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Engineering Guide for Interoperability of Communication Based Train Control (CBTC) Signal Systems for Urban Rail Transit

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THE TECHNOLOGY & EQUIPMENT COMMITTEE OF CAMET
THE NATIONAL ENGINEERING LABORATORY OF
URBAN RAIL TRANSIT COMMUNICATION AND OPERATION CONTROL

The China Association Of Metros (CAMET) is the China national first-level association in the field of urban rail transit in China. We focus on contribution to urban rail transit planning, design consultation, investment financing, engineering design, operation management and equipment manufacturing. Our founding members are research institutes and universities, etc. whom gathered together to form this association. Since its establishment on October 14, 2011, the nationwide, industry-based, non-profit social organization has played an important role in serving the technological development of China's rail transit industry, promoting industrialbest practices and building multi-party communication channels. The Technology & Equipment Committee is a subordinate unit of the CAMET. It aims at assisting government departments to promote the autonomy of urban rail equipment, serve member units, and promote healthy/sustainable development of the industry.

The National Engineering Laboratory of Urban Rail Transit Communication and Operation Control (URCC) is led by Traffic Control Technology Co., Ltd., which adopts collaboration and innovation model of 'politics, industry, learning, research, and practice' to operate. It composes of the Beijing Jiaotong University, Beijing MTR Construction Administration Corporation and Beijing Subway Rolling Stock Equipment Co. Ltd.who jointly applied to the National Development and Reform Commission who give approval to this first national-level urban rail signal system technology platform.

This white paper is one of the major research results of the National Engineering Laboratory. It aims to provide decision-making direction for the owners of urban rail transit construction companies, provide design guidelines for designers, and provide operational and maintenance guidance for operators.

This Engineering Guide for Interoperability of Communication Based Train Control (CBTC) Signal Systems for Urban Rail Transit clearly realize the advantages of CBTC signal system interoperability with traditional CBTC systems. It comprehensively summarizes the tremendous work and experience gained in interoperate the different Chongqing CBTC operated lines. The successful experience of this pioneer project provides a sound basis for recommendations in the various stages of the project like: preliminary design, bidding, engineering design, testing and commissioning, safety assessment, and revenue operation by introducing typical cases of interconnection and intercommunication.

Finally, we look forward to the future development in urban rail interconnection and interoperability. Please feel free to contact us with any questions or suggestions for this book.

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Engineering Guide for Interoperability of Communication Based Train Control (CBTC) Signal Systems for Urban Rail Transit

Preface

With the development of urban rail transit, the uneven distribution of passenger flow, low resource sharing rate and increasing cross line pressure; the call for inter-connectivity of urban rail transit systems are becoming more and more demanding. In recent years, the State has vigorously supported the development of the equipment production industry. The domestic urban rail transit road network has an economy of scale. The core technology of the CBTC signal system has also been mastered by some of the top domestic suppliers and it has the technology to achieve interoperability.

Under the guidance of the National Development and Reform Commission and The China Association Of Metros; the Chongqing Rail Transit (Group) Co., Ltd. whom built the Chongqing Ring Line, Line 4, Line 5 and Line 10 was tasked to carry out a nationwide demonstration of an interoperability project. CAMET's Technology & Equipment Committee and the National Engineering Laboratory of Urban Rail Transit Communication and Operation Control organized relevant units to comprehensively summarize the experience gain from the Chongqing CBTC signal system interoperablity project to prepare this guide. The preparation of this guidance document is intended to provide guidance and decision-making basis for the future construction and operation of rail transit CBTC signal systems in interoperability.

This guidance document explains the necessity for interconnection and intercommunication of CBTC signal systems, and proposes the technical requirements for realizing interoperability; from the aspects of feasibility, preliminary design, bidding, engineering design, test and commissioning, safety assessment, and revenue operation… etc. It also explains the implementation path of CBTC signal system interconnection and intercommunication, introduce the typical engineering case of CBTC signal system interconnection and intercommunication, and finally look forward to the future development trend of interconnection and interoperability.

This guideline is proposed by the Technology & Equipment Committee of CAMET and URCC.

Disclaimer: Please note that some of the contents of this section may involve patents, and the publisher of this guideline will not be responsible for identifying such patents.

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Introduction

China has been rapidly expanding its urban rail system in an unpresidented rate. In order to meet the needs of urban rail transit interoperability to achieve the goal on economy of scale, resource sharing, technological superiority and sustainable development, the CHINA ASSOCIATION OF METROS took the lead in developing this set of guidelines and standards for CBTC System interoperability in China.

The series of guidelines and standards compose of 4 major volumes: Urban Rail Communication Based Train Operation Control (CBTC) Interoperability System Specification, Urban Rail Communication Based Train Operation Control (CBTC) Interoperability Interface Specification, Urban Rail Communication-based Train Operation Control (CBTC) Interoperability Test Specification and Urban Rail Communication-based Train Operation Control (CBTC) Interoperability engineering specification. Each volume is further structured as follows:

a) System Specification for Interoperability of CBTC System for Urban Rail Transit (Volume 1)
   - Part 1: General System Requirements
   - Part 2: System Architecture and Functional Allocations
   - Part 3: Onboard Electronic Map Data List
   - Part 4: Hazzard Analysis of Interoperability

b) Interface Specification for Interoperability of CBTC system for Urban Rail Transit(Volume 2)
   - Part 1: Balise Protocol
   - Part 2: Train-wayside Communication Protocol for CBTC system
   - Part 3: Interface between On-board ATP/ATO and Vehicle
   - Part 4: Interface of ZC-ZC Communication Protocol
   - Part 5: Interface of CI-CI Communication Protocol
   - Part 6: Interface of ATS-ATS Communication Protocol
   - Part 7: Interface of MSS - MSS Communication Protocol
   - Part 8: Onboard MMI

c) Test Specification for Interoperability of CBTC System for Urban Rail Transit (Volume 3)
   - Part 1: CBTC Train Control
   - Part 2: Intermittent Train Control

d) Engineering Specification for Interoperability of CBTC System for Urban Rail Transit(Volume 4)
   - Part 1: Engineering design
   - Part 2: Safety Assessment
   - Part 3: Basic Delivery Conditions

On April 28, 2015, the Technical Equipment Committee held a meeting in Beijing to initiate the preparation of LTE-M equipment requirements and standards for interoperability.

1 The Necessity of Interoperability

1.1 The Need in Urban Rail Transit Network

1.1.1 Increase in Urban Rail Transit Operation Scale

As of the end of 2017, the mainland China region (hereinafter referred to as national data refers to as Mainland China, excluding Hong Kong, Macao and Taiwan). A total of 34 cities have opened urban rail transit (hereinafter referred to as urban rail) operations, a total of 166 lines with a total operation length of 5,021.7 km. Among them, a total length of 3881.8 kilometers are subway sections, accounting for 77.3% of the total mileage. The length of light rail and other urban rail transit lines are 1,139. 9 kilometers, accounting for 22.7% of the total mileage. The length of newly opened lines in 2017 reached a record high of exceeding 800 km (868.9 km) for the first time, an increase in 62.5% as compared with the 534.8 km (increase 334.1 km) total in 2016.

