Design and debugging of subway standby mode hardware circuit based on LCU

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ABSTRACT

With the vigorous development of urban rail transit industry in recent years, the quantity and quality requirements for subway vehicles are higher. The existing electric control system of subway vehicles is controlled by the contact scheme represented by relay, which has many shortcomings such as high cost, high failure rate, and no redundancy in logic cascade. If the single point and relay fault in the control circuit, the subway vehicles cannot operate, and the problems of vehicle cleaning and rescue will occur. This paper introduces a design scheme of the standby mode of subway vehicle control circuit. The programmable logic control unit (LCU) is used to design bypass, which can affect the key control circuit of the train, so that the subway can continue to run to the station in the fault state, avoid the congestion of the line, and solve the problem of vehicle clearing and rescue caused by the fault.

Keywords: Relay scheme; Hardware circuit; LCU retrofit design

1. INTRODUCTION

At present, the golden age of development of urban rail transit system. By December 31, 2021, a total of 50 cities in mainland China have built 9,192.62 kilometers of urban rail transit lines, of which 7,253.73 kilometers are subways, accounting for 78.9% [1]. With the expansion of subway investment scale in various cities, more and more subway vehicles are required in quantity and quality, and reducing the failure rate, delay rate and clearance rate of vehicles has become the main index to measure the quality of subway vehicles. As the center of the low-voltage control circuit of subway vehicles, the electrical control cabinet contains important circuits such as emergency braking, pantograph, cab occupancy and traction control circuit, etc. Its electrical control circuit is mostly composed of a large number of time relays and intermediate relays [2]. The stability of these circuits is closely related to the normal operation of subway vehicles, and when the key electrical control loop relays or lines that affect the establishment of traction conditions are faulty, the trains will not be able to pull. In the 1980s of our country once imported more than 150 8K electric locomotive from France, because the operation time is too long, relay control system can not be used normally, Fengtai locomotive Depot combined with related scientific research units, combined with the overhaul on the model non-contact LCU transformation, It is proved that the modified vehicle has high reliability, reduced maintenance cost and reduced daily maintenance work [3]. LCU logic control unit has been applied to SS6B electric locomotive, and good results have been achieved [4]. SS8 and SS9 electric locomotives also used LCU logic control units on some vehicles, which proved to run smoothly [5]. With the extensive use of various types of harmonious AC drive electric locomotives, logic control units are widely used, such as HXD1 series, HXD2 series, HXD3 series, etc. [6-8]. In foreign countries, Siemens applied logic control unit in railway, and ABB represented by MICAS system, whose drive control level was based on 8097 single chip microcomputer and applied to vehicles to reduce the risk of outage during normal line operation [9-10]. GE also developed AC600 AC transmission diesel locomotive and adopted the EM2000 control system based on the logic control unit of 32-bit microprocessor, reaching the world leading level [11]. The logic control unit combined with microcomputer control technology has been widely used in the electrical control system of railway vehicles.

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This paper takes the vehicles of Ningbo Metro Line 2 as the research object, constructs the bypass as the backup circuit through LCU, completes the transformation of the original electrical control circuit of subway vehicles, and realizes when the relay control circuit has problems, It can be converted to the standby mode controlled by LCU, which completes the transformation and design of the subway electrical control system.

2. ALTERNATE MODE CIRCUIT DESIGN OVERALL SCHEME

The design idea of the standby mode is to string the LCU standby mode circuit into the emergency traction loop. In the case of emergency braking of the vehicle, the function of the application mode can be opened to realize the compulsory possession of the vehicle, the compulsory raising of the arch, the compulsory closing of the high-speed circuit breaker, and the compulsory traction of the vehicle (when pushing the traction handle). The standby mode will disable the detection function or functions triggered by tight conditions, including zero speed detection of the door, closed state detection of the door, brake application and relief detection, arch raising condition detection, network fault detection, hardwire and network conflict, alert detection, etc. When starting in standby mode, LCU is used instead of contact for control. The overall design scheme of its electrical control system is shown in Figure 1.

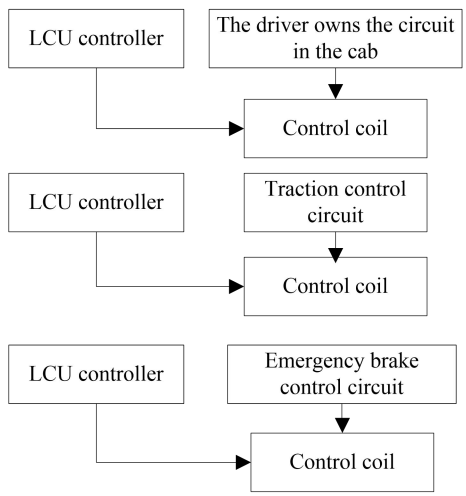

Figure 1. Overall scheme of circuit design in standby mode

3. HARDWARE CIRCUIT DESIGN OF STANDBY MODE ELECTRICAL CONTROL SYSTEM

3.1 Design of alternate mode switching control circuit

When the total wind pressure of the train is normal, it can be switched to the standby mode. The circuit diagram is shown in Figure 2. In order to prevent misoperation, 2 knob switches are provided to control the train to switch between relay control mode and LCU control mode. The simultaneous operation of 2 knob switches is necessary to activate the standby mode. When switching to the LCU standby mode, the LCU will bypass the relay control logic signal in part of the control loop, and the train is controlled by the LCU. When switching to hard wire mode, the LCU leaves all output ports in no output state, and the input ports only monitor data. The train is controlled by the hard wire circuit of the relay.

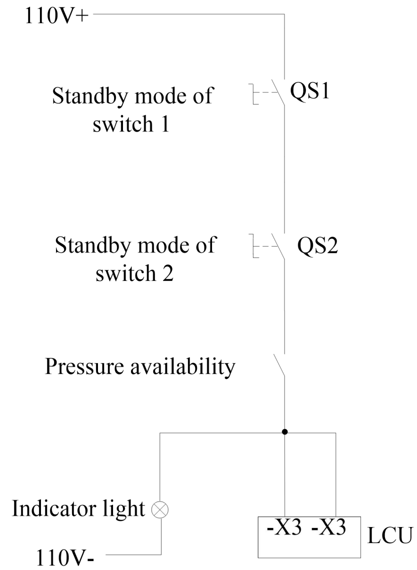

Figure 2. Alternate mode switching control circuit

3.2 Circuit design of driver's compartment in standby mode

The design of the possession control circuit in the driver's cab is shown in Figure 3. When a relay failure makes the driver's cab unoccupied, the standby mode knob switch can be operated to transfer the control mode to "LCU" control mode. At this time, the LCU with the driver's controller key in the "ON" position will collect the standby mode and activate. The logic of cab possession will be controlled by the local LCU. Meanwhile, all the contacts of cab possession relay affecting the train moving car will be bypassed by the LCU.

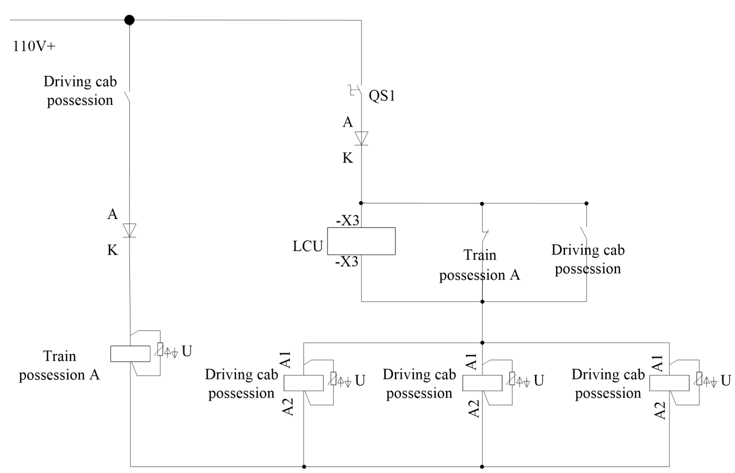

Figure 3. Circuit design of the driver's compartment in standby mode

3.3 Design of traction control circuit in standby mode

The traction control circuit is shown in Figure 4. When there is a relay fault in the traction control circuit, the control mode is switched to the "LCU" controlled standby mode by operating the standby mode knob. When the driver pushes the direction handle of the controller to the forward position, presses the alert button and pushes the main control handle to the traction position, the LCU will output signals to bypass all the hard line logic of parking brake relief, lock of the left door of the train, lock of the right door of the train and emergency brake. When the LCU detects that the emergency brake is applied, the LCU blocks the traction instruction bypass signal.

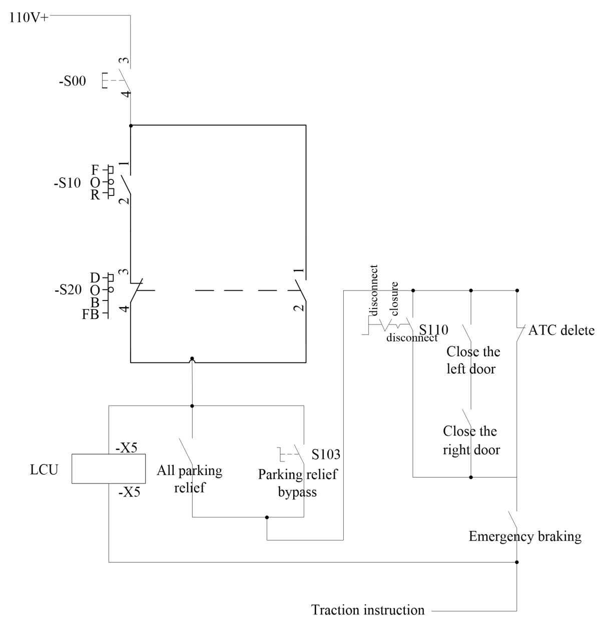

Figure 4. Design of traction control circuit in standby mode

3.4 Design of emergency braking circuit in standby mode

The emergency brake control circuit is shown in Figure 5. When there is a relay fault in the emergency brake control circuit, the standby mode knob switch can be operated to switch the control mode to standby mode. After activating in standby mode, as long as the LCU does not detect that the emergency stop button is operated, conditions such as VCU emergency braking, overspeed under emergency traction, unavailable total wind pressure, and alert button will be bypassed. If the LCU input signal is collected and emergency braking is applied to the train, the LCU software control logic is used to implement zero speed to alleviate emergency braking.

