Discussion on Train Operation Control Technology of Rail Transit and Structural Optimization of Its Electromechanical Equipment Monitoring System

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Abstract: At this stage, the continuous development of rail transit trains in China has provide more convenient travel conditions for people. Train operation control technology of rail transit, as a technology to ensure the safety of rail transit trains, has also been developed. Based on this, this paper analyses the present situation and planning of high-speed railway and urban rail transit in China, and expounds the train operation control system of high-speed railway and the train operation control technology of urban rail transit, especially after the completion of the Metro line, because the functional structure of the electromechanical equipment monitoring system is complex, the test practice is insufficient, and the coordination of various specialties is difficult, it is often difficult to open on time. Even if the line has been put into operation, there are still some functions that must be continuously tested and checked. The research shows that the reason for this problem is that the traditional electromechanical equipment monitoring system structure uses hierarchical distributed bus network control mode, which can be solved by optimizing its structure.

Keywords: high-speed railway train; urban rail transit; train operation control technology: rail transit; mechanical and electrical equipment; monitoring system; structural optimization.

1. Introduction
In the past ten years of development, China's rail transit has made great achievements. Light rail, urban subway and other rail transit systems have been rapidly built and expanded, which has alleviated the urban traffic pressure in China. At the same time, the formation of the concepts of high-speed rail network, zero transfer of high-speed
rail and the same city effect provides more convenient conditions for people to travel, promotes the process of urban-rural integration, and improves the level of modernization in China. In China, the construction and development of rail transit, including high-speed rail, is an important strategy, among which the safety of rail transit operation is the most important. In order to ensure the safety of rail transit, the signal system plays an important role. As the core technology of the signal system, the train operation control system and technology have developed rapidly in China. Mechatronic equipment monitoring system is an important part of rail transit. It takes computer technology as the core, monitors and manages all kinds of mechatronic equipment used in metro stations and tunnels. Once problems are found, effective measures can be taken to solve them, ensure the safety of passengers, realize energy conservation and environmental protection, optimize the allocation of resources, and improve the level of equipment management. Objective [1]
The status quo and planning analysis of high-speed railway and urban rail transit in China Railway technical standards and equipment level have been greatly improved. From 2013 to 2017, China's railways completed a fixed assets investment of 3.9 trillion yuan, adding 29.4 million kilometers of new railway operating mileage, including 15.7 million kilometers of high-speed rail, which is the most concentrated and intensive period of railway investment in history. By the end of 2017, the operating mileage of national railways will reach 127,000 kilometers, of which 25,000 kilometers are high-speed rail, accounting for 66.3% of the world's total high-speed rail. The electrification rate and double-track rate of Railways rank first and second in the world respectively. In February 2017, China promulgated the "Thirteenth Five-Year Plan for the Development of Modern Integrated Transportation System". It is expected that by 2020, a safe, green, convenient and efficient modern integrated transportation system will be basically built. Transportation modernization can be achieved in some areas. The operating mileage of the National Railways will reach 150,000 kilometers, of which the operating mileage of high-speed railways will be 30,000 kilometers. The double-track rate and the electrification rate are over 60% and 70% respectively. To meet the needs of our national economy and social development, the main technical allocation involved has reached or approached the advanced international level.
As far as the development of urban rail transit in China is concerned, by the end of 2017, 165 urban rail transit lines have been put into operation in mainland China, with the length of operation lines reaching 5033 km. Among them, the metro is 3884 kilometers, accounting for 77.2%; the length of other urban rail transit lines is about 1149 kilometers, accounting for 22.8%. According to the data published by China Prospective Industry Research Institute in the Report on Market Prospect and Investment Strategic Planning of China's Urban Rail Transit Industry in 2018-2023, it
can be concluded that by the end of 2017, the average operating mileage of China’s rail transit lines was 28 km, the average operating mileage of monorail was 42.1 km, the average operating mileage of light rail was 36.6 km, and the average operating mileage of Metro was 3 km. About 0.6 km, while the average operation history of maglev, tram and APM (unmanned system rail transit) is relatively short.

2. Analysis of Train Operation Control System of High Speed Railway
Signal system is the nerve and brain of railway, which supports the efficient and safe operation of railway system. With the continuous development of communication, control and computer technology, train operation control system, as the core of signal system, has been well developed. Under such conditions, China's high-speed railway and urban rail transit are developing towards networking, digitalization, intellectualization and integration.

