ANALYSIS OF THE ARCHITECTURE AND RELIABILITY OF DATA TRANSMISSION NETWORK USED FOR RADIO BASED CAB SIGNALING SYSTEM

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Abstract: The application background and basic structure of train control system based on the combination of Radio Based Cab Signaling (RBCS) and Automatic Train Protection (ATP) is introduced. The architecture of the data transmission network used for RBCS is analyzed in detail, together with the reliability of radio data transmission.

1 INTRODUCTION

Communication Based Train Control (CBTC) system is the development trend of train control techniques, which has many advantages compared with Track circuit Based Train Control (TBTC) system. For example, bi-directional train-track communication with large information volume can be realized; close-looped train control can be formed to improve train operation safety; moving block or virtual block can be implemented to enhance traffic efficiency.

Chinese Ministry of Railways (MOR) is now advocating CBTC techniques, and has made a strategy to develop Chinese Train Control System (CTCS) which is now under stepwise implementation. CTCS consists of five application levels, from level 0 to level 4, in which level 3 and level 4 will be based on CBTC techniques. In the near future, part of the technique will be applied on Qinghai-Tibet Railway and Datong-Qinghuangdao Railway.

The Qinghai-Tibet Railway is built on a plateau with perennial frozen soil and very harsh climate. The lowest temperature is –45.2°C and the maximum temperature difference is 35°C. Under these conditions, the parameter of track circuit will change considerably, resulting in the unstable operation of track circuit. Especially, the insulation joint of track circuit will be easily damaged. To the Datong-Qinghuangdao Railway which is a dedicated coal line, a transport capacity expansion plan will soon be carried out, with the goal to increase train weight from 10,000 tons to 20,000 tons. As a result, the traction current will reach as high as 1000~1500A, causing the unbalanced current to exceed the standard by a great margin, which will directly affect the normal operation of track circuit.

In view of above situations, the MOR has decided to use radio to transmit train control information, and has started the research on Radio Based Cab Signaling (RBCS) system, which is now under experiment.

After giving a brief introduction to the train control system based on the combination of RBCS and ATP system, this paper will focus on analyzing the architecture of the radio transmission network used for RBCS, together with the reliability of radio data transmission.

2 RBCS SYSTEM

RBCS is a kind of device that transmits cab signal and train control information by means of radio. It consists of two parts: the station control equipment and the onboard equipment. The transmission network can use either radio data transceiver, GSM-R or TETRA as the transmission media.

There are two types of RBCS. One type is called continuous RBCS because it can provide cab signal both at stations and in sections; another type is called approaching continuous RBCS because it can only provide cab signal when a train is running within station area.

RBCS can work with onboard ATP equipment,

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interrogator/balise, station interlocking, axle counters and so on to realize close-looped train control. As a result, train operation can be continuously tracked and monitored, thus enhancing train operation safety, reducing trackside equipment and lowering maintenance cost.

The working principle of the approaching continuous RBCS can be briefly described as following. When a train enters the effective working area of RBCS, its onboard equipment will apply for registration to the SCC. Upon receiving the registration information, the SCC will pick up the cab signal information related to the train from the station interlocking and send it to the train. After receiving the cab signal information, the onboard equipment will indicate the cab signal to the driver and relay it to the ATP onboard equipment. At the same time, train position and speed, the return receipt of cab signal and so on are sent back to the SCC in order to verify the correctness of the transmitted information. When the train exits the RBCS effective working area, it will be deregistered by the SCC.

3 THE ARCHITECTURE OF DATA TRANSMISSION NETWORK

The radio data transmission network is the foundation of RBCS, and is one of the key technical issues. Many issues concerning the transmission network should be properly addressed, such as network architecture, transmission method, addressing mode, common frequency interference, frame collision, data transceiver deadlock, radio coverage, handover, communication protocol and so on.

The approaching continuous RBCS uses the commercial radio data transceiver to form a data transmission network. There is a onboard radio on each locomotive, and a base radio station at each station, with all radios numbered in a unified way. Thus, a local radio transmission network is formed by the station base radio and all the onboard radios equipment within the station area; the whole transmission network of RBCS is formed by all the local transmission networks along the railway. Same frequency is used for the station and all the trains within its controlled area, to share the channel in a time multiplexing way.

The basic requirements on the data transmission network are the reliability and availability, which include following contents:

(1) To meet the real time requirement of data transmission, in order to guarantee the response time of RBCS.

(2) To meet the requirement of information volume.

(3) To guarantee that a unique communication channel is established between the station and a given train.

(4) To meet the error rate and reliability requirement in data transmission;

(5) To guarantee a reliable radio coverage for all the trains within the station area.

The characteristics of the radio data transmission network are described as following.

3.1 Dynamic Network Organization and Network Mobility

A train approaching a station has to register to enter the local transmission network of a station, and a train leaving the station is deregistered to exit the network. Because a train moves along the line continuously, the members of the station local network are not fixed. On the contrary, it is a dynamic joining and splitting process. In this sense, the whole network formed by all the local networks along the line is mobile.