1.1.2 Increase inUrban Rail Transit Interchange Stations

According to incomplete statistics, as of the end of 2017, there were 3,463 stations in total under construction, including 1,037 transfer stations, accounting for 29.9% of the total number of stations, as compared to 17.1% of the transfer stations in current operation. As a result, the urban rail transit network of each city has gradually grown into massive transport networks.

1.1.3 Increase in Urban Rail Transit Network Complexity

In China's "13th Five-Year Plan", it is clear that megacities and super-megacities shall actively be built with integrated transport networks. Large cities that meet the requirements should combine urban development and transportation requirements to build urban rail transit systems according to local conditions. Such initiative will increase the mileage of urban rail transit operations by 3,000 km. This paves the way forwell-planned multi-model transport network infrastructure.

1.1.4 Constraint of Standalone Construction Mode of Urban Rail Transit System

Urban rail transit has over one hundred years of development. All engineering disciplines have advanced forming mature railway operating systems. However, problems with lines in standalone operation have gradually emerged, as for example:

1) The distribution of passenger flow is not even. As each line operates independently, the excess capacity of the line cannot be utilized;
2) Passengers can only crossline through the transfer stations, which is unable to meet passengers' "fast" and "direct" travel needs;
3) Resourceslike station facilities, trains, traction supplies and others, like commercial and parking capabilities, cannot be shared for better utilization;
4) The cross passenger flow rate is high (65%~82%), and the passenger flow of the transfer station is under great pressure. There is a potential safety hazard but it is fundamentally difficult to solve this by sheer increasing in station size.

Hence, urban rail transit urgently needs a networked operation approach that meets the cross-line and joint-line line demands. The beauty of this approach is: trains do not need to decelerate or downgrade when entering or leaving the other line, and supports trains from other lines operating in each other. The joint-line operation is of great significance for saving passengers' travel time and improving the efficiency of urban rail transit operations.

1.2 The Urban Rail Transit Development

From history of rail transit development, suburban lines serve between the city center, satellite cities and towns at a service diameter of 50km to 100km. The traditional railways (especially high speed lines) emphasizes on city-to-city rapid transport, while metros emphasizes high-density district to district transportation. The characteristics of the sub-urban lines being in standalone operation with relatively low passenger flow and distinct morning and evening peak passenger flow patterns. Metros has very high passenger flow with distinct morning and evening peaks but the passenger tidal flow pattern is not distinct. This gives potential for resource sharing.

Interoperability is in line with the needs for urban rail transit development. Through interconnection and intercommunication, it continuously stores scattered passenger flow, fully utilizes line vacancy rate, realizes cross-line and joint-line operation, reduces passenger transfer time/frequency, reduces construction and operation costs, and improves line capacity.

1.3 The Advantage of Interoperability

Interoperability can reduce waste of line resources (such as redundant infrastructure and idling trains) and achieve resource sharing through the global planning of the metro network. They have the following major advantages:

1) Realize the sharing of rolling stock depots, stabling sidings, main lines, transfer stations, and railway operating systems reducing their associated land, construction and post-maintenance costs;
2) The sharing of trains from different lines will make use of the backup trains(normally idle) from their serving lines as revenue trains in the network, which reduces the number of trains required in the network and effectively reduce train procurement cost;
3) Realize the sharing of the operators and drivers through the standardization of the operation interface and operation rules/procedures. This helps flexible allocation of operation personnel reducing labor costs and training costs.
4) Improve the quality of passenger services by making use of shared resources;
5) Help the realization of integrated urban transit network operation;

6) Flexible staff deployment to improve rapid response and recovery to incidents and failures;
7) Enables fair competition in the railway signal industry due to interoperable technical requirements, which reduces the cost and time on procurement of trains and signal systems for existing line extensions;
8) Optimize the integrated transport network design and construction plan;
9) Significantly reduce the cost and disturbance during major signal modifications or upgrades.

2 Engineering Requirements for Interoperability

The planning of rail transit interoperable network should be based on the urban network layout, the speed target of the line, the train selection, the operation mode,etc. The interoperability requirements should be identified early in the planning stage. Taking advantages of interoperable lines, using resource sharing as basic assumption, and achieving cost efficiency, enacts a resource sharing based interoperable network plan.

Network-wide operation of urban rail transit lines are a systematic approach involving various conditions, such as, line conditions,, boundaries, tracks, traction power, signal, communication, platform doors and trains, maintenance, training, and other related aspects. It shall be managed with in one standard to achieve interoperability.

In order to unify the concept and definitions of trains, line boundaries, running line, structure and signals with respect to speed limits and safe control oftrains, it is necessary to clarify the constraints and requirements of each discipline, coordinate and match the interface relationship between the various disciplines to ensure that the lines are operated under maximum safety and efficiency. New interoperable lines shall follow the latest requirements of the Urban Rail Transit Train Speed Limits and Computability Standards.

2.1 Rolling Stock

The train type should be standardized and operation constraints of the line should meet the train's minimum operation requirements:

1) The same type of trains (Standard Chinese type A, B or C Models) should be selected for the lines involved in the interoperablemetro network to meet the versatility of the trains and maintenance systems in the network.
2) Train selection should take into account line characteristics with respect to its supported line speed, train gauge, structural gauge, traction supply methods, door separation, floor height, wheel/rail profile, pantograph operation limits, detrainment facilities, etc.;
3) The stopping point and door spacing should be compatible with the platform screen doors or other sliding door settings. This also relates to the position of the ATP antenna, proximity plate and other door triggering devices.

2.2 Traction Power Supply

The interoperable lines shall adopt the same or compatible traction supply systems (such as DC, AC and voltage levels). It is advisable to use the same type of traction feed system (such as overhead catenary wire or third rail contacts). Otherwise, trains should be dual equipped different traction power feed configurations.

To optimize traction supply planning, it is a good arrangement for the main transformer substation system to be shared within the rail network with system redundancy.This enables energy saving due to difference in loading between these lines at different time of the day.

In order to create conditions for traction power system compatibility for trains travel over different lines,l the consistent requirements of the traction supply type, supply voltage, and traction supply method for cross-line operation are essential.

2.3 Track and Civil Structure

The tracks of the interoperable lines shall adopt the same structural gauge and track gauge. The structural load capacity of the track and the track bed shall meet the train's operation requirements.

Interoperable lines need to consider the wheel/rail profiles wheel/rail adhesion, minimum horizontal curve, maximum longitudinal slope, safe braking distance and effective platform lengths of the lines involved. Apart from meeting the operational needs; operation efficiency and passenger comfort should also be taken into account.

The structural limits, emergency equipment operation limits, train operation limits, emergency detrainment metrology and platform screen door operation limits of the interoperable lines shall meet the operational requirements of all train types operating in these lines.

