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HITACHI
Inspire the Next

Information and Control Systems

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From the Editor

The social system challenges that have come to prominence in recent years include global warming, insufficient maintenance of aging infrastructure, a low birth rate, and an aging population. Meanwhile, the Internet of things (IoT), which connects numerous devices to networks, has made rapid advances that are giving rise to a trend toward its use in the creation of new societies, markets, and ecosystems. Examples include initiatives aimed at new forms of manufacturing, with the announcement in November 2011 of Industrie 4.0, a joint strategic initiative by industry, academia, and government that is led by the German government. The Industrial Internet Consortium launched by General Electric Company of the USA and four other companies in March 2014 now has more than 200 member companies, and is developing new products, processes, and services through demonstration projects called "testbeds." Japan, too, has seen considerable activity aimed at achieving new growth through open innovation with the establishment of such organizations as the Robot Revolution Initiative and the IoT Acceleration Consortium.

Hitachi has a track record of developing information and control systems for important social platforms intended to maintain a sustainable global and social environment. We build safe and secure products and systems, placing top priority on ensuring reliability. We are also working on the development of systems based on the symbiotic autonomous decentralization concept first announced by this journal in May 2012 to utilize the advances achieved by the IoT to create the social infrastructure of the future. Through collaborative creation, whereby we share challenges with customers and other partners and work together to create new services and other businesses, we intend to combine business growth with solutions for the problems facing society. While this is a major challenge for Hitachi, too, we are pursuing our Social Innovation Business to contribute to the progress of society in many different ways.

This issue of *Hitachi Review* describes the work Hitachi is doing to utilize the IoT for the efficient control of the important systems that underpin society and that are closely associated with daily life, including electric power, transportation, water and sewage, steel manufacturing, and industry, and also the core technologies that support these systems. In this issue's Expert Insights, Prof. Dr. Henning Kagermann, a President of Germany's National Academy of Science and Engineering (acatech), which is playing a leading role in such initiatives as Industrie 4.0 and Smart Service Welt, contributes an article about the fourth industrial revolution as a social innovation in the digital world. In Technotalk, we invited Hidehiko Tanaka, Dr. Eng., President of the Institute of Information Security, for a discussion with staff from Hitachi who are directly involved in its business.

I hope this issue of *Hitachi Review* will leave you with a better understanding of Hitachi's activities and will provide opportunities for the collaborative creation of new value in your businesses and in society at large.

Editorial Coordinator,
"Information and Control Systems" Issue

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Information and Control Systems

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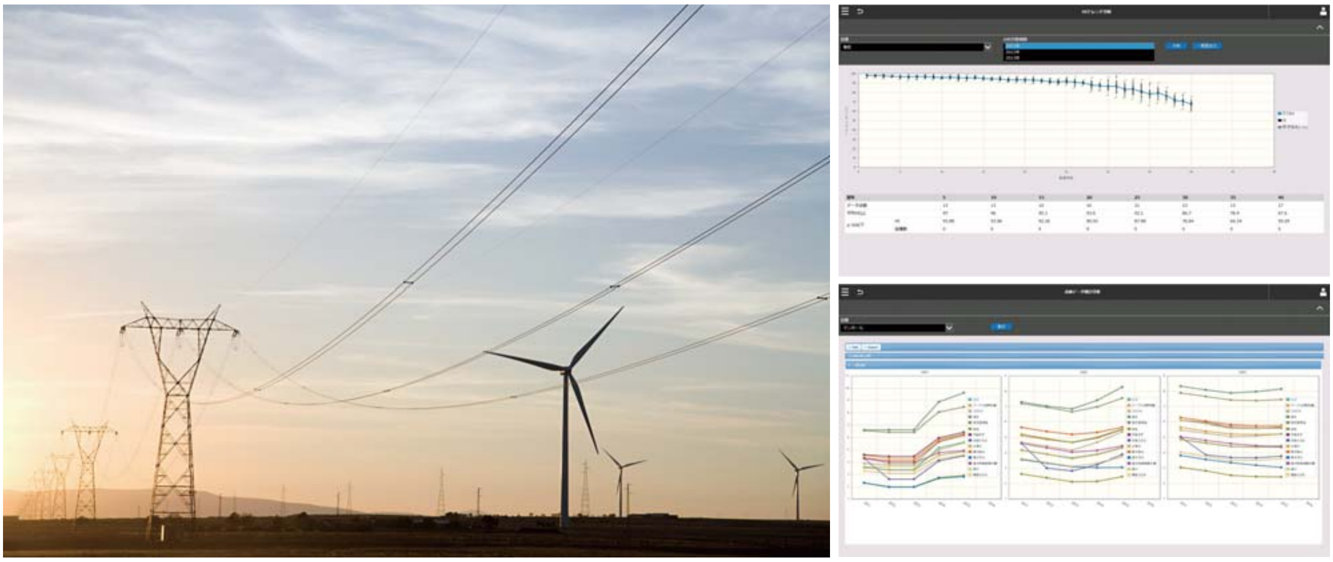
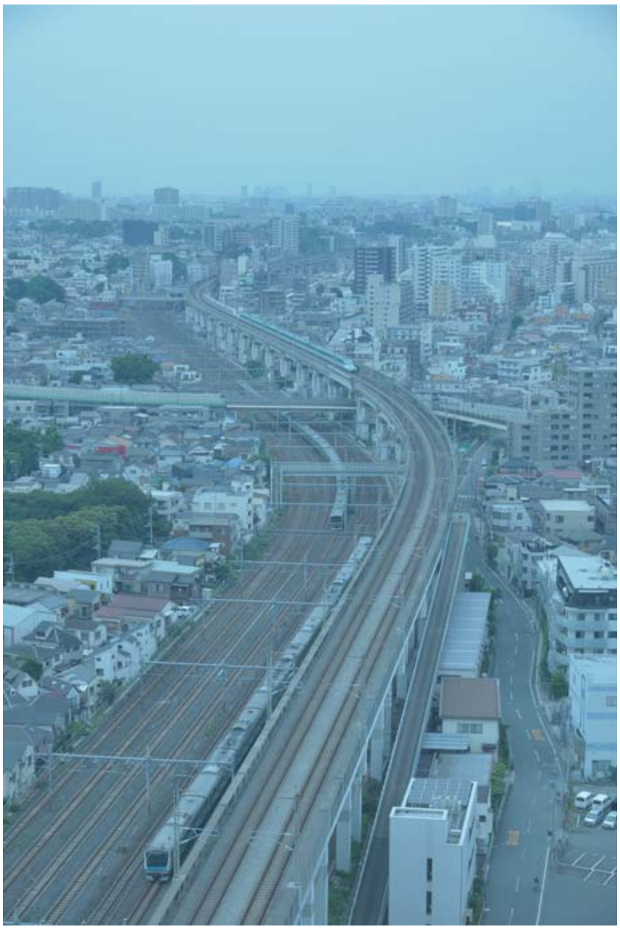
Information and Control Systems

Advances over recent years in big data utilization, artificial intelligence, and such technologies as the IoT are poised to bring major changes to society.
There is a growing trend toward the reform of manufacturing and services by analyzing real-world data and utilizing the correlations these analyses identify.
Hitachi has built up a variety of knowledge through its involvement in the supply of control systems and corporate information systems that support manufacturing and other parts of the social infrastructure.
Currently, Hitachi is advocating the symbiotic autonomous decentralization concept, which facilitates new growth by encouraging interconnections between systems to enable the shared use of data.
Hitachi is accelerating its Social Innovation Business by expanding information and control platforms based on this concept.


Use of ICT to support energy infrastructure (example screens from the key performance indicator support system) [image (left)]


Information and control systems for the transportation sector (image)


Information and control systems for the water supply and sewage sector (image)


Information and control systems for the steel and other industry sectors (image)

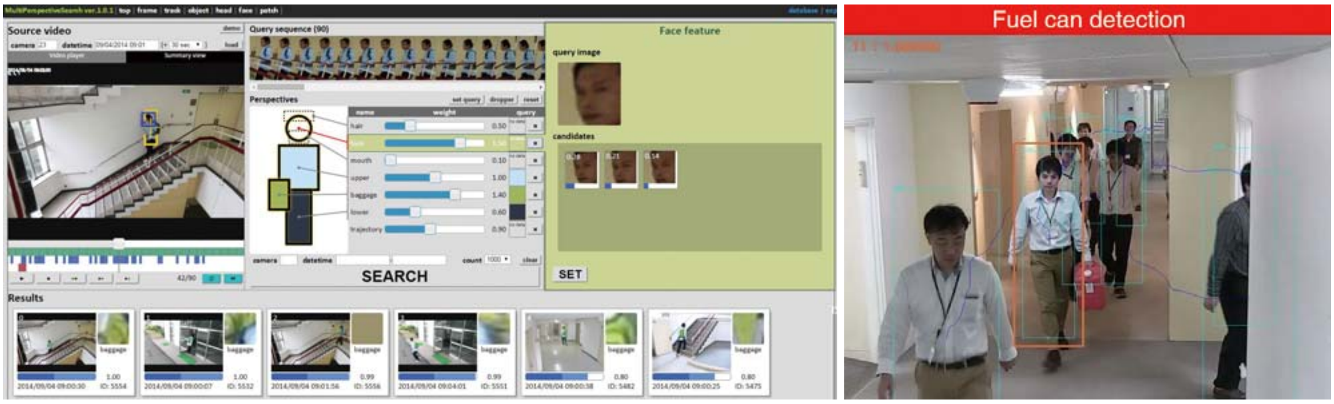


Image sensing techniques (multi-perspective search, realtime detection of people)


Initiatives for smart manufacturing practices that utilize the IoT

Intelligent L2 switch for industrial applications


System for preventing unauthorized access

Unidirectional network equipment


Controller with EDSA certification

Expert Insights

Social Innovation in a Digital World: the Fourth Industrial Revolution

Prof. Dr. Henning Kagermann

President of the National Academy of Science and Engineering

Henning Kagermann is President of Germany's National Academy of Science and Engineering (acatech). He received a doctorate degree in theoretical physics in 1975 at the TU Braunschweig and became a professor there in 1980. In 1982, he joined SAP GmbH (currently SAP SE). From 1998 to 2003, he served as co-chairman of the SAP Executive Board and CEO.

In 2015, the Internet of things (IoT) consisted of about 15 billion connected devices. The data gathered by these smartphones, radio-frequency identification (RFID) chips, and wireless sensors is fuelling web-based services that have disrupted sectors such as transportation and media. But the big changes are yet to come. In 2020, we expect there to be more than 30 billion connected devices. By then, companies in established industries such as automotive, energy production, and engineering will have to adapt to digitalization—or they will lose out to a new breed of Internet-savvy companies. What sets these newcomers apart is their ability to collect customer and product data from heterogeneous sources and use it for innovative business models that focus on customer needs and usability.

In Germany, this digitalization and the challenges it brings became known as Industrie 4.0, a term coined by an alliance of experts from industry and academics gathered by acatech, Germany's National Academy of Science and Engineering. We chose the version number 4.0 back in 2011 because we believed that digitalization and the IoT was initiating a fourth industrial revolution. Did we exaggerate? I do not think so.

So far, industrial revolutions triggered by the steam engine and, later, by electrification and industrial automation have mostly addressed our physical limitations. Digitalization, however, helps us overcome our cognitive limitations. By providing us with near-ubiquitous data, it allows for a much deeper understanding of the world around us. On a more pragmatic level, it enables companies to provide products and services tailored to the needs of individual customers but produced at the cost of a standardized mass-marked equivalent.

Hitachi is well placed to profit from this transformation. Its Data Systems subsidiary is reinventing itself as a big data consultancy that can distil business value from clients' data streams. While Hitachi, the globalized conglomerate, has access to huge amounts of real-time data through its vast offering of products and services in varying industries. Still, Hitachi like many other German industry giants would be ill advised to go it alone.

Web-based services need a specific environment to become economically successful: a huge market that allows rapid scaling, a set of standards for data interoperability, a legal system that protects both privacy and intellectual property rights. This is why acatech started looking beyond Germany and the needs of our national industry. In our project Industrie 4.0 Global, we are interviewing industry representatives and researchers from Japan, China, South Korea, the UK and the United States. I was grateful to speak with Hitachi, Ltd.'s Chairman of the Board Hiroaki Nakanishi about his vision of this global transformation.

The final results are not out yet, but we already see a trend emerging: Success in Industrie 4.0 is not so much a question of geography than of company size. While big firms like Siemens, Bosch, and Hitachi have invested heavily in Industrie 4.0, small and medium-sized enterprises (SMEs) are hesitating. They are falling behind. This is problematic because SMEs are very important for employment, national income, and as suppliers for many globalized corporations. No matter whether you call it the IoT or Industrie 4.0—it is not just about connecting devices, it is about connecting people and economies.