3.2 Star Shape Network Structure

The station local network is a star shape network, with the station base radio at the center, and all onboard radios as the network nodes.

3.3 Using Different Frequencies Alternatively in Different Stations

As shown in figure 1, every three stations use a frequency group, to avoid common frequency interference between stations. Each station has two radios, one is used for up running direction, and the other for down running direction, with two different frequencies for each running direction respectively. For example, frequency F_2, F_4 , F_6 are used for up running direction, and F_1, F_3, F_5 for down running direction.

The frequency used for a train to communicate with the next station can be pre-stored in a balise. When an outbound train passes the balise, the onboard interrogator will pick up the frequency information from the balise and pass it to the onboard control equipment of RBCS, which will accordingly set the frequency of the onboard radio to the new value.

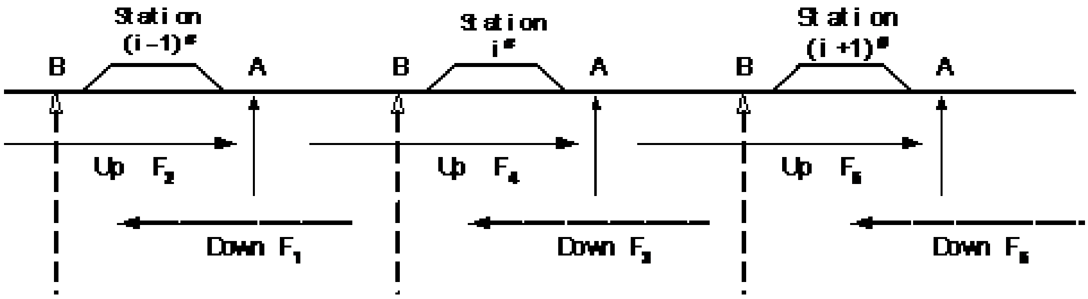

Figure 1: Frequency distribution in RBCS

3.4 Addressing Mode

The radio data transceiver used for RBCS works in addressing mode, because all the radio stations within the station area use the same frequency. Therefore, the network address of the radio should be included in the data frame. When a data transceiver receives a data frame, it will compare the address contained in the frame with its own address. If two addresses match, the data frame will be passed to the main controller for further processing; otherwise the data frame will be rejected.

3.5 Data Frame Collision and Communication Jam

Data frame collision can be avoided by adopting time multiplexing and communication protocol. The communication protocol will put strict constraint on the time slot, the communication sequence of the time slot, as well as the master-slave relationship between the station radio and the onboard radio, in order to guarantee the orderly communication between station and train. During communication, the onboard radio and the station radio may be deadlocked for some reasons. In order to avoid the interruption of the communication, overtime detection circuit is designed to reset the radio.

3.6 Using Changeable Data Frame

The information transmitted by RBCS is divided into three classes. Class I includes the basic train control information; Class II includes the number of the route for train receiving/departure, train number, train actual speed and maximum allowed speed, train position, etc. These above two classes of information are vital train control information. Furthermore, if permitted by time delay. The third class of non-vital information used for the engineering department, communication and signaling department as well as locomotive department can be transmitted. Therefore, different frame format with long, medium and short length can be chosen according to different requirements.

4 RELIABILITY OF RADIO DATA TRANSMISSION

Because RBCS is used as a warrant for train operation on main lines, its reliability, availability, maintainability and safety (RAMS) is very important. The transformation from TBTC to CBTC, is actually the transformation of information transmission channel. Therefore, the unreliable factors caused by the transformation should be properly addressed in system design. In the approaching continuous RBCS, following measures are adopted to guarantee the reliability.

(1) Any transmitted information is constrained by the limitation of target address. In RBCS, the information is transmitted via radio channel in the open space, therefore, each station and on-board control equipment of RBCS must be assigned a unique network address.

(2) Time stamp is used to guarantee the time validity of the information. In RBCS, information is transmitted on time division multiplexing basis, which may be interfered or attacked intentionally or unintentionally, therefore, time stamp is used in the bi-directional communication between train and station, namely, the sender of the information should attach the transmitted information with a time stamp; upon receiving the information, the receiver will check the time stamp for time validity. If the time stamp expires, the information is regarded as invalid and will not be executed

(3) Train registration method. Any train in the controlled area of the dispatcher is assigned a unique train number according to traffic plan. The train number is associated with a registration number. So, only a registered train can perform valid information

transmission in the radio channel.

The three-dimension control puts a strict constraint on the bi-directional communication, namely, only when the information has qualified for the three constraints of address, time stamp and registration number can it be regarded as valid. In the effective working area of RBCS, each train occupies a fixed space at any time, and is assigned a unique registration number.

5 CONCLUSION

The result of the field test of RBCS has proved that the structure of the transmission network and the reliability of RBCS can meet the requirement of train control. The constitution of data transmission network by such methods as dynamic network organization, star shape network, alternative frequency used for different stations, and addressing mode is reasonable and practicable. The three-dimension control technique proposed in the paper can enhance the reliability remarkably.

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