Overview of the Intelligent Operation and Maintenance System for Shanghai Rail transit Rolling Stock

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ABSTRACT
The traditional rolling stock maintenance model based on planned repairs and fault repairs cannot meet the needs of the rolling stock operation and maintenance for superlarge-scaled networks. There is an urgent need to establish a highly automated and information-based rolling stock intelligent operation and maintenance system based on online monitoring. This paper introduces the composition, main functions and application situations for the Shanghai rail transit intelligent rolling stock operation and maintenance system as well as suggestions for further work related thereto so as to provide references for the development of the rolling stock intelligent operation and maintenance system of the rail transit industry.

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1 Foreword
As a green and energy-saving means of transportation, rail transit has been widely used worldwide. In most international metropolises at home and abroad, rail transit has become the main means of transportation for citizens. As of the end of 2019, a total of 40 cities in mainland China (excluding Hong Kong, Macao and Taiwan) had opened 208 operating rail transit lines with a total length of 6,736.2km. Among them, Shanghai had opened 17 rail transit lines with an operating mileage of 705km, with 4,916 vehicles and with nearly 3,000 train maintenance personnel. By 2020, the total length of the entire Shanghai rail transit network will exceed 800km and be equipped with 7,514 vehicles. With the sharply-rising number of trains, the shortened train operation intervals and the postponed time for ending operations, the pressure on rolling stock operation and maintenance is increasing each day. The traditional rolling stock operation and maintenance model based on planned repairs and fault repairs can no longer meet the needs of the rolling stock operation and maintenance for superlarge-scaled networks. Therefore, there is an urgent need to establish a highly automated and information-based rolling stock intelligent operation and maintenance system that carries out real-time online monitoring, intelligent fault diagnosis and pre-alarm for key systems and components of rolling stock thereby ensuring operation safety and equipment reliability.
2 Current Status of Rolling Stock Operation and Maintenance

Shanghai Metro has accumulated over 20 years of historical experience in rolling stock operation and maintenance. However, in dealing with the rolling stock operation and maintenance for the operation of a superlarge-scaled network, traditional maintenance methods have problems such as high maintenance intensity, low efficiency and high labor costs. As early as 10 years ago, Shanghai Metro carried out researches on related aspects of rolling stock intelligent operation and maintenance, and conducted continuous explorations and experiments on train-borne wireless transmission, train-borne online monitoring and trackside monitoring for running trains. In 2017, Shanghai Metro established the prototype of “Shanghai Metro Rolling Stock Intelligent Operation and Maintenance System (shortened as Rolling stock Intelligent Operation and Maintenance System) 2.0” on Shanghai Rail Transit Line 17 (shortened as Line 17). “Rolling Stock Intelligent Operation and Maintenance System 2.0” is to make full use of wireless data transmission, Internet +, artificial intelligence and big data analysis technologies so as to realize intelligent operation and maintenance and status-based maintenance, which is a revolution in the operation and maintenance for rail transit rolling stock. At the same time, Shanghai Metro has also undertaken a national demonstration project for the intelligent operation and maintenance of urban rail transit rolling stocks. The Shanghai metro intelligent rolling stock operation and maintenance system has implemented a network-based intelligent monitoring across the entire rapid transit network in Shanghai. Nearly more than 300 trains in the entire network have been connected to the system. A ground trackside integrated monitoring system of Shanghai Metro has been put in operation for nearly two years. The system is stable and reliable and can effectively improve maintenance efficiency and reduce labor costs.

3 Shanghai Metro Rolling Stock Intelligent Operation and Maintenance System

The Shanghai metro rolling stock intelligent operation and maintenance system consists of the following four parts: the on-board integrated monitoring subsystem, the integrated trackside detection subsystem for rolling stock, the depot maintenance support subsystem and the ground data management and application subsystem, as shown in Figure 1. Among them, the on-board integrated monitoring subsystem, the trackside integrated detection subsystem for rolling stock, and the depot maintenance support subsystem are used for onsite equipment monitoring/inspection data collection, accompanied with part of edge computing and reasoning analysis (such as real-time image analysis of trackside detection and fault identification). The main tasks of the above-mentioned three sections (parts) are to transmit monitoring/detection data as well as data of calculation and reasoning results to an intelligent operation and maintenance platform, and the data center provides unified basic data services and intelligent analyses.

