Research on the Generation Method of CBTC Test Sequence

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Abstract. Before the CBTC line is opened for operation, it should be tested on site to verify whether the system meets functional requirements, design specifications, and operational requirements. At present, there is no uniform test standard for the field test work of the CBTC system, especially the lack of standard and systematic field test sequence generation methods. In this paper, the test-trip based field test scheme is studied, and the test-trip based field test sequence generation method is proposed, and various rules and definitions under the framework of the method are explained.

1. Introduction
In recent years, in order to meet the increasing demand of public transportation, China's urban rail transit has developed rapidly, and CBTC (Communication Based Train Control) has been widely used as a mainstream signal system. The CBTC system is a typical real-time system. Verification and testing are two ways to ensure that the system behaves correctly and implements preset functions. Testing is the only way to test the dynamic behavior of a CBTC system at runtime. Before the CBTC system is put into use, the system's safety, reliability, availability, and functionality should be tested.

2. Test train operation process analysis
Firstly, the operation process of the test train on the simulation test platform during the CBTC system indoor confirmation test is analyzed. In the CBTC system indoor confirmation test, the running condition of the test train can be observed in the trackside simulator, and the initial position of the train can be set. Before the test, the train is placed in the initial position of the test, and the train is set through the initial position setting interface of the train. On the platform. With the participation of other subsystems of the simulation test platform, the indoor confirmation test is carried out, and the test I'll travel process is displayed in the trackside simulator. The test results are mainly expressed by the state of the trackside simulator and the simulation vehicle. After the test is over, the train is placed in the initial position of the next test to continue the test.

In summary, it can be seen that the sequence of execution of test cases in the indoor confirmation test has little effect on the test efficiency. The requirements of the test case for the initial position of the test can be quickly met by the trackside simulator, and the test cases are not connected in series to the test sequence. The necessary CBTC system indoor confirmation test is not carried out in the actual work, and the test sequence is not too much research, because the simulation test train position can be set quickly, and the test sequence is arranged according to the direction of train travel, and the test sequence number is not even according to the indoor confirmation test case number. The efficiency of testing in sequence is no less efficient than other methods.
According to the foregoing description, in the CBTC field test, the test train "runs the circle" in the test line, as shown in Figure 1, the "running circle" is the process of executing the test case. The on-site test train departs from the starting station or the depot, and runs through the test line. The tester observes the test train operation status in the test area centralized station and control center, and issues test commands to the on-board test personnel according to the test requirements to complete the test task. Unlike the indoor test, the on-site test train cannot be placed at any speed, and the train cannot be retreated long distances. The train can only move from the current position to the test target position according to the test line. In order to make full use of a "running circle" for more field testing, an efficient test sequence must be programmed.

3. Test the setting of train running state quantity

In the indoor confirmation test, two tests are executed in sequence. After the first test, the train position may be reset and then the second test is performed, and the running state of the test train undergoes an abnormal transfer. The on-site confirmation test requires the test train to normally transfer to the execution of the next test case after completing the previous test case, that is, the state of the test train is normally transferred between a series of test cases in the test sequence. It can be seen that the state of the train before and after the execution of the field test case is the reference factor of the series test case. According to the on-board equipment constraints of the test case execution conditions, the train running status mainly shows: train control level and driving mode, train speed status, and train positioning status.

According to the overall technical requirements of the domestic CBTC system, the operating level of the system is from IL to BLOC and CBTC. There are various driving modes under various control levels, and the running level of the train and the driving mode are mutually restricted to jointly determine the running state of the train. The combination between train running level and driving mode is shown in Table 1:

| Table 1. Train control level and driving mode |
|----------------------------------------------|
| Run level | IL | BOLC | CBTC |
| RM mode   | 1  | 0    | 0    |
| CM mode   | 0  | 1    | 1    |
| AM mode   | 0  | 1    | 1    |

The AM mode is the automatic train operation mode under ATP monitoring. In this mode, the ATP subsystem ensures the safe operation of the train. The ATO subsystem can realize the automatic operation and reasonable operation of the train in the interval, the positioning of the platform and the control of the door and the safety door. The operation of the AM mode requires manual confirmation by the driver, and the train driver initiates the automatic operation of the train by pressing the ATO start button.

Figure 1. Test the running process of the train
The CM mode is the manual driving mode under ATP monitoring. In this mode, the ATP subsystem determines the maximum allowable speed of train operation, the driver drives the train to run under the ATP protection speed curve, and the ATP subsystem implements all the functions of train automatic protection. The parking of the platform and the switches of the doors and safety doors are manually controlled by the driver. The system should be able to achieve linkage between the door and the safety door.

