Featured Articles

Full Upgrade of ATOS to Improve Safety and Reliability of Railway Services

Yasuhiro Yoshida
Kouhei Akutsu
Yasuhiro Yumita
Ryuji Yamagiwa
Hideki Osumi
Mitsunori Okada
Kiyosumi Fukui

OVERVIEW: Tokyo, Japan's capital, has become one of the world's major cities through the ongoing migration of people from the provinces as the country's economy has grown. The railways serving the Tokyo region are an important part of the social infrastructure that support the functioning of the city over a wide area. Their ongoing development has created a complex and high-density network, including the Chuo and Shonan-Shinjuku Lines, among others. Future railway systems are expected to satisfy new requirements arising from the changing social environment, including the utilization of existing infrastructure to allow different operators to run services on the same track, and further improvements to passenger services. To achieve this, JR-East and Hitachi aim to provide safe and reliable management of railway traffic, and to help improve services to all stakeholders, including passengers, through initiatives such as the fusion of control and information technologies.

INTRODUCTION

WHEN the East Japan Railway Company (JR-East) was established in 1987, very little progress had yet been made on the computerization of train traffic management on its metropolitan lines in the Tokyo region, with traffic management for approximately 92% of lines being performed through the manual operation of signals by the operators and station staff, who communicated via telephone. The difficulty of performing centralized management of train movements in those days meant that traffic management took a lot of time and effort[1]. To transform this situation, JR-East commenced installation of the Autonomous Decentralized Transport Operation Control System (ATOS) for the Tokyo region in 1996. Its objectives included improving the efficiency of traffic management, delivering better services to passengers by providing realtime information about train services, and improving the safety of engineering work.

Because of the system's very large size, with work extending over a long period of time, JR-East adopted an autonomous decentralized architecture, which prevented equipment faults in one place from affecting other parts of the system. This allowed the system to be expanded in stages, one line at a time, including the Chuo Line, Yamanote Line, and Yokosuka Line, for example. This staged implementation technique has facilitated ongoing work to add new lines to the system without affecting those lines where it was already operating. With the system now covering 20 lines, amounting to a combined length of about 1,270 km, it has become an important part of the social infrastructure, essential to the ongoing provision of safe and reliable transportation (see Fig. 1).

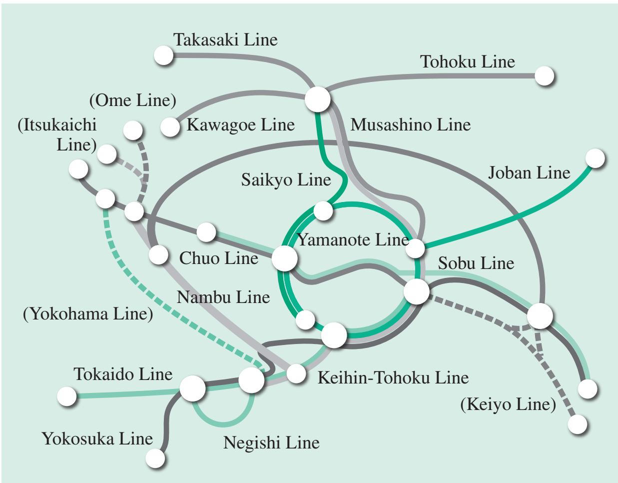

Fig. 1—Railway Lines Managed by ATOS.
Since first entering service on the Chuo Line in 1996, ATOS has been progressively deployed across the major railway lines in the Tokyo region. This deployment is scheduled to be expanded to include the Yokohama Line, Keiyo Line, Ome Line, and Itsukaichi Line in the future.

While reliability and safety remain prerequisites, the demands being placed on traffic management systems have been changing rapidly in recent years against a background of changes in society and the traffic management environment. These requirements include support for the networking of train operations over multiple lines (including the Shonan-Shinjuku Line and the Ueno-Tokyo Line, which is scheduled to commence operation at the end of FY2014), achieving even faster recovery from timetable disruptions, and the use of information and communication technology (ICT) to provide information services to passengers. ATOS has also undergone ongoing hardware configuration changes and software upgrades to enhance its functions, with both the hardware and software configurations having become more complex since the system was first introduced. As a result, improvements have become more costly and difficult.

With the system having been in use for approximately the past 18 years on the same lines where it was first installed, the functions and resources of the initial system (software and hardware) are now inadequate, making it difficult to respond to the requirements and problems described above. Accordingly, it was recognized that a dramatic upgrading and simplification of the system architecture is needed to provide a comprehensive solution.

Train services in the Tokyo region are characterized by their high density, with only a very short period of time between the last train at night and the first train in the morning (the time period available for working on system improvements). Accordingly, switching over to a significantly upgraded system without interfering with traffic management requires a staged switchover procedure with an unprecedented level of difficulty, with work having to be completed during this limited window of opportunity when no trains are running.

This article describes the challenges currently facing ATOS, the upgrades that have been implemented to overcome these, and the migration techniques used for the staged switchover to the upgraded system.

CHALLENGES CURRENTLY FACING ATOS

Improving the convenience and comfort of trains requires support for different types of services and the provision of information that satisfies passengers' needs (see Fig. 2). The following sections describe measures for enhancing information and control.

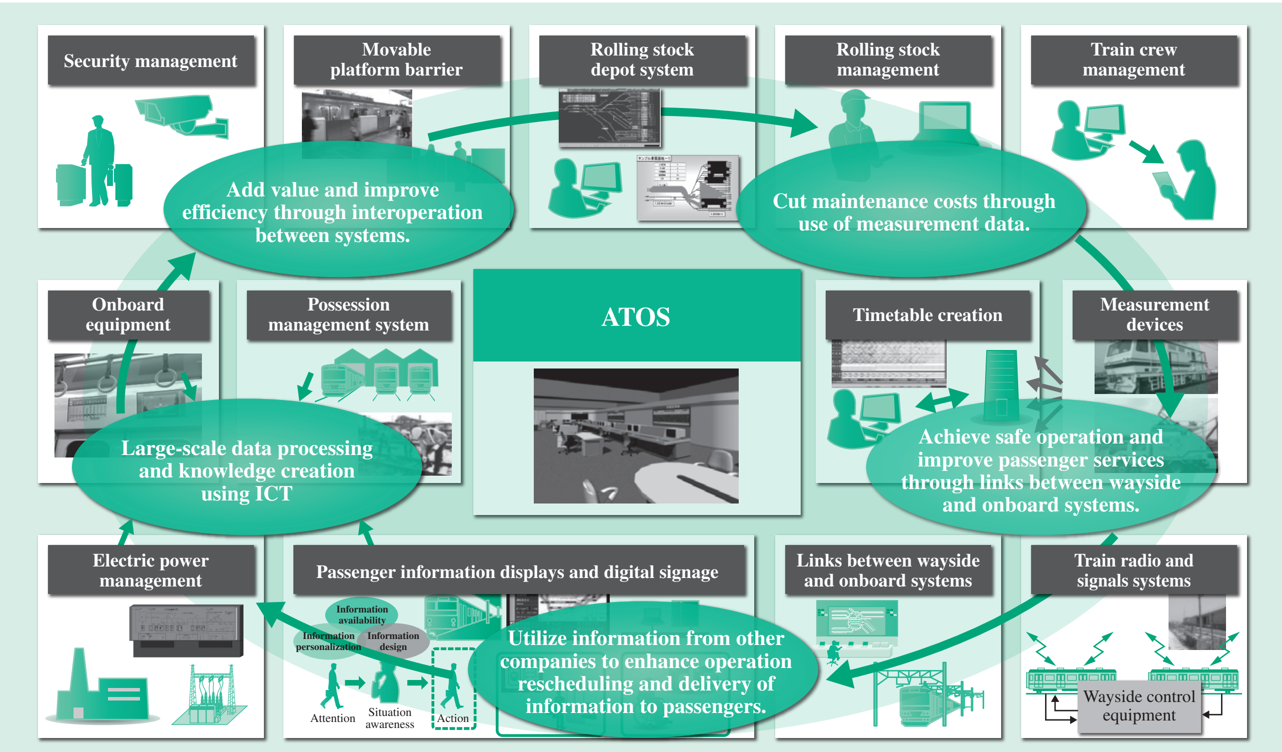

Fig. 2—Overview of Services Made Possible by Fusion of Information and Control.
Hitachi uses advances in information and control to improve services to railway users, station staff, train crew, and others, and to create railway systems that take account of the environment.

Architecture Obsolescence

(1) Establishing a data network environment for expanding services

ATOS links the stations and control center together via a data network so that these sites can coordinate their control operations. An upgrade to a high-speed network will be required in the future in order to make higher quality information available for a wide range of service enhancements. Also, the current network has a single-route configuration, and while it is reliable, achieving a wide range of service enhancements will require even more reliable communications.

(2) Optimization of equipment configuration to improve maintenance efficiency

Because the performance of the ATOS hardware when first installed was so much lower than current hardware capabilities, functions were implemented across a number of devices to spread the load. And, because each function used a large number of devices, it created challenges in terms of obtaining spare parts and space for installation, and keeping maintenance costs down given the large number of different devices that needed to be maintained. Overcoming these challenges while also ensuring reliability will require the use of the latest technology to provide the best possible equipment configuration.

(3) Upgrading human-machine interfaces (HMIs) to improve efficiency of traffic management work

The operation consoles used by operators to perform their routine traffic management work consist of track diagrams [these consoles are called cathode ray tubes (CRT) in ATOS] that display train locations, and train graphs [these consoles are called graphic displays (GDs) in ATOS] that display timetable information. Since personal computers were not yet in widespread use when ATOS was first installed, and since operators at that time were unfamiliar with using information technology (IT) devices, many input procedures based solely on the use of keyboard buttons and mouse clicks were needed for data entry and operation of the CRTs, GDs, and other IT devices. The problem with these methods was that, compared to current IT devices, it took a long time for operators to become familiar with their use. To overcome this, it is necessary for the control systems to use HMIs based on the latest IT so that the different categories of operators can quickly learn how to use them efficiently.

Faster Recovery from Timetable Disruptions

(1) Enhancements to functions that support operation rescheduling

In cases when train operating schedules change as a result of timetable disruptions, delay recovery (operation rescheduling) input can be performed by directly selecting the corresponding timetable data on the GD. Operation rescheduling involves operators working to shorten delays by making supervisory decisions based on their many years of experience. In doing so, they consider a wide range of different operations, including the sequence of train arrivals and departures, station platform allocations, and the splitting or merging of trains. Accordingly, one of the requirements of ATOS, which manages lines with high traffic density, is to shorten delays by lightening operator workloads and reducing dependence on their know-how.

(2) Support for networking of railway traffic

To improve passenger services further, railway traffic in the Tokyo region is increasingly being operated as a network, including the introduction of through-trains (such as the Shonan-Shinjuku Line) that run on more than one line, and trains that run on lines belonging to other railway companies. As a result, the patterns of railway traffic are changing away from the line segmentations chosen when ATOS was first installed. While this is increasing the need for traffic management to deal with networked railway traffic, the functions and resources described above are currently inadequate for this purpose, making this need difficult to satisfy.

The networking of railway traffic means that timetable disruption on a different section of line can affect operations on the line being controlled from a particular GD. In situations like this, the current practice is to use inefficient paper-based methods for passing on information because the GD has no way of showing what is happening on the other line.

(3) Better provision of information for control functions

The current practice when a new restriction is issued is for it to be generated automatically by the notification system and passed on to the relevant trains. However, this places a heavy workload on the operators since the method used to inform all operators that particular sections of track are subject to a restriction is to display a note indicating these track sections on the CRT screens.

Growing Demand for Information Services

Since ATOS has to date primarily been developed for use by operators, it works by collecting information at the control room and using it for traffic management.

While some information is sent on to places where it is relevant, there remains a strong need for providing greater information to various other people involved with the railway (including station staff, train crew, and railway users) in order to facilitate trouble-free passenger travel and improvements to services.

TECHNOLOGIES THAT FUSE INFORMATION AND CONTROL TO SOLVE PROBLEMS

Upgrade to Optimal System Configuration

(1) Network

Hitachi has developed the fault-tolerant TN-1000 network to manage traffic over a wide area and support future service enhancements.

