Integrated Monorail Systems Extending Around the Globe

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OVERVIEW: Hitachi, Ltd. is a leader in the development and supply of straddle type monorail systems providing medium-capacity urban transit. Hitachi has focused its efforts on system integration meeting a various range of needs and requirements from full turnkey projects involving civil engineering structures to the development of smaller monorail systems for smaller capacity systems. Sentosa Express that went into service in January 2007 is one of the systems to transport visitors to Sentosa Island, one of Singapore's most popular tourist attractions. The system is perfectly configurated for the smaller transport capacity required by using reduced size and lightweight monorail cars and employing a compact signaling system. Hitachi is also fully involved in the resort island Palm Jumeirah monorail project in the UAE that is now under construction, and major key systems including the driverless operating system were applied.

INTRODUCTION

SENTOSA Island has an area of 6.4 km^2 and lies half a kilometer away from the southern coast of the main island of Singapore. The Sentosa Development Corporation was formed to oversee development of the island as a resort and tourist attraction, and Sentosa has been undergoing a large-scale capital investment and redevelopment on island itself in line with the government's policy of promoting tourism. The Sentosa Express monorail was constructed as part of this redevelopment to improve access to the island.

The double-track monorail is 2.1 km in length, begins at a terminus in the mainland and stops at three stations on Sentosa Island. The minimum curve radius is 35 m, and maximum gradient is 5.79%. The monorail is designed to carry an initial capacity of

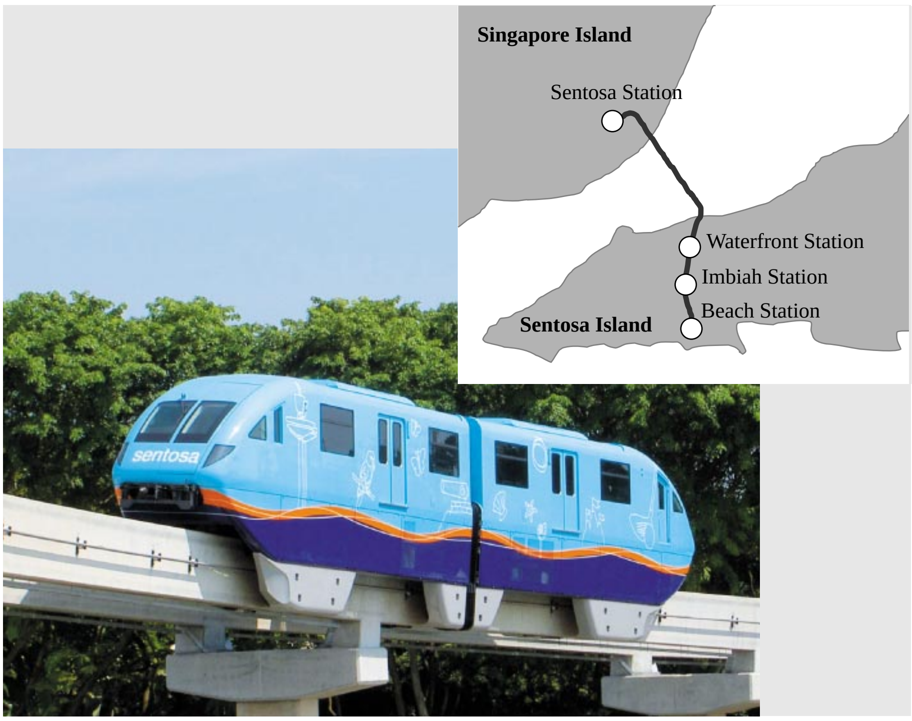

Fig. 1—Sentosa Express Monorail on Sentosa Island and Inset Map of the Line.
The Sentosa Express has operated smoothly providing access to the popular island resort of Sentosa since it was delivered by Hitachi and commenced operations in January 2007.

3,000 pphpd (passengers per hour per direction) during peak hours, and up to 4,000 pphpd in the future, so this is a relatively small-scale transit system. Yet, given the emphasis on promoting Sentosa as a tourist attraction, it was also important to provide a means of access and transportation to the island that builds visitor's convenience and is in keeping with the image of Sentosa as a tourist and resort Mecca.

Here we will provide an overview of the Sentosa Express project that was designed to meet these special requirements, and constructed by Hitachi as a full-design and build project. The paper also describes the current status of the Palm Monorail project now under construction, that will provide the main transportation system within The Palm Jumeirah, a world's first-class resort island development in Dubai in the UAE (United Arab Emirates).

