First Transportation Project APM System for Hong Kong International Airport

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1. Introduction

IHI has recently entered the APM (Automated People Mover) market as we expect global demand to increase. The APM system is growing in popularity, especially for passenger transportation within airports, and there are many new applications being planned, mainly in North America. Our company will meet the increasing needs by means of our original rubber tire type vehicle technology and system integration technique in cooperation with Niigata Transys Co., Ltd. (hereinafter called NTS). Phase 1 of the new APM system construction for Hong Kong International Airport, our first order received, was completed in December 2006. In this paper, we introduce the APM system for Hong Kong International Airport and its technology.

Fig. 2 New APM Vehicle for Hong Kong International Airport

2. Outline

In December 2005, we delivered new 3 4-car vehicles (**Fig. 2**) to add to the existing APM system in the Passenger Terminal Building (hereinafter called existing PTB line) of Hong Kong International Airport (**Fig. 1**). Construction Phase 1 of the new SkyPlaza APM system (hereinafter called SKP line) connecting the neighboring SkyPlaza and Terminal Building 1 has been completed recently. This consists of a 2-station route of about 550 m and a maintenance area, with all the facilities installed underground. Under Construction Phase 2, scheduled for spring 2008, the service will be extended to the ferry terminal SkyPier, which connects Hong Kong International Airport with various places in mainland China and Macau. The length of the route after the extension has been completed will total 1 200 m (**Fig. 3**).

Fig. 1 Complete View of Hong Kong International Airport

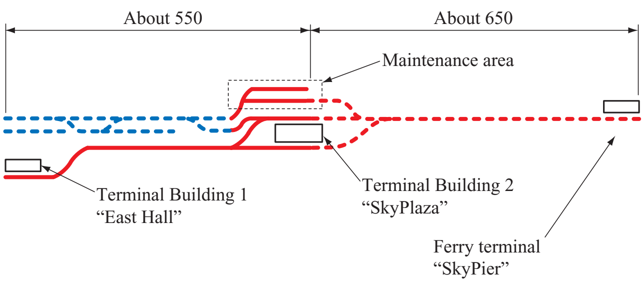

Fig. 3 Approximate Route Diagram (Unit : m)

3. SkyPlaza APM System

The range of this construction work covers reinforced concrete track (excluding the APM vehicle), steel guide rail, maintenance area and power distribution system, power rail, communication system and ATC (Automatic Train Control). Here follows a description of the ATC, a vitally important part of the APM system.

The ATC comprises ATP (Automatic Train Protection) to support safe operation; ATO (Automatic Train Operation) to control automatic operation, including door opening/closing and vehicle accelerating/decelerating; and ATS (Automatic Train Supervision) to command, monitor, and record the operation. The total APM system configuration is shown below.

Rigid conductor power rail	Supplying power to the APM vehicle
Reinforced concrete track	Running surface for the APM vehicle
Guide rail and point switch	For guiding the APM vehicle
Power distribution system	Power receiving, voltage reduction, and distribution
Buffer	For stopping the vehicle
ATP	Automatic Train Protection (safety device of the APM vehicle)
ATO	Automatic Train Operation (automatic operation of the APM vehicle)
ATS	Automatic Train Supervision (system operation, monitoring, and recording)
Communication system	Public address to the vehicle and platform, and intercom between passengers and the operator at the airport's operation control center
Maintenance area	For APM vehicle storage and maintenance

Every subsystem is configured to conform to the domestic APM system. In consideration of redundancy, a dual or duplex hardware configuration is adopted to secure high reliability.

3.1 ATP (Automatic Train Protection)

This is a safety continuous-monitoring type device. ATP can automatically limit the vehicle speed or stop the vehicle, based on information from the APM vehicle ahead or route condition. This device functions independently of the ATO device.