2.4 Communication

The interoperable lines shall adopt the same or compatible radio communication systems. The radio communication system between the ground dispatcher and the train driver shall also consider the communication functions of the network in addition to the functions applicable to the line. The technical requirements of the communication system such as capacity, frequency selection and standards of the whole urban network should meet the requirements of interoperability. Each operating line should be as consistent or compatible as possible.

It is important to rationalize the call-signs of all trains, on-track vehicles and operation consoles to avoid mis-communication.

2.5 Signaling

The signal system shall meet the functional, safety and technical requirements for cross-line and joint-line operation for all interoperable lines involved before interoperability can be achieved. All interoperable signal systems should have common designs for cross line transition, boundary handover, intercommunication technology, interface requirement and a unified electronic map.

In June 2014, the Technology & Equipment Committee of CAMET initiated the preparation of the "Association Standard for Interoperability of Communication Based Train Control system for Urban Rail Transit" specifications. 4 volumes of specifications on System, Interface, Testing and Engineering requirements were finalized with 17 Parts.

These specifications contribute to the standardization of urban rail transit construction, unify equipment procurement standards, which further reduce procurement costs, and improve product versatility, safety and reliability in line with the overall trend of development in the industry.

3 Deployment of Interoperability of CBTC Systems

As a critical system to ensure the safety of urban rail transit operation, the signal system is the key bottleneck for achieving interoperability. The signal systems originally used in China are mainly imported from foreign signal manufacturers. The core technology of these signal systems are not mastered in China. The system architecture adopted between each signal system are not consistent, the interfaces between them are not open architecture, and the communication protocol and interface messages are quite different making interoperability very difficult.

In recent years, on the basis of digesting, introducing, absorbing and re-innovating the foreign train operation control systems, the individual equipment of the CBTC system are independently developed and produced by Chinese companies with great success. The autonomous CBTC signal system developed by various signal companies in China has been successfully launched. As for example, Beijing Metro Line No. 7 and Chengdu Line 3 were design and built by Traffic Control Technology Co., Ltd., Beijing Metro Line 8 by Beijing National Railway Research & Design Institute of Signal & Communication Group Co.,Ltd, Guangzhou Metro Line 7 by China Academy of Railway Sciences and the Shanghai Metro Line 17 opened by Casco Signal Ltd.

With the breakthrough in core technology of signal system, domestic signal integrators have mastered the core technology of autonomy and have gain much experience, mature technology in laying down a good foundation for the development of interoperability standards.

There are three levels of CBTC signal system interoperability requirements: the first is a common technical standards that realizes common CBTC system types; the second is to meet the needs of share line operation and line extensions; and the third is to meet the requirements of cross-line interoperability. The three levels of demand can be implemented in stages.

3.1 Feasibility Study/ Preliminary Design Stage

For the cities planned for Intermodal Transport Network, it is advisable to carry out unified interoperability planning to clearly identify interoperable lines and comprehensively consider the impact to existing lines and other planned lines on the drawing board. The signal system should explicitly use the CBTC signal system, which has proven interoperability capability.

For the non-intermodal transport networks in cities with standalone line operation needs, they should still need to consider adopting CBTC signal system in preparation for future interconnection, line extension and major renovations. We call this 'Interoperability Ready'.

3.1.1 Provision of Interoperability Requirements in Feasibility Study

In the feasibility study stage, it is always a good practice to take into accountinteroperability in the provision of operation and technical requirements before moving into the preliminary design stage. Otherwise, it will be very costly to modify the railway operating systems after a line is in revenue operation.

3.1.2 Preliminary Design to Incorporate Requirements of Interoperability

In the preliminary design stage, it is always a good practice to select the system architecture, interfaceand technical requirements suitable for future extension and interoperability of the line with others to be built in the foreseeable future. Such allowance, though seemed useless at present will give the operation company much flexibility and cost saving for future extensions and interoperability at much lower risks.

3.2 Tendering / Bidding Stage

When interoperable lines go for open bidding, the rail transit construction company shall base on this guideline and specificationas a key component of the bidding documents. The specific recommendations are as follows:

1) Construction of interoperable lines in the same period: Based on the guidelines and specifications for interoperability produced by CAMET, and combined with the

specific requirements of the local cities to come up with a localization interoperability specification and incorporate into the bidding documents for local interoperable lines.

2) Building of interoperable lines in stages: For the lines already built, it shall be allowed that necessary interfaces, track, traction supply and structural limitations, etc. can support interoperability with lines to be built in the future. The signal integrators of the subsequent interoperable lines shall comply with the relevant standards and interfaces of the previous interoperable lines.

3.2.1 Incorporate Interoperability Requirements in Tender Document

In preparation of the tender specifications, it is advisable to incorporaterequirement of 'Interoperability Ready' as one of the basic function of the system. Technically, it is the incorporation of the preliminary design and basic interoperability requirements and the Detailed Design requirements (See Section 3.3 below) into Particular Specification.

As a good practice, it is also advised to put the safety (especially emergency handling) and EMC requirements into the Particular Specifications though they are not being covered by this set of guidelines.

3.2.2 Compliance toInteroperability Requirements

Tenderers should provide product solutions meeting the preliminary design, basic interoperability requirements and Detailed Design requirements (See Section 3.3 below) as a support to the compliance to the 'Interoperability Ready' requirements as stated in the Particular Specifications.

3.3 Detailed Design Stage

3.3.1 Standardization of Train and Signaling Equipment for Interoperability

There are local practices in various regions and cities; including functions, interfaces, and operation rules/procedures. Therefore, this guide recommends the implementation of interoperability within a regional or local rail network, but not one standard across the whole country. This interoperability guideline allows different regions and cities to supplement and refine the standards and norms of technical requirements to fulfill local practices.

CAMET's specifications have been standardized for CBTC signal system interoperability in terms of functional requirements, architecture, interfaces, testing, engineering design and communication. The specific standards and specifications are detailed in the appendixes.

3.3.2 System Configuration Principle

Standardize installation principles for equipment from different signal manufacturers, including balises, trackside antennas, leakage cables, on-board receiving antennas, and train wireless antennas to meet interoperability requirements.

Part 1 of the Engineering Specification for Interoperability of CBTC System for Urban Rail Transit (Volume 4)clarifies the basic principles of engineering design, and indicates the principles for track section identification (including proximity/triggering sections and ground overlap), trackside balise arrangement, signal layout, axle counter configuration, and temporary speed restrictions. The rail transit construction companies can consider the practices of local engineering design and the actual conditions of local infrastructure and trains to modify these principles.

3.3.2.1 System Architecture

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement) and Part 2 (System Architecture and Functional Allocations) spell out what system functions and architecture have been standardized and should be followed.

3.3.2.2 ATS Subsystem Functions

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section 5.1.2 spell out the functional requirements for ATS sub-system and the requirements should be followed.

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part6 (Interfaceof ATS-ATS Communication Protocol), gives details on the ATS sub-system and the specification should be followed.

3.3.2.3 ATP Subsystem Functions

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section5.1.3spell out the functional requirements for ATP sub-system and should be followed.

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 3 (Interface between On-board ATP/ATO and vehicle), gives more details on the ATP sub-system and should be followed.

