Study on the Door Control of the Korean Radio-based Train Control System

MIN-SOO KIM, YONG-KI YOON, SEH-CHAN OH and YONG-KYU KIM
Radio-based Train Control Research Team,
Korea Railroad Research Institute
360-1 Woram-dong, Uiwang-si, Gyeonggi-do,
437-757, KOREA
ms_kim@krri.re.kr http://www.krri.re.kr

Abstract: - The ATP/ATO system is train control system for driverless operation in urban rail and metro rail, and it is important role in the communications based train control system. Especially, the ATO acts as an important role for automatic operation in urban rail with short distance between stations stopping and frequently stops. This paper deals with the door control of ATO which is the subsystem of the Korean Radio-based Train Control System (KRTCS) developed for driverless operation.

Key-Words: - Korean Radio-based Train Control System, Automatic Train Protection, Automatic Train Operation, Door Control

1 Introduction
The railways perform their each function as multiple systems such as vehicles, tracks and signals etc. Therefore, co-operative operations between each subsystem are essential.

Especially, the railway signal or the train control system is in charge of ensuring safe and improving efficiency of railway operations by maintaining a safe separation of a preceding train and a following train [1].

The signal systems installed in Korea are the Automatic Train Stop (ATS), the Automatic Train Control (ATC), the balise(or transponders) and the Automatic Train Protection (ATP) using the track circuit.

The Communications Based Train Control (CBTC) system which is introduced in Korea is a railway signal system based on communications and information technology, and it is consists of subsystems such as the Automatic Train Supervision (ATS), the ATP, the Automatic Train Operation (ATO), the Electronic Interlocking (EI) and Radio Communication Network (RCN).

Of these, the ATO system is an automatic train system to increase the average speed, and it reduces headway of the train to provide the maximum transport capacity of urban railway, and offers convenience and safety of passengers through safe operations such as the stop at the right locations, the train doors control and Platform Screen Door (PSD) control.

This paper deals with the door control of ATO suitable for the KRTCS as a subsystem of the CBTC system for urban rail and driverless operation is possible.

2 The Korean Radio-based Train Control System (KRTCS)

Fig. 1 Configuration of Train Control System of Korean Radio-based Train Control System (KRTCS)

The Korean Radio-based Train Control System (KRTCS) consists of the Automatic Train Protection (ATP) to ensure the safe separation of trains, the Automatic Train Operation (ATO) to provide a high riding quality and an automatic operation in both directions, the Automatic Train
Supervision (ATS) to monitor trains a powerful and flexible, and the Electronic Interlocking (EI) which is responsible for logic integration routes.

Figure 1 shows the system configuration diagram of the KRTCS based on the radio communication including the ATO.

2.1 Automatic Train Protection
The KRTCS consists of the ATP to ensure the limits of safe train separation, ATO to provide a high passenger comfort including jerk limitations and automatic operation in both directions, ATS to monitor trains a powerful and flexible, and EI which is responsible for the information on locking, releasing and switching route.

Fig. 2 Moving Authority (MA) in moving block operation

- Determine train location, speed, and travel direction: Train location, speed, travel direction are determined by the location information with regard to fixed track-side reference point devices (transponders). That is, ATP compensates for the effects of location measurements inaccuracies by accumulated by tachometer.

- Determine limits of safe train separation: ATP determines the limits of safe train separation for a following train, with appropriate consideration of the location uncertainty (position uncertainty) of the preceding train (including any rollback tolerance) using the moving block system rather than relying on existing track circuits. Speed restriction factors for calculating the static speed profile include the followings:
  - the permanent speed limits on section of track
  - the temporary speed limits on section of track
  - any permanent speed restriction applicable to the particular configuration of train
  - any speed restrictions enforced on the train because of train-borne failure conditions

- Emergency braking: If the train does not comply with the limit conditions assigned by ATP, the ATP applies emergency braking within the safe braking margin. Once the emergency braking is applied, the emergency braking will be maintained. Train movement shall be allowed after resetting the emergency brake, when ATP condition is satisfied.

  • Route interlocking: Interlocking to route and switch is a vital function in the intelligent train control system that prevents the collision and derailment of a train, and is protected by ATP.

  • Safe Braking: The minimum distance for safe braking is set based on the maximum stopping distance of the train emergency braking that may occur in the worst case.

2.2 Automatic Train Operation
The ATO (Automatic Train Operation) performs non-vital functions such as regulate train speed, stopping right place and door control under the supervision of ATP, and receive state of the station, operation command, wait command, controlling train door commands, stopping commands and fault checking by communicated with on-board device.

  • Stop train in station: When the train stops on the platform, it uses the distance from the stop point to the transponder in order to provide a comfortable ride for passengers and stopping at the right location.

  • Train speed control: Under the ATP speed supervision, it controls the operation speed in accordance with target speed profile by the ATP functions.

  • Train door control: When the train stops in station, it automatically synchronization to performs the train door opening and closing with the PSD. Also, it performs the train door opening and closing by communicating with the ATS.

The ATO door control which is a subsystem of the CBTC system for urban rail that driverless operation is possible is defined in the functional specification, and it is shown in Figure 3.
3 KRTCS door control
Depending on the train driving mode, the train doors have different door modes.

Table 1 Door mode according to driving mode

<table>
<thead>
<tr>
<th>Driving Mode</th>
<th>Door Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driverless</td>
<td>Auto/Auto</td>
</tr>
<tr>
<td>Emergency</td>
<td>Manual/Manual</td>
</tr>
</tbody>
</table>

The commands sent from the ATS to ATO are follows.

- Holding Command : command for train standby
- Holding Release Command : command for release train standby
- Door Open Command : command for train doors open
- Door Close Command : command for train doors close
- Departure Command : Including the information messages of the next station. The message sent after confirming the train stops at the right location and includes the next station information. When the ATS sends the Departure Command, the ATO performs the door close if it is opened.

And the command sent from the ATS to the wayside ATP is follows.

- Door Open Command : the enable command for the door open

For the train to depart, it requires to receive a departure command from the ATS and departure permission from the ATP. If the train has a holding command, the train may depart after it receives the release command by ATS.

And the holding command is available from the time of stopping at the right locations until the train receives departure permission by ATP.

If the train have the close command separately, the automatic departure is possible when there is the departure command by ATS and departure permission by ATP.

Fig. 4 Operating sequence of Door and PSD in case of auto/auto door mode
The figure 4 shows the door open and close sequence when the train door mode is auto/auto mode and shows interactions between the ATP wayside, the ATP onboard, PSD, Train Door, the ATO onboard, staff and the ATS.

![Door open sequence](image)

(a) Door open sequence

![Door close sequence](image)

(b) Door close sequence

Fig. 5 Operating sequence of Door and PSD in case of manual/manual door mode

The figure 5 shows the door open and close sequence as the train door mode is manual/manual mode.

4 Conclusion

The ATP/ATO systems which is the core of the CBTC(Communication Based Train Control) system is a train control system for driverless operation in urban subway and metro rail, and the ATO acts as an important element for automatic operation in urban subway with short distance between stations stopping and frequently stops.

This paper deals with the ATO door control which is the subsystem of the Korean Radio-based Train Control System(KRTCS) developed for the driverless operation.

References:
[1] KRRI, *Train Control System Requirements Specification(SRS), Ver.4.0, 2012*
[9] *Urban railway signal system standard specification (proposal), Korea Railroad Research Institute, 2007.*