As an APM is unable to run on steel rails and use them for transmitting signals, it adopts a system to receive speed signals transmitted from an inductive loop coil installed in the center of the concrete track, with an antenna installed at the head of the vehicle. As the signal system, it uses a fixed block system that divides the track into fixed blocks and indicates the speed limiting for each block depending on ① the position of a vehicle ahead, ② the point switch direction, ③ the track end and ④ the civil constraints. These signals are used not only to limit speed but also to identify the vehicle's direction and the door opening/closing direction interlock at a station, thus enhancing safety.

For Train Detection (TD) on the track, a check-in/check-out system is adopted utilizing antennas installed at the vehicle head and rear.

For interlocked control of the point switches and the signals, Computer Based Interlocking (CBI) is used as it can flexibly cope with future extension and changes in operation.

Figure 4 shows ATP/TD configuration.

3.2 ATO (Automatic Train Operation)

ATO comprises 3 types of equipment: the on-board ATO controller, the ATO data transmission equipment, and the station ATO equipment. These have the functions of automatic door opening/closing, automatic vehicle starting, decelerating, and stopping on behalf of the driver or attendant. They also make it possible to transmit vehicle information to the operator who is monitoring the operation of the APM at the airport's operation control center, allowing remote control. Here we describe the ATO data transmission equipment and the station ATO equipment.

The ATO data transmission equipment continuously monitors the vehicle's state, making remote vehicle control possible. Like ATP, this is also transmitted and received by means of the inductive loop coil installed in the center of the concrete track and the antenna installed on the vehicle. The on-board alarms and states collected by the ATO data transmission equipment are displayed and recorded on the ATS workstation installed at the airport's operation control center. It also makes possible the resetting of various alarms from the ATS workstation and remote operations such as restarting for the APM vehicle. **Figure 5** shows the configuration of the ATO data transmission equipment.

The station ATO equipment conducts communications between the ground and the vehicle via a transponder installed on the center of the track. It is responsible for opening and closing the vehicle doors interlocking with the platform screen doors installed at the station. Changing or extending of boarding/alighting times is done via the ATS workstation installed at the airport's operation control center. Automatic operation information is transmitted to the on-board ATO controller via the station ATO equipment during stops at stations. Transponders installed on the track identify the vehicle's position, thus enabling automatic operation. **Figure 6** shows the configuration of the station ATO equipment.

3.3 ATS (Automatic Train Supervision)

As its name suggests, the ATS is a supervising device

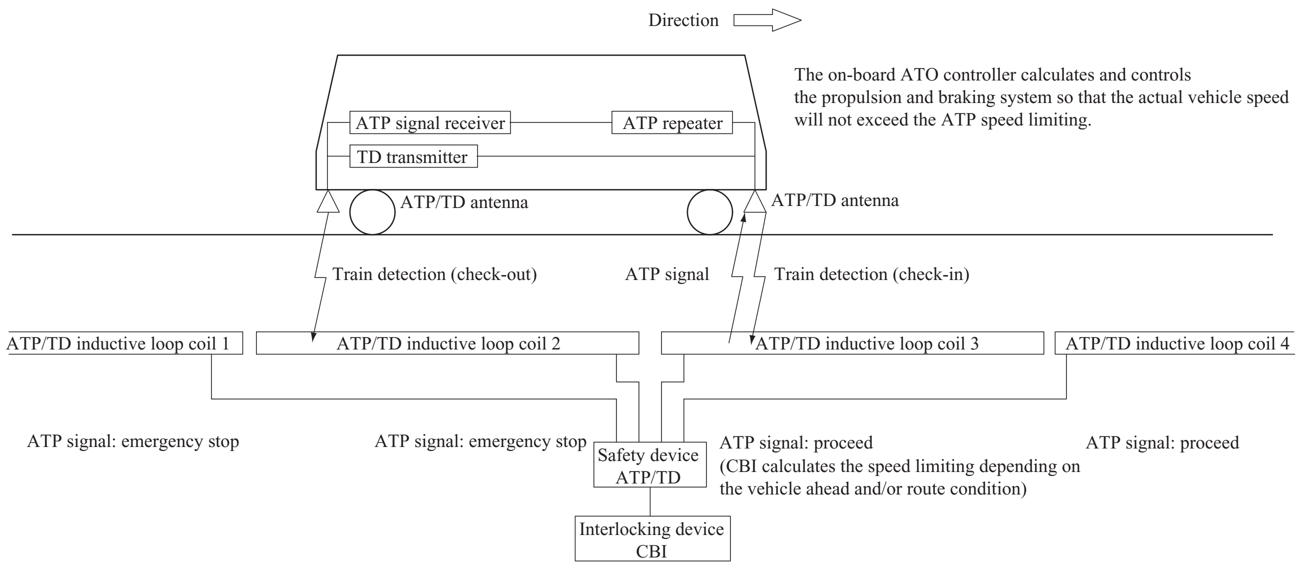

Fig. 4 ATP/TD Configuration

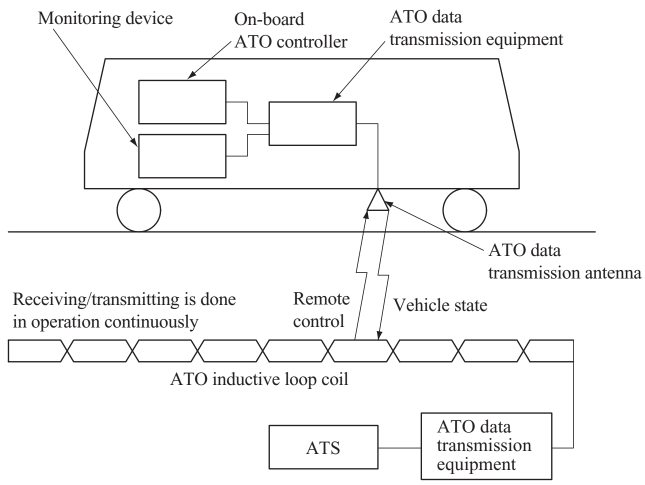

Fig. 5 ATO Data Transmission Equipment Configuration

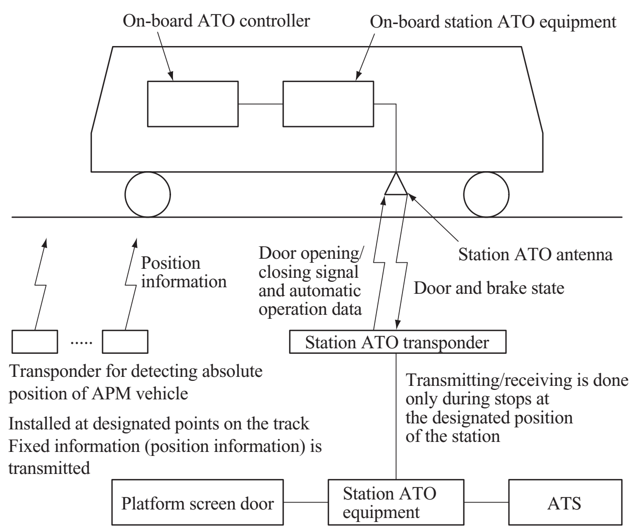

Fig. 6 Station ATO equipment Configuration

and can easily be operated using the LCD monitor and mouse connected to the ATS workstation installed at the airport's operation control center. There are two ATS workstations, and if one unit fails, the other unit installed at the same operation control center can be used as backup. In addition, two ATS workstations installed at the maintenance center have the same backup function, thus assuring high reliability.

3.4 Safety and Reliability

As shown in EN50126 published in 1999 and IEC62278 published in 2002, the so-called RAMS (Reliability, Availability, Maintainability and Safety) standard for railways is becoming increasingly common. In this project as well, we evaluated safety and reliability centering on the ATC equipment. In these evaluations, we calculated MTBF (Mean Time Between Failures), MTTR (Mean Time To Repair) and MTBHE (Mean Time Between Hazardous Events) of each subsystem using such analytical methods as Reliability Prediction, Hazard Analysis and Fault Tree Analysis. These results confirmed that we satisfied the required service availability of 99.9%.

