

## Application of automatic rewinding control system on calender

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**Abstract:** The winding station of the four-roller calender has been upgraded from manual operation to automatic winding. The configuration of the electrical control system, hardware configuration process, testing and calibration, and usage method are detailed. After application, the system control is accurate and reliable, truly helping users achieve efficiency gains with reduced personnel, significantly improving tire production efficiency, and reducing labor costs.

**Key words:** calender; automatic rewinding; ethernet communication

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In today's era, with the improvement of people's living standards, household cars have gradually become commonplace, transitioning from being a rarity. This is a direct manifestation of people's pursuit of convenience and comfort in travel. The surge in car ownership has driven the vigorous development of the entire automotive industry chain, with the tire industry bearing the brunt. Not only has the market demand for tires increased significantly, but consumers have also placed higher expectations on tire quality, making high-quality tires a key direction for industry development.

In the field of tire manufacturing, the calender production line undoubtedly occupies a core position. Its stable and efficient operation directly determines the production efficiency and quality of tires. Currently, the S-shaped four-roller calender, with its excellent performance in achieving one-time double-sided rubber application on cord fabric, has greatly improved production efficiency and is widely used in major tire factories, becoming a key equipment in the tire production process. However, in its dual-station winding process, manual operation was previously relied upon, which had many drawbacks. During the production time of one roll every 8 to 10 minutes, operators not only have to constantly monitor the current winding process to ensure correct operation, package and remove the wound product from the station, but also

prepare the pad cloth required for the next roll in advance. Such a complex task makes the workload of the winding station extremely heavy, often requiring two operators to work together to barely cope, resulting in high labor costs. Moreover, in the event of an operational error or the need to handle non-conforming products leading to winding downtime, it must be quickly resolved within just 1 to 2 minutes. Otherwise, the main calender has to slow down or even stop directly. This not only seriously affects the production schedule but also increases production costs.

With the continuous advancement of technology, automatic winding control systems have gradually been applied to calenders. This system integrates advanced functions such as automatic winding, automatic cutting, and automatic station switching, making operation simple and convenient. The application of this system enables the winding station of the calender to produce high-quality products that meet process standards stably and efficiently, effectively reducing production interruptions caused by human factors. At the same time, it also achieves the goal of reducing personnel and increasing efficiency for users, injecting new vitality into the development of the tire industry and helping enterprises stand out in fierce

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**Biography:** Li Minghao (1982–), B.S., Electrical Engineer, mainly engaged in the electrical design and development of calenders.

market competition.

## 1 Control requirements and control content

The automatic winding control system of the S-shaped four-roller calender mainly includes a rear traction motor, a traction moving motor, a dual-station winding motor, a feeding system, a cutting system, and a pneumatic control system. The traction moving motor rotates to drive the rear traction motor to move in the direction of the product flow to the working position. The traction moving motor is equipped with a potentiometer to calculate the position of the rear traction motor. The 1<sup>#</sup> and 2<sup>#</sup> winding stations each have two positions: the entry position and the winding position. During operation, after position calibration, the traction moving motor first moves the rear traction motor to the entry position. The rear traction motor rotates to pull the rubberized fabric downwards, passing through the feeding device and the force-measuring device to reach the winding motor. The rubberized fabric enters vertically downwards into the angle formed by the winding shaft and the backing fabric that has been placed at the entry. The winding motor rotates to wind the rubberized fabric onto the winding shaft. After the rubberized fabric enters, the traction moving motor moves the rear traction motor to the winding position, detects the tension of the rubberized fabric through a force-measuring bearing, and performs normal winding. When the winding length reaches the set length, the winding stops, the cutting system automatically cuts, and the traction moving motor moves to the next station for the next winding operation. The potentiometer, force-measuring bearing, feeding device, cutting blade, etc., involved in the above winding process, are all connected to the PLC through remote slave stations, and all communication is conducted using Ethernet communication. Parameter setting and display are performed through a human-machine interface, and the automatic operation of winding is controlled through logical operations of the PLC based on the speed, tension, and other states of the calender during operation. This ultimately achieves automatic control of winding.

