Optimization of CTC System of Beijing-Shanghai HSR and Prospect for its Intelligence

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Abstract: In view of the practical application of centralized traffic control (CTC) system of the Beijing-Shanghai HSR and in combination with the line conditions and user requirements, the system is optimized in terms of route self-triggering polling frequency, train receiving route self-triggering timing, train departure route section processing, route self-triggering between yards, wireless route forecasting and automatic train number conversion, which improves the efficiency of automatic route setting of CTC system and the adaptability of high-density and long-major lines. At the same time, according to the intelligent development requirements of railways, the paper proposes the expectation for the centralized traffic control system of the Beijing-Shanghai HSR in terms of intelligent adjustment of TWD, information sharing with traction power supply supervisory control and data acquisition (SCADA) system/disaster monitoring system, intelligent linkage of posts, etc.

Keywords: Beijing-Shanghai HSR; centralized traffic control system; optimization; intelligence

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1 Introduction

Beijing-Shanghai HSR is the high-speed railway built at one time with the longest mileage of track, the highest technical standards and the fastest commercial operating speed in the world[1]. As the traffic dispatching command system of the Beijing-Shanghai HSR, the centralized traffic control (CTC) system is confronted with challenges such as the inter-office train operations for crossing jurisdictions of multiple Railway Group Co., Ltd., high traffic density, and with more hubs. In the course of practical application, optimizations and improvements have been made in the aspects of automatic route triggering, wireless route forecasting, automatic train number conversion, etc. in accordance with the track line conditions and the users' demands, thus playing the important roles in improving the efficiencies for train receiving and departure, reducing the labor intensity and further securing the train operation safety.

2 Route Self-triggering optimization

The automatic route triggering is one of the core functions for the CTC system[2]. The CTC system needs to improve the efficiencies for train receiving and departure as far as possible under the prerequisite of ensuring the safety of automatic route triggering function so as to better facilitate meeting the demands of high traffic density. Optimizations are thus carried out for the automatic route arrangements of the CTC system in the fields of self-triggering polling frequency, train receiving route self-triggering timing, train departure route section processing, and route triggering between yards.

2.1 Improving self-triggering polling frequency

Automatic triggering of the route for the CTC system adopts the polling triggering mechanism which means that when trying the triggering route, making trial again after certain space of time if the detection shows that the triggering conditions cannot be met. In the initial period when the Beijing-Shanghai HSR was put into operation, the spacing period of self-triggering polling for the CTC system was 30 seconds. With the increase of the train operation density, and for improving the efficiency of train receiving and departure at the hub station and reducing the time of waiting for polling in particular, the spacing period of route self-triggering polling for the CTC system is shortened to 6 seconds by way of theoretical calculation and test verification.

2.2 Optimizing train receiving route self-triggering timing

In the early days of research and development for the CTC system, the way that the receiving/passing routes for the succeeding train of the same direction can only be processed after the complete entrance of the front train into the track is adopted, for which such a logic cannot satisfy the characteristics of the high density for train operation of Beijing-Shanghai HSR. With the optimization of the algorithmic logic, the succeeding route can be processed by CTC at the time of 6 seconds following the clearance of occupancy in the overlapping section of both front and rear route crossing[2].

2.3 Train departure route section processing

Generally speaking, the train departure route of the station is processed at one time from the starting signal to the station entrance. The prerequisite for processing the train departure route by the CTC system is the clearance of the train leaving section[3]. At the station with long throat (the Beijing South Railway Station for example), the advance starting signal is usually set in signal design for improving the efficiency of train departure. The original one train departure route from the starting signal to the station entrance is divided into two sections, for which one is from the starting signal to the advance starting signal and the other is from the advance starting signal to the station entrance. For the stations with the advance starting signals, the train departure route will be optimized and processed in sections by CTC so as to improve the efficiency of train departure. It means that the train departure route from the starting signal to the advance starting signal can be automatically processed following the complete entry and leaving of the front train, and the self-triggering train departure route from the advance starting signal to the station entrance is processed following the train leaving and the section clearance, thus improving the train receiving and departure efficiencies of the large stations.