At this stage, China has completed the establishment of CTCS (China Railway Train Operation Control System) train control system technical standard system. After a lot of experimental verification, CTCS system has been successfully applied to high-speed railway. According to different requirements and equipment configuration, CTCS system is divided into five levels, namely CTCS-0, CTCS-1, CTCS-2, CTCS-3 and CTCS-4. The specific characteristics of these levels are as follows: the speed level of CTCS-0 is 120 km/h, the blocking mode is fixed blocking, the train position is corrected to track circuit insulation node, and the transmission of vehicle-ground information uses "track electricity". "Road" one-way transmission and fixed line data are stored in the vehicle data storage chip; the speed level of CTCS-1 is 160 km/h, the blocking mode is fixed block, the train position is corrected to transponder, the vehicle-ground information transmission uses "track circuit + transponder" one-way transmission, and the fixed line data is stored in transponder. Fixed line data are saved in RBC; the block mode of CTCS-2 level is mobile block, train position correction is transponder, vehicle-ground information transmission uses wireless bidirectional transmission, fixed line data is saved in RBC [2].

In CTCS-0 level of China's ordinary railway train operation system, it includes train operation monitoring device LKJ and general-purpose locomotive signal. The main reason why all the line data are saved in the on-board equipment is to avoid the generation of the train intrusion signal, and the relevant drivers take the ground signal as the reference basis in actual driving operation. In the train operation control system of CTCS-1 level, the equipment of CTCS-0 level has been transformed to a certain extent, and the point-type equipment has been added, and the main components of the equipment are the safety type train.

In the CTCS-2 train operation control system, through the use of point transponder, the
information of line parameters, location and temporary speed limit is provided. This level of train operation control system is a point-to-point train operation control system based on point equipment transmission information and track circuit, so there is no need to set up a signal on the ground. In its on-board equipment, the target distance mode curve can be automatically generated to complete the real-time monitoring of train operation safety. In CTCS-3 train operation control system, including wireless block center RBC, wireless communication system GSM-R, station interlocking system and temporary speed limit system TSRS, it is a train operation control system based on wireless communication. In this level of train operation control system, CTCS-2 level control system is used as train backup system.

3. Analysis of Train Operation Control Technology for Urban Rail Transit

Because of its intelligence, efficiency and convenience, urban rail transit train has become an important mode of transportation for urban people to travel everyday. Compared with high-speed railway trains, the operation control technology of urban rail transit trains has obvious differences in the overall demand. At present, the rail transit of major cities in China has been changing from single-track development to the operation of traffic network. In terms of operation, it has completed the development from manual driving mode to ATO (automatic driving mode) and FAO (automatic operation system mode).

Since 2002, China has begun to study the system autonomy of CBTC (train automatic control system based on wireless communication). By 2010, the CBTC signal system developed by China has been successfully operated in Beijing. Up to now, CBTC technology has become the mainstream signal technology used in urban rail transit in China, and its share has reached more than 90%[3]. In CBTC system, the main structure includes vehicle-ground communication equipment, ground equipment and vehicle-borne equipment. Under this mode, the train operation is mainly carried out according to the commands issued by ATS, and the commands such as moving switch, arranging route, lighting and extinguishing light are issued by interlocking equipment. In the closed-loop control based on CBTC technology, the on-board controller of the train transmits the speed, position and other related information to the ground area controller by radio communication. The ground area controller generates the train operation authority according to the location information of the train in the area, and feeds it back to the on-board controller.

In the actual operation of CBTC system, there are many influencing factors, including human error operation, harsh environmental and climatic conditions, etc. At the same time, due to its own complexity, it is necessary to introduce a variety of optimization design models to ensure the safety and reliability of its operation. These optimization
design models include: multi-particle traction and braking characteristic model of single train, information collection and processing of minimum interval between trains. In the operation and maintenance process, operators needs go along the sweep and go from the root to the front in order to find the potential safety hazard in tower crane. Generally, this work can be done in two ways. First one is to drive the cart in which there is basket that can move with the vehicle. Second is that operators climbs along the sweep to do the work.

Monitoring and early warning system model, precise positioning model of sensor coordination of single train under complex line and climate conditions, adaptive coordination and energy-saving control model of multiple trains, etc. Through the use of these optimization models, China's urban rail transit trains have realized the "fish-through" safety tracking of train groups whose main line is less than or equal to
A typical system reliability model is shown in Figure 1. The system reliability evaluation is shown in Figure 2.

4. **Prospect of Train Operation Control Technology in Rail Transit**
Safety, green and high efficiency are the direction of rail transit development and construction. Under such requirements, rail transit train operation control technology will continue to develop towards a more low-carbon, intelligent, networked and open direction. Specifically, China's rail transit train operation control technology will continue to develop in the following areas: First, the improvement of fault detection and intelligent diagnosis technology. In order to detect the status of the equipment in the train in real time and improve the quality of maintenance, the use of monitoring equipment is very necessary. In the future development, we should not only optimize and improve the existing monitoring equipment, but also focus on the application of large data technology and intelligent analysis technology to realize the deep mining of fault data and establish fault model. Real-time analysis of comprehensive data of automatic monitoring can improve the level of automatic fault detection and intelligent analysis, and ensure the safe operation of rail transit trains. Secondly, the research of automatic operation technology.

Next, from the aspect of the structure of the mechanical and electrical equipment monitoring system of rail transit, this paper analyses the structural optimization of the mechanical and electrical equipment monitoring system of rail transit at the present stage in China.

5. **Traditional structure of electromechanical equipment monitoring system**
Traditional mechanical and electrical equipment monitoring system adopts hierarchical and distributed network structure, mainly composed of PLC, sensors and maintenance terminals. The main objects of monitoring are station tunnel ventilation system, station equipment management system, air conditioning water system and other equipment. A set of PLC equipment is set up in the electronic control room at both ends of rail transit. The PLC near the station control room is the main controller and the slave controller at the other end. A set of PLC is set up at the emergency operation panel of the station, and the emergency operation terminal and the main control are connected with it to form the station-level electromechanical monitoring system. Intelligent communication, small-scale control and other equipment are connected to the two ends of the PLC to monitor the mechanical and electrical equipment at both ends of the station, such as air conditioning, low-voltage lighting, etc. The main controller of the station monitoring system and the fire alarm system are connected under the protocol...
converter. In the fire mode, the fire alarm system will issue instructions to the station electromechanical monitoring system. At this time, the station electromechanical monitoring system will start the relevant equipment according to the predetermined mode.[4]

6. Feasibility analysis of electromechanical monitoring

6.1 Structural Adjustment Program

He control equipment of rail transit is the same as the control mode of industrial system. It is a process from centralized control to decentralized control, and the development of bottom equipment from controlled to intelligent. Many years ago, AC400 V switchgear and so on were directly connected to the hard wire in the substation, so that the various devices needed to install the automatic screen to establish a chain relationship. Now each switch is equipped with intelligent protection and monitoring devices, each device is controlled by logical circuit, so that the chain relationship remains safe. A front-end processing unit is installed on the automation screen and connected with the switch cabinet by means of communication. As long as a 64-point DI/O measurement and control unit is configured, it can be connected with the equipment that can not be connected through the intelligent unit. In this way, the reliability is stronger and the debugging pressure of the automation system is reduced. Like the substation automation system, the rail transit system can change the centralized control of the electromechanical monitoring equipment into the decentralized control of each system. Therefore, it is particularly important to improve the electromechanical monitoring system after the structural adjustment.[5]

6.2 Mode Control Function

Mode control is a unique control mode of electromechanical monitoring system, that is, to pre-set control logic of several devices in a certain system, centralized control, such as fresh wind, summer mode, winter mode and other modes of the wind system. After adopting the new structure, the electromechanical monitoring system is only responsible for transmitting the mode signals that must be executed, and the actual control of each equipment is completed by various professional controllers.

7. Conclusion

Concluding remarks high-end PLC controllers with high cost and has been monopolized by foreign manufacturers. The fundamental reason is that the centralized control mode is adopted in the electromechanical monitoring system. There are many I/O modules in the field. To achieve effective communication between each module, the stability of the field bus is required to be very high. Now the most widely used field bus is produced by
Siemens, and many domestic equipment is boycotted outside the door. After the adjustment of mechanical and electrical monitoring system, it is possible to use physical communication in field bus, which can effectively promote the use of various domestic equipment, improve the level of localization of rail transit system equipment, and reduce the cost of equipment purchase.

References