3.3.2.4 ATO Subsystem Functions

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section 5.1.4spell out the functional requirements for ATO sub-system and should be followed.

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 3 (Interface between On-board

ATP/ATO and vehicle), gives more details on the ATO sub-system and should be followed.

3.3.2.5 CI Subsystem Functions

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section 5.1.5spell out the functional requirements for Computer Interlock sub-system and should be followed.

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 5 (Interface of CI-CI Communication Protocol), gives more details on the Computer Interlock sub-system and should be followed.

3.3.2.6 Zone Controller Subsystem Functions

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 4 (Interface of ZC-ZC Communication Protocol), gives more details on the Zone Controller sub-system and should be followed.

3.3.2.7 DCS Subsystem Functions

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section 5.1.6spell out the functional requirements for DCS sub-system and should be followed.

3.3.2.8 Digital Map subsystem

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 3 (Onboard Electronic Map Data List) spell out the functional requirements for MSS sub-system and should be followed.

3.3.2.9 MSS Subsystem Functions

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section 5.1.7spell out the functional requirements for MSS sub-system and should be followed.

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 7 (Interface of MSS - MSS Communication Protocol), gives more details on the MSS sub-system and should be followed.

3.3.2.10 System RAMS Requirements

Under Volume 1 (System Specification for Interoperability of CBTC System for Urban Rail Transit), Part 1 (General System Requirement), Section 5.3 spell out the system RAMS requirements and should be followed.

3.3.3 Standardization of CBTC System Interface Design

3.3.3.1 ATS-ATS Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 6 (Interfaceof ATS-ATS Communication Protocol), gives more details on the ATS sub-system interface requirements and should be followed.

3.3.3.2 ZC-ZC Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 4 (Interface of ZC-ZC Communication Protocol), gives more details on the Zone Controller sub-system interface specifications and should be followed.

3.3.3.3 CI-CI Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 5 (Interface of CI-CI Communication Protocol), gives more details on the Computer Interlock sub-system interface specifications and should be followed.

3.3.3.4 MSS-MSS Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 7 (Interfaceof MSS - MSS Communication Protocol), gives more details on the MSS sub-system interface specifications and should be followed.

3.3.4 Train to Track Communication Interface Design

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 2 (Train-wayside Communication Protocol for CBTC system), gives more details on the Train to Track Communication requirements and should be followed.

3.3.4.1 Balise-VOBC Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 1 (Balise Protocol), gives more details on the Balise to VOBC Communication requirements and should be followed.

3.3.4.2 VOBC-ZC Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 2 (Train-wayside Communication Protocol for CBTC system), gives more details on the VOBC to Zone Controller Communication requirements and should be followed.

3.3.4.3 VOBC-CI Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 2 (Train-wayside Communication Protocol for CBTC system), gives more details on the VOBC to Computer Interlock Communication requirements and should be followed.

3.3.5 Other CBTC system Interface Design

3.3.5.1 VOBC-On-board Equipment Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit), Part 3 (Interface between On-board ATP/ATO and vehicle), gives more details on the VOBC to On-board Equipment interface requirements and should be followed.

3.3.5.2 Human-Machine Interface

Under Volume 2 (Interface Specification for Interoperability of Communication Based Train Control System for Urban Rail Transit, Part 8 (Onboard MMI), gives more details on Human-Machine Interface requirements and should be followed.

3.3.6 Electromagnetic Compatibility Design

The design of CBTC system shall pay attention to both inter and intra-system electromagnetic interference (EMI) within its own line of operation and other interoperable lines. The design shall include measures in accordance with international best practices to ensure that there is no electromagnetic interference:

a) Among the equipment supplied by the supplier,
b) Between the equipment of the supplier and other Interfacing Suppliers; and
c) Between the equipment of the supplier and Plant and Materials of interfacing CBTC systems.

3.4 Testing and Commissioning Stage

This guideline and specification mainly focus on additional testing requirements due to interoperability. Hence, the industrial best practices on testing their own CBTC system is assumed to be thoroughly carried out by the manufacturer(s) and will not be covered by this document. These tests shall include but not limited to:

- Factory Acceptance Tests
- Type Tests
- Production Inspection and Tests
- Hardware Factory Acceptance Tests
- Software Factory Acceptances Tests
- System Integration Test
- System Factory Acceptance Tests
- Post Installation Check-Out

- Partial Acceptance Tests
- Test Run
- Failure Scenario Tests
- Trial Operation

Apart from the normal testing and commissioning required by CBTC systems; additional tests due to interoperability also need to be carried out as described below. It mainly includes three parts: test platform, indoor tests and field tests.

3.4.1 Setup of Interoperability Test Platform

It is highly recommended to build an off-site Interoperability Test Platform for testing of the CBTC system(s) before carrying out field tests. The test platform can support the functional verification, line data verification and protocol validation ofthe intercommunication, which can improve the security, reliability and quality of the field test soft version and create a good debugging foundation for the interoperability function to reduce the workload of field test. It major roles include:

1) Verify Interoperability CBTC function: Verify that each signal manufacturer meets the interoperation requirements;
2) Verify protocol and data: Verify the correctness of the interface protocol and wayside (guideway) data of the interconnection;
3) Verify the following lines to be commissioned: With respect to the different phases of construction and revenue operation test all the requirements on functions, performance and failure scenario of other line(s) in the network;
4) Verify the problem scenario: The platform should have ability to generate different operation and failure scenarios to identify and review various operation and engineering problems with a view to rectify all problems before site tests;
5) Training function: The test platform can simulate various operation and failure scenarios with playback and online fault injection functions. It can be used as a training aid for both operation and maintenance staff for incident and failure handling.

Suggestions on design and construction of the Interoperability Test Platform:

- A number of interoperated lines open simultaneously
  It is advisable to select one Lead Signal Manufacturer to build the test platform. The other signal manufacturer(s) shall cooperate to design and build the test platform by supplying the software and hardware design information of their systems. All other manufacturers should participate in all tests required to verify their part of the system. The completed test platform can be used for the Interface Protocol, System Interface, System Integration and Interoperability Tests by all manufacturers involved to ensure the reliability and safety of the network;

- Interoperated lines open in stages
  The signal manufacturer for the first line should be responsible for design and build of the Interoperability Test Platform in accordance with requirement of this

guideline and specifications. This manufacturer should also design the signal system and allow for all interfaces to 'Interoperability Ready' status. The transit construction company when building the other lines should require the subsequent bidders to design the system in accordance with this guideline and require to pass all tests required for interoperability in this Interoperability Test Platform.

In both cases, the test platform should be built with modular functions and interfaces such that anychange in overall functions or architecture can be easily upgraded to ensure that future manufacturers can easily access and modify the platform.

3.4.2 Indoor Tests

The indoor tests can be divided into two types: the manufacturer's own tests and test platform tests. Each signal manufacturer should successfully complete their own tests before testing in the test platform. These tests shall including but not limited to interoperability related product tests, interoperability system testing and wayside (guideway) data testing in compliance with interoperability requirements.