The RM mode is to limit the manual driving mode. In the RM driving mode, the onboard ATP restricts the train to run at a fixed low speed. The driver displays the driving train according to the dispatch command and the ground signal. When the train runs beyond the fixed speed, the onboard ATP equipment performs emergency braking on the train. Forced train to stop. The safety of train operation is guaranteed by interlocking equipment, ATP vehicle equipment, dispatchers and drivers.

When the output of the VOBC device is completely removed, the driver and the interlocking device ensure the safety of the train and the passenger. This mode of operation is called EUM mode, also known as ATP cut mode.

4. Test case serialization method based on train status connection

The running state of the train before and after the test case is used as the connecting link of the test case. By extracting the train status information before and after the test cases, combined with the positional relationship of the test section where the test case is located, a field test sequence can be prepared to test the line driving direction. By testing the reasonable transfer of the train state, the test cases TC1, TC2, TC3 executed in the test sections TS1, TS2, TS3, respectively, are connected in series into a field test sequence, and the sequence is executable.

In the longer test section, the test train may execute multiple test cases in sequence, and it is possible to construct a test sequence within the long test section by a reasonable connection of the train status. For example, the number of transponders in the interval test section is large, and the positioning test is performed on the adjacent two-two transponders. The positioning test performs multiple positioning test cases in the interval test section.

The test train state is reasonably connected to the train state non-transfer connection, and the train state transition is continued.

(A). Train status non-transfer connection

In the connection mode, the train state after the execution of the previous test case is the train state before the execution of the latter test case, and the state transition process is not required. For example, "authorized departure station test under BLOC level" and "opening prompt test for signal of interval ringless transponder under BLOC level" in the next test section can be connected in series by the connection mode.

(B). Train status transfer

In the connection mode, the train state is different from that of the previous test case after the execution of the previous test case, but the two train states are transferred by a relatively simple means, and the state transition implementation manner is:

a). Train control level and driving mode transfer (ControlDriveMode_Change)
b). Tester controls train speed state change (TrainVelocityChange)
c). the tester sets the train positioning status to be lost ((PositionState_Change)

For example, "Safety docking test in the inspection station in BLOC-CM mode" and "filling the transponder display prohibition information test in BLOC-AM mode" in the next test section, the driver is started to drive the train, and the train driving mode is upgraded at the appropriate position, Test cases in adjacent test sections are concatenated.

5. Field test sequence layout rules

By analyzing the execution process of all on-site test cases, and testing the various operating states of the train before and after the execution of the case, the CBTC system is tested on-site to test the
“running circle” structure, the executable test sequence, and the field test sequence based on the train status. Mainly in three aspects:

(A). Test case serialization

An executable field test sequence can be programmed by concatenating test cases between test sections or test cases in long test sections using a field test case tandem method based on train status connections. The above description does not exactly explain the execution of the field test sequence, and then analyzes the execution of the test case in the test sequence from the two dimensions of time and space.

The time dimension of the field test characterizes the time sequence of the execution of the test case in the test sequence, and the spatial dimension represents the positional relationship between the test case execution positions in the test train running direction. Before analyzing the spatio-temporal characteristics of the test cases in the test sequence, the field test cases are divided into two categories according to the requirements for the execution of each case in the field test:

- CBTC system field test case
- Long area test case
- Short area test case

![Case classification based on test case execution length](image)

The long-area test case runs through multiple test sections during the execution process. By observing the operation of the equipments of the in-vehicle equipment and trackside equipment during the execution of the entire test case, the test results are obtained. The execution position of the test does not correspond to a certain test. Instead of a test section, the test is spread across all the test sections involved. In the short-area test case, the execution area is short and the test cases generally match one test section.

For example, if an approach test is performed at the BLOC level, the execution area of the test includes all test sections from the approach start signal to the approach end point. In the BLOC-CM mode, an inbound approach from station A to station B is carried out, and on-site testing is carried out. The test sections involved in the test are TS1, TS2, TS3, TS4, and TS5. During the entire operation of the train in the above test area, the tester should confirm that the speed curve and the speed limit value of each speed limit area are consistent with the engineering design. The test is a long area test. In addition, the IL level of the following vehicle operating status real-time and display correctness test, BLOC level mobile authorization and signal display consistency test, CBTC level update track occupancy state machine signal display status test are long area test. In the matching of test cases to test sections, such test cases are included in the measurable case set of all relevant test sections.

