Fully digitalized ATC (Automatic Train Control) system of integrated functions of train-protection and interlocking

T. Matsuki[1], T. Okamiya[1], S. Hondo[2] & H. Tsuruga[2]
[1]*East Japan Railway Company, Japan*
[2]*Hitachi Ltd., Japan*

Abstract

An integrated type ATC (Automatic Train Control) system has been developed. An automatic train-protection function and interlocking function are executed on unified hardware of the ATC logic unit on the ground. Integration of hardware: makes the interface between conventional ground side ATC logic unit and interlocking device unnecessary; simplifies the input/output connection among the safety related facilities; and gives a space margin of a signalling cabin. Fully digitalized two-channel hardware architecture realizes a decrease in the number of electro-magnetic relays and of analog circuits being the bottleneck of reliability and availability of conventional train protection and interlocking facilities. The transmitter/receiver unit is mounted DSP (Digital Signal Processor) chips for the filter function to transfer the train-control signal and the train-detection signal via the track circuit. The wayside controller controls the field facilities such as switch-motors and signals without using the electro-magnetic relays of the conventional way. Integration and digitalization of hardware also give improvements not only in the reliability and availability but also in the quick response of the train control and route control. The developed system named SAINT (Shinkansen ATC and Interlocking system) is going to be put into service for the Shinkansen networks of East Japan Railway Company.
Keywords: ATC, interlocking, integration, digital, SAINT, Shinkansen.

1 Introduction

Tohoku/Joetsu Shinkansen was opened in 1982, and is continuing safe and stable transportation service till today. However, 20 years have passed since the

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opening, the present ATC is aged and it is the time to update. Since the present ATC system is using electro-magnetic relays abundantly, its installation space is large. Moreover, electro-magnetic relay has problem of large influence of failure, because of single channel usage. Then, a new ATC system (DS-ATC) utilizing digital and software technologies had been developed. It had been put into service in December 02 in the extension section in Tohoku Shinkansen (Morioka - Hachinohe). Its architecture will be used as a base of integrated interlocking and ATC device for the existing Tohoku and Joesu Sinkansen lines. New system is called SAINT (Shinkansen ATC and Interlocking system).

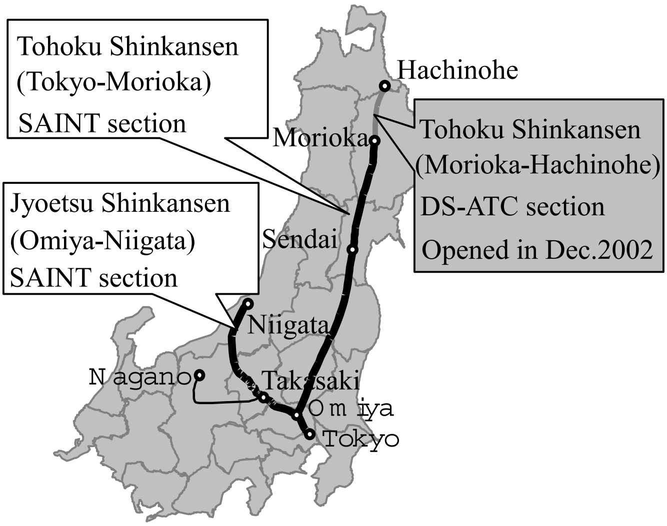

Figure 1: Renewal lines of the system.

2 System development plan

2.1 Concepts

2.1.1 Requirements

The target lines of the development are the Tohoku and Jyoetsu Shinkansen lines which are of the most important high-speed lines in Japan. The network scale is of 767km length and of 26 stations. There has been a strong need from passengers to shorten the travel time with these lines. At the same time, from the standpoint as a railway operator, it is necessary to: shorten the train headway; to boost the performance of train traffic control because that the section between Tokyo and Omiya stations is of deadly high train frequency; to get higher reliability of ATC system as to keep the availability of the network; and to reduce the initial and the maintenance costs. Adding, compulsory requirement to the next ATC system for successful replacement is that the amount of hardware

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of the ground equipment should be small because the setting place is, generally together with the existing ATC system in the common equipment room.

2.1.2 Design concepts

The design concepts are: to apply newest digital and software technologies upon all the devices to minimize the hardware volume; and to take distributed architecture to minimize the influence of local failures. The ground equipment is composed of an ATC logic unit, transmitter/receiver units and signal device controllers for signal lights and switch motors. Adding, a substitute blocking function with a radio communication path will be set against the case of, for example, a track circuit failure between stations.

2.2 Examination of the contents of the development

2.2.1 Rationality of functional integration

An ATC ground system detects occupied tracks. If an ATC system stops by some failure, the location information of trains within the related area becomes unknown, and then the control for switches and signal lights becomes impossible. On the other hand, if an interlocking system stops, the state of switches and routes becomes unknown. The train operation should be stopped in both cases. Therefore, upon the dispatcher's standpoint, it is reasonable to integrate the functions of ATC and interlocking within one device. And of course, the hardware reliability of a station system will be improved surely by the abolition of the interface hardware between an ATC system and an interlocking system.

2.2.2 Utilization of last developments

(1) Conventional ATC system and interlocking system include many electro-magnetic relays. For example, every control circuits in station field for signal lights and/or switch motors are composed of specific wired-logic circuit of electro-magnetic relays. The influence of a failure in such a circuit is very undesirable for the availability of a railway line because of the single channel circuit architecture. In the meanwhile, recently, the use of electronic field signal device controllers with two-channel architecture is coming to be popular. Then it will be effective for the line availability to apply the technology to the interlocking with minimizing the amount of wired-logic circuits.

(2) As for the shortening of the train headway, the assured braking technology had been proven upon the DS-ATC system put into the section between Morioka and Hachinohe stations. The section is the extension part of the Tohoku Shinkansen line and it had been opened in December 2002. The digital ATC logic unit on the ground detects occupied tracks and transmits a digital telegram signal to a train via the track circuit. The on-board ATC device controls the train brake according to a parabolic deceleration speed pattern which is effective to realize shorter headway and also better riding comfort. Then the authors decided to apply this technology for the development.

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2.3 The contents of development

2.3.1 Concentration of devices

(1) ATC function and interlocking function work on the same CPU by integrating the two systems.
(2) Generally the transmitter unit and receiver unit for track circuit have comparably the largest hardware volume in the ground equipment of an ATC system. So that, both has been unified into one with further miniaturization design.

2.3.2 Common hardware

Software processing absorbs the difference in the classification of signal lights or switch motors. So, the number of the types of hardware of device driving interface is minimized. It is expected the cost down of the equipment on the ground and also of the stock of the signal devices for emergency.

2.3.3 Ease of system repair

The software modules and data should be restored according to the change of track equipment. So as to make ease the software and data restore work, the software/data of frequent repair cases are concentrated within an ATC logic unit. On the other hand, the software/data of rare repair cases are distributed upon signal device controllers.

2.3.4 Multiplex architecture

Almost all the hardware devices including the function of previous electro-magnetic relay logic circuits have two-channel or three-channel architecture to improve the system's reliability and rail network availability.

3 System configuration

SAINT has distributed architecture which one ATC logic unit is installed in every interlocking station. The peripheral devices for ATC and interlocking are connected by LAN. The system configuration of ATC and interlocking integration type equipment is shown in Figure 2.

Main devices and functions of integrated type ground equipment are as follows.

(1) Logic controller
It is triple channel and 2 out of 3 system. ATC functions, such as train occupancy detection, train pursuit, and ATC telegram generation, and interlocking functions, such as an open check of setting route, signal lights control, and switch motors control, are processed in the same CPU.