## 2 Overall composition and scheme design of the system

### 2.1 Electrical control system

Using the S-shaped four-roller calender as an example, we will now discuss the automatic rewinding control system. This electrical control system utilizes the CompactLogix series programmable controller from Rockwell Automation. The central processor is 1769-L33ER, the slave module is 1734-AENTR, the frequency converter used is the PowerFlex 750 series AC frequency converter, and the touch screen is 2711P-T7C22D9P. Through Ethernet communication, the PLC collects signals, analyzes and processes them, and controls various motors, valves, and other components to coordinate actions, thereby achieving automatic control of rewinding.

### 2.2 Hardware configuration

After the external communication is in place, hardware configuration is performed through RSLogix5000 software. First, a central processor with model number 1769-L33ER is created in the newly established project, named "zhongce", and its IP address is assigned and saved. Under the configured central processor, the required master input/output modules are configured. This system configures 8 modules and names them respectively. The specific module models and names are shown in Figure 1. The addresses of each component in the network must be within the same number segment, but the addresses cannot conflict. In the subordinate branch of the Ethernet module, the selected slave module 1734-AENTR is created, named "G10\_103", and its IP address is assigned and saved. Under the configured slave module, the required slave input/output modules are configured. This system configures 7 modules and names them respectively. The specific module models and names are shown in Figure 1. Next, configure the required frequency converters. In the subordinate branch of the Ethernet module, the selected PowerFlex 750 series AC frequency converter is created. Open the "Properties" interface of the frequency converter, name it and assign an IP address in the "Identification" interface of "Device Definition". Fill in the "Driver Rating" and "Rating Options" according to the power of the selected frequency converter. Define the extended parameters in the "Input" and "Output" sections of the "Connection Format" interface in "Device Definition". Configure all frequency converters of the automatic winding control system using this configuration method. This system configures 7 frequency converters, and

the specific module models and names are shown in Figure 1. After the configuration is completed, download the program to the PLC for operation. If the configured modules do not display a yellow exclamation mark icon, it indicates that the configuration is correct and can operate normally. If the configuration is incorrect, carefully check whether the model and version numbers of the configured modules are consistent with the actual physical devices. The configuration diagram is shown in Figure 1.

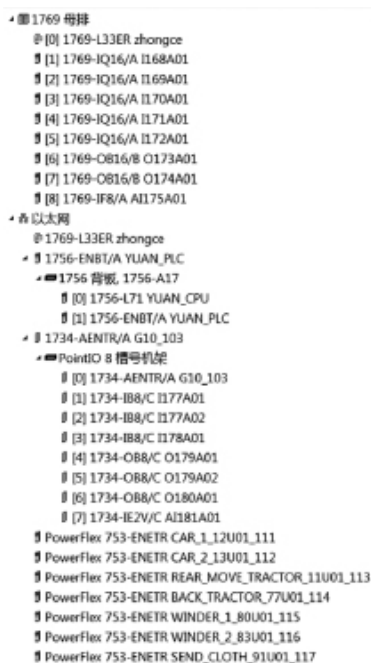


Figure 1 Hardware configuration diagram of automatic rewinding control system

### 2.3 Testing and Calibration

The automatic reeling control system must undergo testing and calibration before use, as this is a necessary condition for ensuring accurate reeling positioning and normal operation.