Main purpose of the test platform tests are to verify joint-line and cross-line operation of the trains from each manufacturer in other line(s). Hence, tests not related to interoperability will not be covered in this document.

The test work is divided into three phases: the interoperability interface test, the interoperability function verification and interoperability engineering data validation phases. In order to ensure smooth progress of the tests, each signal manufacturer should provide at least two interlocking areas as sample sections for initial testing, and gradually increase the interlocking areas according to project progress.

Test cases chosen are very important, the integrity of the test inputs directly affects the integrity of the test results. The test cases for interoperability should strictly be in compliance with the requirements of the test specifications recommended by CAMET. At the same time, it should cover all interoperability and multi-line operation scenarios to ensure that all normal and abnormal operation scenarios are covered.

3.4.2.1 Interactive Interface Tests

Test interface of each manufacturer's interactive systems to ensure that they perform in accordance with the interface specifications that satisfy with the requirements of this guideline. It mainly verifies whether the system interface message format and content meet the interface design requirements.

3.4.2.2 Interactive Function Tests

The indoor test requires functional tests related to the interaction between the train and the trackside systems of each manufacturer, such as:

- Intermittent to continuous mode upgrade test,

- Platform screen door interactive test,
- CBTC train upgrade test,
- CBTC train ZC cross boundary test,
- Train turnback test.

3.4.2.3 Multi-train Simulation Tests

In an indoor simulation environment, input multiple trains of each manufacturer onto each and other manufacturer's line(s), to carry out multi-train tracking tests for various front-to-back tracking combinations.

3.4.2.4 Fault RecoveryTests

Considering that there are differences in fault handling process between various manufacturers. On the other hand, many failure scenarios are difficult to verify in real environment. Therefore, it is necessary to perform related faults and fault recovery tests on most common operating scenarios, such as: rolling, over-shoot markers, ZC hand over for train passage, various failure scenarios on double-car tracking.

3.4.2.5 Operation Scenario Tests

In addition to the tests required to verify the specifications, the system should meet the requirements of other interactive operation scenarios, such as: sectional work window opening test, protection zone release test, red signal passed under intermittent operation, curve test for continuous operation under intermittent ATP, CBTC train stop guarantee test, train clock calibration test, train destination and next station test.

3.4.2.6 Operation Target Tests

The operation capability of different manufacturers' on-board systems could be different when working on different manufacturers' trackside equipment. Hence, we need to verify operation targets such as minimum operation headway, turnback capability and operation speed in the test platform.

3.4.2.7 Wayside Data Verification Test

As part of the verification on manufacturers' meeting the software requirements of interoperability, it is necessary to carry out a function and data verification test for the on-board electronic map. The test produces a test data table based on the interoperable lines under test. An item by item verification test will be performed function-by-function and location-by-location based on this data table. As for example: any upgrade from intermittent to continuous CBTC operation will be tested for every possible route, each Platform Screen Door at every station will test open and close status, and turn-back operation will be tested for each turn-back track.

3.4.2.8 Summary

Based on the above tests, after a city completes a number of interoperable lines, any new interoperable line then added only requires the engineering and wayside data verification test of the newly added line be carried out. The interface test case and functional test case can be reuse used. When buildinginteroperable lines in cities, the results of the interoperability demonstration project, which was based on the industrial norm and best practices, should be reused. CAMET allows adaptation to meeting local practices and special requirements by review of the operational scenario, operation targets, and local engineering and wayside data validation.

3.4.3 Field Tests

Interoperability field test shall be conducted after successful completion of on-site tests on their appropriate trains and trackside system of their designated line(s), as well as the Indoor and Interoperability Test Platform tests. On site, trains may be allowed to perform joint-line and cross-line tests. The field test is divided into single train and multi-train test depending on different stages of the project.

3.4.3.1 Field Test Case Design

On-site interoperability test cases make reference to the indoor test cases to design a field test program to test the actual network-wide cross-line and joint-line operation. The interoperability field test framework is the basis for on-site connectivity testing activities.

3.4.3.2 Field Test Version and Change Control

The software for the field test should be the version that passed the indoor tests, which should be confirmed by the participants concerned. The field test software version control is responsible by the owner of the trackside system of the line concerned. If a party needs to change the software, the owner should first propose the details of the change and the possible impact of the change to others. The other parties affected will analyze the impact of the change and react accordingly. After completing the changed, the software needs to complete the necessary regression tests required under the Indoor Tests before it can be released to site to continue the field tests. All affected parties in each line needs to carry out the necessary changes according to the scope of the change and conduct regression tests to verify success of the change.

3.4.3.3 Test Area and Planning

The test area and planning are led by the owner of the trackside system. According to the actual construction plan and progress of the line, the areas and plans shall be discussed among all parties to come up with reasonable opportunities allocated to all parties to meet the test and verification requirements of each line.

3.4.3.4 Basic Principle for the Tests

When test activities are carried out on site, the principle on passing criteria and resource allocation by the test leader shall be consistent with the indoor test.

Single Train dynamic test on third party track(s) can only be allowed after successful completion of the static tests and obtain safety certification by an Independent Safety Accessor for safe single train operation in the other line(s). Permission from the owner of the trackside system shall also be obtained with necessary safety precautions before test can be carried out.

During single train dynamic test, the tester shall not only pay attention to the function of the signal system, he should also pay attention to wheel/rail wear, pantograph to contact wire wear, turnout status and other abnormal conditions in the test boundary to ensure the safe operation during revenue hours.

Multi-train test can only be carried out after successful completion of the single train dynamic test with Independent Safety Accessor certifying safe for multi-train dynamic test in the other line(s). Permission from the owner of the trackside system of the other line(s) shall also be obtained with necessary safety precautions before test can be carried out.

During multi-train dynamic testing, more attention should be paid to on-board and trackside equipment abnormality and coverage of multi-train tracking scenarios.

3.5 System Assurance / Safety Certification

This document only focus on system assurance and safety certification for the interoperable design and functions of the signal system. The normal system assurance and safety certification processes of the signal system relevant to it designated line is assumed to be properly carried out by the manufacturer concerned.

These activities shall associate with adequate quality control and audit mechanism, which shall include but not limited to:

- System Assurance Planning
- System Hazard Analysis
- Subsystem Hazard Analysis
- Interface Hazard Analysis
- Operation and Support Hazard Analysis
- Failure Mode, Effects, and Criticality Analysis
- Reliability, Availability, Maintainability Analysis
- Quantitative Risk Assessment (Fault Tree Analysis)
- Design Verification and Validation

- Safety Verification and Validation
- Safety Integrity Level Assessment

3.5.1 System Assurance Process

The CBTC signal system interoperability safety assessment includes the generic products and application software for interoperability and specific application assessment. During different stages of the interoperability project, the following process and evaluation principles are recommended to be followed.

3.5.1.1 Cross Acceptance of General Products and Application Software

Cross acceptance of generic products or application software can be accepted by provision of evidence that proper safety evaluation has been conducted by a qualified Independent Safety Assessor (ISA) for the relevant products and applications for the dedicated line satisfying the requirements of CLC-TR50506-1 or equivalent. Based on the evidence provided for safety assessment of these generic product/application, the Interoperability Specific Application Safety Assessor will conduct his assessment on the generic products and application software to determine whether they meets the specific applications required of the project.