(2) TCS (Track Communication Server)
It is triple channel and 2 out of 3 system. It has the function to distribute the ATC telegram (it functions as an occupied track detection telegram) which is

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received from the logic controller, and send out to a track circuit via a transmitter/receiver unit. And it has the function to judge a train position based on the amplitude of the telegram signal received from the track circuit via a transmitter/receiver unit, and to transmit a result of the judge to the ATC logic unit.

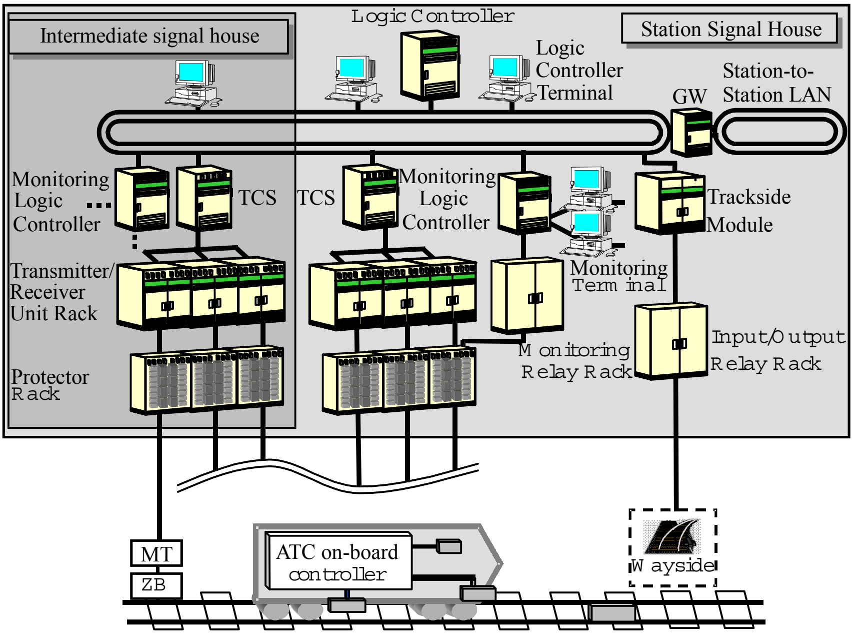

Figure 2: System configuration.

(3) Transmitter/receiver unit
It is double channel system. It has functions: to modulate a telegram received from the TCS: to send the telegram signal into track; to demodulate the telegram signal received from the track; and to transmit the telegram to the TCS.

(4) GW
It is double channel system, and composes the necessary data link between the GW of adjoining stations.

(5) Trackside module
It is double channel system, and controls signal lights, switch motors and input/output interface with external equipment.

(6) Monitoring logic controller
It collects track signal amplitude and other various state data. It outputs the alarm to require the inspection of the equipment so as to avoid a break down of devices by supervising the drift of track signal amplitude during a long period.

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4 Transmitter/receiver unit

4.1 Miniaturization

The number of the track circuit transmitters and receivers is in proportion to the number of the track circuits, then, it is very effective to miniaturize these to save the installation space. As for the DS-ATC system said above, the logical and weak current analog circuits necessary for the transmitter and receiver had been successfully unified into single circuit-board type transmitter/receiver unit utilizing DSP (Digital Signal Processor) technology. Applying the technology, high power circuits such as power amplifier are integrated together with the DSP part into one unit (DSPA). As the result, the amount of the volume of track circuit transmitters and receivers is remarkably reduced.

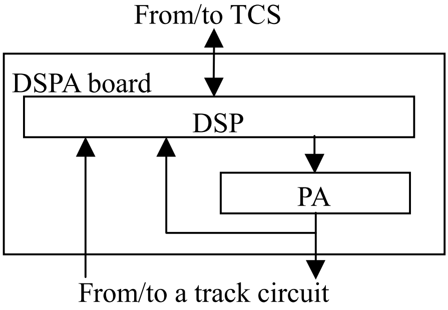

Figure 3: Configuration of DSPA.

4.2 Roles of DSPA

A DSPA unit has a DSP part and PA (Power Amplifier) part. The DSP part processes the logical functions and analog signals. The roles of the DSP part are the followings.

(1) To communicate with the ATC logic unit
(2) To modulate the digital telegram and to drive the PA
(3) To supervise the transmitting signal to a track circuit
(4) To demodulate the signals from a track circuit

5 Signal device controller

5.1 Signal light control board

5.1.1 Hardware classification

So as to decrease the kinds of the signal light control unit, authors investigated and analyzed all the functions of signal light control used the Shinkansen system. Resultantly, the functions are classified into three such as signal lamp control, general purpose low level current drive, and general purpose high level current drive. All types of signal light became to be driven by the three kinds of signal light control board.

5.1.2 Control software and data

For the ease of the software and data restore work with the SAINT system said above, signal light control boards are loaded comparatively the fixed control software and data those have not frequent restore cases. The ATC logic unit generates the control command and the classification information of a signal light. The roles of the signal device controller are to control ON/OFF of a lamp and to monitor the state of lamp current.

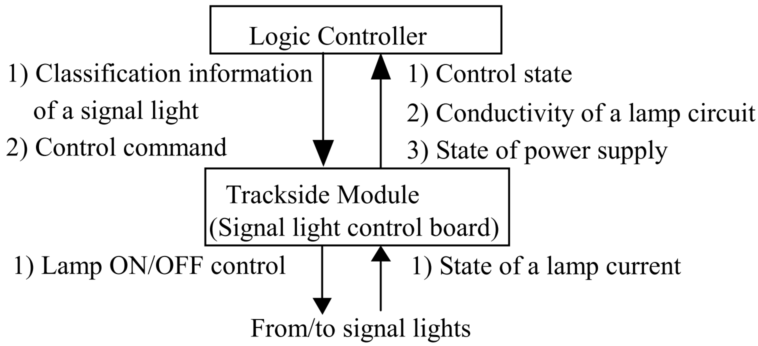

Figure 4: Signal light control.

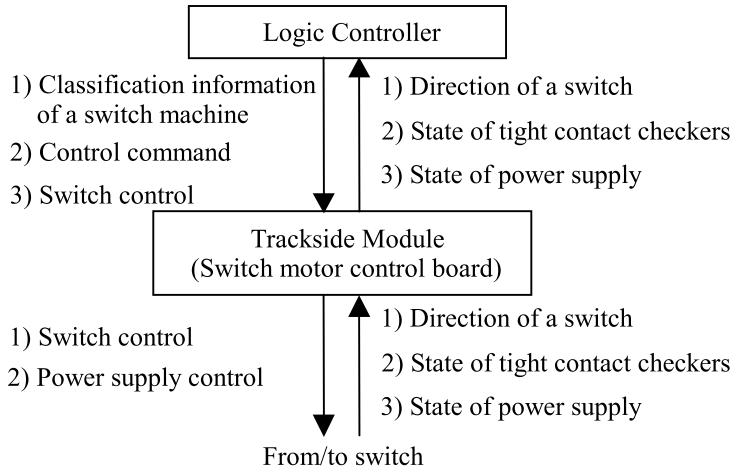

Figure 5: Switch motor control.

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5.2 Switch motor control board

The control software and data for the switch motor control are separately installed into the ATC logic unit and the switch motor control boards in the same manner of the signal light control case. The ATC logic unit is loaded the data of every type of the switch machines, number of tight contact checker of every point. The roles of the switch motor control board are to control the switch direction and power supply for switch motor and to monitor the state of switch machine.

6 Conclusion

An integrated type ATC (Automatic Train Control) system has been developed. Automatic train-protection function and interlocking function are executed on one ATC logic unit on the ground. The system's reliability, availability also the traffic control response are improved. Developed system named SAINT (Shinkansen ATC and Interlocking system) is going to be put into service for the Shinkansen networks of East Japan Railway Company from 2005.

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