Fig. 2—Interior of the Cars.
The design achieves a feeling of unobstructed openness even though the cars are smaller, by using heavier stanchion poles and fold-down seating to accommodate lots of riders.

SENTOSA EXPRESS HIGHLIGHTS

While mastering the latest labor-saving train operation control systems — evolving first from operation with a driver and a conductor to one driver operation, and finally to an automatic train operation without a driver control system — Hitachi has also acquired renowned practical experience and expertise in provisioning diverse straddle type monorail operating systems that can be tailored for the unique requirements of various proposed lines. Hitachi also offers an impressive lineup of systems that can accommodate virtually any passenger capacity from smaller scale 2,000-pphpd systems to larger capacity systems that can carry up to 25,000 pphpd, so the company was well positioned to provide the Sentosa Express monorail with a current pphpd capacity of 3,000 that could grow to 4,000 pphpd in the future.

Based on the company's proven track record and the specific requirements of the Sentosa Development Corporation, Hitachi integrated the whole system, and built and delivered the monorail system as a full-turnkey project. Here we will highlight two key subsystems of the Sentosa monorail that were developed specifically for smaller scale transport capacity systems:

(1) smaller and lighter weight monorail cars linked by an articulated structure, and

(2) a communications-based signaling system that greatly simplified the wayside equipment.

SENTOSA EXPRESS CARS

Design

The exterior of the Sentosa Express cars is sleek and streamlined conveying the image of speedy access to the resort facilities, and each train is decorated with different image colors and designs that appropriately convey the monorail's destination is a popular island resort. Fig. 2 shows the interior of the cars. The color scheme features white walls and ceilings that go well with the green trim, orange seats, and blue floors that convey the image of Sentosa Island — beaches, palm trees, tropical forest, sun and sea.

Overview

The trains consist of two cars that are connected by an articulated bogie and have a body support structure enabling the trains to navigate around sharp 35-m radius curves. The car bodies are made of lightweight aluminum alloy extruded shape—double skin on floors and single skin on the sides, ends, and roofs — which makes the cars both strong and lightweight. The bogies are essentially the same 2-axle bogies used in medium to larger scale monorails, but reduced in size and weight. A bolsterless structure with oscillation absorption system based on pneumatic springs was adopted that accommodates large longitudinal displacement and lateral stiffness to ensure a stable and comfortable ride even navigating sharp curves with a small turning radius of 35 m.

We also thoroughly reassessed the configurations of other key systems and equipment, eliminating some parts and wiring, and optimized the design considering the mass balance to rig the equipment within limited space while of course also ensuring the functionality and reliability required by the train. Considering the tropical climate in which the monorail is operating, each car was equipped with a flat and half-embedding type air-conditioning equipment on the roof and key equipment was implemented in a redundant configuration to avoid the service interruption in the event of an equipment failure.

SIGNALING SYSTEM SIMPLIFYING THE WAYSIDE EQUIPMENT

Signaling System Overview

Signaling systems for large capacity rail systems rely on communications-based train control that continuously monitors the position of each train. But for smaller capacity monorail systems, if the density of trains on the line is such that the fixed block approach can detect the presence of trains between stations, then there is no need for costly continuous train detection without degrading the safety. For the Sentosa Express we therefore erect to choose a new signaling system that substantially reduces deployment as well as maintenance costs. The system is a communications-based train control system that is implemented with far simpler wayside equipment by using

(1) a check-in check-out scheme of fixed blocks between stations,
(2) transponders and train radio equipment to detect trains, and
(3) onboard ATP (automatic train protection) equipment to control the trains.

