New Signaling Systems Featuring Latest Control Technology

Yasumasa Tobita
Ikuo Shimada
Kenichi Ishii
Kenji Oguma

OVERVIEW: A signaling system provides a form of control information that supports safe and stable railway transportation. Signaling systems include interlocking device (which control point machines and signals), ATP (automatic train protection) systems, etc. These systems require continual improvement to meet evolving needs of the future. Hitachi, Ltd. has developed various new signaling systems. The digital ATP system realizes high density operation for rolling stock and provides maximum riding comfort with continuous-curve brake control. Our proposed electronic interlocking device series has dual verification architecture, in which an interlocking device and electronic terminal are mounted on the same rack, to save on space and improve maintainability. The Shinkansen ATP and interlocking system is an integrated system which consists of interlocking devices and ATP logic devices. The system saves space in the area where the equipment is installed and reduces costs. The development of these new signaling systems will contribute to the improvement of railway services in the near future.

INTRODUCTION

RAILWAY companies exist in an environment, that includes various inter-related problems, such as declining birth rates and aging populations, and the increasing diversity of user demand and requirements for high-value-added services. Railway companies require strong responses to these severe business conditions.

In this market environment, Hitachi, Ltd., as a railway systems integrator, aims at the achievement of "total railway system that suits the 21st century," realizes safer and more stable transportation, better passenger service, and improved managerial efficiency. Fig. 1 shows some signaling system products we have developed.

The first signaling system from Hitachi was an electronic interlocking device which entered service in 1993. Hitachi makes the best use of its feature as a manufacturer of the total electric machine to respond to ever-changing market trends and offers various

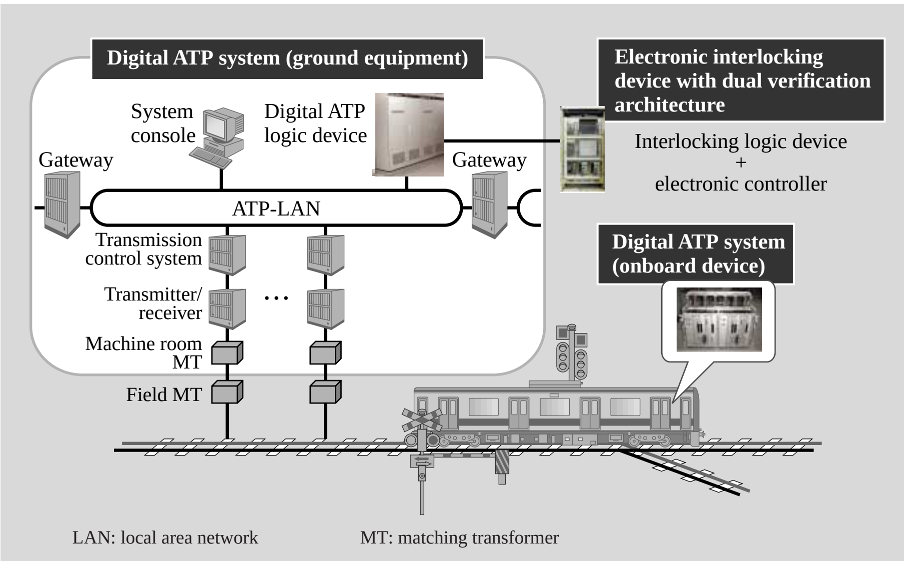

Fig. 1—Outline of Signaling System (Digital ATP System, Electronic Interlocking Device) of Hitachi.
Hitachi offers various devices such as ground equipment (digital ATP system and electronic interlocking) and onboard devices for a total solution of the railway system. It has improved the reliability and safety of the total system and has achieved space-saving and cost reduction for installing the system.

signal-based security systems which feature the latest digital and software technology. In this article, three signaling systems that contribute to higher density transportation are described. An integrated digital ATP (automatic train protection) for ground or onboard mounting, which operates in Tohoku Shinkansen (between Hachinohe and Morioka) in December of 2002, the Shinkansen ATP and interlocking system, and the electronic interlocking device series consisting of dual verification architecture which can be enhanced to suit the scale of a station.

DIGITAL ATP SYSTEM

Digital ATP system makes good use of information and communications technology to raise traffic capacity and greatly improve riding comfort. This chapter explains the developmental concept and gives an overview of the system of the digital ATP system.

Development Concept

The purposes of the digital ATP development are: (1) flexible correspondence with transit-system needs, (2) reduced capital investment, and (3) improved maintenance.

(1) Flexible correspondence with transit needs

A conventional ATP calculates the permissible speed of each blocking section and transmits it to a train through a track circuit of the blocking section. The train receives a series of non-continuous velocity-control signals until it stops. The presence of the train limits the permissible speed on a lot of backward blocking sections so that the conventional ATP is incapable of sufficiently shortening the headway and the driving time.

In the digital ATP, on the other hand, digital LMA (limit of movement authority) information is transmitted to the onboard device through a circuit on the track, and the onboard device controls braking with a continuous speed profile curve that corresponds to the performance of the individual train. This shortens headway and driving times. Moreover, control with a continuous speed curve reduces the incidence of unnecessary braking and makes the ride more comfortable. We can expect a synergistic effect of service enhancement.

(2) Reduced capital investment

Recently, although the number of railway users has not changed greatly, not a few railway companies have come to need higher-density operations to ease congestion in rush hour. The digital ATP system's feature of brake control with a continuous speed profile curve lets the operator reduce the amount of wayside equipment (number of track circuits), thus the company can choose the form of system installed to suit either high-density operation or reduced capital investment, according to the form of business at the site of installation.

The equipment of which an ATP system is composed has various features. A conventional ATP system is composed of a lot of analog components such as relays, filters, and transformers, and the transmission and receiving modules are independent. In the new digital ATP, digital filters based on software and digital-signal processing technology are applied in a single transmitter/receiver module. This realizes the simultaneous processing of eight signal channels and the consolidation of logic processing for ATP.

This lowers the cost of the device and decreases the space taken up by equipment at the site by 40%. Moreover, transmitting the ATP signal and TD (train detection) signal together from the same transmitter reduces the number of external and machine-room cables and improves the theoretical operating ratio by one order of magnitude.

These technologies are also applied to onboard devices so that the receiving and speed-controller modules, which are independent in the conventional system, are integrated in a single unit.

(3) Improved maintenance

In a digital ATP system, diagnosis is always executed on all duplicated modules other than the protector module. In addition, diagnosis of the switch circuit is executed with daily switching of the active module in the duplicated configuration. The operating states of the field equipment that includes the track circuit are continuously observed by the ATP monitoring module, which is connected to the transmitter/receiver through the system's LAN. Based on the statistical processing of the results of condition monitoring for the past year, the supervisory function of the monitor module can output an alarm prompting confirmation and the maintenance of the equipment before fatal system breakdown. This eases maintenance operations such as the prevention of the system breakdown and reduces the need for trouble shooting. So, the digital ATP system achieves high maintainability while eliminating the need for constant maintenance. In addition, we have developed a portable digital measuring device for use in fieldwork, i.e. track circuit adjustment, etc., and this contributes to a performance improvement for fieldwork.

Configuration of Digital ATP System

In the digital ATP system, the ATP signals transmitted to the onboard device includes LMA information and supplementary speed-limit information. The onboard device controls braking, applying a precalculated continuous curve of permitted speed, which is based on the brake performance of the train and the railway track database.

Fig. 2 shows the configuration of the digital ATP system. All functions of train location detection and LMA calculation, which are implemented as hardware logic in a conventional ATP system, are realized as software for the ATP login device and transmitter/receiver devices.

TD and ATP messages are transmitted to transmitter/receiver devices composed of DSPs (digital signal processors) over the ATP-LAN, transmission control system, and IO (input and output)-LAN. The transmitter/receiver device applies MSK (minimum shift keying) to modulate the digital signal, and this is transmitted to the track circuit. The transmitted signal is received by the other transmitters/receivers and demodulated by the DSP module of the receiver device. Thus, the application of DSP in TD/ATP signal processing enables a great reduction in the size of transmitter/receiver units for digital ATP systems.

Fig. 3 shows configuration of the onboard device. The receiver module of the onboard device of the new digital ATP also applies a DSP to process the ATP signal. All signal-processing functions such as filtering, detection of phase, and demodulation are processed by a signal processing software, so that the onboard device is compatible with conventional ATP systems and the device can process both signals for the new

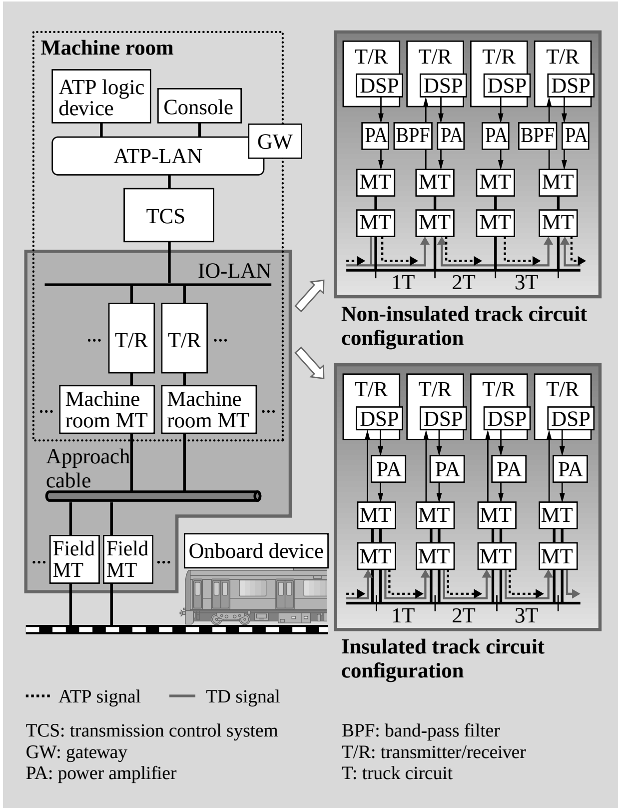

Fig. 2—Configuration of Digital ATP System.
The digital ATP system consists of an ATP logic device, ATC-LAN, IO-LAN and transmitter/receivers. Insulated/non-insulated track circuits are available.

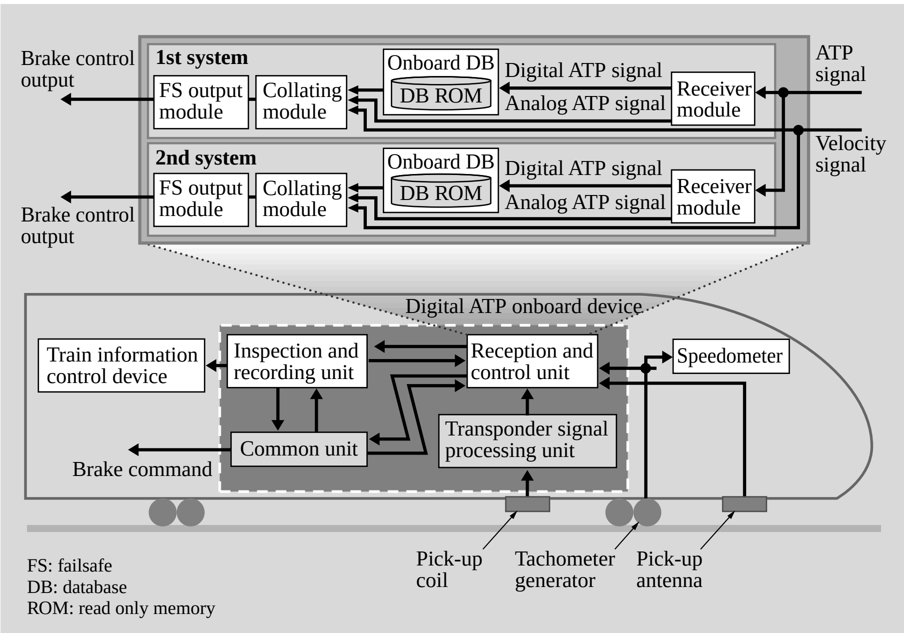

Fig. 3—Configuration of Digital ATP Onboard Device.
Referring to the profile data on DB, the onboard device can adequately control the speed of the train for its braking performance.

digital system and those for the conventional system.

The permitted speed profile is calculated on the basis of railway track data and the braking performance of the train. The profile is installed in the database of the onboard device. The onboard device refers to the profile data and thus executes speed control that suits the train's braking performance. The database configuration enables the automatic switching of system function in response to changes in track layout and the control system.

Integrated Signaling System: Digital ATP and Electronic Interlocking

In the system-updated sections of Tohoku and Joetsu Shinkansens, the digital ATP and interlocking functions are integrated in one system, eliminating and most of the relay devices. The integrated system is called Shinkansen ATP and interlocking system. The ATP and interlocking functions are both implemented as software logic. The system has functionality for the direct control of field equipment such as signals and point machines, and this leads to higher reliability for the system and reduces space requirements for equipment installation (see Fig. 4).

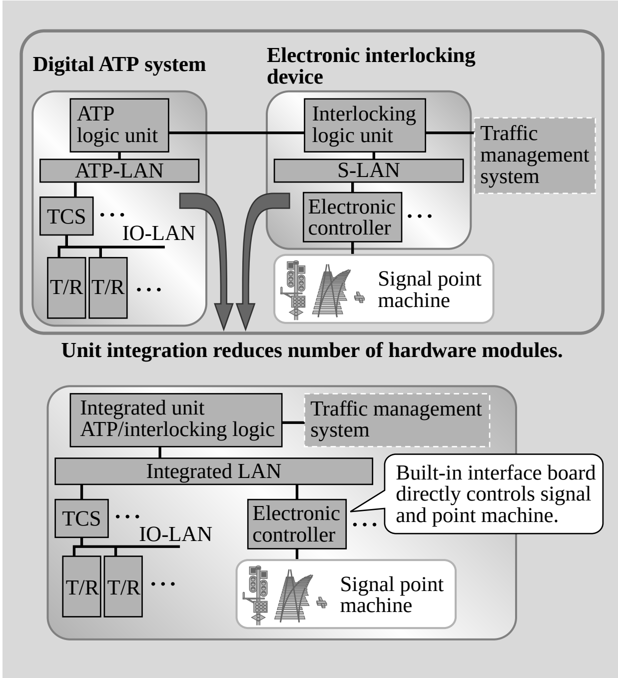

Fig. 4—Integration of ATP Logic Unit and Interlocking Unit.
Implementation of both logic, ATP, and interlocking into one unit achieves high reliability in the system and space saving.

Application Cases

The digital ATP system is applicable to the Shinkansen, commuter lines, and subways. The Hachinohe extension of Tohoku Shinkansen entered service in December 2002. The main lines of Tohoku and Joetsu Shinkansen services are to be progressively upgraded to the digital ATP system in future. Currently, Keihin Tohoku and Negishi Lines have been up graded to digital ATP lines as of December 2003. Yamanote Line is scheduled for upgrade in 2005.

ELECTRONIC INTERLOCKING DEVICE

Need for Electronic Interlocking Devices

An electronic interlocking device of a triple system composition is a high-performance device equipped with a security system application of maintenance work administrative function. There is much demand for such a system. However, there is also a need for a dual dedicated electronic interlocking device. Fail-safe CPU (central processing unit) architecture is required to secure safety and reliability. This is so in the case of electronic interlocking device. Miniaturization is also required because the machine room of many private railway companies where the device will be set up are narrow subway lines. Therefore, a simple hardware configuration is required for miniaturization.

Functions and Features

Hitachi's electronic interlocking device series has a dual verification architecture that satisfies the above needs.

The software is modeled on the time-tested interlocking-table-type logic of the conventional triple-system electronic interlocking device. The interlocking logic and control data of each station are separated so that it is possible to shorten the time for producing an electronic interlocking device and replacing the interlocking logic.

Reliability of the hardware is based on a fail-safe MPU (miro processing unit) architecture in which the results of each calculation by the two MPUs is continuously verified by a purpose-built bus-data comparator.

When the comparator detects a collation error or self-check diagnostic error, the comparator stops all output of the system to keep the overall system safe.

Product Line

The series currently consists of two electronic interlocking devices: One is for a small-to-medium scale applications and the other is for large-scale applications (see Fig. 5). The former is a simple electronic interlocking device in which the logic

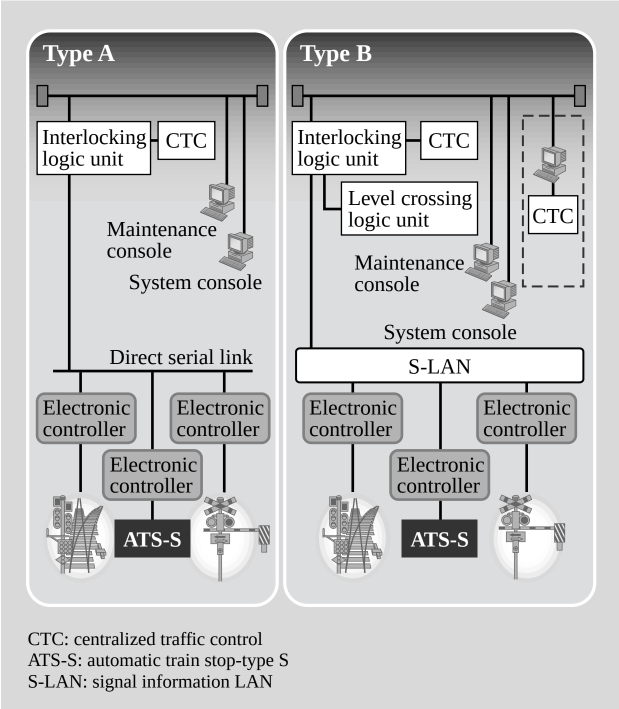

Fig. 5—Hitachi's Electronic Interlocking Device Series.
A product with an appropriate connection, direct serial link, or S-LAN can be selected according to the scale of the station.

module communicates directly with the electronic controllers through a serial link. On the other hand, the latter has a purpose-built signal network (S-LAN) over which the logic module communicates with the controllers. This communication among the logic modules and controllers enables the placement of controllers over a wide area. The control logic of the electronic controllers is independent of that of the logic modules, making the controllers highly responsive.

With this products lineup, the electronic interlocking device series offers the devices that best fit the scales of stations.

CONCLUSIONS

The latest signaling systems from Hitachi has been described, with the focus on a new digital ATP system for Tohoku Shinkansen.

Hitachi will continue to offer systems in which advanced technology is applied in response to various market trends that change over time, and will strongly promote the development of railway systems as a Best Solutions Partner offering total signaling systems for railway companies.

REFERENCES

(1) M. Matsumoto et al., "Assurance Technology in a Digital ATC System for Commuter Line," *Railway & Electrical Engineering*, Vol. 12, No.12, p. 39 (Dec. 2001) in Japanese.
(2) Y. Nagatsugu et al., "Onboard Device Database Generation for Digital ATC System," Railway Cybernetics Symposium, 402 (Dec. 2001) in Japanese.
(3) M. Amiya et al., "Signal Management Method for Non-insulated Track Circuit," J-Rail2001, p. 273 (Dec. 2001) in Japanese.
(4) C. Hattori et al., "Development of ATC Monitor System for DS-ATC," J-Rail2002, p. 5 (Nov. 2002) in Japanese.

ABOUT THE AUTHORS

Yasumasa Tobita
Joined Hitachi, Ltd. in 1981, and now works at the Signaling Systems Design Department, Mito Transportation Systems Product Division of the Power & Industrial Systems. He is currently engaged in the design of ground equipment for the digital ATP system.

Kenichi Ishii
Joined Hitachi, Ltd. in 1991, and now works at the Signaling Systems Design Department of Mito Transportation Systems Product Division of the Transportation Systems Division, the Power & Industrial Systems. He is currently engaged in the development of electronic interlocking devices.

Ikuo Shimada
Joined Hitachi, Ltd. in 1996, and now works at the Rolling Stock Electrical Systems Design Department, Mito Transportation Systems Division of the Power & Industrial Systems. He is currently engaged in the design of the onboard device for the digital ATP system.

Kenji Oguma
Joined Hitachi, Ltd. in 1992, and now works at the Railway Traffic Systems Unit of Hitachi Research Laboratory. He is currently engaged in research and development for next-generation signaling systems. Mr. Oguma can be reached by e-mail at oguma@hrl.hitachi.or.jp.