Technotalk

Symbiotic Autonomous Decentralized Platforms for Faster Fusion of Control and Information

Hidehiko Tanaka, Dr. Eng. President, Institute of Information Security

Soichi Aragane General Manager, Electrical Equipment Information & Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd.

Takeshi Kobayashi General Manager, Transportation Information & Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd.

Naohiko Irie, Dr. Eng. General Manager, Center for Technology Innovation – Controls, Research & Development Group, Hitachi, Ltd.

Hiromitsu Kato, Ph.D. Department Manager, Infrastructure Systems Research Department, Center for Technology Innovation – Systems Engineering, Research & Development Group, Hitachi, Ltd.

Takashi Hotta, Dr. Eng. Chief Engineer, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd.

New uses for IT are leading to growing activity in initiatives aimed at innovation in manufacturing and other parts of the social infrastructure. Drawing on the strength of its experience in control systems for social infrastructure and other industries, Hitachi is also working on fusing these with information systems. The symbiotic autonomous decentralization concept is the key to creating new value through interoperation between different systems. Hitachi intends to pursue further advances in social infrastructure and industrial systems by expanding, into a wider range of industries, the platforms it offers that are based on this concept and built using associated technologies.

New Value through Coordination of Data across Different Systems

Hotta: There has been growing activity in initiatives aimed at innovation in manufacturing and other parts of the social infrastructure that take advantage of new trends in information technology (IT) such as the Internet of things (IoT). Hitachi has been working on control technology for social infrastructure and other industries for many years and also, in recent years, on the fusion of control and information with reference to these initiatives, during which time we have identified a number of challenges that need to be overcome.

Professor Tanaka, our guest today, specialized in such fields as artificial intelligence and distributed processing while at The University of Tokyo and is now President of the Institute of Information Security where he is currently engaged in research and teaching on security technology for information systems. Professor, I hope you will be able to give us the benefit of your experience by offering your views on this work by Hitachi.

Hidehiko Tanaka, Dr. Eng.

President
Institute of Information Security

Graduated in electrical engineering from the Graduate School of Engineering, The University of Tokyo. Following appointments as head of the Graduate School of Information Science and Technology at The University of Tokyo and head and lecturer at the Graduate School of Information Security at the Institute of Information Security, he took up his current position in April 2012. His fields of expertise include computing architectures, parallel processing, artificial intelligence, distributed processing, and media processing. He is a professor emeritus at The University of Tokyo.

Soichi Aragane

General Manager, Electrical Equipment Information & Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1987. Having worked in the past on the design of monitoring and control systems for the water industry and at Beijing Hitachi Control Systems Co., Ltd., he took up his current position in 2014.

But before that, I would like to ask each of you to tell us about your own responsibilities.

Aragane: My Electrical Equipment Information & Control Systems Division deals mainly with two different industries. That is, we work on monitoring and control systems for water supply, sewage and other water-related systems, and for rolling mills and other processes in the steel industry. For the water supply and sewage sector, our main focus in Japan is on the maintenance and upgrading of existing facilities, and with the falling population, there is anticipated to be demand for the extension of systems to cover wider areas through business integration with neighboring local governments, and also joint operation of their maintenance services. Because the number of experienced technical staff will fall in the future, we are looking at ways to support management and operations that incorporate such technologies as the IoT.

Kobayashi: My Transportation Information & Control Systems Division handles traffic management systems for the Shinkansen and for major conventional railway services such as the system for the Autonomous decentralized Transport Operation control System (ATOS). While the railway industry in Japan, Hitachi included, is expanding its horizons offshore, domestically we are working with customers to look at ways of improving security. One of the challenges will be to strengthen both the cyber and physical security of railways in the Tokyo region, in particular, in the lead up to the international sports event in 2020. In the case of physical security, we are able to offer systems such as those for detecting dangerous items or suspicious individuals utilizing explosives detection, image recognition, and other such technologies.

Irie: I work at the Research & Development Group investigating new technology and business opportunity that utilize the IoT. The aims of the IoT can be broadly divided into the use of IT for the smart production of goods and services and for their wise use. By linking together systems that span both domains, Hitachi's aim is to achieve growth through the sharing of value across all the stakeholders involved with goods and services.

In railways, for example, because Hitachi is involved in the production of rolling stock as well as the control systems that support operations, we are launching an initiative to collect data on the operating conditions and movement of rolling stock with aims that include improving utilization and maintenance efficiency. In the future, we intend to expand this type of integration and use of data to a wide range of other industries, including energy, public services, and manufacturing. The key to achieving this is the symbiotic autonomous decentralization concept that is a further development of the autonomous decentralization concept on which the ATOS is based.

Tanaka: What does this concept involve?

Irie: The original autonomous decentralization concept was about building systems with excellent reliability and expandability by allowing subsystems to share information collected through realtime sensing of the equipment being controlled so that the individual subsystems are able to operate autonomously. The concept has been put into practice with control systems such as those used in the transportation and steel industries. The idea is to extend this to the system level, and rather than just optimizing on-site facilities and equipment, to achieve corporate-wide optimization and the optimization and creation of value across entire value chains, including other companies, through the sharing, analysis, and use of information all the way up to the management level. The aim is to use this concept as a basis for building platforms that share value by linking different systems together.

Tanaka: While I understand that, on a technical level, it

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General Manager, Transportation Information & Control Systems Division, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1986. He is currently engaged in the design and development of information and control systems for the defense, public sector, and railway industries.
Having worked in the quality assurance division, he took up his current position in 2015.

Naohiko Irie, Dr. Eng.

General Manager, Center for Technology Innovation – Controls, Research & Development Group, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1990. Having worked at Hitachi's Central Research Laboratory in the past on research and development in such fields as mainframe, server, and system LSI architectures, he is currently engaged in the research and development on IoT products and platform.
Dr. Irie is a member of the Information Processing Society of Japan (IPSJ).

is not enough just to provide the links, what are the main considerations for combining symbiosis with autonomy.
Irie: To begin with, advanced sensing techniques for collecting the required data and big data techniques for handling large amounts of different types of data are essential. The integration and analysis of data across different systems is particularly important, for which purpose we use the proven Pentaho software. One of the other techniques we deploy for the analysis and use of big data is the Hitachi AI Technology/H artificial intelligence developed by Hitachi. Along with the incorporation of security techniques, the key points include coordinating these components to share and analyze information and provide precise feedback to the workplace.

We also aim to extend our platforms by building up operational know-how and other knowledge about specific sectors and then deploying this in different sectors.
Tanaka: It is important to start off with an expandable platform. However, do you find it difficult to get customers to understand the value of using such platforms?
Kato: That's right. At the Research & Development Group where I work we have developed the NEXPERIENCE / Cyber-Proof of Concept tool for simulating business value that can perform simple calculations of the profitability and benefits to society of social infrastructure projects. First of all, we support customers in taking on new challenges by using simulation as a basis for visualizing the benefits. The aim is to convey the value and other benefits that will overcome the challenges they face through a process of collaborative creation with the customer, using tools like this.

My own department also provides research and development support for the work of the operational divisions represented by you here today, and with regard to the symbiotic autonomous decentralization concept, we are working on research into determining concepts and architectures in the form of system technologies, translating these into implementations, and assessing them through actual system development.

Anticipated Uses for Artificial Intelligence Technology

Tanaka: Please tell me about the artificial intelligence technology you referred to earlier.
Kato: Hitachi AI Technology/H is used as a means of optimizing business and other activities. It works by identifying which items in large amounts of relevant data are correlated with desired outcomes, and automatically generating suggestions for improving the outcomes. This is more efficient that the existing process of manually testing hypotheses, with the advantage that it can consider a much larger number of parameters. We believe that artificial intelligence can demonstrate its usefulness in a symbiotic autonomous decentralized world where interoperation between systems and data occurs in ways that extend beyond past practices.
Irie: A feature of the technology is that, by analyzing big data that includes not only sales data, equipment operating conditions, and other such information, but also information on things like human behavior and communication that have been difficult to deal with in the past, it can find data correlations that would not occur to humans, such as identifying relationships between staff working practices and service quality. The technology has potential in a wide range of applications and we have started supplying business improvement services that use Hitachi AI Technology/H.
Hotta: I understand that artificial intelligence includes the use of deep learning techniques for things like

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Department Manager, Infrastructure Systems Research Department, Center for Technology Innovation – Systems Engineering, Research & Development Group, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1995. Having worked on research and development into new services and the operation, monitoring, and control of information and control systems for the water, automotive, railway, and other industries, he is currently engaged in the research and development of autonomous decentralized systems technology for the Social Innovation Business.
Dr. Kato is a member of the IEEE.

Takashi Hotta, Dr. Eng.

Chief Engineer, Control System Platform Division, Services & Platforms Business Unit, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1983. He is currently engaged in managing research into information and control systems and power electronics at the Hitachi Research Laboratory. Having previously headed Hitachi's Yokohama Research Laboratory, he took up his current position in 2013.
Dr. Hotta is a member of the IEEE, The Institute of Electrical Engineers of Japan (IEEJ), The Institute of Electronics, Information and Communication Engineers (IEICE), the IPSJ, and the Society of Project Management.

automatically identifying anomalies in surveillance camera video. We can expect the combination of artificial intelligence with cameras and other sensor technology to lead to further advances in the fusion of control and information.

Aragane: Given the labor shortages caused by a falling population, labor-saving practices for plant maintenance will be a long-term challenge for manufacturing and other parts of the social infrastructure, making this another area where we can expect to see the technology deployed.

How to Achieve the Safe Fusion of Control and Information

Tanaka: A major challenge that arises from the ongoing fusion of control and information is security. Whereas reliability can be achieved by practices such as system redundancy, for reasons of ensuring safety, there are cases in social infrastructure in particular when it is and when it is not permissible for services to shut down, and you can't just put a lid on whatever you want. I believe this to be particularly problematic in a symbiotic autonomous decentralized world.

Kato: That's right. The design concept used under the original autonomous decentralization systems concept was for nodes to improve resilience to faults by making their data available for mutual access so that they can perform autonomous diagnosis of other nodes and protect themselves if an anomaly is found. We are considering extending this same concept to security.

Furthermore, control systems tend to have a hierarchical design with defensive systems invariably provided for the most important components that connect directly to the equipment being controlled, such that the minimum level of safety can be maintained even in the event of a problem occurring at a higher level. I see the basis of symbiotic autonomous decentralized security as being the provision of demarcated interconnections by, for example, installing gateways between the information system level close to services and the control system level.

Aragane: Traditionally, control systems have been designed on the basis that protection is provided for those areas that need it not by software but physically using currents and so on. But even if the way in which signals are sent to the higher levels has changed, the idea of hierarchical protection will likely remain the same.

Irie: For the security of social infrastructure that is required to respond to threats and ensure the continuity of service supply, we have proposed the Hitachi system security concept. This is expressed in terms of "adaptivity," "responsivity," and "cooperativity." The concept defines three requirements for social infrastructure security. These are: to provide ongoing countermeasures to increasingly diverse threats by working through the plan, do, check, act (PDCA) cycle; to respond promptly to unanticipated attacks so as to minimize damage; and to prevent the spread of damage to other interdependent systems by coordinating across organizations and systems and maintaining a shared situational awareness. The concept has been proposed to the International Electrotechnical Commission (IEC) with the aim of having it adopted as a global standard.

Kobayashi: Combined with comprehensive control system safety and security, the use of information can deliver new value to both the operators and users of railway services, for example, by integrating the railway reservation, smartcard ticketing, and other systems with the traffic management system to enable realtime changes to departure times or to provide additional services based on actual user levels. Our aim is to use initiatives like this not only to provide greater convenience for users but also to increase value throughout the industry and society as a whole by enabling the world of control systems to take advantage of the possibilities of the information world.

Tanaka: It is highly significant that Hitachi has built up such a trusted brand in the field of control systems. I look forward to your delivering even greater benefits to your customers and other parts of society through the use of information systems with this brand as a foundation.

Hotta: Given that the past practice with social infrastructure systems has been to make improvements at the level of individual systems, there remains great potential for utilizing IT to optimize the infrastructure as a whole. Hitachi intends to continue enhancing its control system technology in order to contribute to Social Innovation. Thank you for your time today.

Overview

Information and Control Systems

—Open Innovation Achieved through Symbiotic Autonomous Decentralization—

Naohiko Irie, Dr. Eng.
Akihiro Ohashi
Takeshi Onodera
Hiromitsu Kato, Ph.D.

TRENDS IN SOCIAL INFRASTRUCTURE

THE manufacturing industry in particular has been home to considerable activity in recent years targeting new innovations based on the IoT[(a)]. This has included standardization initiatives and the creation of ecosystems that tie together the manufacturing and IT industries, with the launch in the USA of the Industrial Internet Consortium (IIC) led by General Electric Company (GE), and the launch in Germany of the government-led Industrie 4.0 initiative.

The aims of the IoT can be broadly divided into improving the efficiency of the producers of

(a) IoT
An abbreviation of "Internet of things." A technology for automatic recognition, measurement, interoperative control, etc. achieved by providing communication functions in various devices that, in the past, were not connected to networks and connecting them to the Internet to exchange information.

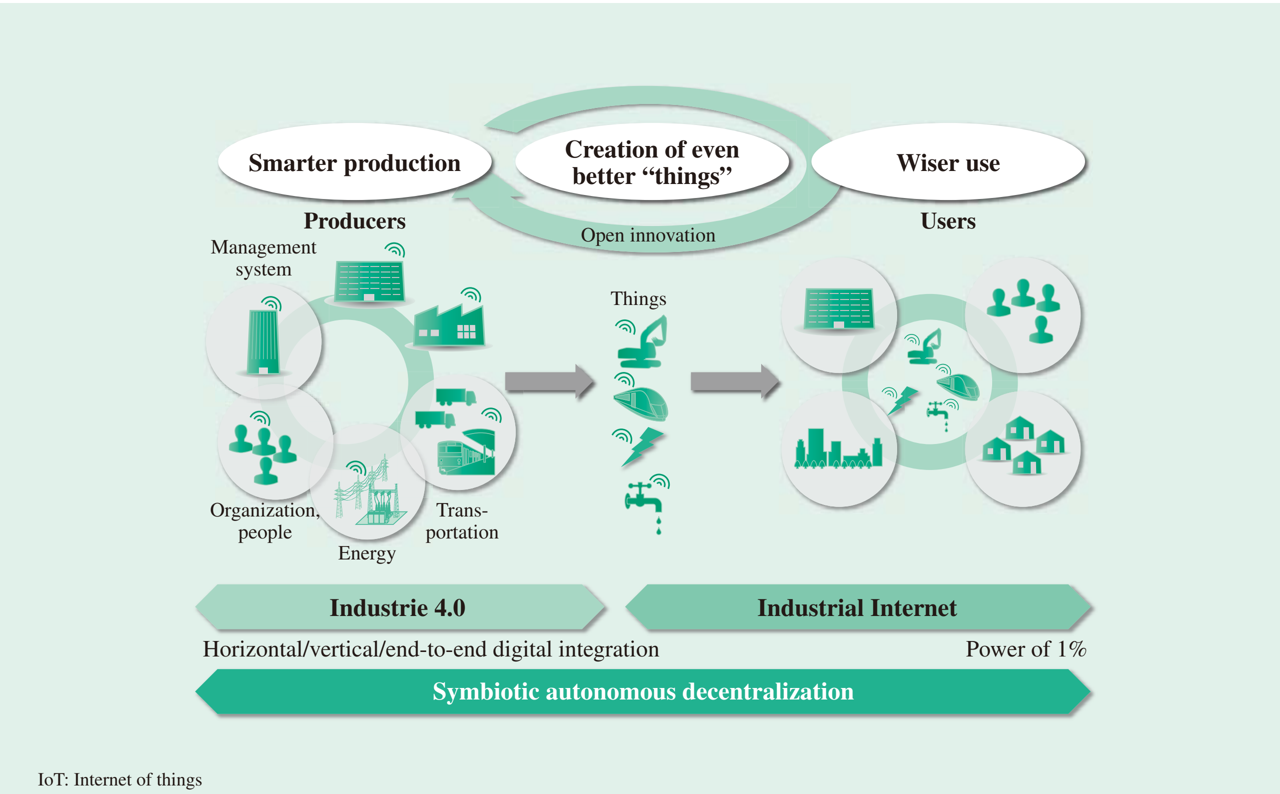


Fig. 1—Role of IoT.
The IoT enables smarter production and wiser use by utilizing information from "things," and facilitates the creation of even better "things."

things[*1], and improving convenience for the users of these things (see Fig. 1). Smarter production can be achieved by producers using the IoT in plants and equipment (as shown on the left side in Fig. 1) to deliver benefits such as higher productivity and lower inventory. Industrie 4.0 is primarily focused on this aspect, seeking to achieve three forms of integration, namely vertical integration to link management and production facilities, horizontal integration to link factories together, and end-to-end digital integration to tie together design, manufacturing, and maintenance(1).

Meanwhile, it is also possible to use things more wisely by collecting and utilizing data on how they are used (as shown on the right side in Fig. 1), with benefits that include optimized maintenance and more efficient ways of using these things. It is this that is the main target of the IIC, such as fitting sensors to gas turbines or aircraft engines, for example, and analyzing the data to improve things like utilization and maintenance efficiency. An improvement of 1% in efficiency can deliver significant benefits(2).

The progress of the Internet economy in recent years has created a variety of new practices and information links between stakeholders. This is ushering in an era of open innovation in which a steady stream of new business models are being created, such as taxi dispatch or accommodation information services. It is anticipated that this will encourage new growth by establishing new value chains and industry structures for things through cross-industry flows of big data generated from the field via the IoT(3).

Hitachi has long been involved in the development of the systems used in the production of things, namely the control systems used for energy, transportation, water, sewage, and other parts of the social infrastructure, and the control systems used by manufacturers of products such as steel, automobiles, and pharmaceuticals. Hitachi also has extensive experience in the development of core information systems, such as those used for finance, the public sector, and corporate information. It has proposed the symbiotic autonomous decentralization concept, which encourages new growth by drawing on the knowledge acquired through this work and supplying the value created by linking together different systems and practices to all the stakeholders involved with things.

*1 This refers not only to the products of the manufacturing industry but also to the electric power, water, and other utilities provided by social infrastructure.

This article presents an overview of the symbiotic autonomous decentralization concept and describes what Hitachi is doing to implement it.

SYMBIOTIC AUTONOMOUS DECENTRALIZATION CONCEPT

Hitachi's concept of autonomous decentralization has its origins in control systems. Drawing on advances made since the 1970s in such technologies as networks and microcomputers, Hitachi has developed autonomous decentralized control systems with excellent reliability and expandability by sharing the information required for control across controllers, servers, and other control nodes so that each node can perform its own functions autonomously based on this information. These systems have been put to use in such fields as transportation and the steel industry(4).

Advances in sensing, networking, and big data analytics in recent years have created the potential for open innovation through the shared use of information from plants and equipment by management and other relevant stakeholders as well as within the control system itself. In other words, control systems have evolved from being a network of things to an Internet of things that makes information more widely available. In response, Hitachi has devised its symbiotic autonomous decentralization concept, which extends the concept of autonomous decentralization described above to the system level (see Fig. 2).

In a symbiotic autonomous decentralized system, the individual systems at factories or belonging to other stakeholders act as autonomous entities. While they each operate autonomously using their own internal information, to optimize their collective operation, they also collect real-world information (sensing) and make it available in cooperating fields (shared-access platforms). The cooperating fields perform problem analyses using the wide variety of collected and archived information and plan countermeasures for optimizing both system-wide KPIs(b) and the KPIs for the individual autonomous systems (thinking). These countermeasures are then provided to the individual autonomous systems as feedback so that they can achieve their applicable KPIs (acting).

(b) KPI
An abbreviation of "key performance indicator." A KPI is distinguished from other indicators used to monitor the progress of business processes by pointing out particularly important indicators of performance. A quantitative index that measures the degree to which organizational objectives have been met.

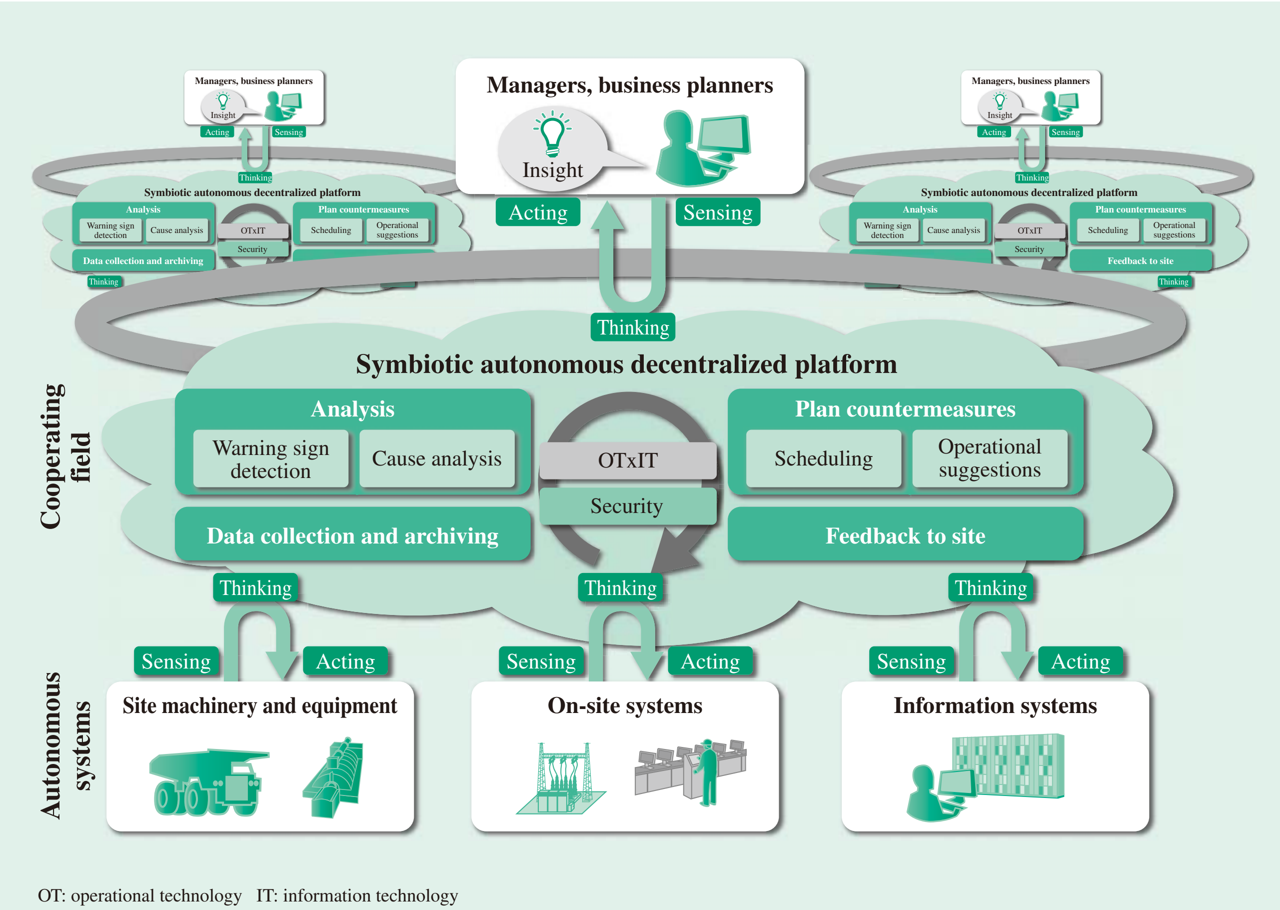


Fig. 2—Symbiotic Autonomous Decentralization Concept.
Activities can be optimized in terms of management considerations and new value chains created by collecting and archiving data from a variety of on-site systems, analyzing it and planning countermeasures, and providing information back to the site as feedback.

By using data-driven knowledge obtained via the IoT collected on the cooperating fields in conjunction with knowledge of system configurations and operation in such fields as energy, transportation, water, sewage, and manufacturing, which Hitachi calls operational technology (OT), it is possible to achieve optimal operation in ways that would not be possible by relying solely on knowledge of the individual autonomous systems. New business models can be created by sharing the various forms of knowledge generated by and collected in the cooperating fields with stakeholders from other industries.

INFORMATION AND CONTROL PLATFORM TECHNOLOGY FOR IMPLEMENTING SYMBIOTIC AUTONOMOUS DECENTRALIZATION

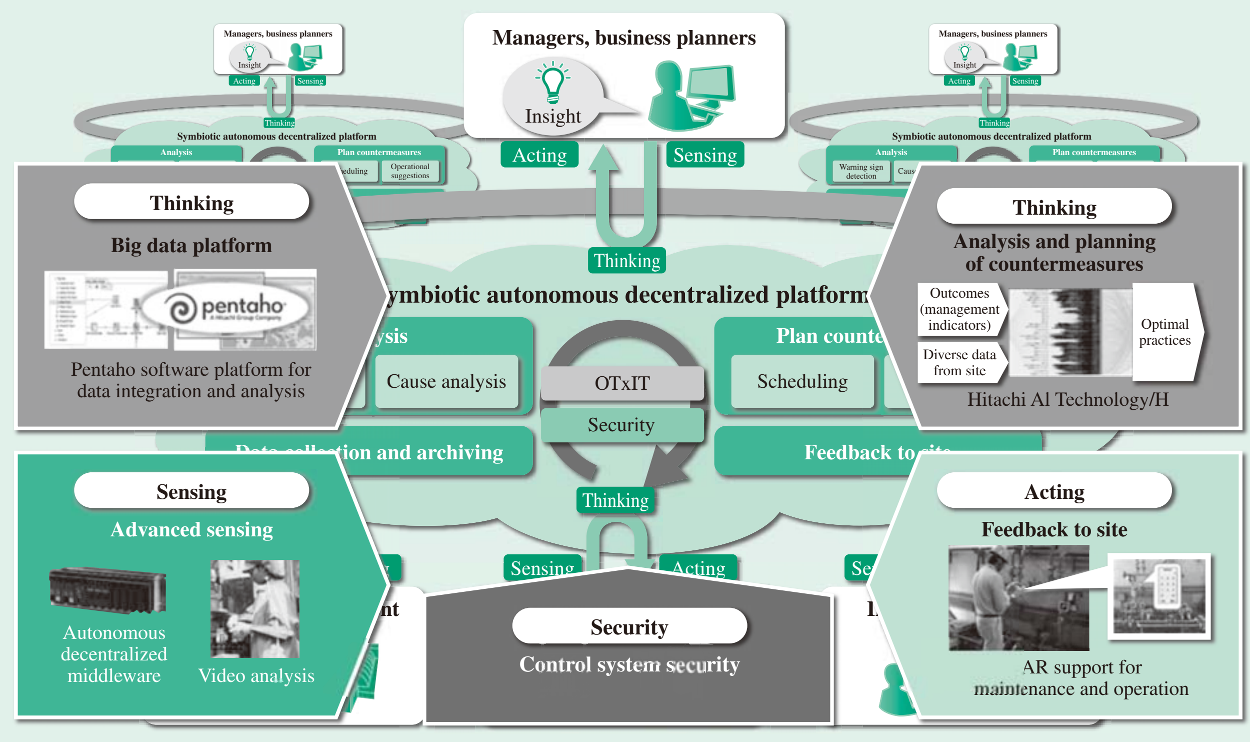
The following four requirements must be satisfied in order to implement systems based on the symbiotic autonomous decentralization concept (see Fig. 3).

(1) Advanced sensing to achieve the "sensing" objective
(2) Big data platforms for collecting and archiving a variety of data and techniques for analysis and for planning countermeasures to achieve the "thinking" objective
(3) Ways of providing feedback to the workplace to achieve the "acting" objective
(4) Security techniques to protect the cooperating fields and autonomous systems

The following describes work by Hitachi on each of these requirements.

(1) Advanced sensing

Advanced sensing requires data acquisition techniques for sending data to information systems; data that, in the past, was only used within control systems. To achieve this, Hitachi has developed communications middleware that utilizes a framework for data sharing in autonomous decentralized systems. Furthermore, as the falling cost of cameras and advances in video analysis techniques are making it possible to perform sophisticated surveillance



AR: augmented reality

Fig. 3—Technology for Building Symbiotic Autonomous Decentralized Platforms.
The required technologies include advanced sensing, big data platforms, techniques for analysis and the planning of countermeasures, techniques for providing feedback to the site, and security.

(sensing) of plant workers and equipment, Hitachi is developing techniques for tracking what is going on across entire workplaces.

(2) Big data platforms and techniques for analysis and the planning of countermeasures

Big data platforms need to deal with the three characteristics of big data, namely volume, variety, and velocity. Dealing with variety is particularly important in the implementation of symbiotic autonomous decentralization in order to handle data from a wide variety of systems. This field has seen notable advances in open-source software (OSS), and Hitachi is promoting the use of the Pentaho software platform for data integration and analysis.

For tasks such as analysis and the planning of countermeasures, there is rising demand for artificial intelligence (AI) as a way of uncovering new knowledge from large volumes of data that could not be obtained by manual methods. For this purpose, Hitachi has developed Hitachi AI Technology/H[5]. This AI takes those outcomes that are used as management indicators, and a wide variety of data from the workplace, and inputs these all at once to analyze the many relationships between this data and automatically identify the factors that have the greatest influence on maximizing the outcomes. The technology has proven its worth in a variety of fields, including logistics, plants, and call centers.

(3) Providing feedback to the workplace

This means the provision of feedback to control systems, workplace staff, and so on. In the former case, this requires modifications to systems such as MESs[c] or DCSs[d]. It is anticipated, meanwhile, that

(c) MES
An abbreviation of “manufacturing execution system.” An information system used at a manufacturing plant to execute production plans. Key functions include allocation and monitoring of production resources, work scheduling, manufacturing instructions, specification and document management, plant data collection, worker management, product quality management, process management, equipment maintenance management, product tracking and product range management, and the analysis of actual data.

(d) DCS
An abbreviation of “distributed control system.” The control of production or other processes in which, rather than having a single controller perform centralized control of everything, the equipment used in the system is equipped with control functions and performs integrated control with mutual coordination.

feedback to staff will become increasingly important in the future, with work proceeding on applications like the use of augmented reality (AR)[(e)] for maintenance support and the use of wearable devices.

(4) Security

Because control systems in the past tended not to be connected to IT systems, security problems were believed to be comparatively rare. In anticipation of the use of the IoT, however, control system security techniques are important for protecting systems against external cyber-attacks. Control system security requires multiple levels of defense, including security gateways that defend against intrusions from outside the system, mechanisms for detecting incidents such as unauthorized intrusions or virus infections, and security controllers that protect equipment against unauthorized intrusions or viruses. Hitachi is working on the development of these respective technologies and products.

HITACHI INITIATIVES FOR ACHIEVING SYMBIOTIC AUTONOMOUS DECENTRALIZATION

To implement the symbiotic autonomous decentralization described above, Hitachi is taking steps to apply these practices in social infrastructure and manufacturing, and is developing platform technologies. This section describes these initiatives.

Applications in Social Infrastructure

(1) Shinkansen integration system

While the Computerized Safety, Maintenance and Operation Systems of Shinkansen (COSMOS) system of the East Japan Railway Company has used an autonomous decentralized control system, the characteristics of this system were utilized in system development undertaken in preparation for extensions to the Shinkansen network (the extension of the Hokuriku Shinkansen to Kanazawa and of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto[*2]). These extensions required trains to share sections of track used by other railway companies and to integrate with newly developed systems (see p. 26).

(e) AR
An abbreviation of "augmented reality." The overlaying of information provided by a computer onto an actual environment or object. Examples of AR techniques used in practice include providing additional information about real-world objects visible through a transparent device or camera by displaying text, images, or other electronic information over the object.

*2 The Hokkaido Shinkansen to Shin-Hakodate-Hokuto opened for business in March 2016.

(2) Energy management for water supply and sewage infrastructure

As water supply and sewage infrastructure is a major user of energy, requirements include reducing energy costs and shifting or cutting peak demand. Hitachi is working on demand response practices that involve interoperation between water and energy systems to achieve more advanced water supply operation plans. Other work includes the optimization of treated water quality and energy consumption in sewage treatment control (see p. 34).

(3) Energy systems

The demands that will be placed on future energy infrastructure include the installation of new renewable energy capacity, upgrading of aging plants, deployment in emerging economies that suffer from skill shortages, and combining safety and security of supply with economic and environmental performance. The key to achieving these lies in stakeholders (power utilities, maintenance suppliers, equipment vendors, and users) seeking not only to find their own best solutions, but also working together to optimize the overall industry. Hitachi is working on the development of systems that minimize waste (energy losses) without compromising the autonomy of individual stakeholders by using the IoT and other information and communication technology (ICT) to collect real-world data and replicate value chains in cyberspace, and to devise measures for things like more sophisticated operation or the identification and application of knowledge (see p. 20).

Applications in Manufacturing

(1) Next-generation global production management

The objective here is to avoid major product recalls by installing cameras at assembly or machining factories to collect and analyze workplace video, including video of production machinery and workers, and by linking this video to the manufacturing execution system, so as to simplify the task of determining the scope of any defects that occur at these factories and to help in other ways such as providing feedback to production practices. Hitachi is also working on product quality improvement at a global level by consolidating and analyzing information from factories around the world to determine the cause of defects and suggest improvements (see p. 47).

(2) Steel industry control systems

Because the control systems used in the production of flat and long steel products are subject to frequent retrofits and modifications, Hitachi has long engaged in the practice of using autonomous decentralized systems with excellent expandability. It is also seeking to achieve more advanced control by using ICT for data collection and analysis and providing feedback to control systems in realtime. These practices have been applied to strip thickness control, and Hitachi plans to expand the scope of this use of information even more (see p. 41).

(3) Next-generation IoT-based production system for high-mix low-volume production

While Hitachi's Omika Works has engaged in improvements to design and manufacturing in the past, these initiatives have been fragmented and have not extended beyond improvements to specific areas. Accordingly, the site is building a next-generation IoT-based production system with the aim of optimizing overall operation from a management perspective while also dealing with customized products that will only grow in diversity in the future (see p. 58).

Development of Platform Technologies

(1) Vision sensing systems

Video surveillance systems are increasingly being installed to provide physical security, and Hitachi is working on the use of these as on-site sensing systems for resolving management challenges. To achieve this, Hitachi is developing video analysis techniques that can analyze video in realtime to transform it into meaningful information (see p. 53).

(2) Social infrastructure security

The risk of cyber-attack on information and control systems is growing year by year, with the increased vulnerabilities associated with use of the IoT becoming a concern. Hitachi has proposed the "Hitachi system security concept," which focuses on system-wide continuity and expandability, and supplies security solutions based on the concept (see p. 64).

(3) Information and control platforms

Implementing symbiotic autonomous decentralization requires new open-access practices for the secure collection of data from plant systems. Hitachi is developing networks, data collection middleware, and control security products that are designed for this purpose (see p. 70).

CROSS-INDUSTRY DEPLOYMENT AND OPEN INNOVATION

This article has given an overview of the symbiotic autonomous decentralization concept and platform technologies, as well as the work Hitachi is doing to implement these.

In the future, Hitachi plans to deploy this concept and technology in a variety of sectors, including energy, transportation, urban development, and manufacturing. It also aims to use open innovation to build value chains that span multiple industries, and in which diverse knowledge is shared to facilitate new growth.

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Featured Articles

Energy Infrastructure and ICT Systems

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Takashi Fukumoto
Yasuo Sato
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OVERVIEW: While nations around the world consider what constitutes the best mix of electric power sources given the adoption of renewable energy, and with both developed and emerging economies facing their respective workforce and equipment challenges, electric power infrastructure needs to remain in continuous operation with safety as its top priority. To support the energy infrastructure, Hitachi supplies solutions that improve the value of power systems to customers by making the best possible use of ICT based on highly reliable plant control technology built up over time. This involves working closely with customers to assess what is happening in the workplace and identify challenges in order to use ICT to implement total solutions for the electric power business that extend from improving the operational efficiency of equipment and optimizing maintenance to speeding up business operations.

INTRODUCTION

AS exemplified by such initiatives as Industrie 4.0 and the Industrial Internet, advances in information and communication technology (ICT) are accelerating the pace of innovation in industry. By giving access to previously unavailable information and other data and providing greater processing capacity, this has opened up extensive possibilities, including expanding the scope of optimization, sophisticated processing, the dissemination of better practices, and the integration of industries from different sectors(1). This has been accompanied by dramatic growth in the number and range of stakeholders, equipment, and other factors involved in the operation and control of specific processes. In place of past operating practices based on information and data from a limited range of sources, the requirement now is for machinery, equipment, organizations, and industries to deal with information and data from a much wider scope. When this happens, it opens up the potential for innovation in ecosystems made up of traditional stakeholders(2).

Nations around the world are responding to the problem of global climate change by looking at what constitutes the best mix of energy sources in their electric power systems, including the adoption of renewable energy. Meanwhile, developed economies are having to deal with aging equipment and falling numbers of skilled staff, while emerging economies face the challenges of establishing infrastructure and recruiting skilled staff. Compounding these challenges, the energy infrastructure is an essential service that needs to remain in continuous operation with safety as its highest priority(3).

Given these circumstances, the key to the safe and reliable maintenance of operational continuity together with ongoing sound management is the use of ICT and its potential for bringing innovation to the industry.

This article covers the current state of electric power systems and presents examples of new solutions that use ICT, together with the new challenges facing the industry and the outlook for its future.

ICT SYSTEMS OFFERING NEW POSSIBILITIES FOR ENERGY EFFICIENCY

Increasing Importance of ICT

Hitachi interprets the plan, do, check, act (PDCA) cycle used to optimize operations in the electric power business as follows (see Fig. 1).

Plan: Formulate plans for equipment operation, shutdowns, maintenance, and upgrades that optimize performance at a system-wide level.

Do: Follow sound operation and maintenance practices based on the plans.

Check: Monitor equipment efficiency and problems, analyze and assess equipment data, and conduct internal audits and management reviews.

Act: Improve maintenance practices, reprioritize work, remedy equipment problems, take preventive measures, and train staff.