2.4 Route self-triggering between yards

There exist routes between yards for the Hongqiao Hub and the Nanjingnan Hub of Beijing-Shanghai HSR, for which there is the situation that the route for the front far-end station of train operation needs to be processed first before the signal can be opened for the near-end station if the route is to be processed at the interlocking terminal. The principle of automatic triggering route for CTC is to process the route station by station according to the sequence of plan for train operation, which means that the CTC system needs to process the route of the relevant train of the near-end station first and then the train route of the far-end station. To achieve the automatic triggering of routes for the two stations having relations between yards, the CTC system optimizes the route triggering logic under such scenario. When the forward near-end station of train operation needs the route to be processed, the far-end station should be noticed first with the information of the train number requiring for processing the train route in advance, for which the far-end station, upon receiving such information, will process immediately the train route if it is certain by judgement that the train number is just the one of the first train in that direction requiring the processing of train route in advance, and meanwhile give the feedback of information for successful processing to the near-end station. The near-end station, upon receiving the information for successful processing, will check the plan of the station itself once again and execute the self-triggering operation if it is certain that the train number is still the one of the first train in that direction requiring the triggering of the train route[4]. The logic thus achieves the automatic triggering function of routes for the two stations having relations between yards, and effectively avoids the happening of mistaken processing in the intermittence between the communication and the processing of the two stations due to the sequence adjustment of the plan.

3 Wireless Route Forecasting Optimization

Wireless route forecasting is an important function of the CTC system, for which the main principle is to forecast the route processing situation to the train through the wireless system such as GSM-R following the route arrangement of the CTC system. In the course of the Beijing-Shanghai HSR construction and operation, the wireless route forecasting of the CTC system refers mainly to the functions such as optimizing the wireless route forecasting for the inter-office operating trains and increasing the wireless departure route forecasting.

3.1 Wireless route forecasting optimization for inter-office operating trains

Correct reception of the wireless train number information is the prerequisite for accurately sending the wireless route forecasting by the CTC system. GSM-R system sends the wireless train number information to the CTC system according to the inter-office dispatching jurisdiction ranges. The inter-office operation of the Beijing-Shanghai HSR leads to the failure of the trains operating in the sections of the inter-office boundaries in obtaining the wireless train numbers and further leads to the failure in sending the route forecasting. The inter-office dispatching jurisdiction ranges are schematically shown in Fig. 1, from which the up train operates from C station to B station. When the train operates in the section between C station and B station, B station has got the route processed and needs to send the wireless route forecasting to the train at that time. However, due to the fact that the train has not yet entered the track under the jurisdiction of the A Railway Group Co., Ltd., GSM-R system of the company cannot send at the time the wireless train number of the train and thus leads to the failure of the A Railway Group Co., Ltd. in sending the wireless route forecasting.

The CTC system achieves the bidirectional transmission function of the train number in the section of the boundary through the interactive wireless train number of the system's inter-office boundary, among which the A Railway Group Co., Ltd. sends the wireless train number information in the range from A station (excluding A station) to B station (including B station). The B Railway Group Co., Ltd. sends the wireless train number information in the range from B station (excluding B station) to C station (including C station). The forward Railway Group Co., Ltd. of the train operation receives in advance the wireless train number information and thus achieves the normal reception of the wireless route forecasting for the train of inter-office operation.