Paying particular attention to safety, we evaluated hazard risk in accordance with ASCE 21-96 normally used as the standard for APM systems. This method is used to quantitatively evaluate hazard risk from occurrence frequency and hazard category. As a result, for events recognized as high risk, we took measures to reduce the risk and confirmed there is no safety problem with any part of the system.

These results, including the design process, were certified by a third institution.

4. APM Vehicle

For the existing PTB line, we manufactured 3 4-car APM vehicles to cope with the airport's increasing number of passengers. The design was based on NTS vehicles with a proven track record in Japan (**Fig. 7**). One noticeable

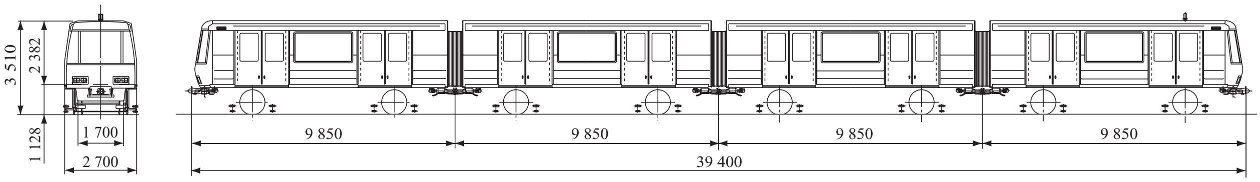

Fig. 7 APM Vehicle Set (Unit : mm)

Fig. 8 Appearance of APM Vehicle Formation

difference from the original design is the lack of an emergency exit on its front because it does not use the track as an emergency escape route. Its large windshield is now a standout feature. Its body is made of stainless steel, and its bogie uses a side guide steering system, original NTS technology (**Fig. 8**). Each car consists of a driving bogie and trailing bogie. The propulsion system comprises a CI (Converter-Inverter) controller whose inverter equipment uses IGBT (Insulated Gate Bipolar Transistor) elements. The converter on the power supply side converts 3-phase AC power to DC power while controlling the harmonics, therefore greatly contributing to the simplification of the power substation installed on the ground.

The on-board ATC equipment communicates with the wayside ATC equipment by means of the inductive loop coil installed in the center of the track. Like the APM system in Japan, the inductive loop coil is installed independently for the ATP and ATO. For the on-board ATC equipment, the dual or duplex hardware configuration is adopted to enhance the redundancy as on the wayside. **Table 1** shows the specifications of the APM vehicle.

Table 1 Specifications of APM Vehicle

Item	Specification
Formation	4 cars (fixed)
Number of formations	delivered 3
Capacity	76 passengers/car
Weight	13.2 t/car
Maximum dimensions	Length 9 850 mm Width 2 700 mm Height 3 510 mm
Body structure material	Stainless steel
Primary Electric system	3-phase AC 600 V, 50 Hz
Gauge	1 700 mm, guide face spacing 2 800 mm
Vehicle performance	Maximum speed 70 km/h Operation speed 62 km/h Starting acceleration 0.97 m/s^2 Maximum service deceleration 1 m/s^2 Emergency deceleration 1.5 m/s^2
Current collector	Rigid conductor 3-wire system, side contact type, continuous earthing
Propulsion system	CI control, IGBT element, VVVF inverter (automatic load compensation system, with regenerative brake)
Brake system	Electric command electromagnetic straight air brake (emergency brake, parking brake)
Bogie and guide system	4-wheel side guide steering system
Drive system	Right-angle drive type, differential gear mechanism
Propulsion motor	Three-phase, squirrel cage, self-ventilated induction, 110 kW continuous rating

5. Conclusion

Phase 1 of the APM project of Hong Kong International Airport has recently been completed. This project is a strategically important project for IHI as we launch our transportation business. We intend to expand the sales of our transportation systems throughout the world by taking advantage of the technologies experienced through this project.

We express our heartfelt thanks to Airport Authority Hong Kong, the owner, for its continued support in the execution of this project.