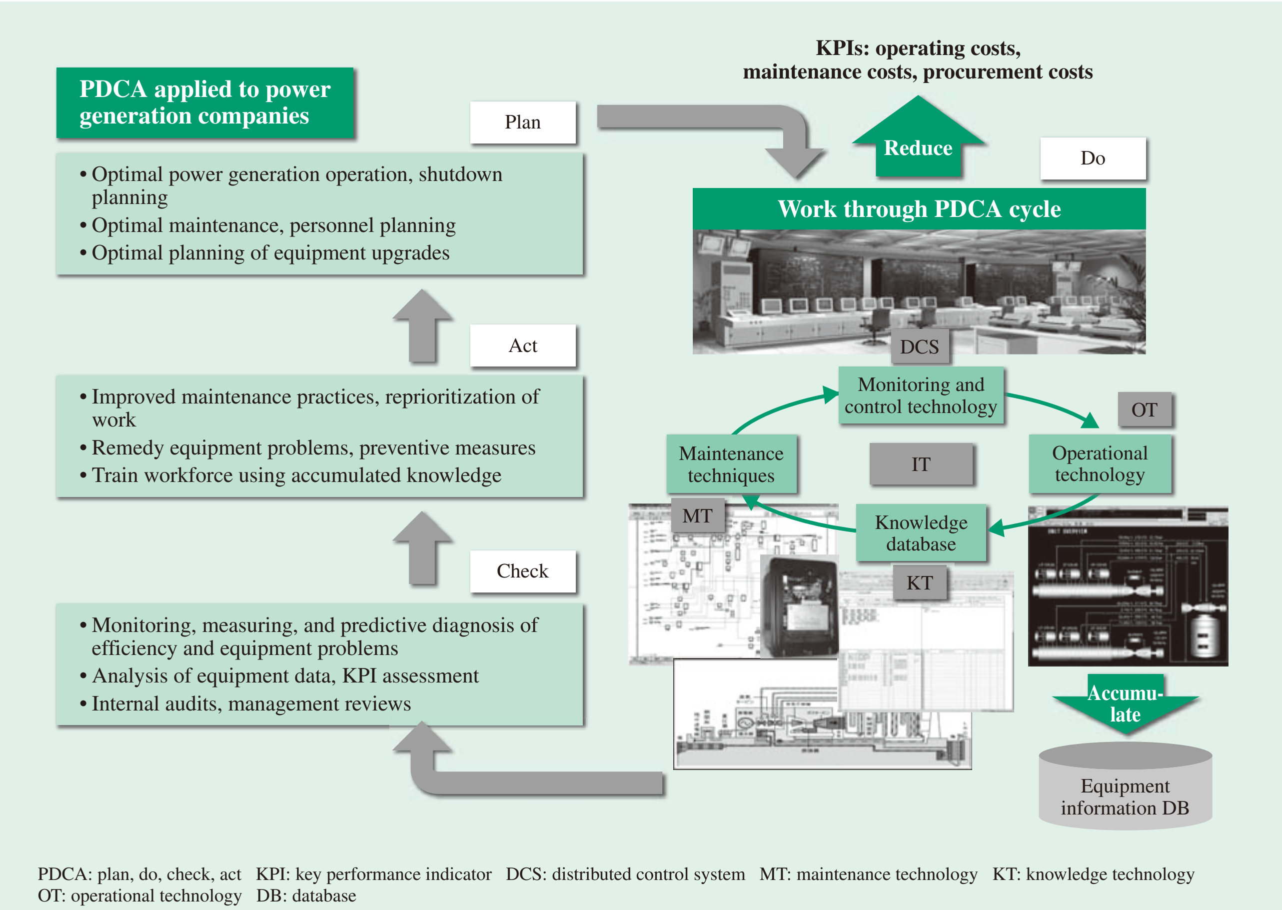

Fig. 1—PDCA for Optimal Operation of Electric Power Businesses.
Working through the PDCA cycle effectively and efficiently requires accurate decision making based on extensive operational experience and knowledge.

In the case of a power plant, for example, working through the PDCA cycle effectively and efficiently requires accurate decision making based on extensive operational experience and knowledge, while also making effective use of plant data items numbering anywhere between several hundreds and several tens of thousands together with a wide variety of information about equipment and machinery. The major challenges to achieving this include obtaining and rapidly up-skilling highly skilled staff.

In the future, use of ICT that supplements human skills will become an increasingly important factor in overcoming these challenges. In response, Hitachi has been developing new solutions that will improve the overall efficiency of the energy infrastructure through a fusion of control and ICT. The following are some notable examples.

(1) System for cost-based analysis of operational efficiency

To quantify improvements in operational efficiency at power plants, Hitachi has developed a system that takes maximum advantage of large amounts of collected sensor data and other maintenance information to analyze current costs and forecasts.

(2) Support system for optimizing operation and maintenance

Hitachi is currently developing a system that supports optimal operation by automatically determining operation patterns under different operational circumstances from plant data items that number in the tens of thousands, and assessing the benefits based on the results of simulation using physical plant models (see Fig. 2).

A feature of the system is that, by plotting information such as the results of potential fault detection and the modeling of plant data on a fault tree analysis (FTA) diagram, it presents information about maintenance, operation, and other procedures, and about the associated background factors, in a form that makes sense to operators and other staff, while also building up knowledge in the form of FTA itself.

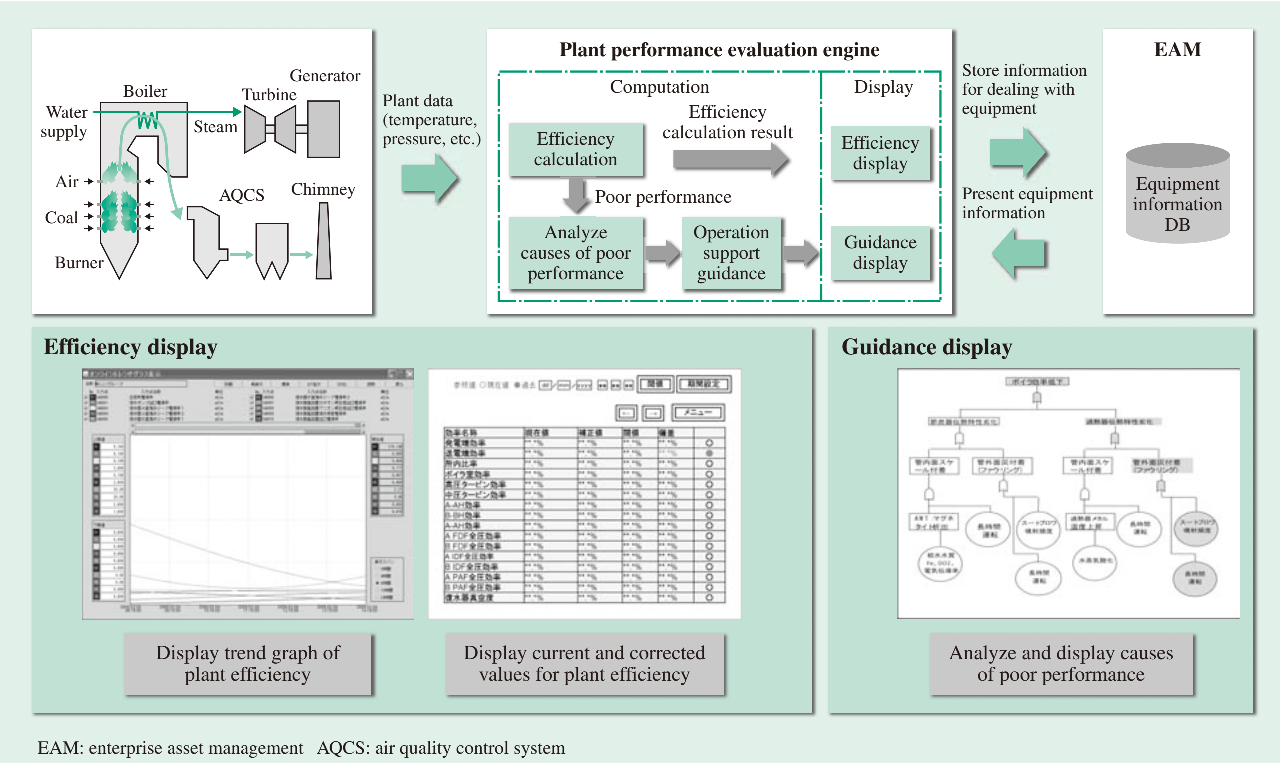

Fig. 2—Example Solution for Evaluating Plant Performance.
Hitachi is developing systems that perform realtime analyses to determine the causes of poor performance from large amounts of plant data and provide guidance on optimal operation.

(3) Visualization tool for management key performance indicators (KPIs) and risks

Hitachi is developing management improvement solutions that include a tool for improving power generation efficiency, incorporating analysis of the causes of poor power plant efficiency, improvements to boiler combustion efficiency, and reductions in the load on the environment, and a plant diagnosis tool that uses a proprietary clustering technique. These solutions are marketed together with consulting on installation.

Based on control technology and packaged as systems or services along with information technology (IT) business systems, these solutions can improve workforce skills and deliver efficient power plant operation by offering all-in-one know-how that covers everything from energy system planning to maintenance. Hitachi is currently marketing the solutions to customers in Japan and elsewhere by offering to tailor them to the specific challenges facing each customer (see Fig. 3).

Symbiotic Autonomous Decentralization with Advanced ICT

Hitachi has in the past promoted the concept called autonomous decentralization, which refers to systems that can respond rapidly to changes such as internal faults or new functions(4). Systems that adopt autonomous decentralization can establish relationships between themselves autonomously through the hierarchical addition or removal of autonomous components whenever a fault occurs or a new feature is added. This makes the overall system capable of rapid and ongoing expansion(5).

In the case of systems that support social infrastructure, Hitachi believes that the following ICT elements are required for symbiotic autonomous decentralized systems that incorporate ICT while still following the autonomous decentralization concept.

(1) ICT for system-wide connectivity

This means serving as a platform for the exchange of information and data. This interconnects information systems belonging to a large number of stakeholders, collecting information and data from the individual systems and providing information and data from the platform to them.

(2) ICT for system-wide coordination and optimization

This relates to the overall operation of social infrastructure with consideration for its system-wide efficiency. Explicit instances of this sort of ICT can serve as optimization or management centers, or it

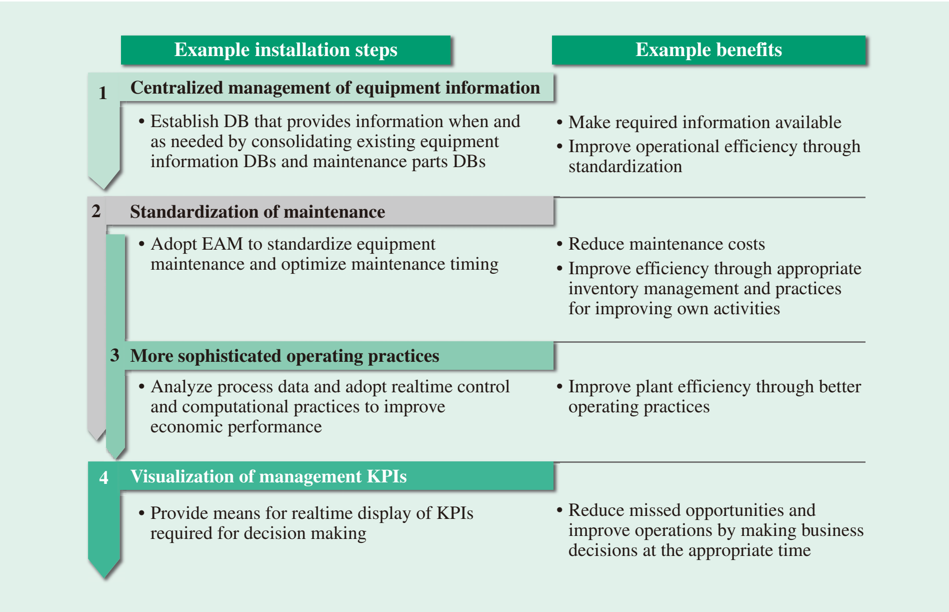

Fig. 3—Example Installation of Solution for Working Closely with Customers.
Hitachi is consulting with customers about their specific challenges and, based on a common understanding of their current situations, is marketing solutions that suit their budgets and the issues they face.

can operate implicitly whereby matters are handled through individual autonomous decision making. In the latter case, some form of mechanism is required to guide these decisions, such as a formal system, market rules, or business model.

(3) ICT for individual businesses

This element of ICT integrates with cooperating fields (shared access platforms) to supply or retrieve information and data in these cooperating fields.

(4) ICT associated with operations at individual businesses

This ICT element includes functions for interoperating with other businesses through these businesses making their own autonomous decisions, and functions for businesses to make optimal use of their own resources.

Along with serving as a platform for the electric power business, the application of symbiotic autonomous decentralized systems in the energy infrastructure is also becoming a core technology that will make a major contribution to the development of this business.

For example, by providing a capability for integrated management by sharing the results of efficiency analyses conducted for individual power plants across a number of such plants at different locations, rather than limiting them to single plants, or by providing a capability for the organic combination of management information on such things as fuel markets, consumers, or the redistribution of electric power, which have not been managed at power plants in the past, and simulating business scenarios in cyberspace, it is possible to improve value to customers in ways not possible in the past by adopting autonomous decentralization over a wide area (see Fig. 4).

Hitachi has built up capabilities in the control field for coordinating and maintaining high system reliability, and for resolving operational problems. The aim is to combine these with ICT to supply systems or services that help solve operational problems while maintaining close relationships with customers to

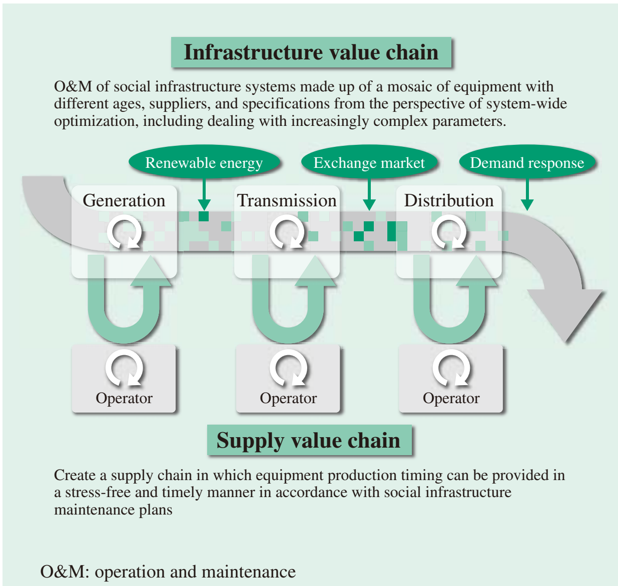

Fig. 4—Use of Symbiotic Autonomous Decentralized Systems in Energy Infrastructure.
The aim is to increase value to customers by adopting autonomous decentralization over a wide area.

deal with management challenges such as delivering best practices in a timely manner or making decisions (choosing between tradeoffs) in a variety of different situations that in the past have been difficult or time-consuming due to uncertain information.

USE OF OODA LOOP TO ENHANCE SECURITY

In addition to compliance with international and industry standards, it is important for new electric power businesses in particular to implement required security measures, and to determine the level of security in accordance with the importance (safety or extent of damage) of the equipment concerned.

The electric power business requires both physical security measures that counter the security threats that arise from the installation of machinery and all forms of electrical and control equipment, such as power plants and substations; and cybersecurity measures that counter threats to information and control systems that use ICT. Furthermore, because growth in the sophistication and scope of services means that they now have an influence on the operation and management of power generation, transmission and distribution, and retailing, there is also a need for measures to deal with an even wider range of security threats. Due to the use of ICT practices, it is expected that threats like these will have impacts that occur quickly and over a wide range, and that they can affect all aspects of the business.

To repel the sophisticated cyber threats that now exist, rather than only providing adequate security functions during the development phase, security measures for the operational phase are growing in importance. In the operational phase, the security of a system is assessed by collecting and analyzing data from various different points within the system with the aim of maintaining the security features incorporated during development. As a result, problems that arise are detected and dealt with quickly. That is, in addition to the PDCA cycle that covers activities from planning to improvements and repair, quick and accurate decision making together with faster and stronger security measures can be achieved through use of the observe, orient, decide, act (OODA) loop[(6), (7)].

CONCLUSIONS

While this article has presented examples from the energy infrastructure, all social infrastructure systems require the same sort of sustainable systems in the sense of being able to expand and grow in stages. Sustainability is achieved by natural world systems that go through a repeated process of construction and decay, followed by regeneration.

To achieve sustainable growth of the social infrastructure, Hitachi ICT systems seek not only to provide appropriate operation, but also to establish a cycle in which reinvestment in the social infrastructure is facilitated by supporting investment decisions and enabling appropriate cost recovery. Hitachi intends to provide sustainability in ways that make economic sense throughout social infrastructure systems.

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Featured Articles

Traffic Management Systems for Expanding Shinkansen Network with Trouble-free Operation of Mutual Direct Trains

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Shuujirou Tamura
Yoshihiko Tsuchiya
Masahiko Isogai
Kenji Ohta
Tetsunari Yamami
Makoto Sato

OVERVIEW: In this time of global environmental problems and overcrowding in cities, the value of railways is being reappraised because of their role as a means of transportation that can handle large volumes with excellent energy efficiency compared to automobiles or aircraft. The Shinkansen is Japan's flagship high-speed railway, with a network that has been expanded in accordance with plans established by the Nationwide Shinkansen Railways Construction and Improvement Act. This has included steady progress on expanding the network over recent years, with the opening of the extension of the Hokuriku Shinkansen to Kanazawa in March 2015 and the launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto in March 2016. These two new Shinkansen services include mutual direct trains, meaning through-train services that operate over more than one railway company jurisdiction. While the operation of these services is more complicated than those that only involve a single company, they still need to ensure that the Shinkansen operates reliably and that passengers can enjoy trouble-free services. To achieve this, the Shinkansen traffic management systems need to support safe and reliable operation by ensuring that services match customer needs. Hitachi has been involved in developments and improvements to the Shinkansen traffic management systems that ensure the trouble-free operation of these mutual direct trains.

INTRODUCTION

RAILWAYS are a means of transportation that can handle large volumes with excellent energy efficiency compared to automobiles or aircraft, making them an important part of the social infrastructure. The Shinkansen is Japan's flagship high-speed railway and is known around the world for providing safe and punctual services. The Shinkansen traffic management systems, meanwhile, play a major role in ensuring this safety and punctuality.

The expansion of the Shinkansen network is being undertaken in accordance with plans established by the Nationwide Shinkansen Railways Construction and Improvement Act in 1973. This expansion has continued into recent years, with the Hokuriku Shinkansen between Nagano and Kanazawa commencing operation in March 2015 and the Hokkaido Shinkansen between Shin-Aomori and Shin-Hakodate-Hokuto in March 2016 (see Fig. 1).

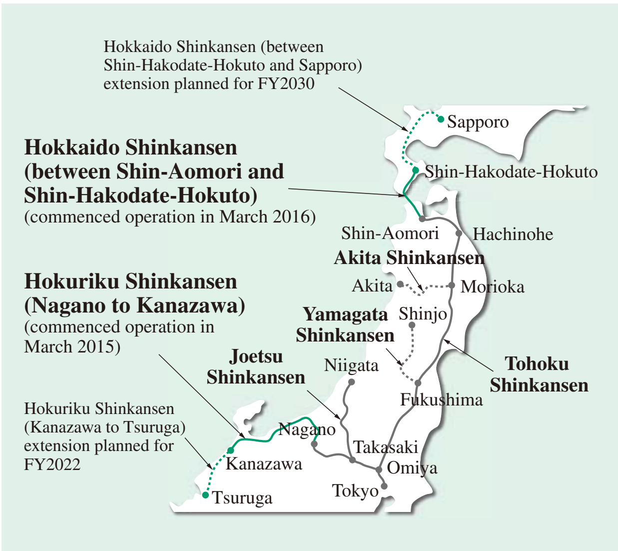

Fig. 1—Expansion of Shinkansen Network.
The expansion of the Shinkansen network brings significant benefits to industry and other parts of society by shortening travel times between regions.

These two new services include "mutual direct trains," meaning through-train services operated jointly by two different railway companies. The opening of the extension of the Hokuriku Shinkansen to Kanazawa includes joint services run by East Japan Railway Company (JR-East) and West Japan Railway Company (JR-West), and the launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto includes joint services run by Hokkaido Railway Company (JR-Hokkaido) and JR-East. While the operation of mutual direct trains must take account of the borders between railway company jurisdictions, customers should be able to ride on the Shinkansen without having to concern themselves with such issues.

This article describes the computerized safety, maintenance and operation systems of Shinkansen (COSMOS) and the CYGNUS* traffic management systems used by the Shinkansen that have undergone further development and improvement to satisfy these requirements.

OVERVIEW OF COSMOS TRAFFIC MANAGEMENT SYSTEM

COSMOS provides comprehensive management for the Tohoku, Joetsu, and Hokuriku Shinkansen lines, covering everything from operational planning to traffic management, rolling stock management, and engineering works management. It was developed with the aim of upgrading the Computer Aided Traffic Control (COMTRAC) system installed when the Tohoku and Joetsu Shinkansen entered service in 1982 to a total system based on a new concept that could deal with the growing volume and changing nature of traffic, and commenced operation in 1995. The traffic management system in COSMOS serves as a comprehensive management system for traffic on the Shinkansen line and supports safe and reliable train operation that can cope with the increased complexity of Shinkansen operations that has resulted from operational practices that include high-speed, high-density services with the coupling and decoupling of rolling stock, diverse rolling stock configurations, and track extensions.

Traffic Management System

The traffic management system manages train operation over the course of a day. In addition to

* A name coined from a combination of letters taken from "traffic control system," "standard and narrow gauge," "north of earth," "united of operation and maintenance," and "Hokkaido Shinkansen."

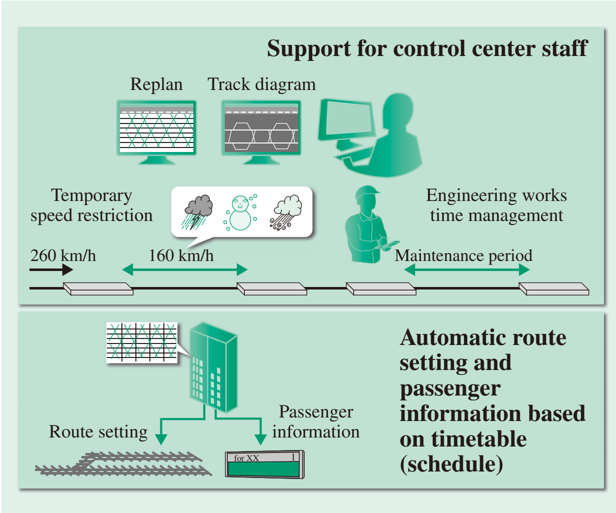

Fig. 2—Main Functions of the Traffic Management System.
In addition to performing automatic control of train movements in accordance with the schedule, the system also provides functions that support the work of control center staff.

functions such as automatic route setting and passenger information that are based on the train schedules, it also supports the work of control center staff who need to coordinate traffic in accordance with changing operational circumstances when abnormal situations arise. Support functions for control center staff include a track diagram function for presenting information about actual operation, a replan function that supports same-day replan work, a temporary speed restriction function that sets speed limits based on railway line conditions, and engineering works time management that manages the times when the railway line is in use by trains and when it is available for performing engineering work (see Fig. 2).

One of the major features of the COSMOS traffic management system is train running prediction, which forms part of the replan function, and predicts future operation based on the train running result (actual data) and constants such as predefined basic running times (time between stations) and displays the results on operators consoles in table format. Train running prediction helps control center staff anticipate future operational circumstances and assists decision-making for same-day replan work.

Autonomous Decentralized System

The COSMOS traffic management system is an autonomous decentralized system in which a traffic management hub located at the control center is linked to automatic route setting at each station via a wide-area optic fiber network.

In addition to control link redundancy and support for open networks that include a variety of different types of computers, autonomous decentralized systems can also adopt a hierarchical system configuration. Because this feature simplifies the retrofitting of new equipment, it can easily cope with the installation of station equipment, such as when a new station is commissioned.

DEVELOPMENT IN PREPARATION FOR OPENING OF THE EXTENSION OF THE HOKURIKU SHINKANSEN TO KANAZAWA

Overview of Opening of the Extension of the Hokuriku Shinkansen to Kanazawa

The Hokuriku Shinkansen commenced operation between Takasaki and Nagano in October 1997. The opening of the extension of the Hokuriku Shinkansen to Kanazawa added services between Nagano and Kanazawa, with direct trains between Tokyo and Kanazawa commencing from March 2015.

The two main features of the opening of the extension of the Hokuriku Shinkansen to Kanazawa are as follows.

The first is that it was larger than other new Shinkansen services added in recent years, adding approximately 240 km of railway line and seven stations.

The second is that two of its stations, at Iiyama and Joetsumyoko, fall under JR-East jurisdiction whereas the other five stations from Itoigawa to Kanazawa are in the JR-West jurisdiction. This means that the Tokyo-Kanazawa service of the Hokuriku Shinkansen is the first to involve mutual direct trains (see Fig. 3).

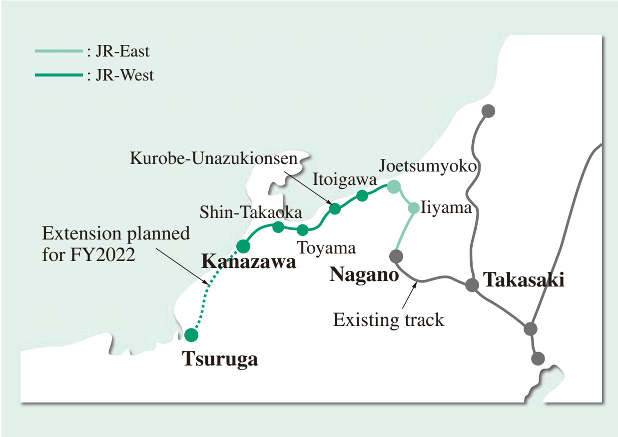

Fig. 3—Opening of the Extension of the Hokuriku Shinkansen to Kanazawa.
The Hokuriku Shinkansen services between Tokyo and Kanazawa that commenced in March 2015 include the operation by JR-East and JR-West of mutual direct trains. The newly opened railway line extends for approximately 240 km and includes seven new stations, with Joetsumyoko Station being the boundary between the two railway companies. The two stations on the Tokyo-side (Iiyama and Joetsumyoko) are under JR-East jurisdiction and the five on the Kanazawa-side (Itoigawa, Kurobe-Unazukionsen, Toyama, Shin-Takaoka, and Kanazawa) are under JR-West jurisdiction.

System Configuration

The opening of the extension of the Hokuriku Shinkansen to Kanazawa required the implementation of a traffic management system that could deal with these mutual direct trains.

Accordingly, the COSMOS traffic management system previously used only at the JR-East control center was upgraded to operate under a single system/dual control centers configuration (the two control centers being those of JR-East and JR-West respectively). This involved upgrading and retrofitting traffic management servers and operators consoles at the JR-East control center, and retrofitting operators consoles at the JR-West control center. In addition, new automatic route setting was installed at all of the new stations from Iiyama to Kanazawa.

These upgrades and retrofits enable the COSMOS traffic management system to perform comprehensive management of the entire lengths of the Tohoku, Joetsu, and Hokuriku Shinkansen lines.

Development of Functions Required for Trouble-free Operation of Mutual Direct Trains

The advantage of the single system/dual control centers configuration is that it enables the two railway companies to centrally manage their respective Shinkansen schedules and other information on the same system. However, because their control centers also manage operation of Shinkansen services within their own jurisdictions, the system also needs to provide trouble-free operation of mutual direct trains and ensure that checking is performed reliably within their own jurisdictions. New functions were developed to satisfy these requirements.

One example of such a new function is the cross-checking of same-day replan.

Because the respective control centers have different jurisdictions, the control centers must notify each other whenever a schedule change is made to mutual direct trains that cross the borders between railway company jurisdictions, and the schedule must be updated accordingly. Furthermore, after the replan, the changes must be validated by both companies.

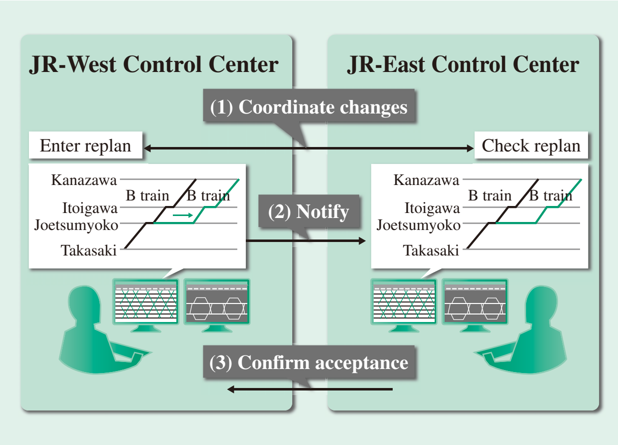

Fig. 4—Cross-checking of Same-day Replan.
A same-day replan for mutual direct trains can be performed reliably by having the two systems perform their respective checks.

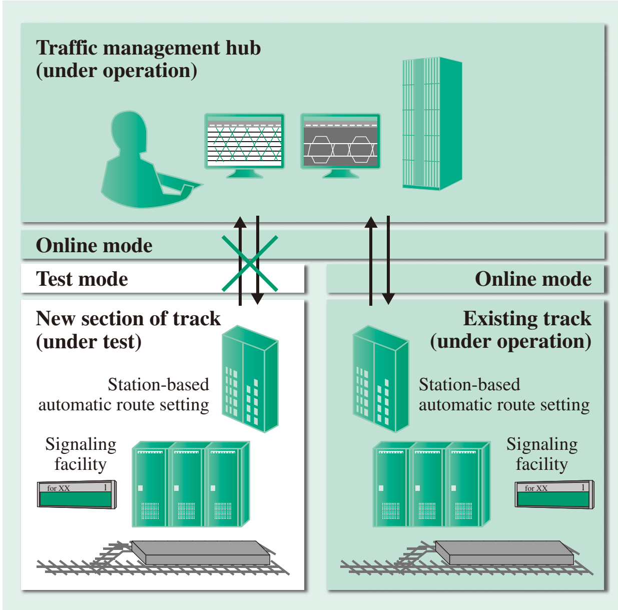

Fig. 5—Connection Control Based on Autonomous Decentralized Configuration.
Equipment under test is able to coexist with equipment under operation by taking advantage of the support that an autonomous decentralized configuration provides for staged implementation.

To achieve this, a cross-check notification technique for sending pre-adjusted replan details from the control center where they were entered to the other control center was developed that took advantage of the single system/dual control centers configuration. This ensures that checking is performed reliably using the system when a schedule change occurs for a mutual direct train that crosses the borders between railway company jurisdictions (see Fig. 4).

Other newly developed functions that helped achieve trouble-free operation of mutual direct trains included sending notification to the other control center about control operations associated with temporary speed restrictions and company-specific control restrictions for the operators consoles.

Field Testing

New signaling facilities were installed for the opening of the extension of the Hokuriku Shinkansen to Kanazawa. Accordingly, testing was conducted aimed at ensuring safety in preparation for full-scale system operation, including signaling facility testing and testing of connections between signaling facilities and station-based automatic route setting.

The challenge facing these tests was that the traffic management hub to which the station-based automatic route setting being tested was connected was under operation, meaning that the overall system needed to include both equipment that was under operation and equipment under test.

To deal with this, the testing took advantage of autonomous decentralized system functions that support staged system implementation for the connections between the traffic management hub and station-based automatic route setting. Testing was completed despite the presence of both equipment that was under operation and equipment under test by using a test mode (in which the link to the traffic management hub is disconnected) when testing station-based automatic route setting in conjunction with the signaling facility, and using an online mode (in which the link to the traffic management hub is connected) for central connection testing and system switchover (see Fig. 5).

DEVELOPMENT FOR LAUNCH OF THE HOKKAIDO SHINKANSEN TO SHIN-HAKODATE-HOKUTO

Overview of Launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto

The Hokkaido Shinkansen to Shin-Hakodate-Hokuto was launched in March 2016, adding new services between Shin-Aomori and Shin-Hakodate-Hokuto (and approximately 149 km of railway line and three stations) and providing direct service between Tokyo and Shin-Hakodate-Hokuto.

The two main features of the launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto are as follows.

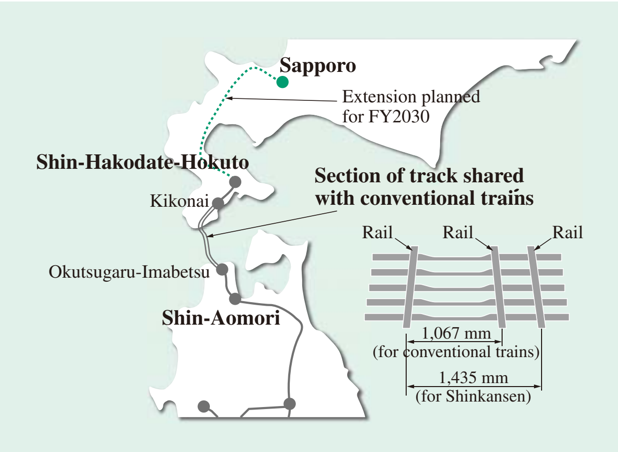

Fig. 6—Track Used by New Hokkaido Shinkansen that is Shared with Conventional Trains.
This was the first time for a Shinkansen line to share dual-gauge track with a conventional line. The Shinkansen and conventional trains are able to share track by laying an additional rail for Shinkansen use next to the narrower-gauge track used by the existing Tsugaru Kaikyo Line.

The first is that it uses the existing Seikan Tunnel linking Honshu with Hokkaido, and is the first Shinkansen line under the Nationwide Shinkansen Railways Construction and Improvement Act to share dual-gauge track with a conventional line (the Tsugaru Kaikyo Line) (see Fig. 6).

The second is that the new services between Shin-Aomori and Shin-Hakodate-Hokuto run on the Hokkaido Shinkansen line operated by JR-Hokkaido while the services between Tokyo and Shin-Aomori run on the Tohoku Shinkansen line operated by JR-East. This means that services between Tokyo and Shin-Hakodate-Hokuto now involve mutual direct trains jointly operated by JR-Hokkaido and JR-East.

System Configuration

The launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto required the implementation of a system that can manage traffic on the new Hokkaido Shinkansen line. The challenge was that, whereas the Shinkansen has exclusive use of sections of track previously managed by COSMOS, the Hokkaido Shinkansen line also has conventional trains running on shared track that includes the Seikan Tunnel. Given the difficulty of using COSMOS to manage schedules for conventional freight trains with very different operating practices, a decision was made for the JR-Hokkaido jurisdiction to develop a new integrated Shinkansen system (CYGNUS) for the Hokkaido Shinkansen line that is separate from COSMOS, and that can perform integrated management of both the Shinkansen and the conventional trains that run on shared track.

The CYGNUS traffic management system that manages train operations in the JR-Hokkaido jurisdiction over the course of a day is a centralized system that locates automatic route setting and support functions for operations control at the control center. Display of information about the status of operations along the entire length of the Hokkaido Shinkansen line, automatic route setting, and scheduling are all performed on the traffic management hub. The CYGNUS traffic management system also has functions for engineering works management, with the procedures for entering, starting, and completing a job being performed on the system.

Development of Functions Required for Track Shared by Shinkansen and Conventional Trains

The CYGNUS traffic management system required the development of new functions for handling configurations (the sharing of track by Shinkansen and conventional trains) that were not covered by the previous Shinkansen traffic management system.

One of these was the integrated departure sequencing function. The CYGNUS traffic management system manages lines used by the Shinkansen and conventional trains as separate sections of track. However, the challenge was that decision-making for automatic route setting becomes more complicated if the departure sequence for shared sections of track where lines used by the Shinkansen and conventional trains come together from these different sections of track are handled separately. In response, decision-making for automatic route setting of Shinkansen and conventional trains entering from these different sections of track was made simple by only integrating the departure time order for the departure sequence of Shinkansen and conventional trains on shared sections of track.

A second example is Shinkansen prioritization. The fact that sections of track are shared by Shinkansen and conventional trains means there is a risk that disruptions to the conventional trains' schedules will also disrupt the Shinkansen schedule. Accordingly, functions were developed to give priority to maintaining the punctual operation of the Shinkansen.

Shinkansen prioritization is broadly divided into two functions. The first is a train running prediction function that issues a warning prompting the control center staff to replan when it detects that a delay to a

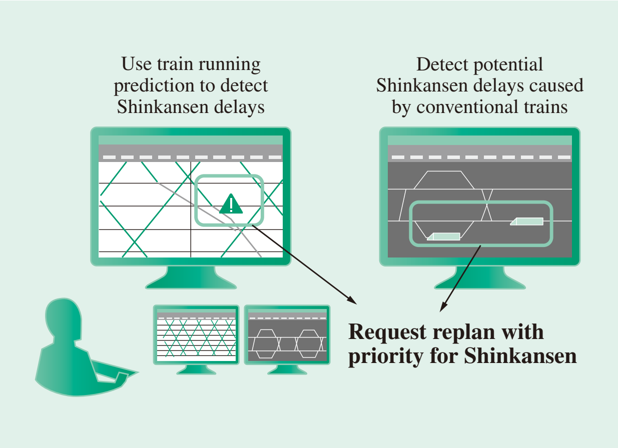

Fig. 7—Shinkansen Prioritization.
By giving priority to Shinkansen mutual direct trains, this manages operation in such a way that delays to conventional trains do not cause delays to the Shinkansen.

conventional train will cause a delay to the Shinkansen. The second function prevents the conventional train from proceeding and prompts the control center staff to replan when it detects that a delay to a conventional train will cause a delay to the Shinkansen based on the predicted time at which the trains will arrive at their next stations (see Fig. 7).

By prompting control center staff to replan, Shinkansen prioritization ensures the punctual operation of the Shinkansen and manages operation in such a way that delays to conventional trains do not cause delays to the Shinkansen.