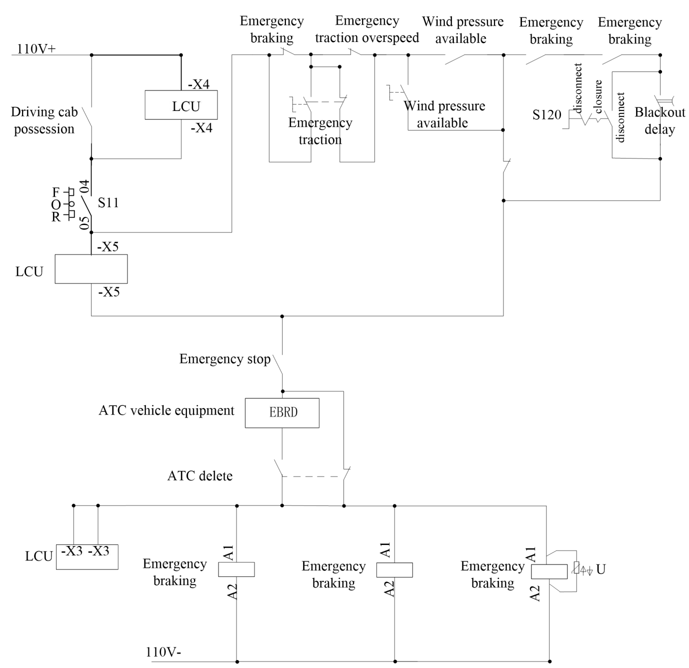

Figure 5. Design of emergency braking circuit in standby mode

4. SPARE MODE ELECTRICAL CONTROL SYSTEM HARDWARE CIRCUIT DEBUGGING

4.1 Debugging method

This hardware circuit is mainly designed to debug the standby mode circuit of subway vehicles under the condition of relay failure. The carrier of debugging is carried out on the original prototype of subway vehicles. The debugging on the prototype is divided into three parts: driver possession control circuit, traction control circuit and emergency brake control circuit. Based on the original relay control circuit, the relay fault is artificially set to simulate the subway relay fault, and test whether the subway control circuit can switch to the LCU control circuit smoothly when the relay circuit fails. This verifies whether the standby mode of LCU can be started successfully.

4.2 Debugging process and result analysis

The debugging process, respectively to the driver possession control circuit, traction control circuit, emergency brake circuit debugging.

(1) Debugging of possession control circuit in driver's cab

When the relay is working normally, all output ports of the LCU are in no output state. When the driver controller is closed, the relay is electrically drawn and the cab loop at the non-operating end is interlocked to ensure that only one cab is in possession of the whole train. The switch of the standby mode was switched to the "LCU" control mode. The LCU was successfully activated, indicating that the hardware circuit of the standby mode in the driver's cab was successfully debugged.

(2) Traction control circuit debugging

Under the condition that the relay works normally, operate the direction handle of the driver controller in the driver's cab, press the alert button, push the main control handle to the traction position, all parking brakes have been relieved, all doors of the train are locked, and no emergency braking is applied to simulate the state of the train issuing traction command. A relay fault was artificially set in the traction control circuit, and the standby mode was switched to the "LCU" control mode. The LCU was successfully activated. Indicates successful debugging of the hardware circuit in the standby mode of the traction control circuit.

(3) Emergency braking circuit debugging

In relay control mode, the train will issue an emergency braking command when the cab occupation signal is lost, or the direction handle of the driver controller returns to the "0" position, or VCU applies emergency braking, or overspeed under emergency traction condition, or total wind pressure is unavailable, or the alert button is not pressed for more than 3s.

When the artificial emergency brake control circuit relay fails, the standby mode knob switch can be operated to switch the control mode to standby mode. Switch the standby mode to the LCU control mode, and the LCU is successfully activated. Indicates that the emergency brake circuit standby mode hardware circuit debugging is successful.

5. CONCLUSION

In order to improve the reliability of subway vehicles under emergency condition and avoid the problem of clearing passengers and rescue of subway vehicles caused by relay fault, the standby mode of LCU under emergency condition is designed. Through the design and transformation of the hardware circuit, the hardware circuit of LCU standby mode is designed on the basis of the original circuit, and the feasibility of the circuit is verified, which provides the basis for the subsequent design of the standby mode control system.

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