Straddle-type Monorail Systems with Driverless Train Operation System

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OVERVIEW: With close to four decades of experience developing and deploying straddle-type monorail systems, Hitachi has now added to its lineup of standard/larger model monorails with a smaller, standardized, cost-effective monorail system. In a parallel development, Hitachi has refined its DTO (driverless train operation) system and has now demonstrated the system in medium-capacity transit systems.

INTRODUCTION

HITACHI has close to 40 years of experience in developing and supplying straddle-type monorail systems as medium-capacity transit systems to augment the conventional larger capacity train and subway systems in urban areas.

Starting with Tokyo Monorail that went into service in 1964, a number of straddle-type monorail systems have been deployed throughout Japan including Kitakyushu Urban Monorail in 1985, Osaka-Monorail in 1990, Tokyo Tama Intercity Monorail in 1998, and most recently Okinawa Urban Monorail that began operating on August 10, 2003. Turning to the overseas market, Hitachi recently won a contract to supply monorail cars and other equipment for China's Chongqing Monorail that is now under construction.

Recognizing the company's excellent reputation in building smaller, standard, cost-effective monorail systems, Hitachi was also chosen to build Sentosa Express (new monorail system) connecting Singapore to Sentosa Island (see Fig. 1).

This article highlights the main features of Hitachi's straddle-type monorail systems and DTO (driverless train operation) system.

FEATURES OF STRADDLE-TYPE MONORAIL SYSTEMS

The primary features and advantages of Hitachi's

Fig. 1—Image of Sentosa Express (New Monorail System) Operating in Singapore.
Based on decades of experience with larger monorail system technologies, Hitachi has developed a small, standard and cost-effective straddle-type monorail system to meet the transportation needs of small to medium-sized cities.

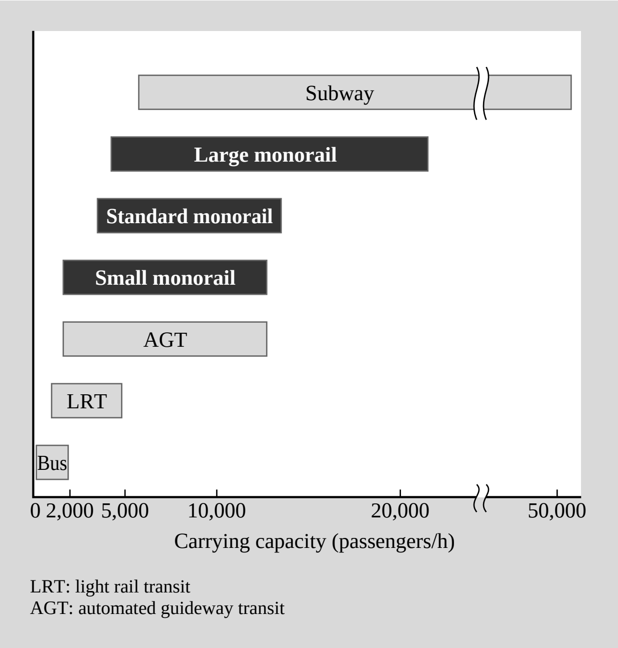

Fig. 2—Carrying Capacity of Different Transportation Systems.
Monorail systems can transport between 2,000 (small system) to 25,000 passengers (large system) per hour.