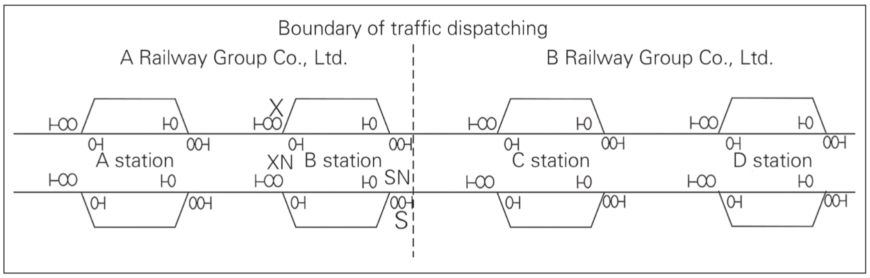

Fig. 1 Schematic diagram of inter-office dispatching jurisdiction range

3.2 Wireless departure route forecasting function

The function of the wireless receiving route forecasting for the CTC system is mainly to offer to the train the forecasting of processing for the receiving route or the passing route. In the course of practical operation, the traffic department puts forward the functional demand for "wireless departure route forecasting", which means that the system sends the forecasting information of the successful processing for departure route (or passing route) and that of the name for the next station to the train driver following the processing of the departure route (or the passing route). Such function has been included in the *Provisional Technical Conditions for the Intelligent CTC System*[5]. In July 2021, the wireless departure route forecasting function of the CTC system for Beijing-Shanghai HSR was started to be used, which has reduced the labor intensity of combined manual and vehicle-engine control and guaranteed the safety of railway transportation with good performance of operation.

4 Automatic Train Number Conversion

In the course of the high-speed railway operation, train numbers are the important symbols of HSR trains and also the important parameters of the CTC system for making plan adjustments and automatic route arrangements. Beijing-Shanghai HSR has multiple originating and arrival stations and there exist many cases such as it crisscrosses to operate with multiple other tracks of HSR in the meantime, change of train numbers for trains entering and leaving the depot, change of train numbers for arrival trains turning into originating trains due to turnaround, and change of train numbers for cross-line trains for parallel operation. If the train numbers are revised manually, it needs to take up a lot of energy from the controller (foreman). Therefore, the function of automatic change for train number is added to the CTC system so as to achieve fully automatic generations and changes of the train numbers for trains entering and leaving the depot, of the train numbers for originating and arrival trains of the turnaround station, and of the train numbers for cross-line trains for parallel operation at the turnaround stations and the stations for cross-line trains for parallel operation where train numbers are automatically changed based on the train operation plan. According to the statistics, the reduction of manual revision of train numbers for a single day for the CTC system of the Beijing South Station of Beijing-Shanghai HSR reaches over 300 times.

5 Prospect for Intelligence

Currently, the work of intelligence for the dispatching command system of HSR train operation has been carried out in good order with the formal promulgation and implementation of the *Intelligent High-speed Railway System Architecture 1.0*[6]. The intelligent CTC system is the replenishment of demands for intelligence on the basis of the existing CTC system and the intelligent CTC system for Beijing-Shanghai HSR is the development orientation for the next-step traffic dispatching command. In combination with the practical situation of the Beijing-Shanghai HSR, the core functions of the intelligent CTC system for the HSR such as the intelligent adjustment of train working diagram, the combination of CTC with the acquisition and monitoring operation of the traction power supply data (SCADA) system, the combination of CTC with the disaster monitoring system as well as the intelligent linkage of posts will be taken as the emphases of the current researches and future applications[7-9].

5.1 Intelligent adjustment of TWD

Preparation and adjustment of the train working diagram (TWD) are the important work of the high-speed railway operation, and in the case of emergency in particular, it will be especially important for the rapid adjustment of the TWD. At present, the adjustment of TWD mainly relies on the manual work to complete, for which on the one hand the labor intensity is great, and on the other hand the adjustment quality and effects of the TWD will vary with each individual due to the differences of experience and level of traffic controller and the interference from the psychological factor that is liable to have in the case of emergency.