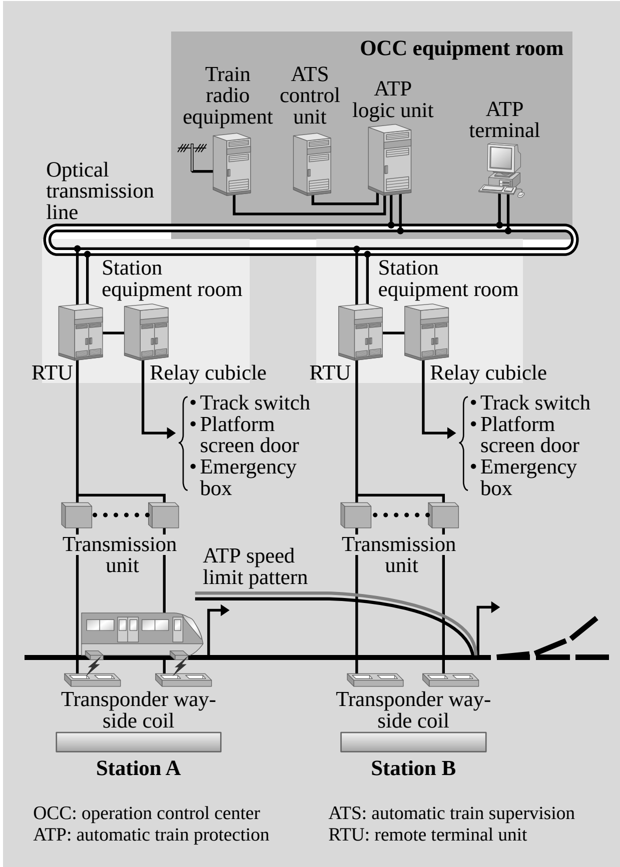

Fig. 3—Signaling System Schematic.
The signaling system is supported by transponders deployed along the track, and the wayside equipment is greatly simplified by reducing equipment between stations.

Fixed Blocks Between Stations Signaling System

In this system, blocks are defined as the distance between stations, and two transponder wayside coils are installed at the train stopping positions in stations just before the boundary with the next block. Trains are detected and controlled by sending control information back and forth between the wayside equipment and the onboard equipment via the transponders and train radio equipment.

Train detection method

As illustrated in Fig. 3, the wayside ATP logic unit determines whether a train is present or not based on train information received from onboard ATP systems (train ID and train status) via the transponders. When the state indicted by the transponder changes from not present to present, this means that a train has been detected at the location where that transponder is installed; when the state changes from present to not present, this means that the train is now moving away from the transponder in the direction it is traveling. A data message conveyed by the train radio equipment is used to indicate that a train has completely departed from a block. Once a train leaves a station, the ATP logic unit knows that the train has completely cleared the block because it receives the distance that the train has traveled from the transponder at the station from the onboard ATP system via the train's radio equipment.

Train control method

Fig. 4 shows a block diagram of the onboard ATP system that controls the speed and braking of trains. Essentially, the onboard ATP control unit generates an ATP speed control pattern to the next stopping block based on ground information (stopping block and G/R signal) received from the wayside ATP logic unit via the ATP transceiver. Brake control is then activated based on the speed of the train which is detected by the tacho-generators and pulse sensors. A number of speed limit patterns are generated by the ATP control