3.5.1.2 Assessment of Specific Applications

The signal system interoperability special application safety assessment can adopt a cross acceptance principle. The ISA of the present line can accept evidence of the other ISA who conducted safety assessment on interoperability of the other line provided that the assessment process is properly done and satisfies the CLC-TR50506-1 or equivalent standard. Thus, those evidence does not require re-assessment. However, the following condition needs to be complied before the test train can operate in the other line:

The ISA of the present line needs to obtain authorization from the owner of the trackside system of the other line to allow the train to enter their boundary. The ISA of the other line shall issue a safety authorization for the joint-line/cross-line testing and trial operation after evaluation. The scope of authorization shall include all systems under the system integrator in that Line. The purpose of authorization is to make all parties clear on what tests can be carried out under the authorization. As for example: single train test and adjustment, multi-train test and adjustment, test run, trial operation, etc.

3.5.1.3 Generic Product/Application Differential Assessment

When the assessment exists difference in compliance standard of the generic product/application from that required by this document, the Signal system contractors (integrators)/ suppliers should analyze the differences between both standards and supply to the Specific Interoperability Safety Assessor for analysis to ensure compliance and all possible hazards satisfactorily addressed.

3.5.1.4 Change Control for Generic Product/Application during Construction Stage

During construction period, when the generic product/application require changed/ upgraded, the responsible company shall organize the interoperability integrators to carry out a change impact analysis of the specific engineering application and ensure that the changes are implemented by the responsible integrators with proper verification and validation.

All Independent Safety Assessors involved in the network need to be informed. Any change that affects generic product and application software require to be re-assessed as described in 3.5.1.1 and 3.5.1.3 above, while changes involving specific applications need to be re-assessed as described in 3.5.2.2 above.

3.5.1.5 Change Control for Specific Application during Construction Stage

Before trial operation of the interoperability network, the responsible authority should establish a Change Control Board (CCB) and employ safety assessor to evaluate the risks and mitigation measures after this upgrade in operation to ensure that the change process is safe and controllable.

3.5.2 Safety Assessment Principle

- Interoperability safety assessment is based on mutual recognition of the work of other parties involved in the safety assessment.
- ISA of the present line is responsible for safety assessment of all on-board and trackside equipment in that line.
- For trains from another line entering the present line, the signal integrator (manufacturer) needs to provide evidence to prove that the on-board equipment of the other line satisfies all safety requirement needed for interoperability.
- For trains from the other line entering into the present line, the present line needs to supply and validate all engineering and operation data with their own ISA to conduct assessment for such request. The other line shall be responsible for such data conversion, testing and safety assessment.
- ISA of the present line when granting assessment report/authorization/certificates, such statement should cover all system integrators and on-board equipment.
- All authorization/certificate should satisfy present line trains going into the other line for cross line test/adjustment, trial run, trial operation and operation; or trains from the other line going into the present line for test/adjustment, trial run, trial operation and operation.
- All contractors (integrators)/ suppliers' signal system shall satisfy all requirements for interoperability like: interfaces, protocols, train control algorithm (e.g. setback, anti-roll protection, safety separation), etc.

4 Reference Cases of Interoperability of CBTC Systems

4.1 Chongqing Rail Transit

4.1.1 Background

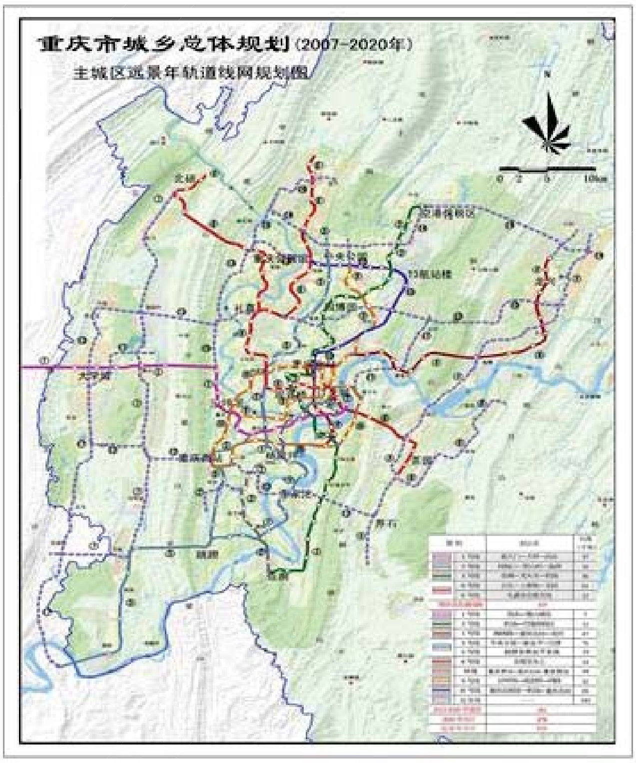


Figure 1 - Chongqing Rail Transit Plan 2007~2020

As of the end of 2014, Chongqing Rail Transit(Group)Co.,Ltd.has completed and put into operation a network of metro transit backbone consisting of Line 1, Line 2, Line 3 and Line 6, that are the main transport trunk of the city. The total length of the metro line is 193.65km.

According to the "Chongqing Urban Rapid Rail Transit SecondRound Construction Plan (2012-2020)", the plan indicates Line 4, Line 5, Loop Line, Line 6, Line 9, Line 10shall be completed by 2020. A total of 9 rail transit lines including Line 10 giving a total mileage of more than 400km, as shown in Figure 1.

Chongqing Rail Transit is committed to researching and implementing interoperable network operation to meet the demand of passengers for fast and direct travel and maximize operational efficiency. Chongqing Rail Transit (Group) Co., Ltd. takes the opportunity on design and build the loop line (comprising of line 4, line 5 and line 10)by using the second round of Chongqing Rail Transit Construction Plan, to realize network-wide interoperability.

In order to achieve interoperability, Chongqing Metro tried to standardize the technical specifications for trains and signals, which are the basic prerequisites for planning track layout and stations that can realize cross-line and joint-line operations. In the same time, Chongqing goes fornetwork-wide operation management philosophy and build a common data network to support their network-wide operation,and eventually succeed in extending their operation and management to the entire metro network in Chongqing.

4.1.2 Major Achievement

In December 2016, the Chongqing Interoperability test platform was commissioned.It was laying the foundation for product and application software commissioning, providing strong support for project implementation and testing of the interoperable CBTC signal system.