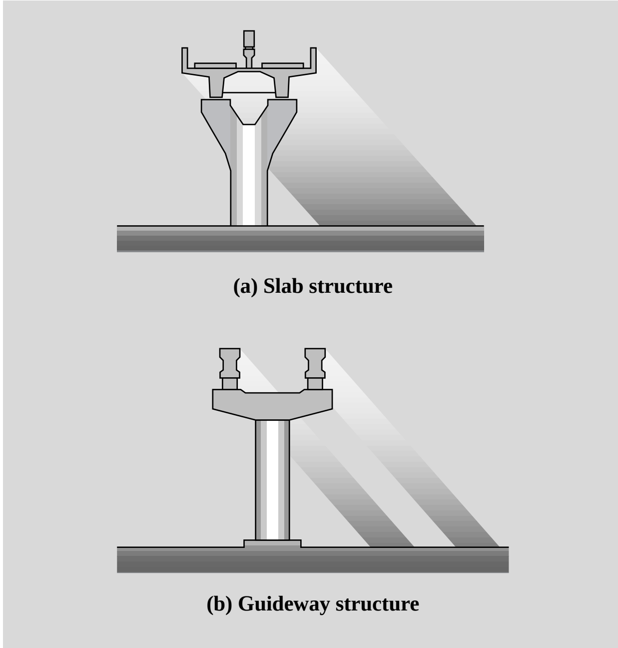

Fig. 3—Slab versus Guideway Cross-sections.
The guideway structure lets through a lot more light than the solid slab, and the simpler structure of the guideway is aesthetically less obtrusive and harmonizes better with urban environments.

straddle-type monorail systems are summarized as follows:
(1) The construction period to deploy a monorail is far shorter than to build a subway, and the construction costs are less expensive; that is, roughly one-third for building a large monorail system and one-sixth for a small-scale monorail system.
(2) Three scales of monorail system with different carrying capacities are available: the small straddle-type monorail system has a carrying capacity of 79 passengers per car, the standard system is capable of carrying 100 passengers per car, and the large monorail system can carry up to 173 passengers per car. Having a transport capacity of 2,000 (small system) to 25,000 passengers/h (large system), they can flexibly accommodate a wide range of municipal planning needs (see Fig. 2).
(3) Monorail vehicles with rubber tires can negotiate steep grades (6%) and small-radius curves (40-meter curves for the small monorail). Rubber tires also provide a quiet, comfortable ride for passengers.
(4) Monorail vehicles run on a simple guideway structure that can be deployed in narrow, confined spaces. The narrow guideway also allows more light to reach street level than the conventional slab structures, and harmonizes nicely with urban environments. The track beam width is relatively narrow ranging from 700 mm for the smaller monorail to 850 mm for the large monorail, so measures to prevent damage from snow are easy to implement and normal operation is generally unaffected by the weather (see Fig. 3).
(5) Cars are connected by walkthroughs as a standard safety feature, and a rescue train is available that can respond immediately in emergency situations.
(6) With close to four decades of field-specific expertise, Hitachi can support every aspect of a successful monorail deployment from planning and design to manufacturing and maintenance. Hitachi is able to supply the rolling stock, transport management systems, platform gates, and every element of a total transportation system that meets the needs of passengers and operating companies alike.

STRADDLE-TYPE MONORAIL OPERATIONS

One-person Operation

The ability of a single operator to run the train is indispensable to save labor cost in the operation of urban transport systems, and a one-person operation system has been used on straddle-type monorails since Kitakyushu Urban Monorail began operating in 1985. In a recent development in September 2002, Tokyo

Monorail, the only monorail operated by a two-person crew (driver and conductor), was converted to a one-person operation with the installation of an automatic announcement system and other improvements in the trains in conjunction with improved platform gates and other platform-side upgrades.

Driverless Train Operation System

To reduce labor costs even further, DTO system for urban transport systems that permit trains to operate without an on-board driver at all have drawn a great deal of attention in recent years. Hitachi has been investigating and refining a DTO system for application to straddle-type monorails for years, and has now succeeded in developing the first DTO system including ATO, platform gate and other supporting equipment to be actually installed on a conventional commercial monorail route in Japan. Note that there is one train attendant who rides at the rear end of the monorail who assists passengers by providing information, monitors the opening and closing of doors, and is ready to take charge in case of an emergency. As a sidelight, the first fully automatic unmanned monorail in Japan was constructed and operated during Osaka Expo '70, Japan's World's Fair.

Obviously, a DTO system must be capable of

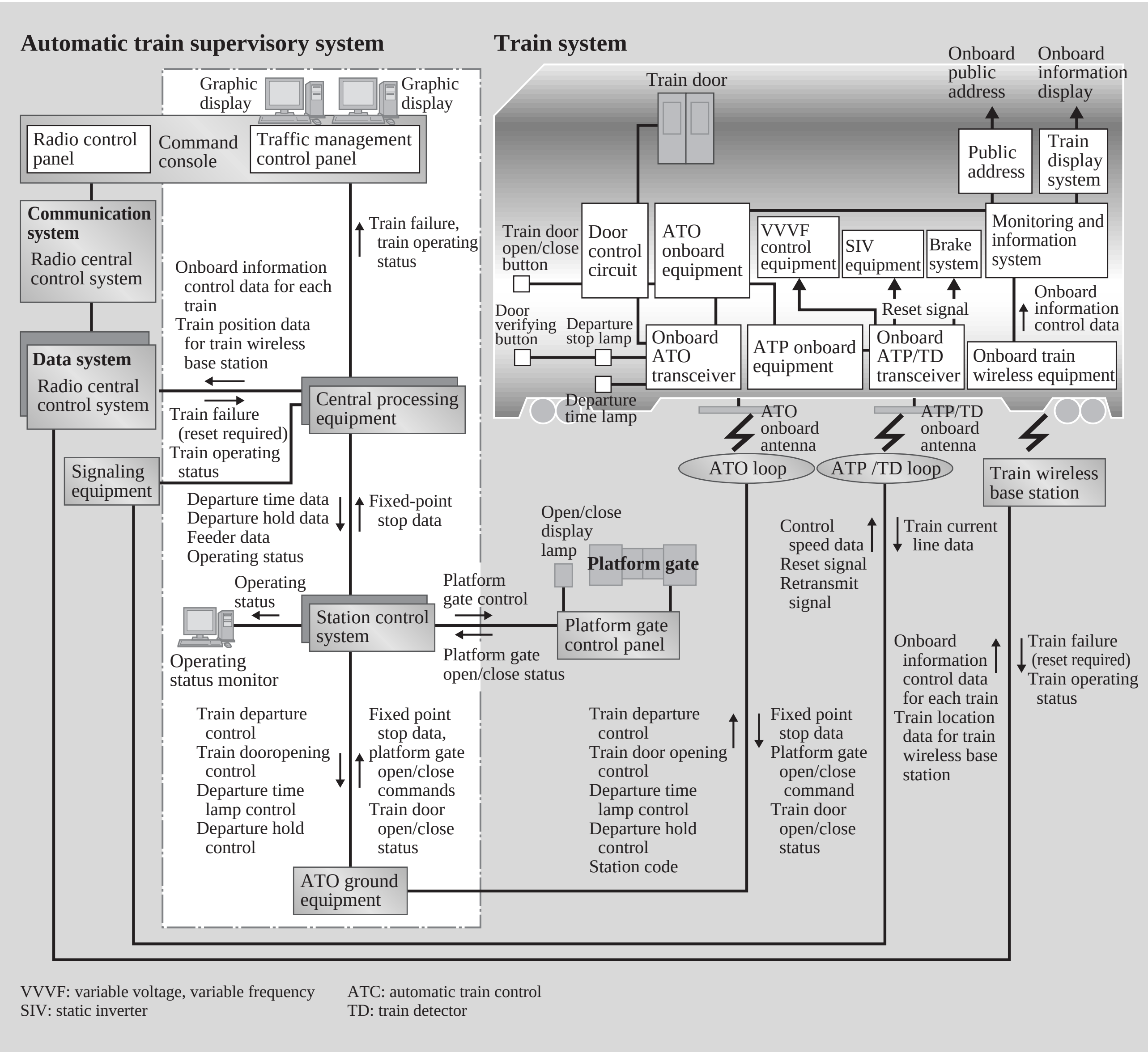

Fig. 4—DTO System Overview.
Interrelated equipment including the ATS (automtic train supervision), various onboard systems, and platform gates are functionally integrated.

performing all of the regular tasks formally done by the driver under the one-person operating system — operating the train, resuming normal operation when the train stops between stations, avoiding danger (particularly around station platforms), etc. — either automatically or remotely. Kitakyushu Urban Monorail and Tokyo Tama Intercity Monorail were the first systems to operate using Hitachi's ATO (automatic train operation) system. Now let us consider the main elements and subsystems needed to implement a DTO system for monorails (see Fig. 4).