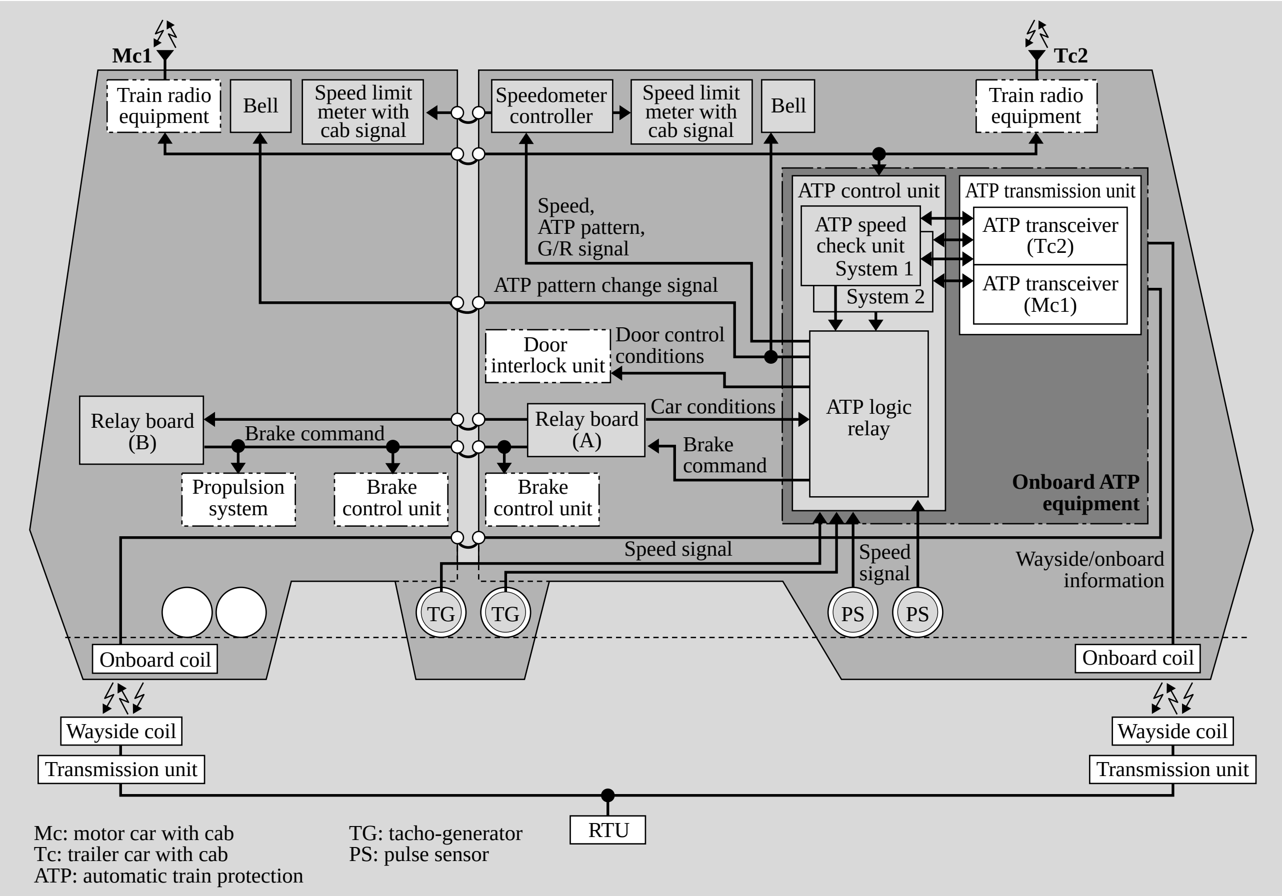

Fig. 4—Onboard ATP System Schematic.
The onboard ATP system has a fully redundant configurations with redundant ATP speed check units, and two ATP transmitters, one at either end of the train (Mc1 and Tc2).

system — a weak brake pattern, a service brake pattern, or an emergency brake pattern — and if any of these patterns are exceeded, a brake command signals to apply the brakes as appropriate for each pattern.

The train speed is controlled by the onboard ATP system, but the trains can also be operated manually between stations at speeds below that dictated by the ATP speed control pattern. In the event of an emergency, the onboard ATP system receives an emergency stop message via the train radio equipment, and issues an emergency brake command that trips the brakes and brings the train to a stop.

THE PALM JUMEIRAH TRANSIT SYSTEM

Hitachi is currently involved in a number of major projects in Dubai in the UAE, including the Palm Jumeirah Transit System shown in Fig. 5. The project involves a 5.4-km double-track monorail connecting a station on the Dubai mainland with three stations on The Palm Jumeirah, a new resort area on a vast resort island built out into the ocean. The trains are medium sized consisting of three cars, and will operate driverless using Hitachi's well-proven automatic train

Fig. 5—The Palm Jumeirah Transit System.
The project involves a driverless automatic operation system monorail connecting the Dubai mainland with The Palm Jumeirah, a new resort area on a vast artificial island. The monorail is expected to be the main access to the island.

Fig. 6—Civil and Structural Work now in Progress.
Some of Hitachi's manufactured systems and equipment have already been delivered and are now beginning to be installed.

operation system with an attendant. Leveraging the company's expertise and experience in building monorail systems, Hitachi is manufacturing and supplying the rolling stock, the substations, other mechanical and electrical systems, and the integrated automatic operation system that is the core operating system for the monorail.

The current status of the project is shown in the photographs in Fig. 6. The civil engineering and structural work is now about 70% complete, and some of Hitachi's manufactured systems and equipment have already been delivered and are now beginning to be installed. Meanwhile, rolling stock for the Palm Jumeirah Transit System is now being manufactured at Hitachi's domestic facilities in Japan.

CONCLUSIONS

This paper provided a summary overview of two state-of-the-art straddle type monorail systems demonstrating Hitachi's leadership in this field: the Sentosa Express developed as a full-turnkey project in Singapore, and the Palm Jumeirah driverless transit project now under construction in Dubai in the UAE. The Sentosa Express has provided access to the popular island resort of Sentosa since it commenced operations in January 2007, and the monorail has received accolades for riding comfort and stylish design.

Building on its expertise integrating cutting-edge technologies with legacy systems, Hitachi is committed to satisfying the diverse needs and local aesthetic preferences of local rail operators while enhancing their image through the manufacture and provisioning of state-of-the-art straddle type monorail systems.

REFERENCE

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