Signal works for improving transport capability and for replacing superannuated signal facilities is showing a trend of increasing yearly. Since signal facilities employ electric voltage control via signal cables (metal), the construction of signals requires the underground laying of an enormous length of signal cables and on-site testing over a long period of time.

For this reason, in order to improve the ease of works and alleviate on-site testing in the construction of signals, "development of a network signal control system" that involves the adoption of optical network technology in the control of signal facilities in station yards is underway. This paper describes an overview of the development of such a system.

1 Introduction

At the present time, the control of signal equipment and electrical switches in station yards is undertaken via signal cables (metal) that are laid underground between the signal equipment room and the various signaling devices and utilizes electric voltage control. For this reason, when implementing signal construction work such as the replacement of interlocking devices, time consuming work is required for the underground laying of the enormous length of cable, interconnection of the core wires of the cables that amount to several times the lengths of the cables themselves, and linkage tests in order to confirm that the interconnections of the core wires are correct. It is this process that is a factor in the generation of impediments to transportation by means of reducing the underground laying of signal cables, wiring interconnection work, and linkage tests, a decision has been made to develop a network signal control system that undertakes control through transmission of digital information by linking such signaling equipment as signals and electric points in the station yard to the signal equipment room using optical cables.

2 Overview of the System

The network signal control system delivers and receives information such as the exchange of control and display information between the control equipment in the signal equipment room and the on-site signal device through the transmission of information using an optical network and is configured as shown in Figure 1.

A logic part (FCP) that is equivalent to the current electronic terminal is installed in the equipment room. Based on the control information
from the interlocked equipment and the display information from the related signal equipment, the FCP determines the control information for the signal equipment that is targeted.

Control information destined for the signal equipment is converted into data that are transmitted to the various signal equipment. The compact control terminal that is incorporated into the signal equipment controls such items as the switching of the signal lights on or off or reversing the points electrically based on the data that are transmitted and on the numerical constant that defines the method of control for each feature.

Through the use of this system, in addition to enabling the on-site wiring interconnections to be significantly reduced, it is possible to reduce the wiring interconnection of the cables for linking the FCP in the room for the signal equipment to the on-site signal equipment. For this reason, not only will the on-site work be reduced to a significant extent, linkage tests for checking the wiring interconnections will also be reduced, thus greatly improving ease of construction.

### 3 Development Schedule

In order to achieve putting this system (Equipment Number 1) into practical use within fiscal 2006, a decision has been made to separate the development work into two phases. The development required for putting Equipment Number 1 into practical use will be carried out in Development Phase 1 and development work for extending adoption from Equipment Number 2 and forward will be carried out in Development Phase 2.

Figure 2 shows an overview of the development schedule.

### 4 Content of the Principal Development (Development Phase 1)

#### 4.1 Logic Part of the Equipment Room (FCP)

The logical processing of signal control that is undertaken by the logic part of the equipment room (FCP) is the same as that of the current electronic terminals. In the case of electronic terminals, the on-site signal equipment is directly controlled electrically via a signal cable but with FCP, the control information to the signal equipment is output to the network in the form of data.

The FCP determines the control information for the signal equipment targeted for control and transmits this information in the form of a broadcast (transmission from one to many) of an electronic message to all compact control terminals. Each compact control terminal extracts the part of the control information that is applicable to that particular terminal from the electronic message and controls the signal equipment. The result of the control is sent back to the FCP as a display electronic message in unicast form (transmission from one to one). Processing for preserving the security of information having to do with safety employs a method that complies with IEC 62280 (the safety of security control via transmission).

#### 4.2 Compact Control Terminal (FC)

The compact control terminals (FC) may be the signal equipment incorporated type or the externally mounted type. Moreover, the externally mounted type may be either of two types, the closure accommodated type or the equipment box accommodated type.

When incorporating the FC into signal equipment, significant compactness and conservation of electricity are required. For this reason, the development was undertaken assuming the following.

1. That the signal equipment will employ LED signals;
2. That the electrical voltage and current will be standardized by controlling each lamp independently even when multiple lamps are concurrently lit such as when signaling restricted speed (YY) or deceleration (YG).

#### 4.3 Mechanism of the Signal Equipment that Incorporates a Compact Control Terminal

In order to achieve reduction of the signal cables and the work involved in wiring interconnection, it is necessary to mount a compact control terminal on the signal equipment and reduce the wiring interconnection work between the compact control terminal and the
signal equipment to the extent possible. Moreover, in order to mount the control terminal in the mechanism of the signal equipment, such factors as “achieving electrical insulation and segregation,” “measures regarding temperature, vibration and noise” and “ensuring leeway in the length of the optical cable” are required. This development initiative targeted color signal equipment, relay signal equipment, and shunting signal equipment.

4.4 Optical Network
In this system, the optical transmission equipment (parent station) was installed in the room for the signal equipment, and optical transmission equipment (sub station) and compact control equipment were incorporated into or externally mounted on signal equipment or electric point equipment as compact control terminals and the configuration involves the linking of these using optical cables. The optical cables were linked to these devices using connectors. The optical network that forms the basis of this system adopts the EPON (Ethernet Passive Optical Network) method. This is a general purpose transmission method that is used in FTTH (Fiber to the Home) and is also appropriate for the formation of networks for security control from the following perspectives.

(1) By causing the optical cable to branch in the vicinity of the signal equipment using optical couplers, maximum signal communication of 1 to 32 is enabled. Through this, it is possible to reduce the length of optical cable that needs to be laid underground.
(2) The optical couplers do not require an electric power source, and for this reason the configuration of the branching parts is simple.
(3) Since one core wire of the optical cable enables two way communication, it is possible to reduce the number of core wires, and for this reason, the construction is simple.

4.5 Compilation Facility for Monitored Information in the Steady State
In the past, steady state monitoring of signal equipment relied on the measurement of electric voltage and current in the room for the signal equipment. With the system under development, the values of the electric voltage and current of the signal equipment and the point equipment may be measured by the compact control terminal. For this reason, a decision was made to develop a “compilation facility for monitored information in the steady state” that compiles the values of the electric voltage and current measured by the compact control terminal in the room for the signal equipment via the optical network. For the time being, it has been decided that this facility is to transmit the monitored information to the existing steady state monitoring system.

Figure 3 shows the configuration of the steady state monitoring system.
4.6 Network Management Tools
This system adopts an EPON method network that utilizes TCP/IP. For this reason, network management tools are required in order to facilitate investigation of the causes upon generation of network failure, to speed up the recovery work and to change the network configuration.
Concretely, the general purpose network monitoring server and SNMP (Simple Network Management Protocol) are used in order to achieve the function of network monitoring, function of configuration management, function of supporting change of the network configuration, and function of compiling monitored information.

4.7 Various Tests
4.7.1 Environment Resistance Test
Since compact control terminals that are comprised of electronic equipment are incorporated in the vicinity of railway tracks and in particular in signal equipment, measures having to do with the environment have been identified and reviewed as important issues from the beginning of the development work. In principle, the environmental conditions that apply the JIS standards and international standards that have been applied to past signal equipment were determined as values that need to be satisfied at a minimum and a decision was made to undertake type qualification tests based on these conditions.
Moreover, various environmental data were measured during monitored run tests in order to strengthen the environmental measures as required. In the future, environmental data will be measured at other locations where the environment for the installation of signal equipment is severe as it is at Tsuchiura Station and it is the intention that the results of such measurements should be reflected in this system.
(1) Temperature
In determining the temperature conditions for use of compact control terminals incorporated into signal equipment, the internal temperature of various signal devices was measured in the latter part of August 2004. As a result, it was found that the internal temperature was highest for shunting signals and relay signals made from sheet metal, registering about 60 degrees centigrade, while the temperature was found to be about 50 degrees centigrade in the case of color light signal equipment made from resin.
For this reason, it was determined that in order to incorporate compact control terminals that are comprised of electronic devices, the internal temperature would need to be reduced by 10 degrees centigrade or more. Accordingly, a decision was made to confirm the effect of the use of heat shield coating (white ceramic coating with both heat insulating and heat reflecting features).
Upon having compared the internal temperature of equipment coated with the heat shield coating and equipment coated with normal coating, it was found that a temperature reduction of about 10 degrees centigrade could be achieved with the heat shield coating.
For this reason, in this development initiative, the upper temperature limit when in use was set to be +55 degrees centigrade providing that the heat shield coating is used.
(2) Lightening Surge
Grounding is difficult in the environment of installation of signal equipment into which a compact control terminal is incorporated and since access for the purpose of maintenance is also limited, the situation is one in which the use of protective devices is also difficult.
For this reason, a decision was made to employ the electrical insulating method as a measure against damage of the compact control terminal from lightening.
On the other hand, in the case of compact control terminals that are contained in equipment boxes and connected to the on-site signal equipment via signal cable (metallic), protective devices were attached to each circuit leaving the site and the connecting line was linked to a frame ground in order that a lightening surge will not flow through the compact control terminal as a result of a build up of electrical potential in the vicinity of the terminal.
(3) Electromagnetic Noise
The conditions were set based on international standard (IEC-62236-4) with respect to electromagnetic compatibility in a railway environment and a decision was made to conduct tests at a dedicated site.

4.7.2 Comprehensive Tests in the Factory
In the comprehensive test conducted in the factory, a system modeled after a large scale station (Utsunomiya Station) was formed and a "total system performance confirmation test" and an "evaluation of the ease of maintenance and construction assuming actual use" were conducted.
Moreover, a monitored run system was set up at Tsuchiura Station in order to verify that the new system "would not affect the existing signal control system" and to verify "the method of comparison of operations against the existing signal control system."
4.7.3 Maximum Load Test
In the maximum load test, a system having the maximum load was formed using various simulators in order to verify that "the various functions will not mutually exert negative impact and will operate in a normal manner" and that "when a load that exceeds the design value is applied, the system will operate on the side of safety."

4.7.4 Monitored Run Test
A temporarily constructed network signal control system was linked to the existing electronic signal system of Tsuchiura Station in a manner that enabled separate compilation of control information from the existing electronic signal system and a long term monitored run test was conducted (Figure 4).

On the other hand, the materials and method of work of the optical cable, optical element box, and other such parts were also subject to the evaluation, and multiple types were constructed on-site in order to evaluate the ease of work.

Moreover, the maintenance personnel of the JR East Group and the construction company were asked to undertake replacement and other work assuming the replacement of signal equipment for maintenance of this system or due to improvements in the station, and the ease of operation and construction was also evaluated.

The principal items evaluated are as follows.
(1) Control Performance
The fact that the status of control of the existing signal equipment and the network signal equipment that was temporarily constructed coincides and the fact that the deviance of the control timing is within the standard value are being evaluated.
(2) Transmission Performance
This system transmits control information from the logic part of the equipment room in the signal equipment room via an optical network to the on-site signal equipment. For this reason, the fact that the transmission cycle is within the standard value and the fact that the probability of the occurrence of a reversal in the order of transmission or abnormality of transmission is within the standard value are being evaluated.
(3) Environment Resistant Performance
The stable performance of this system over a long period will be confirmed. Moreover, the intention is to install a sensor within the signal equipment to measure temperature, vibration, noise and other factors in order to identify the causal relationship exerted by environmental conditions in the event of abnormality in the signal equipment.

5.1 Data Production Support Tool
The data production support tool automatically generates and examines the control constants in order to control the compact
control terminal.

5.2 Compact Control Terminal (Track Display Type Shunting Indicator, Multiple Route Indicator)

The indicators of the track display type shunting indicator and the multiple route indicator use numerous display lights (lamps/LED) in order to display specific patterns (alphanumeric characters) such as those for departure points or destination points. In this development initiative, the plan is to use a method whereby the control circuit of the display indicator is driven via a serial circuit from the compact control terminal that controls the shunting signal equipment or the shunting signal indicator of the main unit. Through this, it is believed that the signal cable and interconnection work may be reduced and the link test may be simplified.

5.3 Compact Control Terminal (Track Circuit)

At the present time, SMET is being adopted as the train detection device in station yards. This involves transmitting signals to multiple track circuits in a station yard in a time sharing manner and receiving these at all times in order to detect whether or not there is a train on the track circuit. The installation of SMET is concentrated in the signal equipment room.

In the current development initiative, review will be undertaken on the extent to which the train detection devices should be dispersed to the site and the schedule calls for development to be undertaken towards reducing the sending and receiving cables and the wiring interconnection work.

6 Conclusions

The development for Phase 1 of this system has about been completed and monitored runs are being conducted at Tsuchiura Station on the Joban Line. In the future, based on the evaluation conducted through this test, the target is for putting the network signal control system into practical use in fiscal 2006. The intention is to make steady progress in the development work for Phase 2 and to work towards extending the adoption of this system. Moreover, in the future the intention is to incorporate the compact control terminal into electric switch equipment and to develop an "inter-station network signal control system" that will enable application of this system to inter-station signal equipment. In addition to these initiatives, the target in the future is to form a comprehensive "network signal control system" that can also be applied to crossings.

References: