Development of CBTC for Global Markets

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OVERVIEW: On December 30, 2011, on a monorail signals system for Chongqing in China, Hitachi commissioned its first CBTC system to be installed outside Japan. The Chongqing Monorail 3rd Line is a long-distance service with a total length of 55.6 km (39.1 km currently in use). Moving block control based on radio communications has been installed along the entire length of the line to allow high-density services with a headway (interval) between trains of only 120 seconds. The system was designed from the outset to allow for future enhancements, and incorporates the latest technology for driverless operation. Building on the success of projects such as this, Hitachi intends to continue operating its business globally in the future.

INTRODUCTION

IN 1997, Chongqing was designated China's fourth direct-controlled municipality (meaning it is administered by the central government), the others being Beijing, Shanghai, and Tianjin. The largest of the four, it comprises 19 districts, 15 counties, and 4 autonomous counties. In June 2010, it became the first inland national development zone with the establishment of an inland special taxation zone combining both port and airport. It has grown to become the largest industrial city in China's southwest, acting as an economic gateway to the west and providing the land and water transportation infrastructure vital to economic development.

Central Chongqing straddles two major rivers, the Yangtze and Jialing, with a topography characterized by limited land area and steep gradients that are unfavorable to the construction of railway lines. Accordingly, the city chose to install monorails, recognizing these as being best suited to the geographical conditions. Chongqing Monorail 2nd Line commenced operation in June 2005, and was followed in 2011 by Chongqing Monorail 3rd Line, which incorporates the latest technology.

This article gives an overview of the communication-based train control (CBTC) system for Chongqing Monorail 3rd Line, the first such system supplied by Hitachi outside Japan, and describes the future prospects for the global deployment of CBTC.

Fig. 1—Map of Urban Transportation Services in Chongqing and Monorail Vehicle.
As indicated by the "3," Chongqing Monorail 3rd Line runs through the city from north to south. It has the highest number of passengers of all the city's lines, and includes stations that also serve lines 1, 2, and 6.

OVERVIEW OF CHONGQING MONORAIL 3RD LINE

Project Summary

Chongqing Monorail 3rd Line runs from north to south across the city's two main rivers, with 39 stations along a total length of 55.6 km and a final termination at the city's northern airport (see Fig. 1).

Service commenced on stages 1 and 2 of the line (approximately 40 km between Ertang and Jiangbei Airport) on December 30, 2011. This made it the world's longest such line at that time. Table 1 lists the main technical specifications.

System Configuration

Fig. 2 shows the system configuration.

(1) Wayside equipment configuration

The wayside system consists primarily of traffic management equipment that manages the status of traffic on the line and issues commands for vehicle movement, interlocks that control vehicle movement based on the commands from the traffic management equipment, automatic train protection (ATP) equipment that uses position, movement, and other vehicle information to generate control information for each train on the line to control the headway between trains, and the base stations that provide radio communications with the trains.

(2) Onboard equipment configuration

Onboard systems include onboard ATP equipment that determines train position and performs brake control based on commands from the wayside, radio units for communications with the wayside, displays for presenting information to the driver, and a control panel for entering operational commands.

(3) Other components

In case of a fault in the CBTC system, Chongqing Monorail 3rd Line also has a separate backup system for train position detection. This backup system uses axle sensors to determine train position.

Overview of CBTC System Control Functions

(1) Moving block control

Whereas the track circuit method used in the past determined train position in terms of fixed track segments, the CBTC system uses moving block control whereby "limit of movement authorities" for each train are updated and sent to the trains in realtime, based on actual train movements.

(2) Use of onboard positioning for position detection and safety margin distances

Because it determined train position in terms of track circuit segments, the track circuit method used in the past did not have to deal with errors in train position. In the CBTC system, on the other hand, train position is determined by wayside ATP equipment and uses position information generated by onboard devices on each train that work by integrating speed sensor information. This means there is a potential for error in the positions produced by the onboard ATP equipment, and therefore that it is possible for a train's position in the system to be different to

Table 1. Main Technical Specifications of Chongqing Monorail 3rd Line

In addition to the standard monorail specifications, the line also includes the latest CBTC technology.