For testing, we perform self-tuning on each frequency converter, using Rockwell's CCW (Connected Components Workbench) software to accomplish this process. We connect the software to the frequency converter to be self-tuned via Ethernet, click to enter the "Wizard" interface, and then click "Start" in the "PowerFlex 753 Startup Wizard" dialog box. In the pop-up dialog box selection list, we select "Motor Control" in the first step, where we choose "Induction Flux Vector" and "Speed Regulation" modes in the "Motor Control Mode" tab. In the "Feedback" tab, we select the corresponding

port where the encoder feedback board is plugged in. In the second step, we select "Encoder Feedback Port", check the "Encoder Configuration" option according to the encoder parameters provided with the motor, and fill in the "Encoder Pulse Count". In the third step, we select "Motor Data", filling in various motor data according to the motor nameplate. In the fourth step, we select "Auto-tuning", which allows the drive to sample the motor characteristics and then correctly set its bandwidth and gain. Without additional load, we first click "Static Adjustment", and after the adjustment is complete, we click "Rotation Adjustment". When the motor stops rotating after the adjustment, we click the "Finish" button at the bottom to complete the self-tuning function for this frequency converter. We perform self-tuning for all frequency converters in this control system following the above steps. After all self-tuning is completed, we connect the motor to the roller and jog the motor to observe whether the direction of the roller's movement is the same as the set direction. If the direction of the roller's movement is opposite to the set direction, we swap the motor and encoder phase sequence or modify the direction of the motor and encoder in the frequency converter parameters, and then perform another test on the direction of the roller's movement until all rollers move in the correct direction. The testing work is complete.

Calibrate the position of the traction and moving motor.

First, start the traction and moving motor to move from the 1# winding position to the 2# winding position. During this process, monitor the potentiometer signal in the PLC. The signal from the potentiometer should change from small to large and should be continuous without any sudden changes. Second, click the "Calibration Valid" toggle button, which turns green to indicate that the calibration function is activated. Start the traction and moving motor to touch the protective limit switches on both sides of the dual-position winding (corresponding to the red indicator lights in Figure 2), and record the signal values of the potentiometer when each limit switch is touched in the program. Measure the actual distance between the two limit switches and calculate the distance in the program. Start the traction and moving motor to move to the actual winding-in position and winding position of the dual-position winding, and record the signal of the potentiometer at the current position (corresponding to the green indicator

light in Figure 2) in the program. After completing the above operations, click the "Calibration Valid" toggle button, which turns blue to indicate that the calibration function has stopped. The calibration is complete. The calibration screen is shown in Figure 2.

