[ii] Information and Control Systems for Industrial Process Control

Digital Solutions for Steel Industry

From Operations to Production and Maintenance Support

This article describes Hitachi's services for steel plants that provide operation support by intelligent analysis, advance prediction of steel sheet characteristics, quality control by machine learning, anomaly detection in motors and drives, and maintenance support by remote control. These services are the result of integrating its domain knowledge of steel control accumulated over many years in the field of OT and combining it with state-of-the-art IT, including AI. This article also describes Hitachi's total seamless solution that can be used to meet customer goals from the factory floor to the operations management level. Hitachi has started to provide cutting-edge solutions using advanced IT with a key focus on development and production of high value-added steel products that meet the needs of end users, visualization of quality traceability and productivity improvement throughout the entire plant, and remote and predictive plant maintenance that minimizes the downtime of equipment and operations.

Gosuke Hayashi
Yoshitoshi Akita
Akihisa Fukumura
Shinsuke Teramoto
Ken Kuribayashi

1. Introduction

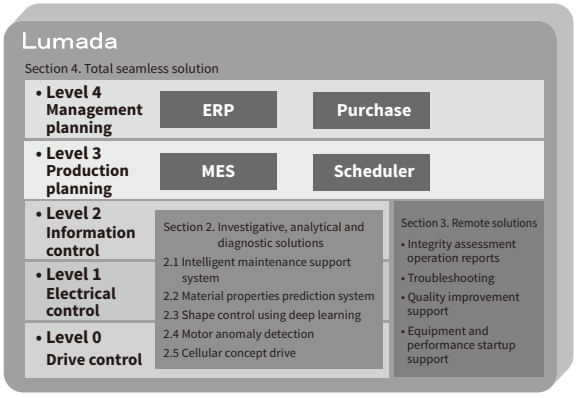
Recent developments in IT have spurred the development of even faster networks and the ability to process even larger amounts of data. Data hubs have made it possible to collect and utilize data with multiple interfaces, and analytical technologies such as artificial intelligence (AI), which requires enormous computational processing, have advanced to enable wider practical application. Against this backdrop, steel manufacturers have been focusing on projects to digitize knowledge in operations and maintenance, and are working to produce high value-added steel sheets and other products that could not be produced in the past and to reduce energy consumption to realize more environmentally-friendly operation, as typified by carbon neutrality, by improving the efficiency of operations and maintenance.

Hitachi has long been providing control systems to steel manufacturers, and by adding the Lumada concept advocated by Hitachi and combining its accumulated control domain knowledge with the latest IT, Hitachi is implementing initiatives to support customers in developing next-generation plants. Information and control systems in steel plants can be broadly classified into Level 0 for drive control, Level 1 for electrical control, Level 2 for information control, Level 3 for production planning, and Level 4 for management planning, as shown in **Figure 1**. For these management levels, Hitachi has started to provide various digital solutions that meet customer needs.

In this article, investigative, analytical, and diagnostic solutions for the steel industry for steel plant Level 0 to Level 2 are described in section 2, remote solutions that support troubleshooting, quality improvement, and running of trial operations and other processes remotely and in a timely manner are described in section 3, and total seamless solutions that can flexibly respond to various customer goals

Figure 1 — Management Levels and Solutions Provided for Steel Plants

Information and control systems in steel plants can be broadly classified into Level 0 to Level 4. For these management levels, Hitachi has started to provide various digital solutions that meet customer needs. This article presents these solutions in sections 2 to 4.



ERP: enterprise resources planning MES: manufacturing execution system

from the factory floor to the operations management and factory operation levels, including Level 3 and Level 4, are described in section 4.

2. Investigative, Analytical, and Diagnostic Solutions for Steel Industry

Five typical solutions for investigation, analysis, and diagnosis, which are implemented by skillfully editing the data collected from the plant, are shown below.

2. 1 HITSODAS, an Intelligent Maintenance Support System

In steel plants, it is necessary to reduce the thickness tolerance deviation, prevent sheet breakage, and stabilize the shape to improve the quality and yield of product steel sheets. Although factor analysis is essential for these improvements, due to the wide variety of steel grades, thicknesses, and widths produced, manual analysis requires an enormous amount of time, and results vary depending on the skill of the analyst.

To address these issues, Hitachi has developed and offers Hitachi Self-organized Diagnosis and Analysis System (HITSODAS), an intelligent maintenance support system that aims to support the analysis of data collected from plants.

HITSODAS is composed of BASE, which is the basic function, and three extended functions: quality analysis (QA), process human interface (PH), and dynamic synergy control (DS). BASE collects and visualizes data in units of product coils. QA performs long-term storage of the features calculated from the collected data in a database for providing data analysis support functions such as information searches and statistical analysis. PH provides a means of examining production issues from a more multifaceted perspective by synchronously playing back the collected data with video images captured by video camera. DS has functions for the purpose of performing efficient control model tuning using the collected data[(2), (3)].

Hitachi has developed a new HITSODAS with improved graphical capabilities and operability, and has been providing the system, consisting of BASE and QA, primarily to customers outside Japan since 2019. In the future, the company plans to provide a system configuration that also includes PH and DS to customers inside and outside Japan.

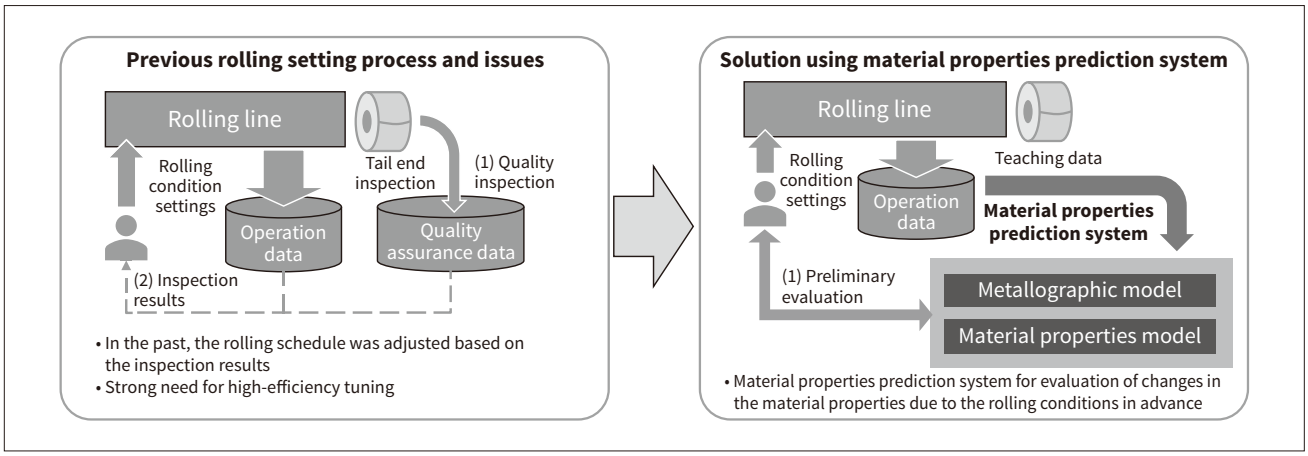
2. 2 Material Properties Prediction System for Determining Optimal Rolling Conditions

In hot rolling, in addition to dimensional control of the steel sheet (sheet thickness and width), it is important to create material properties such as strength and elongation that are critical for high-value-added materials. In addition, to achieve the desired material properties, it is necessary to optimize the combination of the chemical composition of the steel sheet, pressure distribution during rolling, cooling rate, and other factors. In the past, the rolling schedule was adjusted by the customer based on the inspection results of the steel sheet after rolling. There has been a rise in the need for achieving high efficiency. To better manage this process, Hitachi has developed a material properties prediction system that can evaluate changes in the material properties due to the rolling conditions in advance (see **Figure 2**).

There are various types of steel sheets, which are broadly classified into carbon steel, alloy steel, and stainless steel, and then further subdivided into a number of varieties. This developed system covers most steel types by using the metallurgical and mechanical properties prediction models developed through the company's own research. The prediction model automatically extracts the history of rolling and steel sheet temperatures from the time the slab is charged in the furnace to the time it is coiled in the down-coiler, using information detected from sensors and simulation technology that interpolates between the two, and analyzes changes in metallurgical properties (grain size, volume fraction of each crystalline structure, dislocation density, etc.), and the mechanical properties (strength, hardness, elongation, etc.) of the steel sheet are predicted from the chemical composition and the metallurgical properties that are ultimately obtained. Furthermore, by changing the chemical composition and rolling conditions from a dedicated Web screen, the corresponding changes in mechanical properties can be analyzed, making it easy to derive the rolling conditions to obtain the desired properties. This model can also be used as a tool to simplify quality reports and quality inspection

Figure 2 — Solution Using Material Properties Prediction System

In the past, the rolling schedule was adjusted based on the inspection results of the steel sheet after rolling. There has been a rise in the need for achieving high efficiency. To better manage this process, Hitachi has developed a material properties prediction system that can evaluate changes in the material properties due to the rolling conditions in advance.



processes for steel sheets, and Hitachi is planning to provide analysis services through cloud computing in the future.

2. 3
Shape Control System Using Deep Learning

In the field of shape control, which controls the rippling on rolled steel sheets, Hitachi provides a shape control system that uses deep learning to digitize the operation methods of skilled workers and apply them to automatic control to improve quality and reduce the workload. Generally, AI-based control technology is expected to enable building of control models from data without the need for tuning and to enable improvements to control performance with each update of the control model. However, due to operational issues such as the fact that AI is a black box and requires trial and error, and the fact that the building of control models is complicated and resource-intensive, some users do not update their models frequently enough.

To resolve this issue, the company developed a graphical user interface (GUI) maintenance tool for this system and a method to evaluate the control performance of the control model before and after applying it to actual machines (see **Figure 3**). The GUI maintenance tool can build a control model with simple operations under conditions that incorporate the operational requirements. This method of evaluating the control performance before and after applying the model to actual machines reduces the risk when applying a new control model to an actual machine by quantitatively evaluating the control performance of the AI-built control model before applying it to the actual machine, and reduces the burden on the user for monitoring after updating the control model by visualizing the control performance after application. These features improve operability in building the control model and applying it to actual machines and assist in selecting the optimal control model.

In the future, Hitachi will apply this technology to actual machines to verify its effects on improved operability, and also develop technologies to automatically update the control model based on control performance evaluation to improve performance.

2. 4
Motor Anomaly Detection Solutions

Periodic maintenance and inspection are essential for the stable operation of motor-related equipment such as motors and gearboxes. Currently, maintenance technicians patrol the harsh site environment and conduct inspections based on their experience and expertise, relying on appearance, sound, vibration, and other characteristics. However, ensuring safety during inspections, improving work efficiency, and passing on the expertise of skilled maintenance technicians have become key issues.

To address these issues, Hitachi began offering an anomaly detection solution in October 2019 that automatically detects signs of anomalies based on electrical current data in plant motor-related equipment. In addition to the ease of installation, which enables diagnosis based on data from current sensors that are already installed in the control panel or can be easily installed, without the need to install sensors directly on the on-site equipment, it also enables both stable operation of the equipment and the reduction of maintenance costs through predictive diagnosis.

Hitachi has combined its knowledge of operational technology (OT) as a motor manufacturer and the analysis technology developed by its proprietary AI to engineer a solution using a predictive diagnosis technology that automatically detects signs of anomalies based on the sensing data from the current sensor. By capturing minute changes in the motor's current behavior and extracting features that represent the degradation state of the target equipment, and by using machine learning to find anomalies from the motor's normal state, Hitachi has been able to detect

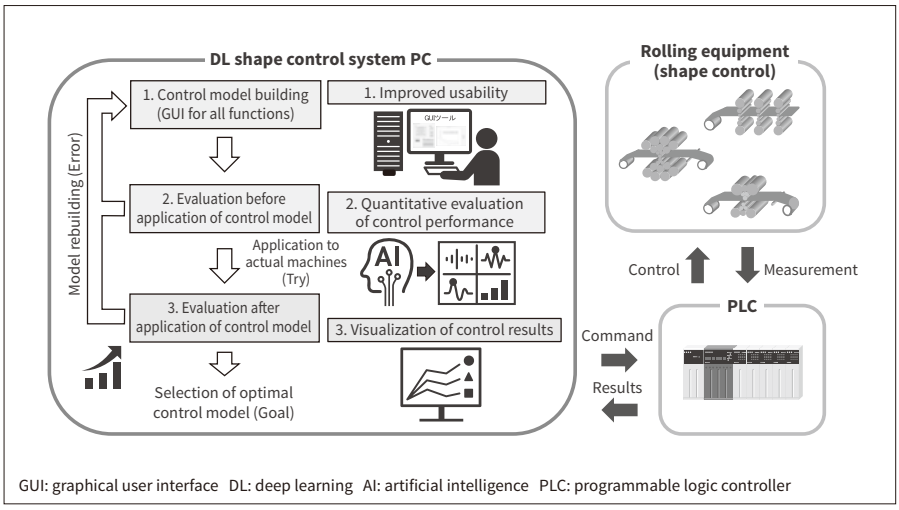


Figure 3 — Control Model Operation Support Methods Using AI

A GUI maintenance tool and a method to evaluate the control performance of the control model before and after applying it to actual machines are used to improve user operability in building the control model and applying it to actual machines and to assist in selecting the optimal control model.

anomalies with high accuracy[3]. This detection technology can be applied not only to steel plants, but also to various fields where motors are used, and it represents a pioneering solution as a new form of maintenance for these types of equipment. In the future, Hitachi plans to expand the scope of application to include diagnosis of insulation degradation, to integrate control using existing steel control networks, and to provide remote maintenance support through cloud computing.

2. 5
Advanced Motor Drive System with Cellular Concept

Hitachi provides motor drive systems to drive rolling mills based on the cellular concept and also has been developing a retrofit business since 2019 that takes advantage of these features. The cellular concept is a design concept that divides system functions into the smallest units and achieves total functionality by combining them, while retrofit is a concept of improving old equipment and keeping it operational. From an economic and environmental standpoint, it is desirable to use equipment for as long as possible, and the sustainability of products is improved through partial updates of problematic cells, such as those parts whose production has been discontinued. It is also possible to improve the functions of the control cell through replacement with new ones, and the company developed a sensor self-checking function as one of these new functions[4].

Sensor information is not only used to control the drive system, but in recent years, the health of sensors has become important for predictive diagnosis and other applications. For this reason, the system identifies the location of a failed sensor using Hitachi's proprietary diagnostic technology based on multiple sensor information, and then continues operation by substituting the data from the failed sensor location with an estimated value from other sensor signals. This reduces the risk of unplanned stoppages of equipment due to sensor failure, and because the failed sensor location has been identified, planned maintenance can be performed efficiently. The motor drive system has many other components and various drive conditions, and the company will continue to develop diagnostic technology and control functions to further enhance maintenance services and ensure stable operation of equipment.

3. Remote Solutions

As it develops global businesses for steel systems, Hitachi is developing steel remote solutions for providing optimal and rapid support to customers.

This solution is a maintenance service that uses remote technology to enable integrity assessment of facility operations and improvements in operation quality. This service consists of three main components: integrity assessment operation reports, troubleshooting, and quality improvement support. A maintenance environment was created to simulate the electrical room of a plant by remotely connecting the local data collection terminal from Hitachi's support center, enabling verification of the system operation status (see **Figure 4**).

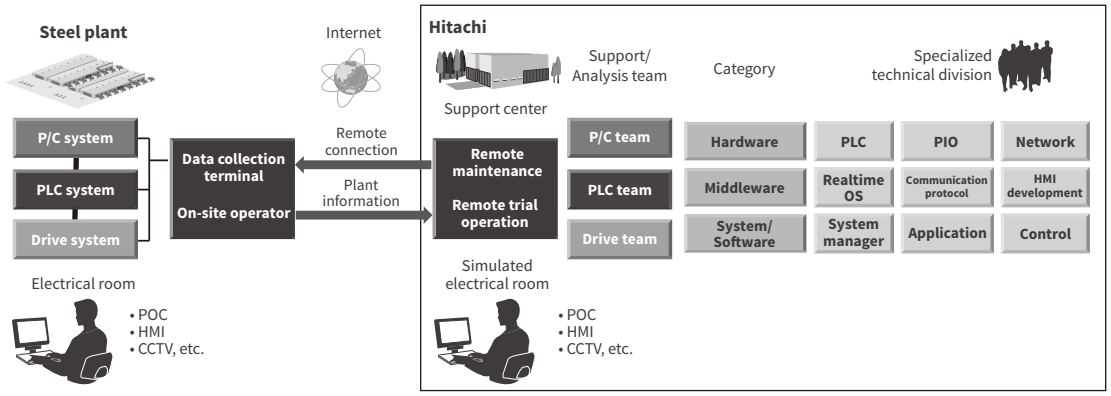
By acquiring rolling information, operation information, alarm information, and plant line video images from the data collection terminal and analyzing the data, the company assists in the stable operation of steel plant equipment, quality improvement, and quick problem resolution.

Hitachi also supports the series of processes necessary up to equipment operation by using trial operation in the same environment. Remote support for trial operation has given the customer extra flexibility in determining for themselves the ideal timing and duration of trial operation and freed them from time constraints. This allows for optimal and rapid support for improving startup of equipment and its performance.

The company will continue to expand the functions of this technology to meet the increasing demand for remote business.

Figure 4 — Steel Remote Solution Configuration Diagram

A maintenance environment was created to simulate the electrical room of a plant by remotely connecting the local data collection terminal from Hitachi's support center, enabling verification of the system operation status.



P/C: process computer PIO: process input output OS: operating system HMI: human machine interface POC: process operator's console CCTV: closed circuit television

4. Total Seamless Solution

The previous chapters described Hitachi's OT solutions in the field of steel control, which can help manufacture high-value-added products and achieve the goals of improving productivity. These solutions are extremely effective in resolving issues such as achieving higher quality and higher efficiency, and contribute to further advancements in control.

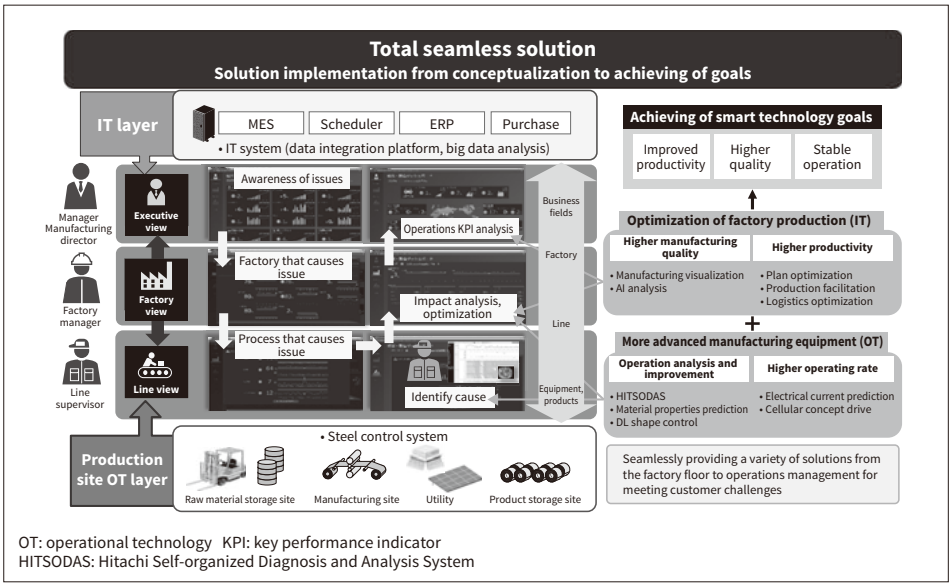
However, the importance and priority of the issues and goals to be resolved vary with customers' production operations, and the investment budget for implementing them is limited. For this reason, it is important to develop concepts and plans that take into account the current situation and the future, and to conduct investment without waste. Recently, while there has been a rush for transformative change as companies move to adopt smart technology and implement digital transformation (DX), there have been a number of cases where change has not progressed because of the difficulty of subsequent utilization and rollout, such as when companies try out new technologies on a one-time basis or implement solutions that focus only on immediate issues.

Hitachi has begun providing implementation support services as a total seamless solution, offering a wide range of solutions from OT, exemplified by control technology, to cutting-edge IT such as big data analysis and data integration platforms. These services allow the company to respond flexibly to various customer goals and issues, from the factory floor level to the operations management and factory operation level (see **Figure 5**).

In the implementation support services, for example, for the objective of applying smart technology to production, the company first thoroughly analyzes the current situation (AS-IS) and issues, and then determines a TO-BE image to be realistically achieved through smart production.

Figure 5 — Total Seamless Solution

Hitachi has a suite of solutions ranging from IT to OT, which can be seamlessly combined and adapted to meet the various challenges of customers and help them achieve their goals for smart technology.