Modeling is conducted through the system for the data of the intelligent CTC system such as the comprehensive track data, the vehicle data, the disaster monitoring information, and historical disposal law to realize the intelligent adjustment for the train operation plan and achieve the objective of rapid and rational adjustment for the TWD[7]. When the system receives the information of equipment failure, closure of the section and track can be set based on the equipment failure to complete the operations for detention or stop of the train path and track adjustment. When the system receives the disaster alarms for wind, rain and snow, real-time calculations of the data for the train position, ranges of speed restriction and values of speed restriction will be carried out so as to make corresponding adjustments for the train operation plan. The system can make the forecasting of train delay based on the situations of detention, stop and speed restriction, and forecast the early arrival or delay of trains from the other Railway Group Co., Ltd. through the inter-office interface. Meanwhile, adjustments can be made for the originating time of train according to the minimum turnaround time when the train is delayed at the turnaround station. Emphasis for the intelligent adjustment of the TWD should be laid on the solution of automatic adjustments for the cross-platform and inter-office operational plans.

5.2 Combination of CTC and SCADA systems

At present, applications and notices for the construction plan of power supply interruption and transmission or appearance of temporary power supply interruption in the field are executed between the traffic controller and the controller for power supply through telephone communication or other management system, for which the controller for power supply operates the interruption of power supply from the feeding section on the SCADA system and the traffic controller sets the states of power supply interruption or resumption to enable the CTC system to control the train signal. With the combination of the CTC system with the SCADA system for traction power supply, integrated management and control for the operation of power supply interruption and transmission can be achieved, which means that the traffic controller and the controller for power supply execute the management function through the interactive applications and notices for the power supply interruption and transmission between the systems and can in the meantime control the train operation with or without power supply traction while further achieving the operation of power supply interruption and transmission for the SCADA system, and the CTC system can realize the control to prevent the electrical traction train (EMU train) from entering the area of power supply interruption. The combination of the CTC system with the SCADA system is required to lay emphasis on the solution of problems for real-time and accurate information transmission so as to ensure timely and accurate control of safety[7-8].

5.3 Combination of CTC and disaster monitoring system

Terminals are allocated at the traffic control console for the disaster monitoring system to mainly display the disaster alarm information such as those for wind, rain and snow. Upon observing the alarm information, the traffic controller will prepare and send the information such as for temporary speed restriction and wireless dispatching orders on the CTC system. With the achievement of combination of the CTC system with the disaster monitoring system, the intelligent CTC system can receive the alarm information about wind, rain and snow for the disaster monitoring system and display it on the display screen of the CTC traffic control monitoring, from which the CTC system can assist the traffic controller to prepare rapidly the wireless dispatching orders and the orders for temporary speed restriction, and meanwhile complete the intelligent adjustment of the train operation plans according to the information of speed restriction[9]. The combination of CTC with the disaster monitoring system is required to lay stress on the solution and disposal of the problem of variability existing in the disaster information such as those for wind, rain and snow.

5.4 Intelligent linkage of posts

Currently, the posts for the train receiving and departure operation of the high-speed railway cover mainly the station foremen, field assistants, integrated controller of passenger transport, etc. and the information requiring transmission include those for confirmation of the train receiving and departure plans, conditions of the train receiving and departure operation, etc. Current means for transmitting information of operation from different posts are mainly through mobile phones and walkie-talkie.

The intelligent linkage system of posts will allocate the mobile intelligent terminal for different posts of the station, which can achieve the function of uploading and delivering the information of operation. The mobile intelligent terminal can make use of the Wi-Fi or 4G/5G special network of the station, with which the intelligent CTC system will issue the train receiving and departure plans, the requirements for operation, the dispatching orders, etc. to the relevant posts, and the staffs of different posts can transmit the information about water supply/sewage suction operation as well as the short notes acknowledging receipt of the orders to the station foremen through the mobile intelligent terminal.

6 Conclusion

System optimization and function improvements have been greatly carried out for the CTC system over the past ten years since the Beijing-Shanghai HSR opened to traffic. In combination with the current development trend of modernization and information technology for the railway equipment, the CTC system intelligence of the Beijing-Shanghai HSR will be the future development orientation and the intelligent CTC system will improve the operation levels of traffic dispatching command for the traffic dispatching command center and the stations, thus providing better supports for securing the train operation safety and improving the traffic efficiency[10].

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