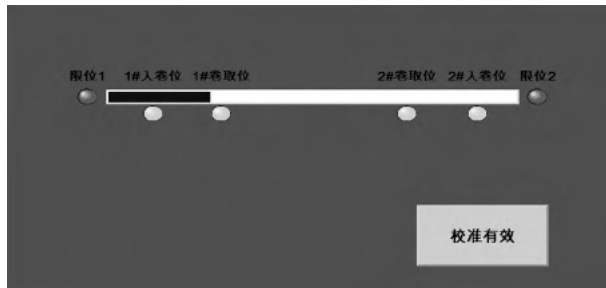


Figure 2 Calibration screen of automatic rewinding control system

## 2.4 Software programming

The automatic rewinding control system is programmed

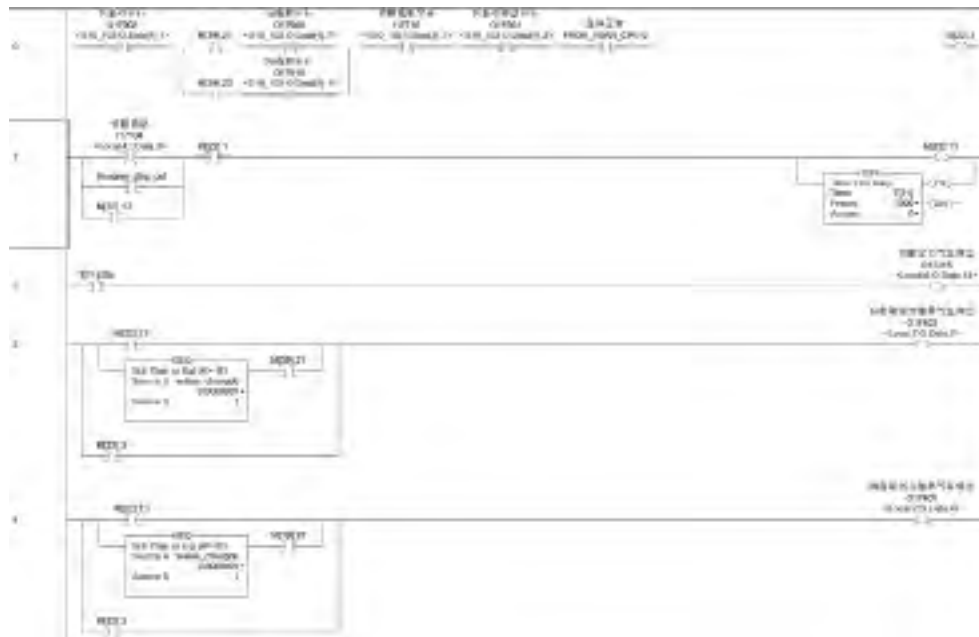


Figure 3 Part of the program for the automatic rewinding control system

## 3 Usage of automatic reeling control system

Introduction to the functions of various parameters in automatic rewinding control: Enter the desired rewinding length in the "Length Setting" section; click the toggle button "Length Auto Effective" to turn it green, indicating that automatic length measurement has been enabled. When the rewinding length reaches the length set in "Length Setting", the rewinding action stops, and the cutting knife automatically

using Rockwell RSLogix5000 software. Rockwell RSLogix5000 software integrates many control instructions, which are relatively independent, have a single function, and have a clear structure. During programming, only the instructions for the corresponding function need to be called. Some functional modules can also be customized, which reduces a lot of repetitive editing work, eliminates many intermediate variables that need to be defined, and ensures the integrity and uniformity of functions. Separate subprograms are established to program each part of the system. This classification makes programming and searching more convenient and clear. The automatic rewinding control system program is edited according to the control content described earlier. Some of the programs are shown in Figure 3.

starts to cut the adhesive tape. If it is blue, it indicates that automatic length measurement has stopped, and rewinding, cutting, and other operations are all performed manually; the "Length Display" section displays the current rewinding length, facilitating the operator's grasp of the rewinding length during operation; the "Length Reset" button is used to manually reset the current rewinding length; the "Rewinding Set Value" is used to set the rewinding tension. "1# Rewinding Actual Value" and "2# Rewinding Actual Value" display the

tension during rewinding at the corresponding rewinding station; clicking the toggle button "Rear Linkage Rewinding Auto" turns it green, indicating that automatic rewinding has been enabled. If it is blue, it indicates that the automatic rewinding function has stopped and manual rewinding is in effect. Usage method of automatic rewinding control: ① Set all parameters on the usage screen. ② Click the toggle button "Rear Linkage Rewinding Auto" on the screen to disable the automatic rewinding function. ③ Rotate the "Rear Linkage Single/Linkage" knob on the control box to the "Rear Linkage Single" position, and then press the "Rear Traction Move Front Point" or "Rear Traction Move Rear Point" button to move the rear traction motor to the desired rewinding position. When the indicator light at the corresponding position turns green, rotate the "Rear Linkage Single/Linkage" knob to the "Rear Linkage Linkage" position. ④ Click the toggle button "Rear Linkage Rewinding Auto" on the screen to start automatic rewinding. The automatic rewinding function will continuously rewind roll after roll of adhesive tape products according to the set parameters under continuous production on the host machine. The usage screen is shown in Figure 4.

## 4 Conclusion

In tire production, the winding station of the calender has become an obstacle to efficiency improvement due to



**Figure 4 User interface of the automatic winding control system**

its heavy workload and the potential for errors in manual operation. The application of an automatic winding control system has successfully overcome this dilemma. This system incorporates advanced logic control and computing functions to precisely control the winding process and achieve automatic production. Practical tests have shown that the system is stable and reliable, and it has been operating stably on the S-shaped four-roller calender equipment. The winding station that previously required two operators can now be easily handled by one person, effectively helping enterprises reduce labor input, improve production efficiency, achieve the goal of reducing personnel while increasing efficiency, and promote tire production towards intelligence and efficiency, injecting new impetus into the development of the tire industry.