefficiencies, while improving operator safety and overall system reliability. The drive itself replaces contactors and other low voltage products used to bring winch motors direct-on-line, instead ramping the motor smoothly to the correct speed/torque. This reduces the impact on the ship's electrical network during winch operation.

The anchor control function provides a perfect example of the winch control program's built-in protection functions. These include slip detection, which detects any high load on the chain should it become snagged when raising the anchor. Such a high load creates a speed difference between the winch drum and the motor shaft and activates a load switch. The speed/torque of the winch motor is immediately reduced to a level set by the winch manufacturer. This prevents damage to the motor shaft, winch drum or clutch between the drum and motor.

Torque control, the common requirement

All these embedded crane and winch control drive applications must fulfil one common requirement – very precise and powerful torque control. The key to the success of the control programs in ABB's

2 Waste handling crane

Built-in application software provides customers with solutions designed to the requirements of many different installations while speaking the language of their specific application.

industrial drives is the patented direct torque control (DTC) motor control platform → 5. This delivers the performance levels and protection functions demanded by materials handling applications.

In contrast to the way that conventional AC drives control input frequency and voltage, DTC uses motor flux and torque as primary control variables. This allows accurate control of speed and torque with or without pulse encoder feedback from the motor shaft. A key benefit of DTC is that it enables the drive to achieve full torque at zero speed without the need for a feedback encoder. Using a feedback encoder can be a problem on board a vessel as the harsh climate on deck can often damage the encoder itself or interfere with the feedback signal to the motors.

Furthermore, DTC offers an exceptionally fast response time of 25 microseconds in the control loop between the application (eg, crane or winch) and the motor control embedded in the drive. This is approximately 10 times faster than the typical response time possible through conventional flux vector control.

DTC's ability to work with a wide range of motors helps reduce retrofit costs when upgrading from older control methods. For example, when retrofitting a three-speed/three-winding marine winch with an ABB industrial drive, the existing motor can still be used, and the drive will use only one of the three motor windings. This significantly reduces upgrade costs and downtime.

Embedded software comes with the benefits of adaptive programming which enables the user to integrate external control logic, create new functions or to modify existing logic.

DTC, in combination with the embedded control programs, enables the customer to specify a single product with the control solution built-in. No other control components are required, saving on overall systems costs as well as increasing reliability by reducing the number of possible failure points.

DTC: Heart of the movable bridge control system

Building on the extensive experience gained from the crane and winch control programs, ABB developed a movable bridge control application featuring ABB industrial drives. These drives feed power to the electric motors which drive the span or deck of the bridge and control the bridge's mechanical disk or drum brakes.

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3 Harbor grab crane

They are increasingly being used on a variety of movable bridges, either as part of a new build or in a refurbishment or renovation program and tend to replace hydraulic drives or DC drives operating with DC motors.

The drives provide step-less, variable speed and torque control for the electric motors that are used to either lift or turn the deck around its axis, over a wide range of operating speeds and loading. They can positively control the speed of an AC motor when the motor is being driven, or back-driven or overhauled, such as when a span heavy bascule or vertical lift bridge is being lowered. The control program, along with DTC, ensures accurate control of speed and torque with or without pulse encoder feedback from the motor shaft. It provides the accurate slow speed control with high torque levels essential for bridge applications.

Bridge control applications

In a movable bridge, when several drives are connected to the same system, the master-follower drive arrangement can be used. It enables coordination and load sharing for different kinds of motors operating within the system. However, other movable bridge applications require synchronized lifting. Within bridge applications there are two common master-follower control methods.

Follower in torque control mode

If two motors are connected to each other via a mechanical shaft, for instance when two motors are lifting opposite sides of a bridge at the same time, then the master drive is speed controlled. This determines how fast the bridge raises or lowers. The follower is torque controlled which results in the load being shared exactly between the master and follower.

Follower in synchro control mode

If two motors are not connected to each other, such as when the bridge is designed for each motor to work independently in raising or lowering the bridge, yet at the same time, then the master is speed controlled. This determines how fast the bridge raises or lowers. In this instance, the follower is operated in synchro mode to enable symmetrical lifting. This means that the two parts of the bridge are synchronized to lift at the same time and at the same angle.

Symmetrical lifting with synchro control

Often the drives on either side of the bridge need to be perfectly synchronized when raising the bridge. To ensure the required level of accuracy, a standard incremental encoder can be used to feedback the deck position with respect to each variable speed drive. The encoder is essential in synchronizing the drive, based on the position of the master as measured by the encoder. The synchro control routine, built into the drive's bridge control program, works together

4 Winch – ropes from the dock

5 Direct torque control (DTC)

Direct torque control – or DTC – is the most advanced AC drive technology and has replaced traditional open- and closed loop type pulse-width modulation (PWM) drives. It is called direct torque control because it describes the way in which the control of torque and speed are directly based on the electromagnetic state of the motor but is contrary to the way in which traditional PWM drives use input frequency and voltage. DTC is the first technology to control the "real" motor control variables of torque and flux. Because these parameters are directly controlled, there is no need for a modulator – as used in PWM drives – to control the frequency and voltage. This in turn dramatically speeds up the response of the drive to changes in required torque. DTC also provides precise torque control without the need for a feedback device.

with DTC to provide the required level of synchronization. Synchro control can be used on a system with one master and up to four followers.

Electric motor mechanical brake control and torque memory

The bridge control program also features an integrated brake control logic that, in turn, utilizes torque memory and pre-magnetizing to open and close the mechanical brake safely and reliably. The mechanical brake may be inside the motor (disk brake) or outside the brake (drum brake). Alternatively, both can be used at the same time for additional safety. The brake control logic within the drive includes a function that enables the drive to hold the shaft stationary until the mechanical brake takes over. The "slow down" safety control function limits the speed to a preset level in critical zones. High and low limit sensors stop the drive at the end positions. The "fast stop" safety control function is used in emergency situations.

Speed monitor and speed matching

The speed monitor function ensures that the motor speed remains within safe limits to prevent overspeed. The speed matching function continuously compares the speed reference and the actual motor shaft speed to detect any possible difference. One of these functions will stop the motor immediately if a fault should occur in the operation of the motor.

Dedicated, application specific software

Embedded software works together with the advanced DTC platform in ABB's industrial drives to offer significant performance advantages and precise control for a variety of materials handling applications. Not only does it enable many crane and winch control applications to be up and running virtually 'out of the box' it also comes with the benefits of adaptive programming (AP). This enables the user to integrate external control logic, to create new functions or to modify existing logic – for example to enable variable ramp timing during the bridge opening cycle.

Built-in application software provides customers with solutions designed to incorporate the requirements of many different installations while speaking the language of their specific application. The control program's extensive built-in functionality provides a cost effective solution for customers who are aiming to minimize their use of external discrete components. Through working in close cooperation with customers, listening to their needs and moving in anticipation of market trends, ABB will continue to lead the development of embedded control programs for industrial drives.

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