	Parameter	Phases 1 and 2
Operations	Rolling stock system	Monorail (rubber tires)
	Operating mode	ATO with single driver (Driverless operation for reversing direction)
	Trainset configuration	Six cars
	Operation at rolling stock depot	Under driver control (with inhibit functions to prevent inappropriate operation)
	Operating speed	75 km/h
	Headway between trains	120 s
	Length of line	40 km
	Number of stations	29
CBTC specifications	Control system	Moving blocks
	Type of radio transmission	Radio (via access point)
	Radio frequency	2.4 GHz
	Vehicle position detection at system startup	Onboard: Onboard position confirmation when vehicle passes balise Wayside: Position acquired from onboard position notification

ATO: automatic train operation CBTC: communication-based train control

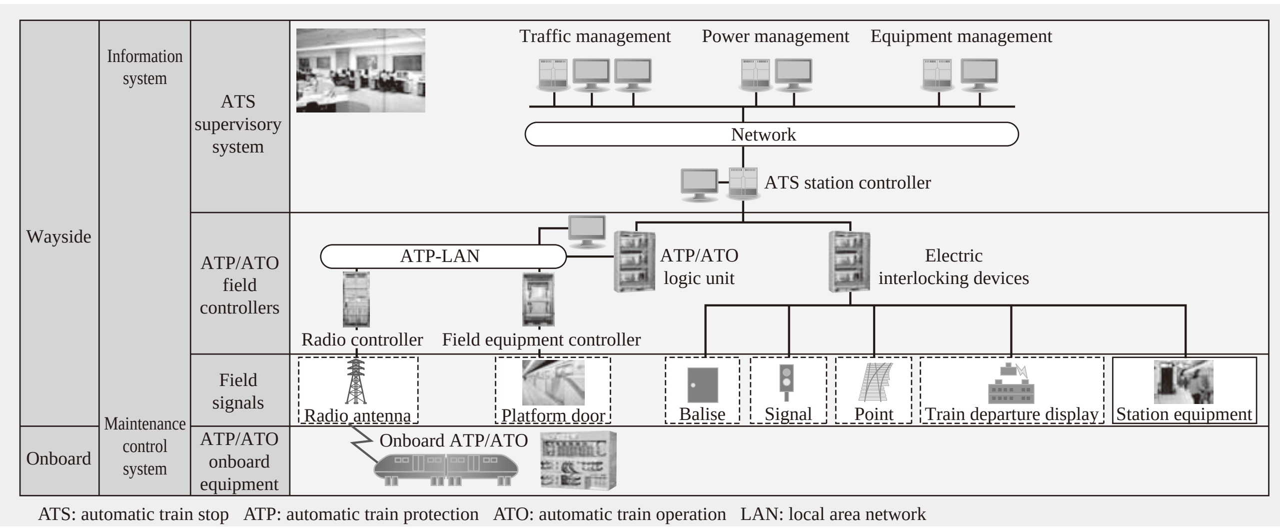

Fig. 2—Overall Configuration of Chongqing Monorail 3rd Line.

The CBTC system can be broadly divided into four levels, consisting of the ATS supervisory system, ATP/ATO field controllers, field signals, and ATP/ATO onboard equipment.

its actual position. Accordingly, a train positioning method that allows for position detection error when determining positions is needed. Also, this error in positioning needed to be considered when setting the safety margin distance between the reference points for the protection pattern for stopping by the onboard ATP equipment and the absolute stop position.

(3) Use of radio communications for positioning

The previous track circuit method used physical means to detect train position, which meant that the wayside equipment detected the train position itself, independent of any notification from the train. Also, because a fault in the track circuit was interpreted as the train being at that position, the train position was never uncertain. On the CBTC system, in contrast, because positioning needs to be done using positioning information from the onboard ATP equipment, relying on communications between train and wayside, the train position becomes uncertain if radio communications are interrupted. Consequently, the CBTC system allocates a fixed protection margin if radio communications are interrupted. Fig. 3 shows a flow chart of how the CBTC system works.

SOLUTION DESIGNED FOR GLOBAL MARKETS

While paying close attention to experience from Japan, the prospect of future sales in the global market was taken into account when determining the specifications for the signals system for Chongqing Monorail 3rd Line. The following sections describe the strengths of Hitachi's CBTC system.

Driverless Operation (UTO)

Emphasizing past experience with monorails in Japan, the signals system for Chongqing Monorail 3rd Line has been designed on the basis that the trains will mainly be operated by automatic train operation (ATO) with a single driver. As a special case, however, the system also incorporates an unattended train operation (UTO) function for use when reversing direction at a station. The purpose of this function is to avoid the time delay while the driver moves to the control console at the other end of the train (because the headway available for reversing direction is short). This requirement was included in the specifications from the initial design stage.

The sequence of operation is: traffic management issues automatic driving command → determine automatic movement to execute → select automatic control console → proceed to departure platform under automatic control. This provides all the elements required for UTO using established technology throughout.

The IEC 62267 standard of the International Electrotechnical Commission (IEC) defines four levels

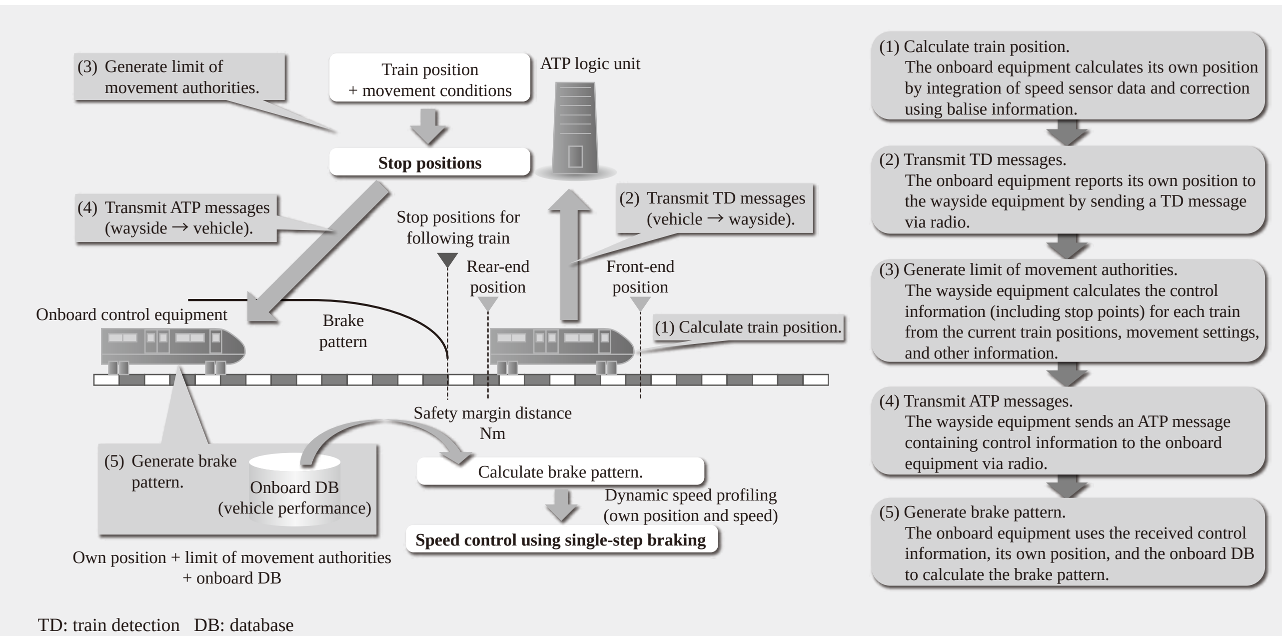

Fig. 3—Flowchart of CBTC System.

Moving block control is implemented using onboard position reporting devices that operate via the industry/science/medical space-wave radio band (2.4 GHz). The use of radio allows for the transmission of a high volume of control messages and continuous detection of train information.

of automation, and there is growing demand for UTO in new CBTC projects for urban transportation in other countries. In addition to the technology provided for Chongqing Monorail 3rd Line, Hitachi also has extensive operational experience with driverless operation in Japan (on the Nanakuma Line of the Fukuoka City Transportation Bureau, Nanko Port Town Line of the Osaka Municipal Transportation Bureau, Seaside Line of Yokohama New Transit Co., Ltd., and Tokyo Waterfront New Transit Yurikamome). Hitachi intends to combine these technologies to establish its own comprehensive CBTC solution.