DB

重庆市工程建设标准

DBJ50/T-250-2016

重庆轨道交通列车控制系统(CQTCS)标准

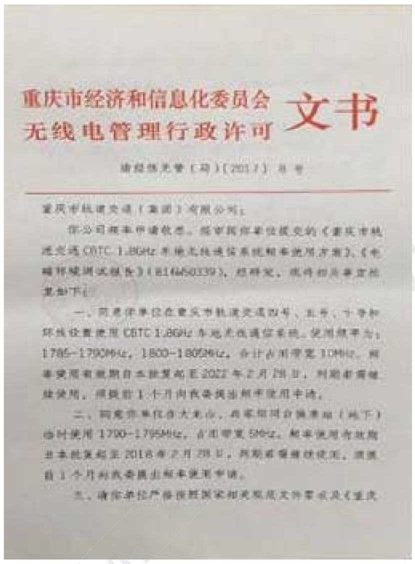
Standard for ChongQing rail transit Train Control System

2016-12-14 发布 2017-02-01 实施

重庆市城乡建设委员会 发布

In February 2017, Chongqing Railway Company issued the local standard “CQTCS Standard for Chongqing Rail Transit” (DBQ50/T-250-2016) for Chongqing Project, as shown on left.

In February 2017, the frequency utilization plan (1.8GHz train-to-ground radio communication) for CBTC system of Chongqing Rail Transit was approved by the Municipal Economic Commission with frequencies: 1785MHz ~1790MHz, 1800MHZ~ 1805MHz for interoperability allocated, as shown on right.


重庆市经济和信息化委员会
无线电管理行政许可 文书

On August 25, 2018, trains from the Chongqing Loop Line, Line 4 and Line 10 entered into trial operation in the Line 5 territory. This nation-wide pioneer project on interoperability erects an important milestone that marks the beginning of interoperability era in China. This also proves that the China has major breakthrough in metro interoperability technology.

4.2 Qingdao Metro

4.2.1 Background

A total of 16 lines are planned as a long-term vision for the Qingdao Urban Rail Transit Network. The total track length is about 807km, as shown in Figure 2 below. The rail transit network has a high density and targets for interoperability and network-wide operation. Qingdao City has planned five lines (Line 8, Line 12, Line 13, Line 14 and Line 16) in the Jiaonan-Huangdao-Jiaodong Airport area to form an interoperable transportation network. After interoperable, each line can realize inter-deployment of trains during peak hours to achieve the purpose of resource sharing. The surrounding passengers can have express service to Jiaodong International Airport.

Right from the beginning, Qingdao Line 13 was designed with interoperability ready during opening with capability to interoperable with Line 12 and Line 8 which were built later. Trains are being designed with seamlessly switch over for across line operation.

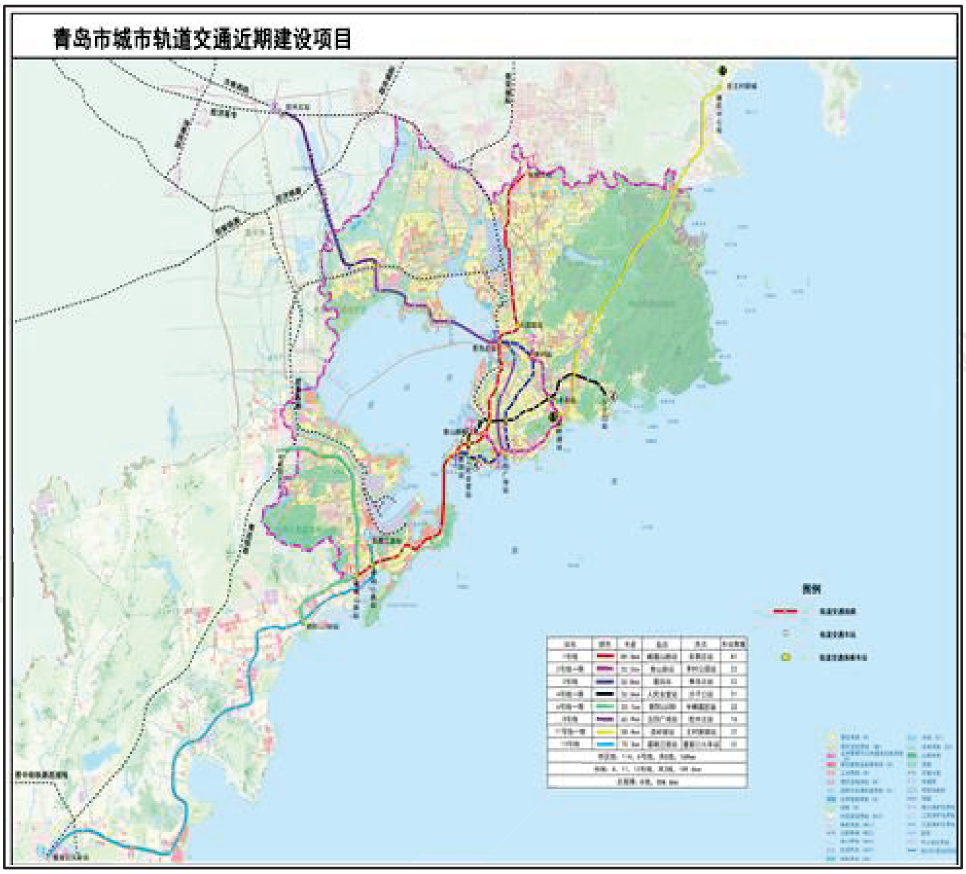


Figure 2 - Qingdao Metro Plan

4.2.2 Major Achievement

In the second half of 2017, the interoperability test platform was successfully commissioned. From the second half of 2017 to the beginning of 2018, under the organization of the Qingdao Interconnection Standards Editorial Committee, the preparation of the first draft of the signal system interoperability requirement was completed. The standard adds localization requirements based on full compliance with CAMET's standards. The main contents of the increase are as follows:

- Taking into account localization requirements, the principle of equipment numbering, interlocking table compiling, and equipment layout are standardized.
- Add new ATS man-machine interface standard, which stipulates the requirements on layout, display of elements and some operational requirements by Qingdao Metro.
- Added man-machine interface specification, which stipulates the train MMI display and human-machine interaction button configuration.
- In March 2018, the Qingdao Metro organized an Expert Review Meeting, and the first draft of the Interoperability Standard passed afterthe expert reviewed.

- It was planned to complete the preparation of interoperability standards in the first half of 2018, and the preparation of general specifications and communication specifications will be completed by the end of 2018 with 2 to 3 signal manufacturers that are taking part in the testing and commissioning.

4.3 Beijing MTR Construction Administration Corporation

4.3.1 Background

Beijing Rail Transit Construction Management Co., Ltd. took the lead in completing the project "Development of Key Signal Technologies and Equipment for Rail Transit Interoperability" (Phase I). The project aims at the Beijing-Tianjin-Hebei rail transit integration planning and respond to the inter-connected and cross-line operation requirements for the Beijing City. At the same time, combined with the development direction of urban rail transit signal system standardization, it breakthroughs and masters the key technologies of interoperability for signal systems. This further encourages the standardization and technological advancement in rail transit interoperability products and interfaces into industrial production.

4.3.2 Major Achievement

Based on the latest best practices in China and aboard, the project proposes a set of multi-line joint-line and cross-line interoperability requirements satisfying the needs of Beijing City. It gives technical solutions thaton-board signal system is unable to safely operate on other manufacturer's trackside equipment.Identified and resolved problem of "control signals" at transition track, breaking through in key requirements for signal function allocation, train-to-ground communication interface, electronic map and train safety protection. Achieve standardization of signal system equipment interfaces, and drive the research on key technologies of interoperability for other disciplines such as track, trains, and traction power supply.

The following results are achieved in the Phase I Project:

- Resolved key signal technology for interoperability
- Designed and built signal on-board equipment that fulfilled interoperability and accredited with interim safety certification
- Built the Interoperability Test Platform and passed the Indoor Tests. It passed the expert committee review after verifying all requirement for interoperability
- Completed the interoperability technology knowledge base, which gives strong support to CAMET in producing this guideline and requirements.

Based on results of this Phase I research, the bidding for the FAO of Beijing Line 3, Line 12, Line 17 and Line 19 had interoperability requirement stated.

4.4 Changsha Metro

4.4.1 Background

Changsha Metro Development Plan (2016 to 2022)

The first round of construction planning of Changsha Urban Rail Transit was approved between 2008 and 2015. Under the first approved phase, Line 1 and Line 2 was approved with a total length of 45.92 kilometers. The second round of construction was approved between 2012 and 2018. Under the second approved phase, Line 3, Line 4, Line 5 and West Extension of Line 2 was approved with a total length of 96.3 kilometers.

The third round of Changsha Urban Rail Transit Construction Plan (2017-2022) was approved by the National Development and Reform Commission on March 15, 2017, with a scale of about 122km. The plan includes the first phase of Line 6, Line 7, North Extension Phase I of Line 1, West Extension Phase II of Line 2, North Extension of Line 4, and North Extension and South Extension of Line 5, as shown in Figure above.

The signal system for the first phase of Changsha Rail Transit Line 4 and the first phase of Line 5 will be designed in accordance with the interoperability standards to achieve joint-line operation and equipped with interfaces for cross-line operation. This is the first set of interoperability lines employing CAMET's recommended standard for interoperability.

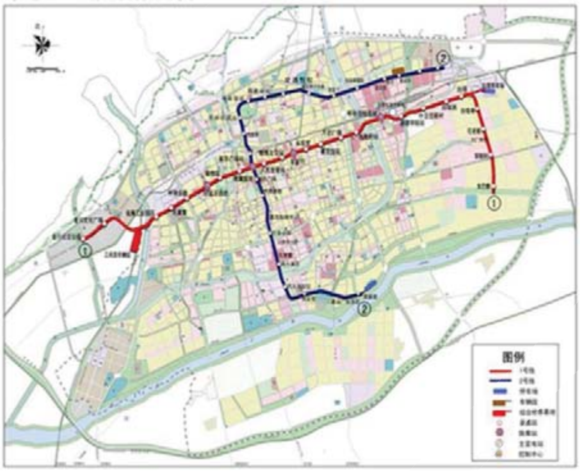
4.4.2 Major Achievement

Among the interoperability specifications of CAMET, 12 of them are adopted with optional modification on detailed configurations and requirements. Formulate relevant standards and principles for 9 Changsha interoperability projects.

The interoperability test lab was completed in the end February 2018. The simulator and its data configuration were completed and entered the verification and validation stage.

4.5 Hohhot Rail Transit

4.5.1 Background



According to the urban planning requirements of Hohhot, the long-term planning rail transit network consists of 5 lines with a total length of 154.9 kilometers. Among them, Hohhot Line 1 and Line 2 are the transport backbone, which are planned to be completed in 2020 (as shown in Figure above). In order to solve the problem that the city center will be relatively concentrated requiring high-frequency metro services, all 5 lines will be designed with joint-line and cross-line interoperability capabilities.

4.5.2 Major Achievement

Completed the first interoperability design review meeting in March 2018.

5 Conclusion

The National Demonstration Project for CBTC Signal System interoperability has overcame common problems worldwide. It had technology breakthrough and achieved great results. Interoperability can optimize resources, maximize system efficiency and performance, and improve service quality. The project lies the foundation for network-wide rail transit operation with improved passenger satisfaction and creates huge social benefits.

This guide serves four purposes:

1) Promote interoperabilitystandardsto enhance the standardization and normalization in local urban rail transit construction;

2) Allow rail transit construction companies to fully understand the meaning of interoperability;
3) Share the achievements and experience gained in CBTC signal system interoperability;
4) Guide future metro construction on implementation of Interoperability.

In the same time, the FAO system in Beijing Yanfang Line has obtained safety validation and opened to public in end of 2017. The interoperable FAO system will be a natural selection for upgrading signal systems or line extensions to enable network-wide operation.

6 Reference Documents

- Interoperability Technical Specifications
  1) General System Requirements T/CAMET 040010.1—2018
  2) System Architecture and Functional Allocations T/CAMET 040010.2—2018
  3) Onboard Electronic Map Data List T/CAMET 040010.3—2018
  4) Hazard Analysis of Interoperability T/CAMET 040010.4—2018
  5) Balise Protocol T/CAMET 040011.1—2018
  6) "Train-wayside Communication Protocol
  7) for CBTC system" T/CAMET 040011.2—2018
  8) Interface between On - board ATP&ATO and Vehicle T/CAMET 040011.3—2018
  9) Interface of ZC-ZC Communication Protocol T/CAMET 040011.4—2018
  10) Interface of CI-CI Communication Protocol T/CAMET 040011.5—2018
  11) Interface of ATS-ATS Communication Protocol T/CAMET 040011.6—2018
  12) Interface of MSS-MSS Communication Protocol T/CAMET 040011.7—2018
  13) Onboard MMI T/CAMET 040011.8—2018
  14) CBTC Train Control T/CAMET 040012.1—2018
  15) Intermittent Train Control T/CAMET 040012.2—2018
  16) Engineering Design T/CAMET 040013.1—2018
  17) Safety Assessment T/CAMET 040013.2—2018
  18) Basic Delivery Conditions T/CAMET 040013.3—2018

- Long Term Evolution for Metro (LTE-M) Specifications
  1) System requirements T/CAMET 04005.1—2018
  2) General system architecture and function specification T/CAMET 04005.2—2018
  3) Classification and requirements for integrated carrying information T/CAMET 04005.3—2018
  4) Air interface T/CAMET 04006.1—2018
  5) Data interface between evolved packet cores T/CAMET 04006.2—2018
  6) Trunking service functions and interface T/CAMET 04006.3—2018
  7) Carrying CBTC services and interfaces T/CAMET 04006.4—2018

8) System equipment technology T/CAMET 04007.1—2018
9) Terminal equipment technology T/CAMET 04007.2—2018
10) Data service interoperability test T/CAMET 04008.1—2018
11) Trunking service functions and interface test T/CAMET 04008.2—2018
12) System test T/CAMET 04008.3—2018
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16) Network IP address allocation T/CAMET 04009.2—2018
17) Equipment coding T/CAMET 04009.3—2018
18) Construction T/CAMET 04009.4—2018
19) Engineering acceptance T/CAMET 04009.5—2018