For the functional test of filling the transponder repeating signal state in BLOC-CM mode, for the circuit studied in this paper, it is known from the execution condition of the test that the test execution area should be filled in the transponder and the associated interval signal. It is nearby, so it is matched to the TS2 test section. The test execution area is relatively short and belongs to the short area test. Typical short area test cases include train positioning test, parking window test, and some fail-safe related tests.

Based on the division of short-area test and long-area test, it is not difficult to analyze the spatio-temporal characteristics of test cases between field test sequences: for the series connection between
two short-area test cases, the execution of the case is determined according to the positional 
relationship between the driving directions. The sequence, that is, the execution time of the test cases 
in the sequence does not coincide, and the spaces do not overlap. For example, after performing the 
"in-station safe stop test in the BLOC-CM mode" in the in-station test section, the "filled transponder 
display prohibition information test in the BLOC-AM mode" in the next test section is executed.

(B). Priority test group priority grouping principle
According to the constraints of the train control level in the test case, the CBTC system field test cases 
are divided into four categories, namely, the level mode conversion test case, the IL level test case, the 
BLOC level test case, and the CBTC level test case.

According to the train status, the serial field test case can be connected in a reasonable manner. The 
the case of a test case in the previous test section can be different from the case level in the test case set of 
the latter test section. If the above two test cases are to be connected in series, it can be known from 
the above that The train status transfer connection should be carried out, that is, the control level 
conversion, and the conversion of the control level needs to meet certain conditions, and cannot be 
performed anytime and anywhere in the field test. If the line condition of the test section in the latter 
test case does not satisfy the level conversion, the scene Test cases fail in tandem, and field test cases 
with different levels of visibility are not easily concatenated into executable sequences. For example, 
if the train is converted from the IL level to the BLOC-CM level, the train should be upgraded and 
converted at the active transponder that can transmit the BLOC MA, and the train's highest control 
level and driving mode are preset to be low. For BLOC-CM, if it is not met, the maximum preset 
should be reset before parking. In addition, not all control levels can be directly converted. For 
example, the CBTC level cannot be directly converted to the BLOC sector, and can only be transferred 
to the BLOC level after being converted to the IL level.

In summary, the conditions for controlling the level conversion are more demanding. Even after 
various operations have completed the level conversion, it is also a test of the train to take a certain 
time, at the cost of running a distance, during which no test is performed, the level conversion process 
is the former The "empty run" process described. The core objective of the test-trip-based CBTC 
system field test sequence research is to minimize the "empty run" process. Therefore, the sequence 
arrangement based on the test train status connection should follow the principle of prioritization of 
the same level test case to avoid different levels of test cases. In series, it is best to ensure that the test 
sequence of a “running circle” in the field test consists of the same level test case.

(C). Hierarchical mode conversion test concatenation test case principle
When constructing a field test sequence, the same-level test case priority grouping principle can 
avoid the concatenation of different test cases at different levels. This principle also indirectly 
excludes the control level and mode conversion operation in the field test sequence execution, and the 
level mode conversion test is the CBTC system. Part of the on-site test content, for this purpose, this 
article can use this type of test to link the characteristics of different levels of mode test cases, use the 
level mode conversion test in the field test case series to test the serial test case, and arrange the 
corresponding test before and after the level mode conversion test case. Compared with the 
hierarchical mode conversion test case, the sequence is separately organized. The test sequence 
constructed under this principle contains more test cases, which reduces the “empty run” process of 
the field test. For example, for the tier mode conversion test "RM mode upgrade BLOC-CM", the 
"train positioning test" or other fail-safe function test that can downgrade the train to the RM mode can 
be programmed before the case execution position; its execution position can be arranged after Test 
cases in BLOC-CM mode, such as "BLOC-CM upgrade BLOC-AM test" or test related to opening 
function in BLOC-CM mode.

6. Conclusion
This paper mainly studies the test-trip based field test scheme, and details the framework of the Test-
trip based CBTC field test sequence generation method. Wherein, the method of dividing the test 
section based on the axle counting device is adopted; the execution process of the test case is analyzed,
and the constraint quantity representing the execution condition is mined; and the test section execution condition is reversed to introduce the feature quantity of the test section, thereby ensuring The test segment feature is related to determining the test case execution position; establishing a matching method between the test case and the test segment, that is, using the test case execution constraint expression to check the test segment feature quantity, and analyzing the matching channel; analyzing and testing the train status Information, determine the train status connection as a link between the test cases in the Test-trip, and give the three rules of the test sequence generation.

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