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Development of high-speed railway signal testing technology and its application in system safety assessment

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Abstract. With the rapid development of high-speed railway technology, the complexity and accuracy of signal system are constantly improving, which puts forward higher requirements for signal testing technology. As a key link to ensure the normal operation of high-speed railway signal system, signal testing technology has experienced the evolution from basic manual testing to highly automated and intelligent testing. In the early stage, high-speed railway signal testing mainly relies on manual operation and simple equipment, and the performance is evaluated by field observation and recording data. Subsequently, with the development of technology, the automatic test system came into being, which significantly improved the efficiency and accuracy of the test, simulated the operation of the signal system in various scenarios, and helped engineers quickly locate and solve potential problems. In recent years, with the help of AI and big data technology, the emergence of intelligent test system has realized the automatic identification and optimization suggestion of abnormal situation of signal system, which has provided strong support for the continuous improvement of the system. High-speed railway signal testing technology plays a vital role in system safety assessment. This technology can not only detect system faults, but also verify the function and performance of the system to ensure the safety and reliability of the whole signal system. Taking the CTCS-3 train control system as an example, the signal testing technology based on simulation testing has conducted a comprehensive safety assessment of the train control system by constructing a virtual test environment and simulating the real train operation scene, which provides a strong guarantee for the safe operation of high-speed railways. However, the signal testing technology also has limitations in system security assessment, such as technical dependence, scene limitation, cost issues and update challenges. In order to further improve its application effect, this paper suggests strengthening technical training, increasing real scene simulation, optimizing test cost, continuously updating technology and introducing intelligent technology.

Keywords: System Safety Assessment; High-Speed Railway; Signal Testing.

1. Introduction

As an efficient and fast mode of transportation in modern society, the safety and reliability of high-speed railway are very important. In the high-speed railway system, the signal system plays an important role, which is responsible for the control and scheduling of trains to ensure the safety of trains in high-speed operation [1]. With the rapid development of high-speed railway technology, the complexity and accuracy of signal system are constantly improving, which puts forward higher requirements for the testing technology of signal system.

Signal testing technology is the key link to ensure the normal operation of high-speed railway signal system, which can effectively detect potential problems and faults in the system, so as to repair and optimize it in time [2-3]. With the progress of science and technology, the signal testing technology is constantly innovating and developing. From the initial basic function testing to the advanced simulation testing, the evolution of each step has greatly improved the safety and reliability of the high-speed railway signal system [4].

This paper discusses the development of high-speed railway signal testing technology, and analyzes its important application in system safety assessment. The evolution and present situation of signal testing technology and its concrete practice in system safety assessment are expounded in detail,

which provides valuable reference and basis for the continuous optimization and safe operation of high-speed railway signal system.

2. Development of high-speed railway signal testing technology

High-speed railway signal testing technology is an important technical field that keeps improving with the rapid development of railway traffic. It has experienced the evolution from basic manual testing to highly automated and intelligent testing, which provides strong technical support for the safe and stable operation of high-speed railway [5].

In the early development of high-speed railway, signal testing technology mainly relies on manual operation and simple testing equipment. Testers need to manually set test parameters and evaluate the performance of the signal system through field observation and recording data. Although this method is basic, it provides a certain guarantee for the preliminary verification of railway signal system under the technical conditions at that time.

With the development of technology, the signal testing technology of high-speed railway begins to develop towards automation and intelligence. The appearance of automated testing system greatly improves the efficiency and accuracy of testing [6-7]. These systems can automatically execute test cases, collect and analyze test data, so as to quickly locate and solve potential problems. In addition, automated testing can also simulate the operation of signal system in many different scenarios, helping engineers to better understand the performance and stability of the system.

In recent years, with the rise of AI and big data technology, high-speed railway signal testing technology has ushered in new development opportunities. Intelligent test system can automatically identify the abnormal situation of signal system through machine learning and data analysis technology, and provide optimization suggestions [8]. This technology can not only improve the efficiency of testing, but also provide strong data support for the continuous improvement of railway signal system. It is worth mentioning that the development of high-speed railway signal testing technology also benefits from the progress of simulation technology. By constructing a virtual railway signal system environment, testers can comprehensively test and verify the signal system without affecting the actual operation [9]. This simulation test method not only reduces the test cost, but also improves the safety and controllability of the test.

