Position Control for Industrial Overhead Crane

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INTRODUCTION

Automating crane control can be the key to increasing both productivity and throughput of a manufacturing facility. One such project was performed by Avtron Manufacturing, Inc. at a facility in central Ohio. Avtron’s customer has a very sensitive process for the conversion of material from one form to another. Machinery is spread-out in the facility and manual control of the cranes is difficult and slow. Operators must continuously monitor the cranes movements and adjust the crane accordingly. Parts obsolescence and maintainability were also a factor.

BACKGROUND

Cranes at the facility were originally installed in 1980 with a GE drive and PLC controlled by an Avtron position system. A single drive was used to provide power to all four motions: Hoist, Trolley, Bridge and Rotate. Having a single power converter allows the crane to only move one direction at a time. A series of contactors was used to switch the desired motors on and off the power converter for control.

The original crane was installed with an Avtron position control system. Avtron’s original position control was run from a single processor unit that brought in pulse generator feedback for position and thumb-wheel inputs for a reference. An output was then provided to the drive control system to move the crane in the desired position. Hardware functioned well and was in place for over twenty years.

Over the years the crane downtime slowly crept up and maintenance was becoming more of an issue. The existing programmable logic controller (PLC) was now obsolete and parts were no longer available. The DC drive was analog which was also obsolete and hard to maintain. Although the Avtron system was over twenty years old, it was still maintainable and most parts were still available.

The manufacturing floor is broken into three zones with each having its own overhead crane. Recent orders for its product have forced the customer to add capacity and run the cranes at a higher rate. This requires the cranes to be more reliable. Avtron was asked to evaluate the system and propose a solution for the customer.

After a site visit by one of Avtron’s crane engineers, it was determined that Avtron would propose replacement of the drive, PLC and position with modern hardware. Position control would no longer be a separate system but integrated into the PLC and drive.
SYSTEM OPERATION

Drive Control System
A new crane control system was installed based on Avtron Manufacturing, Inc.’s ADDvantage-32 DC drive package. A new DC drive with individual field supplies was installed to power the four motions of the cranes. An integrated field supply in the ADDvantage-32 was used to power the hoist field to ensure the best response and control. Avtron’s crane control firmware was installed that provides support for three different motions out of one controller. This allows a single drive to optimally control the crane. Figure No.1 shows the drive control arrangement.

Figure No.1 – Drive Power Arrangement

System coordination was originally handled with an obsolete PLC. A new unit was installed that was current and the latest technology. The new PLC would provide interface to the drive control system and handle all inputs and outputs for the crane. In order to reduce learning curve for the operators, the existing controls were left in place and reused.
Crane Operation
Machinery is laid out in a grid arrangement on the manufacturing floor. All machines are identical and are fed from the top by the cranes. Material is both loaded and unloaded from the same location. A service corridor divides the machines in half giving floor access so that the material can be carted in to the machine area and picked-up by the cranes. This reduces the travel distance the cranes need to move.

Machinery is represented by a target number which consists of a row and spot number. Machine locations are entered by the operator on a set of thumbwheels. After entering the coordinates, the operator can press the GO button which will cause the crane to automatically move to the desired position. Actual placement or pick-up of the material is then performed manually by the operator. Figure 2 shows a simplified view of a typical location.

Figure No.2 – Typical Machinery Positions

Control of the crane was accomplished by adding a new programmable logic controller (PLC) to interface with the new DC drive. Limit switches, interlocks and fail-safe control are handled by wiring directly to the PLC input and output modules. A high speed counter card is installed to provide an interface with two existing pulse generators located on the Bridge and Trolley wheels. Tracking the Bridge and Trolley wheels allows the system to measure the actual position of the cranes.
Machines are positioned on the floor in an X-Y coordinate system with the X position being controlled by the Bridge motion and Y position by the Trolley motion. Feedbacks are monitored continuously in order to track the cranes position. Each of the three cranes has its own service area which is defined by the end of its rail system. Cranes do not overlap and can not mechanically run into each other. Hard-wired limit switches are used to provide a fail-safe boundary for the entire crane at its end of travel (EOT) limits.

A service corridor runs down the middle of the machine area to provide access for material. Material is brought to the manufacturing area on carts which are moved to the service corridor for loading. Cranes are manually operated to ensure peoples safety and to ensure safety of the product. Material that either comes or goes from the service corridor follows one of two processes:

**Loading of a Machine**
Material is carted in from other areas of the facility to the service corridor isle. Cranes are manually positioned over the load and the hooks lowered. Once the load is lifted off the ground, the operator can put the crane into automatic mode via a pushbutton located in the cab. A set of thumbwheels are set to tell the crane what machine location is desired. Cranes were designed so the load hangs in front of the operators cab. Both the cab and load rotate from the same point so that the load is always in front of the operator. If the crane is put into automatic, the system analysis the loads position and rotates the crane cab into the correct position.

Each motion is run independently from the single DC drive controller. Cranes first trolley down the service corridor until the proper aisle is located. After the crane stops, it bridges to the target location of the desired machine. A final trolley is then performed to move the load into position over the machine and the load is lowered to a preset height. The operator then manually sets the load into the machine for the final operation.

Once the hooks are above a safe height, the operator has one of two options. Pressing the Aisle button will trolley the crane back to the aisle allowing the operator to select another location in that aisle. If the desired machine is not in the same aisle or another operation is desired, the Home button is pressed returning the crane back to the edge of the Service Corridor.

**Unloading of a Machine**
Cranes must always start from the service corridor to perform automatic operations. When a machine is ready to be unloaded, the operator can once again select the desired location as if he were loading a machine. The crane will then automatically position itself over the desired machine where the load is then picked up. Once again the operator can press the aisle button to position the crane back into the aisle or the home button to move all the way back to the service corridor.

**Crane Automation**
Automatic operation of the crane requires two key components in the automation. Component one is distance to stop calculator and its associated software, and component two which is the position feedback and its software. Each must be programmed and set-up properly for the system to work.
**Stopping Distance Calculator**
In order to stop the crane at a precise location, the distance required to stop in both the Trolley and Bridge directions must be calculated. This presents several challenges due to a single drive providing control for both motions. Each motion has a unique ramp rate associated with it. The ADDvantage-32 also provides an S curve to the ramp rate to smooth out the acceleration and deceleration of the crane. S curves must be taken into account for an accurate stopping distance.

A stopping distance calculator is activated whenever the crane gets a predetermined distance from its target. The actual distance to the target point is measured and compared to the stopping distance calculator. Once the two distances are equal, the drive is issued a stop command allowing it to ramp-down to the desired position. If the S curve is not taken into account, the crane would fall short of its targeted stopping point.

Avtron’s ADDvantage-32 DC drive has the capability to run three different motions from a single drive. To achieve this, the drive software has three separate recipes stored, one for each motion. When a particular motion is selected, the recipe values such as speed gains, ramp rates, s-curve values, etc. are loaded into the appropriate locations. Time delays and errors are eliminated because the values reside in the drive and are not required to be downloaded from another device.

**Position Feedback Monitor**
The second piece required for the automatic control of the crane is the position feedback and tracking system. To accomplish this, pulse generators are located on the bridge and trolley wheels to produce a pulse stream. These pulses are collected in the PLC through a high-speed counter card to track movement of the crane. Registers are used to store current position so that the X-Y coordinates of the crane can be measured.

Pulse generators are not absolute devices (Store the value within the device), so a reference point must be provided. A fixed target point must be provided that never changes. The best points to use are the end of travel limits located at the extreme travel areas of the crane. These switches provide a starting point from which the position feedback can be started from.

Appendix A shows a flowchart of the calibration procedure carried out by the system. Each motion has its own calibration routine so that any or all can be calibrated at any given time. In order to calibrate the crane, it must be located in the service corridor and in manual mode. Pressing the calibrate push button starts the calibration process. The operator can calibrate any motion by running it manually to one of the stop limits. For example, the operator trolleys the crane manually in either the +Y or –Y directions until the stop limit is passed. When this limit is detected, the system resets the limit counters to the appropriate value so that the starting position point is determined. This value will not change until the crane is calibrated again. Repeating the process for the other motions completes the calibration of the system.

A target tolerance can also be entered that determines the amount of error allowed by the system. Each axis has a + and – tolerance value for measurement of the target area. This is important when material being loaded into the machine has a larger tolerance window than normal. It takes the system less time to get into position increasing throughput.
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**Automatic Mode Operation**
Appendix B shows the control flowchart for the automatic operation of the crane. When the operator presses the target pushbutton, the system reads the thumbwheel values to determine if a valid location is selected or not. If the value is not valid, the system resets and waits for the target PB to be pressed again with a valid number. If the number is valid, the destination is entered into the system.

Cranes must always start from the Service Corridor. Automatic mode first checks to see if the Trolley is already at the desired aisle. If it is, then no Trolley motion is required. If it is not, the crane must Trolley to the desired aisle location. A subroutine in the PLC is called to start the movement of the crane in the Trolley position and its position is monitored. Speed of the crane is also monitored and a routine is used to measure the distance required to stop for the crane. Both the actual and desired positions are monitored by a third routine. Once the actual distance to the Aisle and Stopping distance are equal, a stop command is issued to the drive, stopping the crane at the correct Aisle.

Once the Aisle is reached, the system determines the location of the Rotate. If the load and cab are not in the proper position to go down the aisle, the system automatically rotates the crane to the proper position which will face the crane towards the machine when it enters the target zone. A routine is called that determines the actual rotate position and runs the rotate motor in the proper direction, providing the correct orientation.

Now that the crane is in the proper orientation, it is bridged down the Aisle to the proper target position. A routine is called that compares the target location to the actual location. Bridge motion is provided and the distance to stop routine is run again. Actual distance is compared to the stopping distance until they are equal at which time a stop command is given to the drive. This stops the crane at the desired target position.

**CONCLUSION**

Automatic position control can be a very effective way to increase productivity and accuracy of a crane. It also provides a safer environment for the facility because operators can pay more attention to their surroundings while the load is moved. In manually operated cranes, operators must concentrate on the load and its movements creating potential hazards to people and equipment. Operator fatigue is also reduced due to a lower level of concentration required during long moves.

All three cranes were successfully upgraded with new drives, PLC and automation. Customers obsolete components were replaced eliminating the maintenance issues experienced before the upgrade. Reducing the system components also has reduced the system complexity and provided a better level of diagnostics. Downtime has virtually been eliminated with no drive or system hardware failures to date.