3.1 On-board integrated monitoring subsystem

Figure 2 shows the topological graph of the intelligent monitoring and diagnosis system for the key onboard subsystem of rolling stock based on the on-board intelligent information Ethernet. The on-board intelligent information network fulfills the functions such as data collection, data processing, data storage as well as on-board pre-diagnoses for traction, auxiliary, pantograph, running parts, air conditioning, PIS and other key subsystems of rolling stock.
3.2 Trackside integrated detection subsystem for rolling stock

The trackside integrated detection subsystem is mainly composed of inspection modules for 360° rolling stock appearance inspection, wheelset size inspection, current collector inspection, tread defect inspection and temperature inspection for the equipment under vehicles, thereby achieving the inspection and repair for rolling stock appearance, wheelset size and current collector via machine rather than via manpower. The onsite installation diagram of the trackside integrated detection subsystem for rolling stock is shown in Figure 3.

3.3 Depot maintenance support subsystem

The depot maintenance support subsystem can
reduce the tedious work of rolling stock maintenance, optimize the operation process, reduce the labor intensity, improve the working environment and improve the maintenance efficiency. This subsystem consists of the modules supporting depot maintenance, i.e., modules of intelligent inspection robots, the inspection management for depot process equipment, the visualized monitoring for maintenance platform, intelligent toolbox and warehouse management and business applications of 5G videos, etc. The schematic diagram of depot maintenance support subsystem is shown in Figure 4.

**Figure 4.** Schematic Diagram of Depot Maintenance Support Subsystem.

### 3. 4 Ground data management and application subsystem

The ground data application and management system is mainly composed of the four modules named as follows: multi-dimensional data acquisition for rolling stock operation and maintenance, basic data management for operation and maintenance, expert system for intelligent operation and maintenance of rolling stock, external platform and shared service system. The application business structural diagram of the ground data application and management system is shown in Figure 5. The multi-dimensional data acquisition for rolling stock operation and maintenance mainly includes: on-board monitoring, trackside inspection, depot maintenance data collection; the basic data management for operation and maintenance mainly includes: master data management, car-type protocol analysis, basic train information, train structure tree, fault dictionary, user information, whole line role management, etc.; the expert system for intelligent operation and maintenance of rolling stock mainly includes: knowledge base, maintenance operation support, train service evaluation, business support management, special business topic analysis, etc.; the external platform and shared service system mainly includes: fault reporting platform, construction management platform, supply chain management platform, spot and routine inspection management platform, enterprise assets management platform, etc.
4 Application of Rolling Stock Intelligent Operation and Maintenance System

At present, the on-board integrated monitoring subsystem has been applied to a total of 300 trains of Shanghai Metro, covering multiple car types. The trackside rolling stock detection subsystem has been put into use in Zhujiajiao Base of Line 17, as well as in Jinqiao Base shared by Line 9 and Line 12. The mobile spot and routine inspection sub-subsystem of the depot maintenance support subsystem has been put into operation in more than 7 lines, and the tool management sub-subsystem thereof has been applied to Line 17. Since the opening of Line 17 at the end of 2017, “Shanghai Metro Rolling Stock Intelligent Operation and Maintenance System 2.0” was set online simultaneously. After the system was completed and put into actual operation, it has played an important role in train maintenance, with the main KPI indicators significantly improved, with daily inspections of vehicle maintenance turned into 8-day (every 8 days) inspections, with the passenger-to-vehicle ratio decreased by 20%, with the train availability rate increased by 3%; with the production efficiency increased by 25%, with the cost reduced by 25%, with the energy consumption per unit output reduced by 12%, with the equipment downtime shortened by more than 25%. The system can carry out the automatic data collection and monitoring, which no longer requires a large amount of human resources engaged in multi-point data collection manually on site, thus effectively improving maintenance efficiency and reducing maintenance and repair costs.

Shanghai Metro will further accelerate the construction and implementation of the rolling stock intelligent operation and maintenance system so as to fully apply “Shanghai Metro Rolling Stock Intelligent Operation and Maintenance System 2.0” to more than 1,200 trains for the 18 lines of Shanghai’s entire rapid transit network as well as all its 27 maintenance bases by 2022.

5. Conclusions and suggestions

The Shanghai metro rolling stock intelligent operation and maintenance system can achieve full coverage status monitoring and data acquisition for key components of rolling stock, shorten maintenance time of the whole lifecycle equipment management, effectively reduce failure risks during
the online operation of rolling stock, improve operation quality and ensure operation safety; at the same time, it can significantly reduce the costs for maintenance and guarantee, increase the efficiency for maintenance guarantee and improve equipment reliability. While Shanghai Metro vigorously promotes the application of “Rolling Stock Intelligent Operation and Maintenance System 2.0” to its entire rapid transit network, it will also focus on the implementation of the following research work.

(1) To formulate whole lifecycle maintenance procedures and establish maintenance management modes based on the exploration for the whole lifecycle operation and maintenance mode of the rolling stock intelligent operation and maintenance system.

(2) To establish standard systems so as to regulate the industry development; to develop the technical standard systems and application management systems that are applicable to different vehicle types, equipment suppliers, and characteristics of various lines of Shanghai rail transit network.

References


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