The development of high-speed railway signal testing technology is a process of continuous innovation and progress. From manual testing to automatic testing, and then to intelligent testing, every step of evolution provides a stronger guarantee for the safe and stable operation of high-speed railways.

3. Importance of safety evaluation of high-speed railway signal system

High-speed railway signal system is a key component to ensure the safe and efficient operation of trains. With the continuous expansion of high-speed railway network and the continuous improvement of train running speed, the safety and reliability of signal system become particularly important [10]. Therefore, a comprehensive safety assessment of high-speed railway signal system is an indispensable link to ensure the safety of railway transportation.

The safety assessment of high-speed railway signal system can find and correct the potential safety hazards in the system in time. Through professional safety assessment, the hardware, software and network communication of the signal system can be comprehensively inspected and tested, so as to identify possible problems and risks. This helps to take preventive measures before problems occur and avoid safety accidents.

Safety assessment is helpful to improve the stability and reliability of signal system. High-speed railway signal system needs long-term stable operation in various complex environments, and safety assessment can find the performance of the system under extreme conditions, and then put forward

suggestions for improvement and optimization. By constantly improving the stability and reliability of the system, it can be ensured that the train can arrive at its destination safely and on time under all circumstances. In addition, the safety assessment of high-speed railway signal system is of great significance for improving passengers' confidence and satisfaction. When passengers choose high-speed railway as their mode of travel, the first consideration is safety. Through regular safety assessment and public assessment results, passengers' trust in the high-speed railway system can be enhanced, and the reputation and competitiveness of railway transportation can be enhanced.

The importance of safety assessment of high-speed railway signal system is self-evident. It is not only a necessary means to ensure the safety of railway transportation, but also a key link to improve system stability and passenger satisfaction. Therefore, we must attach great importance to and continuously promote the safety evaluation of high-speed railway signal system to ensure the safe, efficient and sustainable development of railway transportation.

4. Application of signal testing technology in safety evaluation of high-speed railway signal system

4.1 Specific function of signal testing technology in system security assessment

In the safety evaluation of high-speed railway signal system, signal testing technology plays a vital role. This technology can not only detect system faults, but also verify the function and performance of the system, thus ensuring the safety and reliability of the whole signal system.

Signal testing technology has a remarkable effect in detecting system faults. By simulating various operating scenarios and abnormal situations, the testing technology can effectively reveal the hidden faults or defects that may exist in the signal system. For example, simulating scenes such as train overspeed and signal equipment failure in the test can check whether the signal system can respond timely and accurately and prevent potential safety risks.

Signal testing technology is also used to verify the function of the system. High-speed railway signal system contains many complex functional modules, such as train control, signal display, turnout control and so on. Testing technology can verify these functional modules one by one to ensure that each module can work normally according to the design requirements [11]. This kind of functional verification is helpful to find logical errors or functional defects in system design, so as to correct them in time.

Signal testing technology can also evaluate the performance of the system. In safety assessment, performance testing is a crucial link. By simulating the train running under different conditions, such as high-speed running and emergency braking, the test technology can collect the performance data of the system under these extreme conditions. These data are not only used to evaluate the response time, accuracy and stability of the signal system, but also provide strong data support for system optimization and improvement.

4.2 Safety evaluation of CTCS-3 train control system based on simulation test

Signal testing technology is widely used in the safety assessment of high-speed railway signal system, among which the safety assessment of CTCS-3 train control system based on simulation test is a typical practical application case. CTCS-3 class train control system is an important part of China's high-speed railway, which is responsible for train operation control and safety protection. In order to ensure the safety and reliability of the system, the signal test technology based on simulation test is adopted to conduct a comprehensive safety assessment.

In the process of safety assessment, the simulation test environment of CTCS-3 train control system is constructed (Figure 1). This environment can simulate the real train running scene, including track layout, signal equipment status, train running status and other factors. By testing and simulating various possible operating conditions and abnormal conditions in this simulation environment, the safety and performance of the train control system are comprehensively evaluated.

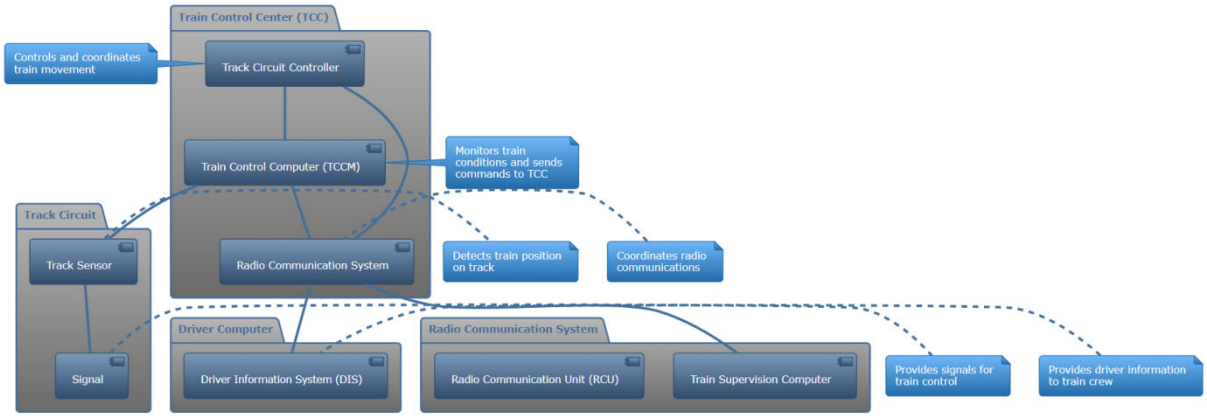

Figure 1 CTCS-3 level train control system

In the simulation test, a series of test cases are designed, including train running under normal conditions, emergency braking under abnormal conditions, signal equipment failure and other scenarios. Observe and record the reaction and performance of the train control system in various situations by executing these test cases. In the test of analog signal equipment failure, deliberately set a signal equipment failure, and then observe whether the train control system can detect the failure in time and take corresponding safety measures. In this way, the safety and reliability of the train control system under abnormal conditions are verified.

Through the safety evaluation of CTCS-3 train control system based on simulation test, the potential problems and risks in the system can be found, and the system can be repaired and optimized in time. This not only improves the safety and reliability of train control system, but also provides a strong guarantee for the safe operation of high-speed railway.

4.3 Advantages and limitations of signal testing technology in system security assessment

Signal testing technology shows obvious advantages in the safety assessment of high-speed railway signal system, such as high efficiency, comprehensiveness, repeatability and prevention, which can quickly and accurately detect problems and faults, comprehensively cover various operation scenarios, ensure the stability and reliability of the assessment results, and prevent safety accidents by finding and correcting problems early. However, it also has limitations, including technical dependence, scene limitations, cost issues and update challenges. Although it can simulate a variety of scenarios, it is difficult to completely replicate all the complex situations of real operation, and it is highly dependent on equipment, software and personnel skills. At the same time, the cost of advanced technology equipment may be high, which increases the total cost of evaluation, and with the upgrading of signal system, testing technology needs to be constantly updated to adapt to new characteristics.

In order to further improve its application effect, it is suggested to strengthen technical training and regularly improve the professional skills of testers; Increase real scene simulation, and cooperate with the railway operation department to obtain actual data for accurate simulation; Optimize the test cost and explore cost-effective test methods and equipment; Continuous technical update, keep communication with suppliers to adapt to system upgrade; Introduce intelligent technology and use AI and big data to improve automation and accuracy. Through these improvement measures, the existing limitations can be overcome, the efficiency, comprehensiveness, reliability and prevention of testing technology can be enhanced, and the railway safety can be guaranteed more effectively.

5. Conclusion

High-speed railway signal testing technology is the key link to ensure the normal operation of train control and dispatching, and it is very important to improve the reliability and safety of signal system. With the progress of science and technology, from manual testing to automatic and intelligent testing,

high-speed railway signal testing technology has experienced remarkable development. In particular, the introduction of AI and big data technology makes the test more efficient and accurate. The technology based on simulation test provides a new method for the safety evaluation of high-speed railway signal system, which can carry out comprehensive test and verification without affecting the actual operation, and improve the safety and controllability of the test. Through professional safety assessment, the potential safety hazards in the system can be found and corrected in time, the stability and reliability of the signal system can be improved, the passengers' trust in the high-speed railway system can be enhanced, and the reputation and competitiveness of railway transportation can be enhanced. Although the signal testing technology shows the advantages of high efficiency and comprehensiveness in the safety assessment of high-speed railway signal system, it also has limitations such as technical dependence and scene limitation. Therefore, it is necessary to strengthen technical training, increase real scene simulation, optimize test cost and other measures to further enhance its application effect.

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