**Functional Allocation and Door Control of ATO for the Korean Radio-based Train Control System**

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**Abstract:** - The Communication Based Train Control (CBTC) performs train position report immediately and movement authority transmission through wireless communications between a wayside control center and on-board vehicle computers. And it has effect of increasing the railway capacity by allowing the high-density train control through a high capacity of information transmission between the on-board and the wayside. Also, it reduces the maintenance cost because it does not use the existing track circuits. The Automatic Train Protection (ATP)/Automatic Train Operation (ATO) is fundamental 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 a key role for automatic operation in urban rail with short distance between stations stopping and frequently stops. This paper describes the door control including platform screen door (PSD) and functional allocation of ATO which is responsible for the automatic operation and the door control as a subsystem of the Korean Radio-based Train Control System (KRTCS).

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

**1 Introduction**

Railway systems are group of individuals with vehicles, tracks and signals, and therefore the effective interaction among the subsystems is a core role.

Train control system or railway signal plays a key role in ensuring safety separation between the trains operation in the territory and improving efficiency of railway operations by protecting train collision between a preceding train and a following train [1].

Train control systems already operating in the domestic railways include Automatic Train Stop (ATS), Automatic Train Control (ATC), and Automatic Train Protection (ATP) using balise (or transponder) and track circuit.

Communication Based Train Control (CBTC) recently introduced in Korea is a railway signal system based on communications and information technology, and consists of sub-systems such as Automatic Train Supervision (ATS), ATP, Automatic Train Operation (ATO), Electronic Interlocking (EI) and Radio Communication Network (RCN).

Among them, ATO system is an automatic train system that can increases the commercial speed and reduce headway of the train to provide the maximum transportability of the subway train, and offers safety and conveniences of passengers through the safe operations such as an accurate stop on the station, train door/Platform Screen Door (PSD) controlling, and so on.

This paper deals with the door control, the function allocation and the design of the functional requirements of the ATO suitable for KRTCS (Korean Radio-based Train Control System) as a subsystem of the CBTC with driverless automatic operation.

**2 KRTCS**

The KRTCS consists of the ATP to ensure the limits of safe train separation, ATO to provide a high passenger comfort including acceleration/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.

**2.1 ATP function**

- 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 with a 200 [m] interval). That is, ATP
compensates uncertainty which is affected 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

- Maximum speed that would allow the train.

**Fig.1 Moving Authority (MA) in moving block operation**

Dynamic speed profile develops a speed profile (braking curve) based on train speed limit by section and variable data determined according to the static speed profile.

- **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 ATO function**

The ATO performs non-vital functions such as regulating 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.

**Fig.2 KRTCS ATO Primary ATO functions**

### 3 Design and Functional Layout of ATO for KRTCS

ATO of the KRTCS is allocated and designed in six functions as shown in figure 2.

ATO functions, the 'Awake Train' function, is intended to awake trains which are in stabling locations (in workshop, sidings or in the line) before they enter service (operation) when a train equipment is powered up and a cab is activated by remote action from the ATS. Also, the 'Sleep Train' function is intended to set the trains to sleep in stabling locations (in depot, sidings or in the line) after they leave service (operation) by remote action from the ATS.

The following describes the details of the allocations and design of the remaining four functions except indication device.
3.1 Determine the ATO operating speed profile
This function is intended to determine the operating speed profile (including service acceleration/deceleration rate) in accordance to the train protection profile and taking into account notably the following factors:
- Stopping points (target points)
- Driving mode
- Braking performance
- Jerk limitation
- Train Strategy and Regulation Strategy
- The system response time including the rolling stock reaction time

The ATO shall determine the operating speed profile in accordance with the dynamic speed profile of ATP and to enable the train to stop at the next stopping point. Also, it shall determine the operating speed profile to enable the train to stop or skip as commanded by the ATS and shall choose operating speed profile in accordance with the regulation strategy.

If it shall determine the operating speed profile to start a train after a stop between stations automatically as soon as the authorization to depart is given.

3.2 Inching control
This function is intended to the train stops at the right location automatically to enter the station, but if it is retried the train stops at the right location cause of failure (under-run, over-run) to stop at the right location.

It is also intended to includes perform the inching operating by the ATS operator's command when the ATO system’s automatic inching (exceed the number of retrials) was failed.

If the train stopped outside of the stop tolerance, the ATO system shall precede the train to the next station and if the train fails to reach the stopping point at the platform, the ATO system shall jog the train forward automatically until it does so.

If the train failed to stop at the right location after performing the automatic inching by the ATO system, the ATO system request the remote inching to the ATS for the stop at the right location.

The ATO system which received a command to remote inching from the ATS shall perform the inching control. The ATO system shall be on standby status if the ATO system does not receive remote inching command from the ATS.

3.3 Regulate train
The ATO system shall deliver deceleration to the rolling stock relying only on the service brake.

This function is intended to transmit propulsion and braking signal in accordance with train operating profile, and shall determine the operating speed profile (including service acceleration/deceleration rate) in accordance with the train protection profile.

In other words, regulate train speed means the transmit propulsion and braking signals appropriately in accordance with the train operation profile.

4 KRTCS door control
This function is intended to command train doors and platform doors (if installed) opening when opening authorization conditions are met.
Also, this function is intended to command train doors and platform doors (if installed) closing when the train want to close the doors to depart.

The ATO system shall transmit opening signal to train doors and platform doors (if installed) in accordance with established procedures if the door mode is set to be opened automatically. And the ATO system shall transmit opening signal to platform doors in accordance with established procedures, if the door mode is set to be opened manually and platform screen doors are installed.

Also, the ATO shall transmit opening signal to train door and platform door (if installed) in accordance with the established procedures if the door mode is set to be opened automatically.

Depending on the train driving mode, the train doors have different door modes.

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

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.
The figure 7 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.

5 Conclusion
The ATP/ATO system 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 especially the ATO acts as an important element for automatic operation in urban subway having frequently starting and stopping at the short distance between stations.

This paper deals with the train door control including the PSD and the function design of the ATO system as a subsystem of the Korean Radio-based Train Control System (KRTCS) which is possible for the driverless operation. And the train door control, functional allocations of the ATO were performed to apply the KRTCS satisfying driverless operation and interoperability.

References: