Development of ATO System for Korea Standardized EMU

Tae-ki Ahn, Seong-ho Han, Su-gil Lee, Jong-duk Chung, Won-kyong Kim

Urban Transit System Team
Urban Transit Engineering Department
Korea Railroad Research Institute, 374-1, Woulam-Dong,
Uiwang-city, Kyonggi-Do 437-050 Korea

Corresponding Author :
Tae-ki Ahn Phone : 81-31-461-8531(ext. 408)
FAX : 81-31-461-8560
E-mail : tkahn@krri.re.kr

Abstract
The automatic/driverless operation of the train is practicable through the technological development of computer and communication.
Every equipment which is set up in the train must have the functions of automatic driving and be interfaced to each other in order that the train can run automatically.
Of all equipment, the important parts of computer systems to perform automatic driving of the train are ATO, TCMS, ATC, TWC, and TRA.
The ATO, above all, is the system for powering/braking command instead of a train operator.
The ATO interacts and gets all its input from TCMS, ATC, TWC and TRA.
The TCMS supplies the ATO with information about the train, such as cab activated signal.
The ATC supplies the ATO with information of speed signalled from wayside.
The TWC supplies the ATO with information about the train route, i.e. the present station and next station.
The TRA supplies the ATO with information about passing PSM.
This paper describes the development of ATO for Korea Standardized EMU, and results of test run on the Sangju test line.

Key words: Automatic Train Operation, Automatic Train Control
1. Introduction

Recently the technological development of computer and communication caused developments of all parts of industrial circles, and automatic/driverless operation of the train is practicable through these technologies connected with trains.

Seoul Subway Line 5, 6, 7, 8 in Korea are run mostly by automatic operation. And also, each self-governing community in Korea plans to automatic/driverless operation in Light Rail Vehicle System, which is often considered.

There are many ways of formation of system that the train is driven automatically. However, the system applied in Korea Standardized EMU is composed of ATO, TCMS, ATC, TWC, and TRA. The ATO performs functions typically performed by a train operator. The TCMS supplies the ATO with information about the train, such as cab activated signal. The ATC supplies the ATO with information of speed signalled from wayside. The TWC supplies the ATO with information of about the train route, i.e. the present station and next station. The TRA supplies the ATO with information of passage of Precision Stop Marker (PSM).

This paper describes the development of ATO that need for automatic/driverless operation of the train and the results of test driving that applied this ATO for Korea Standardized EMU on the test line in Sangju.

2. The configuration to automatic driving for Korea Standardized EMU

Nowadays it is similar to the system configuration which is used for automatic driving of the train, but they are a little different from the process and the way of collection of information.

The ATO has to be interfaced with external system for automatic driving of the train.

There are the ATC, TWC, TRA, TCMS, which are systems directly connected with the ATO to transmit information, and the way of that the ATO measures the speed signal from pulses of tachometer and counts the speed is used in Korea Standardized EMU.

The ATO gives and takes information through communicating with those external systems.

Fig.1 indicates formation of the ATO and external system, and Table.1 indicates information communicating between the ATO and external system.
Table 1. Send/Receive data between ATO and external system

<table>
<thead>
<tr>
<th>External System</th>
<th>ATO send data</th>
<th>ATO receive data</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCMS</td>
<td>TE/BE</td>
<td>Inhibit Driving</td>
</tr>
<tr>
<td></td>
<td>MWB</td>
<td>Start test command</td>
</tr>
<tr>
<td></td>
<td>Powering selection</td>
<td>Cab. Active</td>
</tr>
<tr>
<td></td>
<td>Braking Selection</td>
<td>Activated ATO</td>
</tr>
<tr>
<td></td>
<td>Holding Brake</td>
<td>Year,Month,Day</td>
</tr>
<tr>
<td></td>
<td>Test Complete</td>
<td>Hour,Minute</td>
</tr>
<tr>
<td></td>
<td>ATO Ready</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATO status</td>
<td></td>
</tr>
<tr>
<td>ATC</td>
<td>Send Train Berthed</td>
<td>Speed Command</td>
</tr>
<tr>
<td></td>
<td>ATO Ready</td>
<td>Full Service Braking</td>
</tr>
<tr>
<td>TWC</td>
<td></td>
<td>Present/next station code</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fixed Speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Driving Control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TWC Carrier detect</td>
</tr>
<tr>
<td>TRA</td>
<td>PSM Reset</td>
<td>PSM1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSM2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSM3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSM4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSM5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSM6</td>
</tr>
</tbody>
</table>

According to the Table.1, the ATO is inputted the information that requires determining automatic driving from each equipment. After the TCMS inputs Cab. Active signal and Activated ATO signal, the ATO sends ATO Ready signal to the TCMS and the ATC, then it is built up the condition of automatic driving. After that, the real automatic driving is put into operation by using information of present station/next station code, fixed speed, normal/recovery mode from the TWC and the speed code from ATC. Also, the driving equipment of the train is inputted information of PSM (Precision Stop Marker) by the TRA in order to operate the precision stop to supplement errors of distance.

3. Development of ATO System for Korea Standardized EMU

The train is an inertial object that runs along the track, and powering equipment and braking equipment, which is set up in the train, operates accelerating/decelerating. As regards energy of the running train, there are powering mode which is performed accelerating by consumption of energy, braking mode which is performed decelerating by regeneration of energy or mechanical equipment, and coasting mode which is no consumption or regeneration of energy.

The train is performed by accelerating/decelerating command, but the situation of the train is actually various by reasons of grade and curve of track and condition of track, such as friction. Also, it must be considered that the train doesn’t react to accelerating/decelerating command in the real time because of the feature of the train. In the manual operation mode, while a train operator is driving a train, he takes proper steps of powering, coasting or braking to the condition of track. The ATO substitutes for this kind of the train operator’s function in automatic operation mode of the train.
The ATO orders the train's accelerating/decelerating command instead of the train operator in using the train's real speed, target speed which the train is expected to reach, and condition of track. The ATO which has charge of automatic and driverless driving moves with giving and taking various required information from the related equipment.

The most important part of the ATO's functions is driving control which follows the real train driving from the starting to the stopping. This driving control way can apply various ways, such as PID control, fuzzy control, but now is used mostly the Pattern following way using the PI controller. The developed automatic train control equipment makes a controller by using the time-optimal and PI control way, which can approach the target speed in shortest time.

And also, it is used the distance-to-stop control way, which can stop the accurate place in shortest time by calculating the distance continuously, for a precision stop. Fig.2 indicates the block diagram of such control method.

![Blockdiagram of the ATO control method](image)

Fig.3 indicates the section applied such control method during the train is running.
Control method for each driving section

According to Fig.3, Time Optimal Control method is used for approaching to target speed as fast as possible, and PI Control method is used for keeping the speed in case of being close to target speed.

Precision Stop Control method is used to perform the precision stop by keeping calculating the rest of distance to the stop point and investigating if the train can stop to the stop point or not.

The software of the ATO is composed of Kernel part, communication control part, and application part.

Kernel part performs refreshing hardware and software of the entire ATO system. Communication control part contains functions for communicating with ATC, TWC, and TCMS according to specified protocols. In fact, application part performs the automatic driving of the train.

Formatted software is performed with loading to CPU board that is set up VxWorks, Real time operating system.

The state of the ATO has four states, such as Passive, Active-Idle, Active-Operating, and Error state, and they perform the work by transiting to a stated condition according to the information received from peripheral devices. Fig.4 indicates such State transitions and condition that can transit to each state.
4. The result of test drive

The developed ATO system was tested with setting on the Standardized EMU on the Sangju test line. Now, the ATO, set on the Standardized EMU, includes the track database of the Sangju test line, and the track database has the data of Station code, distance between the two stations, permanent speed restriction, and gradient profile.

The ATO is run by the target speed that is determined by using the data, such as ATC speed code, TWC fixed speed, and permanent restricted speed.

It also has Pre-deceleration function that prevents over-speeding by inserting the permanent restricted speed of the next sector in advance as compared with the current speed.
The target speed is set up 2-3km/h lower than the ATC speed code in consideration of the safety.

The developed ATO has 3km/h in reserve in case of normal mode of the train and has 2km/h in reserve in case of recovery mode of the train.

Fig.5 indicates Sangju test line which the operation of Standardized EMU is tested on.

Sangju test track for Electric Multiple Unit

This test track is managed by Korea Rolling Stock Corporation (KOROS) and designed for test of a trial run as for the train operated on Seoul Subway Line 7, 8.

The entire ATC wayside system is composed of 10 loop circuit which are at each distance of 100m, the distance that the driving is possible is 1,140km from starting point to finishing point, and the driving distance for automatic driving is 946m.

The wayside equipment is operated manually by the wayside signal simulator that is set up in control center, and it was designed for manually dealing with the wayside signal by the off-line in case of automatic driving.

In test track above, the automatic driving test of Standardized EMU was based on the driving distance for automatic driving, 946m, Fig.6 indicates to overlap the several results of automatic driving control under the real regular condition in case that the fixed speed 70km/h was set by the TWC, and at that time the precision stop control is performed within the limits of the allowable error, ±35cm, as the maximum error of precision stop is -13cm.
Speed profile of the train using automatic train operation (fixed speed: 65km/h)

5. Conclusion

This paper described the system of automatic driving for Korea Standardized EMU and the development of the ATO that is the main equipment of automatic driving.

The developed ATO was tested with setting on the standardized EMU made for the test in the test line which the wayside equipment is set up.

The result of testing the developed ATO was generally satisfactory, but hereafter the ATO equipment requires to be developed through devising and testing a variety of ways about the improvement for the energy optimizing, the safety, the confidence, and the comfort.