OT: operational technology KPI: key performance indicator
HITSODAS: Hitachi Self-organized Diagnosis and Analysis System

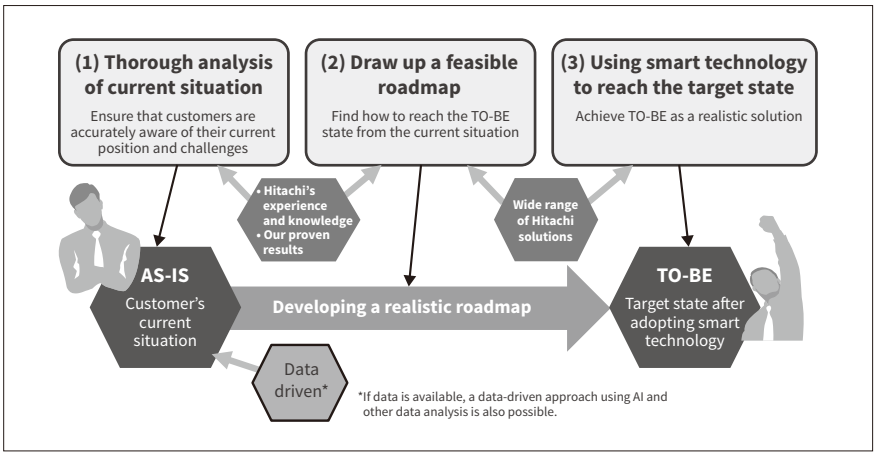


Figure 6 — Smart Technology and Implementation Support
To understand the issues and devise a realistic approach, Hitachi provides implementation support from a broad perspective based on its own proven results, knowledge, and solutions.

Furthermore, by creating a roadmap to the target TO-BE image, the company will help customers implement smart technology. The advantage of this solution is that it enables an accurate awareness of issues from the factory floor to operations management by utilizing Hitachi's knowledge of OT and IT, as well as its proven track record and experience in smart production. Also, by utilizing and integrating a wide range of Hitachi solutions to solve problems and achieve goals, an even smarter system can be built in a feasible way (see **Figure 6**).

In this way, Hitachi has established a system that integrates a wide range of IT with steel control OT at its core and that uses the knowledge and experience built in these fields to enable a flexible response to customer issues and goals. Hitachi will continue to contribute to the development of the industry together with its customers by providing total seamless solutions to a wide range of issues such as environmental concerns.

5. Conclusions

This article has described the major digital solutions Hitachi has been implementing in steel plants. These solutions are made possible by in-house collaboration between IT and research and development divisions and teams specializing in the steel control domain, which is one of Hitachi's strengths. Hitachi will continue to use a variety of formations to support a wide and deep range of customer issues and needs, from control to operations management issues.

References

1) T. Hatanaka et al., "Steel Industry Systems with Integrated Mechanical and Electrical Control for High-quality Production and Energy Efficiency," Hitachi Review, 59, pp. 159–164 (Oct. 2010).
2) K. Kuribayashi et al., "Advances in Steel Industry Control Systems in Era of IoT," Hitachi Review, 65, 5, pp. 41–46 (Jun. 2016).
3) T. Ito et al., "Use of AI to Enhance Steel Production Value Chain," Hitachi Review, 70, pp. 212–216 (Feb. 2021).
4) Y. Akita et al., "Offline Self-Check Function for DC Voltage Sensor of Three-Level AC Drive Systems Used in Steel Rolling Mills," IEEJ Industry Applications Society, 140, 5, pp. 342–348 (May 2020) in Japanese.

Authors

Gosuke Hayashi
Metal Control Systems Engineering Department, Water, Metal and Industrial Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd. *Current work and research:* Administration of computer control system processes and digital solutions for the metals industry.

Yoshitoshi Akita
Metal Control Systems Engineering Department, Water, Metal and Industrial Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd. *Current work and research:* Design and development of motor drive systems. *Society memberships*: The Institute of Electrical Engineers of Japan (IEEJ).

Akihisa Fukumura
Metal Control Systems Engineering Department, Water, Metal and Industrial Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd. *Current work and research:* Design and administration of electrical control systems for the metals industry.

Shinsuke Teramoto
Metal Control Systems Engineering Department, Water, Metal and Industrial Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd. *Current work and research:* Development of control platform and digital solutions for the metals industry.

Ken Kuribayashi
Automation Metals Solutions Department, Industrial Manufacturing Solution Division, Industrial Solutions & Service Business Division, Digital Solutions Division, Industry & Distribution Business Unit, Hitachi, Ltd. *Current work and research:* Administration of digital solutions for the metals industry.