TN-1000 not only increases the transmission speed from 100 Mbit/s to 1 Gbit/s, it also incorporates know-how acquired through experience with control systems, such as how to deal with faults. Also, this highly reliable control network has a loosely coupled redundant configuration with two fully independent routes, so that a fault on one route will not affect the other. It also features a highly reliable dual ring topology using a network configuration control technique for rapid fault recovery that Hitachi developed. However, because redundant communications control requires additional processing over and above what is currently used, and because much of the hardware has low processing capacity having not been upgraded since the system was first installed, implementing redundant communications on this hardware would be difficult. Accordingly, the network upgrade required that communications over the newly installed dual system be achieved without any changes to the existing processing.

To solve these problems, Hitachi used data encapsulation to implement a dual communications system that did not involve any changes to the lower level equipment (see Fig. 3). This provided a reliable, high-capacity network that can continue to operate even if one side of the backbone network shuts down.

(2) Optimization of equipment configuration

Hitachi developed the RS90/1000T for use as a control server, with features that include improved performance by using multi-core central processing units (CPUs), 64-bit operation, and low power consumption. Because the server plays an important role in maintaining reliable operation, memory mirroring based on Hitachi high-reliability drives was adopted to ensure high reliability. By facilitating the integration of multiple devices, this reliable, high-performance server allows equipment configurations that are easier to maintain.

One example is the integration into servers of workstations for GD that were previously installed in each control panel. In the current Chuo Line upgrade, maintenance was improved by using a configuration consisting of client consoles connected to two servers, replacing software that was previously spread across five workstations.

(3) HMI upgrades

Because the uses of different devices, and the tasks and operators to which they are assigned are different, the practice at Hitachi has been to design screen interfaces to suit each device individually. In keeping with that, Hitachi has developed a new HMI that includes standardized presentation and operation and is based on its work on devising common design policies for screen interfaces that appropriately distinguish between system-wide and localized optimization.

Recognizing that the number of users familiar with the operation of more advanced IT devices will likely increase in the future, Hitachi intends to develop HMIs with operations that can be understood intuitively by a diverse range of users (see Fig. 4).

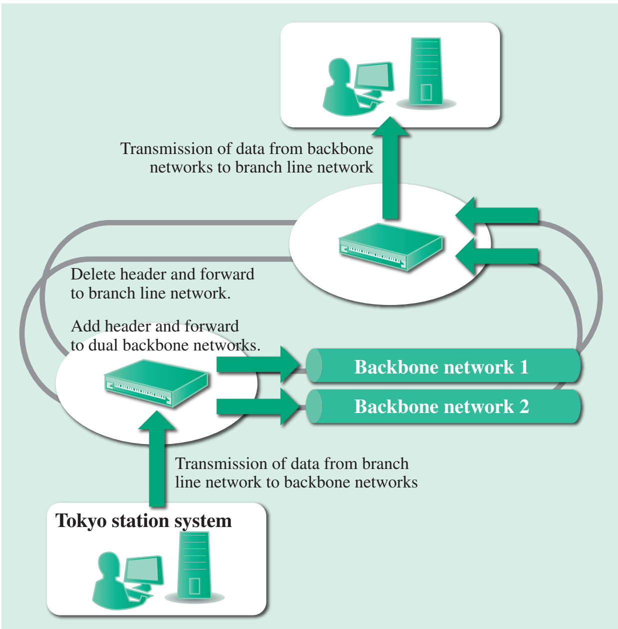

Fig. 3—Highly Reliable Network Communications Using TN-1000.
Because of the large number of networked devices, waiting for performance upgrades to these devices would raise problems of obsolescence on the current network. Accordingly, Hitachi opted for communicating via dual networks, avoiding having to make changes to the networked devices.

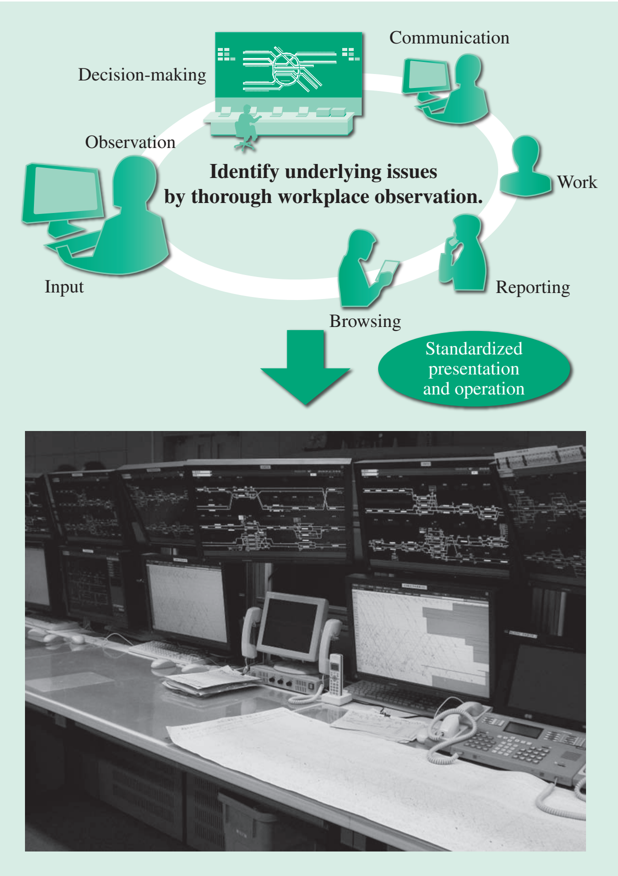

Fig. 4—Standardized Presentation and Operation.
Hitachi improved the "experience value" of screen interfaces by conducting workplace observations and other work to identify the issues faced by operators in order to determine their latent needs.

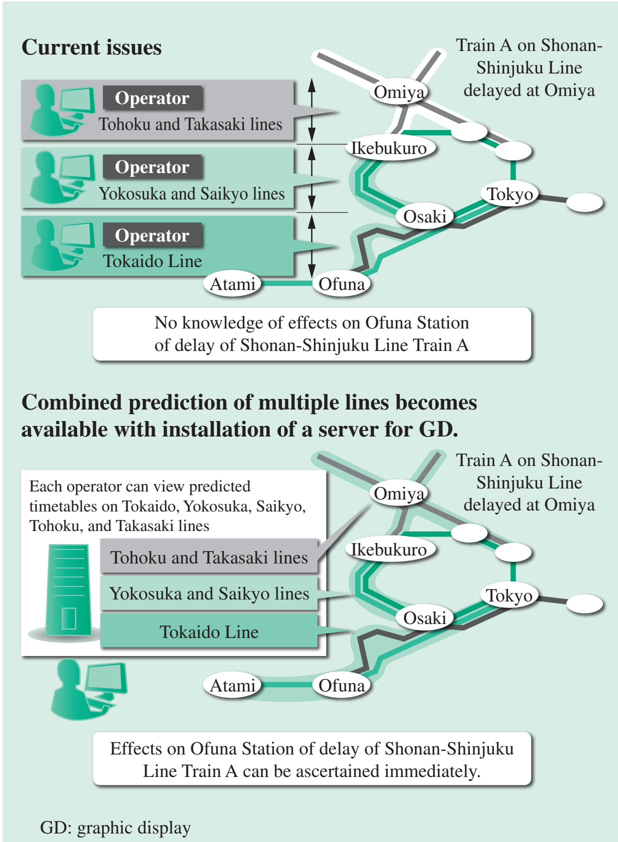

Fig. 5—Overview of Multi-line Prediction by Server for GD.
Currently, details of delays on other lines are conveyed by communication between people. When the new server is installed for GD, it will be possible to obtain predictions about line status that take account of delays on other lines.

Provision of Ideal Environment for Traffic Management

(1) Predicted timetables

Since the ability to predict future traffic situations is helpful when making changes to operating schedules as a result of timetable disruptions, better decision-making about the inputs to operation rescheduling is made possible by verifying the consequences of operation rescheduling after a timetable disruption. Among the features of ATOS that manage high-density railway lines are the complexity of changes to operating schedules and the large number of trains affected. To address this complexity, Hitachi has developed a predicted timetabling function that provides a high level of processing performance and utilizes actual train movements together with computational logic (constraint logic) for modeling train operation. This predicted timetabling function can provide advance warning of future problems such as train delays or the locations of problems, and allows preemptive steps to be taken to deal with the flow-on effects of delays(2).

When this predicted timetabling function is used, improving availability requires the elimination of any inconsistencies that arise during the period when schedule changes are being implemented. Accordingly, providing a function to identify and resolve inconsistencies allows the predicted timetabling function to keep up with the complex operation rescheduling of the Tokyo region, where there is the potential for timetable inconsistencies to arise at multiple locations simultaneously.

Through these innovations, ATOS has succeeded in delivering more efficient recovery from delays by lightening operator workloads and reducing dependence on their know-how.

(2) Centralized management of entire ATOS coverage region rather than line-by-line

Given the networked nature of current operations, a problem on one section of track can have flow-on effects on other lines, leading to a series of other problems. Under these conditions, timetable prediction requires high performance to ensure the timely provision to the operator of the latest predicted timetable, including the affected lines. To achieve this, Hitachi has established the ability to generate seamless predictions that cover all relevant lines, with guaranteed responsiveness and realtime performance. This was done by developing algorithms based on optimized constraint logic to replace the complex procedural programs used in the past. Also, so that the predicted timetables can cover train services that run over a number of lines, the prediction calculation is able to take account of train delays on these other lines. This has succeeded in enhancing the quality of the operation rescheduling function by making available the appropriate inputs for operation rescheduling based on an awareness of train movements throughout the network (see Fig. 5).

(3) Improving provision of information for control functions

Details of restrictions are displayed in realtime on the CRT screens by utilizing the information retained by the notification system. These restrictions are displayed as symbols in the status display window, with further details available from a dialog box. This gives operators a visual representation of restrictions in the section of track under their control, and makes them better able to manage traffic in accordance with the actual situation (see Fig. 6).

Expansion of Information Services

To meet the demand for additional information services, Hitachi has developed an information distribution server for external devices. For security, these utilize technology from control server development to ensure that actions such as the connection and disconnection of external devices do not affect the operation of ATOS. The equipment configuration has also been optimized by taking over the functions of a number of devices associated with information service collation that currently reside in ATOS.

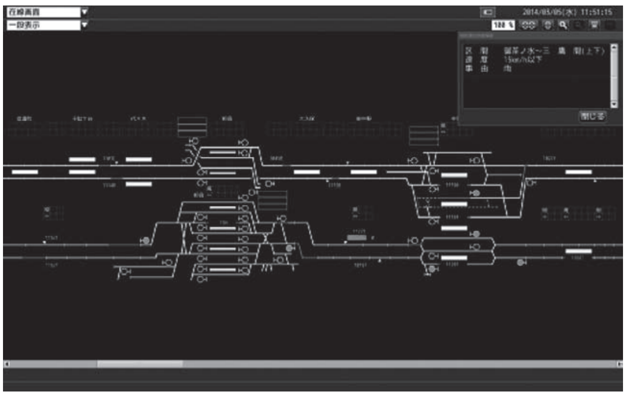

Fig. 6—Display of Restrictions on CRT Screen.
This implements the concept of incorporating restriction notifications into the screen. These were previously posted at the top of the track diagram frame.

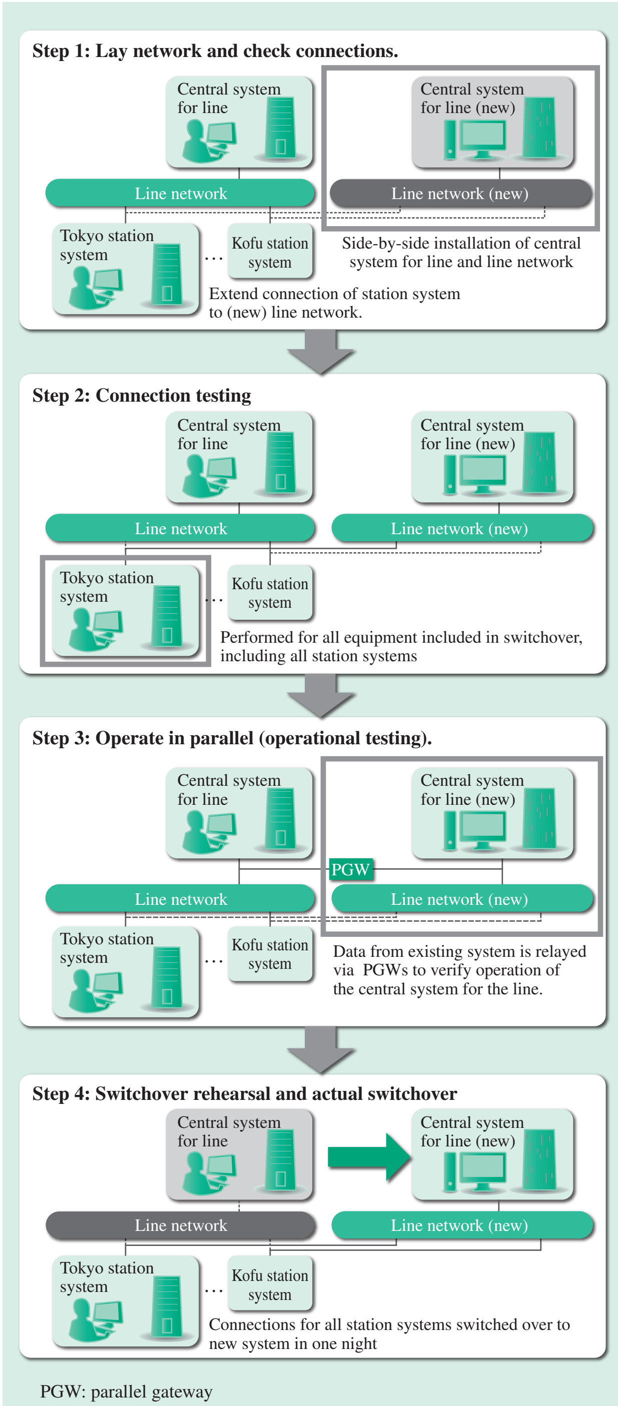

Fig. 7—Switchover Steps.
By verifying the operation of new equipment beforehand, the switchover was able to proceed quickly during the window of opportunity when passenger services were not running.

Seamless System Upgrades

For many of the lines on which ATOS has been installed, the time available for system shutdowns is short, making it difficult to get enough time for on-site system upgrades. As a result, by performing on-site work in stages, Hitachi checked the reliability of the equipment included in system upgrades before switchover. So that the switchover could proceed without affecting mission-critical systems, Hitachi also sought to reduce risk by adopting methods that minimized the number of times equipment needed to be shut down and restarted on the day of the switchover (see Fig. 7).

WORK OUTCOMES

The upgrade switchover described in this article (the central railway line system and network for the Chuo Line) was completed successfully in March 2014. The new predicted timetabling function and HMI have also demonstrated their benefits by shortening the time taken to recover after timetable disruptions. Based on these technologies, the upgrades will be progressively rolled out to the Yamanote Line and other lines to contribute to safe and reliable railway traffic management.

CONCLUSIONS

This article has described a comprehensive upgrade of ATOS to improve its safety and reliability.

In the future, Hitachi intends to introduce further service enhancements, including the incorporation of big data and expanding the scope of computerization through the deployment of information over a wide area, and to continue developing the technologies needed to achieve this.

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ABOUT THE AUTHORS

Yasuhiro Yoshida
ATOS Planning Division, Tokyo Electric Construction and System Integration Office, East Japan Railway Company. He is currently engaged in ATOS development.

Kouhei Akutsu
ATOS Station Construction Division, Tokyo Electric Construction and System Integration Office, East Japan Railway Company. He is currently engaged in ATOS development.

Yasuhiro Yumita
ATOS Central Division, Tokyo Electric Construction and System Integration Office, East Japan Railway Company. He is currently engaged in ATOS development.

Ryuji Yamagiwa
JR Systems Department, Rail Systems Sales Division, Sales & Marketing Division, Rail Systems Company, Hitachi, Ltd. He is currently engaged in sales to the East Japan Railway Company.

Hideki Osumi
Autonomous Decentralized Transport Operation Control System Center, Transportation Information & Control Systems Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the development of railway traffic management systems. Mr. Osumi is a member of The Institute of Electrical Engineers of Japan (IEEJ).

Mitsunori Okada
Autonomous Decentralized Transport Operation Control System Center, Transportation Information & Control Systems Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the development of railway traffic management systems.

Kiyosumi Fukui
Autonomous Decentralized Transport Operation Control System Center, Transportation Information & Control Systems Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the development of railway traffic management systems.