Train equipment reset

The ATS continuously monitors the status of all onboard equipment. In situations where the train stops due to the failure of onboard equipment but can resume normal operation by pressing the reset button, the operator in charge presses the failure reset button on the command console in the OCC (operation control center). This affects the VVVF (variable voltage, variable frequency) control system, the brake system, and the SIV (static inverter) system. Implementing a highly reliable yet cost-effective solution, the reset signal is carried as a spare modulation signal over the ATP loop line, which is installed in the guideway. Note that it was the first time in Japan that this approach of using ATP signals for control purposes other than train maintenance was applied. After the reset is confirmed, the monorail can start to move again by issuing a restart command from the OCC.

In situations where the monorail makes an emergency stop in response to an $ATP0_2$ signal, the monorail can resume operation in response to a restart command from the OCC if all the requisite conditions are satisfied.

Enhanced fallback level

The traffic management system is a centralized system implemented on central equipment for controlling the most important train control functions including timetable management, monitoring the positions of trains, and forward control processing. In addition, equipment for communicating with trains (ATO information) and platform gates and equipment controlling ATO processing is deployed at each station and aboard each train. This equipment was distributed with the goal of improving control responsiveness. Distributing the equipment also helps ensure that the entire system is not brought to a halt, for this enables the ATP to continue working based on the equipment installed at stations even if the central equipment fails, and it also localizes hazards resulting from system malfunctions so that these hazards do not spread to adversely affect the whole system.

The system can handle ordinary and unanticipated stops, say in the event of a power outage or loss of pressure in the air reservoir of the brake system, but to avoid stopping between stations, power can be cut off (fallback) and the monorail can coast either to the next station or at least to a place where passengers can be evacuated from the monorail if necessary. If this is done, the monorail can be brought to complete stop at the evacuation point from the central command room.

Improved platform safety

In a monorail that is operated automatically, there is no driver looking ahead down the track, so improved platform safety becomes critically important. Platform gates are installed to make sure passengers cannot come into contact with the monorail vehicle as it pulls into the platform or fall off the platform. The platform gates are linked to monorail doors so that, when the monorail doors open (or close), a command is automatically sent by the ATS via the ATO ground equipment telling the platform gates to also open (or close). Passenger safety is further enhanced by sensors at the edges of doors and where the doors retract into the sides of the vehicle, thus preventing people from getting caught in the doors or in the door pockets when the doors retract. Sensors are also installed on the guideway to make sure no passengers are left behind between the train and the platform gate. Finally, the ATS constantly monitors the platform gates just as it does the monorail trains. If the train starts to pull out with the gates still stuck in the open position for some reason, an interlock mechanism is implemented so that the ATP prevents the monorail from moving ahead by way of the ATS.

CONCLUSIONS

This article presented an overview of Hitachi's straddle-type monorail system and DTO system that will be used more and more to operate monorails in the years ahead. Hitachi's straddle-type monorail systems have been deployed not only throughout Japan but also in other countries including contracts to build Chongqing Monorail in China and Sentosa Express in Singapore. While none of these existing monorail systems use the automatic operation system, we anticipate a growing need for the system driven by an increasing demand to hold down life-cycle costs including operating costs.

Fully exploiting the unique advantages of straddle-type monorails as a total system, Hitachi has now demonstrated the viability of cost-effectiveness of its DTO system on a regular commercial monorail system for the first time. Looking ahead, we will continue to focus attention on the inherent technological strengths and superior aspects of straddle-type monorail systems as a transport system.

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