Delivering on Requirements for Headway between Monorails

The requirement for the headway between trains is known to be more severe for monorails than those that typically apply on conventional undergrounds. The following are some of the reasons why achieving the required headway between trains is more challenging for monorails.

(1) The nature of monorail vehicles means that their accelerations, decelerations, and top speeds are slower than those of conventional underground rolling stock.

(2) The configuration of points used on monorail lines are such that speed limits are set slower, and the points take a longer time to switch.

(3) A section of siding track is commonly used at locations where the train reverses direction (as in the case of Chongqing Monorail 3rd Line).

The requirement for the headway between trains on other CBTC projects in China (for conventional headway lines) is typically 120 seconds, and this same requirement applies to Chongqing Monorail 3rd Line. This means that the CBTC for Chongqing Monorail 3rd Line needs to deliver equivalent performance to a headway system despite its being a monorail. Nevertheless, the ability of Chongqing Monorail 3rd Line to achieve a 120-s headway under these severe conditions was demonstrated both by simulation and through analysis of actual measurements of headway. This suggests that even shorter headway should be possible under the more favorable conditions that typically apply in conventional undergrounds.

Adoption of International Standards

(1) Radio system

The radio system for Chongqing Monorail 3rd Line uses orthogonal frequency division multiplexing over the general-purpose industry/science/medical radio band to provide the interface between the wayside and onboard systems. In readiness for future deployment in international markets, Hitachi supplies its own proprietary radio products that combine a high level of security and reliability with an architecture that is able to tolerate interference, and is able to install radio systems that can operate seamlessly in different countries regardless of the regulatory and other requirements of radio use that apply in that country.

(2) Balise system

The balise system for Chongqing Monorail 3rd Line complies with European standards. Because of the severe requirements that apply for monorails in terms of the separation between balises and onboard pickups, Hitachi has experience in balise installation, transmission methods, and the design of message data, and has established technology for interfacing between wayside and onboard systems.

Mixed Operation

As described above, the CBTC system uses radio to send information about train positions. If communications are interrupted by external interference or a fault within the radio system itself, position notifications from the onboard equipment are lost and the train position becomes unknown. While this can be thought of as an inevitable consequence of using a CBTC system, safety requirements are being made more stringent throughout the world, and the IEEE 1474 standard specifies an optional mixed operation function whereby the sending of train information via radio is augmented by a physical system for detecting train position.

Detailed design work is currently underway with the aim of providing Chongqing Monorail 3rd Line with such a mixed operation capability so that it can detect non-CBTC trains (trains without onboard radio) during normal CBTC operation. This function is to be offered as one of the options available for augmenting Hitachi’s CBTC solution product.

CONCLUSIONS

This article has given an overview of CBTC system for Chongqing Monorail 3rd Line, the first such system supplied by Hitachi outside Japan, and described the future prospects for the global deployment of CBTC.

Railway signals systems used around the world can be broadly divided into those used on main lines that provide high-speed and long-distance services linking major cities [European Train Control System (ETCS)], and those for the undergrounds, monorails, and other new modes of urban transportation that provide short-distance services within cities (CBTC). A common feature of both of these is a shift to radio-based train control from the track circuit method used in the past for detecting train positions and transmitting control information. Hitachi commenced work on developing these internationally standardized signals systems from an early stage and has completed two separate signals control systems for China, one of each of the above types. Commissioned at roughly the same time at the end of last year, these two systems were supplied to different users and used different state-of-the-art technologies.

Hitachi anticipates installing the CBTC system for urban transportation described in this article in other major cities, in China and around the world, with the market for such systems being larger (in terms of both the number of projects and number of vehicles) than that for main line systems. Building on its success with Chongqing Monorail 3rd Line, Hitachi is seeking to extend its range of CBTC products.

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