Interoperation between CYGNUS and COSMOS Traffic Management Systems

To ensure the trouble-free operation of the Shinkansen, the policy adopted when the Hokkaido Shinkansen commenced operation was to use COSMOS to ensure the consistency of schedules along the entire length of the Shinkansen line between Tokyo and Shin-Hakodate-Hokuto, including the section under the jurisdiction of JR-Hokkaido. The following two points describe the interoperation between the CYGNUS and COSMOS traffic management systems in accordance with this policy.

(1) Scheduling

In accordance with the above policy, COSMOS manages the Hokkaido Shinkansen schedules along the entire length of the Shinkansen line between Tokyo and Shin-Hakodate-Hokuto, while CYGNUS manages the schedules for the Shinkansen and conventional lines between Shin-Aomori and Shin-Hakodate-Hokuto that are under the jurisdiction of JR-Hokkaido. During scheduling, COSMOS generates the schedules for the entire length of the Shinkansen line between Tokyo and Shin-Hakodate-Hokuto and CYGNUS receives the schedule for the section of track under the jurisdiction of JR-Hokkaido from COSMOS and coordinates this with the schedules for conventional train services.

COSMOS traffic management system predicts the schedules between Tokyo and Shin-Hakodate-Hokuto so that it can ensure the consistency of schedules along the entire length of the Hokkaido Shinkansen line between Tokyo and Shin-Hakodate-Hokuto. Because train running prediction (schedule prediction) uses train running results as well as basic running times and other predefined constants, the COSMOS traffic management system requires train running results for the JR-Hokkaido jurisdiction. Meanwhile, because the CYGNUS traffic management system manages traffic in the JR-Hokkaido jurisdiction, same-day train running results from this section of track are kept by the CYGNUS traffic management system. Accordingly, having COSMOS ensure the consistency of schedules along the entire length of the Hokkaido Shinkansen line was achieved by having the CYGNUS traffic management system send the train running results for track in the JR-Hokkaido jurisdiction to the COSMOS traffic management system so that the COSMOS traffic management system can predict the schedules between Tokyo and Shin-Hakodate-Hokuto based on these received train running results.

(2) Engineering works time management

On sections of track managed by COSMOS, the switchover from train operation to the maintenance period (the time reserved for engineering work such as track maintenance) occurs after the final Shinkansen train has gone. To this end, the COSMOS traffic management system manages the train operation and maintenance periods at each station and in the intervals between stations (called the "engineering works time management function"). To ensure trouble-free management, the transition to the maintenance period is based on acquiring notification that the last Shinkansen trains have passed or stopped from the stations.

Similarly, the basis of the approach to engineering works time management on the Hokkaido Shinkansen follows the same concept as used in the past. Because the CYGNUS traffic management system also has to deal with conventional trains, the transition to the maintenance period can only take place after all train traffic has finished, including conventional trains. However, because late night and early morning

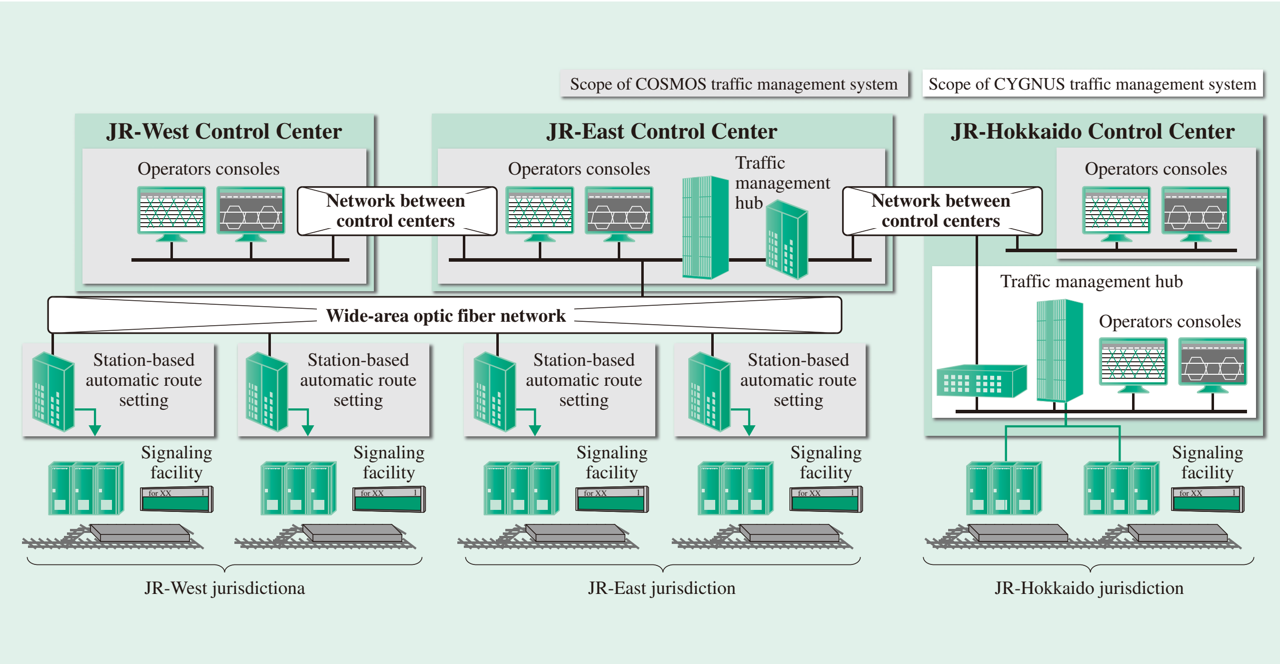

Fig. 8—Overview of Shinkansen Traffic Management System after Hokkaido Shinkansen Commences Operation.
The COSMOS and CYGNUS traffic management systems work together to support safe and reliable Shinkansen operation. The COSMOS traffic management system has a configuration that is distributed between stations and manages Shinkansen traffic across the jurisdictions of both JR-East and JR-West. The CYGNUS traffic management system has a centralized configuration and manages both Shinkansen and conventional train traffic on lines under JR-Hokkaido jurisdiction.

conventional train services run on the sections of track that are shared with conventional trains, the finish time for train traffic on the COSMOS and CYGNUS traffic management systems is very different.

To deal with this, an engineering works time management function that works in accordance with actual operation was implemented by having an end time for Shinkansen traffic on track under JR-Hokkaido jurisdiction, and having the CYGNUS traffic management system send notification that the last train has passed or stopped to the COSMOS traffic management system to notify the COSMOS traffic management system that Shinkansen traffic has finished on track under JR-Hokkaido jurisdiction.

Field Testing

As noted above, the sharing of sections of track with conventional trains is a major feature of the launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto. This was also a challenge during the field testing phase.

As past extensions to the Shinkansen network have involved the laying of new track, signaling facility testing and the connection testing of signaling facilities and system equipment have been conducted independently of existing services. With the launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto, however, the presence of both existing equipment for the conventional line and new equipment for the Shinkansen on sections of track shared with conventional trains imposed the restriction that Shinkansen equipment could not be operated while the conventional line equipment was in use.

Accordingly, on-track trials of the Shinkansen were conducted by switching over to the Shinkansen equipment during the short period during the night when conventional trains are not running. An effort was made to ensure quality efficiently by testing the CYGNUS traffic management system in conjunction with this testing of signaling facilities.

CONCLUSIONS

This article has described the developments and improvements to the COSMOS and CYGNUS traffic management systems made for the recent opening of the extension of the Hokuriku Shinkansen to Kanazawa and the launch of the Hokkaido Shinkansen to Shin-Hakodate-Hokuto.

Since the opening of the extension of the Hokuriku Shinkansen to Kanazawa in March 2015, the COSMOS traffic management system has operated under a single system/dual control centers configuration to support the operation of Shinkansen lines that include the newly opened section of track that spans JR-East and JR-West. Similarly, the COSMOS traffic management system, which is distributed between stations, and the centralized CYGNUS traffic management system have worked together to support the safe and reliable operation of the Shinkansen since the commencement of operation of the Hokkaido Shinkansen in March 2016 (see Fig. 8).

In the future, the intention for the Shinkansen traffic management system is to proceed with initiatives such as the incorporation of new technology and service improvements, and to work on technical developments that ensure safe and reliable transportation.

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Featured Articles

Energy Management and Application of Symbiotic Autonomous Decentralization Concept to Water Supply and Sewage

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Ichirou Yamanoi, Ph.D.
Hitoshi Saito

OVERVIEW: The water supply and sewage sector in Japan is entering a period in which the focus is on operation and maintenance, with the requirement being to maintain safe and reliable services despite aging infrastructure and challenging financial constraints. To achieve this, steps are being taken to consolidate water supply operations by having different utilities work together, and, in the case of sewage, toward coordination with river management based on amendments to the Flood Protection Law, etc. and catchment-wide management based on the Comprehensive Basin-Wide Planning of Sewerage Systems. Accordingly, these moves toward smarter system-wide operation through the interconnection and interoperation of areas that were previously managed independently also has an affinity with the symbiotic autonomous decentralization concept. One example is a trial conducted by Hitachi on the use of water supply operation plans for demand response, with further investigation underway on assisting interoperation between utilities. In the case of sewage, Hitachi is also trialing energy-efficient sewage treatment control as a technology for facilitating regional coordination.

INTRODUCTION

THE water supply and sewage sector in Japan is now entering a period in which facilities built during and after the period of high economic growth are now coming due for replacement, and in which this upgrade work needs to be undertaken in a way that maintains a safe and secure water infrastructure despite constrained finances at a time of falling population. To achieve this, there has been an increasing shift toward initiatives that seek to get a number of water and sewage utilities working together rather than operating independently, or have them collaborate with other sectors.

In the case of water supply, examples include the extensive consolidation that is underway to coordinate some of the activities undertaken by utilities, such as infrastructure sharing and the centralization of management whereby, along with business integration, the utilities pool resources for tasks such as operation and maintenance or water quality testing(1).

In the case of sewage, meanwhile, there are calls for utilities to work with river management agencies in accordance with FY2015 amendments to the law in order to deal with the major rainfall events that have been occurring frequently in recent years(2). Similarly, under the Comprehensive Basin-Wide Planning of Sewerage Systems being promoted by the Ministry of Land, Infrastructure, Transport and Tourism, there is a move toward comprehensive catchment-wide management of things like water quality and energy consumption in ways that take account of local circumstances(3).

The water supply and sewage sectors are energy consumers. This means that, as part of the social infrastructure of a city, they play an important role in achieving not only energy efficiency but also smart energy use on a city-wide level through measures such as cutting or shifting demand peaks by coordinating their operation with the electric power infrastructure.

The information and control systems used in social infrastructure have grown in sophistication along with the need to provide efficiency and sustainability to individual utilities and the social infrastructure sector. It is also recognized that, as interdependent parts within a larger water cycle, the water supply and sewage infrastructures need to adopt a symbiotic autonomous decentralization approach in order to deal with the increasingly complex challenges they face. This means seeking to create new value at the system-wide level through the interconnection and interoperation of individual systems while having them continue to operate autonomously.

This article presents examples of work on energy management in the water industry based on this concept. In the case of the sewage sector, it also presents an example of energy-efficient control of the sewage treatment process, a technology that facilitates energy management.

APPLICATION OF SYMBIOTIC AUTONOMOUS DECENTRALIZATION CONCEPT TO WATER SUPPLY AND SEWAGE INDUSTRY

The practice in the water supply and sewage industry has been to install separate systems at each plant, whether it be a purification plant, sewage treatment plant, or pumping station. These include the administrative systems for activities such as finance, human resources, and public relations; commercial systems for customer inquiries, metering, and billing; and supervisory control and data acquisition (SCADA) systems used for plant operation and maintenance. In the past, these individual systems have provided their respective functions in an independent system, and the symbiotic autonomous decentralization concept under which new value is created through the interconnection and interoperation of these systems has been studied as a way of solving the problems addressed in the previous section.

Fig. 1 shows this concept in the case of a plant SCADA system.

Each water or sewage utility and river management agency has its own SCADA system for the operation and management of purification plants, sewage treatment plants, pumping stations, and so on. The systems have been operated for their respective purposes as closed systems. Now, however, work is being undertaken to establish platforms that provide integrated access through the interconnection and interoperation of these systems. In Hitachi's symbiotic autonomous decentralization concept, these shared access platforms are called cooperating fields.

These cooperating fields facilitate water industry consolidation in various ways by enabling the interoperation of water utility SCADA systems. Furthermore, having the systems of the sewage utilities in a catchment work together can provide IT support for catchment-wide management. Similarly, interoperation with river management agency systems can provide comprehensive flood control support that takes account of both run-off and river water. Smarter use of electric power, such as demand response (DR), is also possible through the use of cooperating fields for interoperation between the electric power infrastructure and water supply and sewage industry.

The following section presents an example of energy management in the water industry that demonstrates how system technologies create new value through the use of cooperating fields.

ENERGY MANAGEMENT THROUGH INTEROPERATION BETWEEN WATER AND ELECTRIC POWER INFRASTRUCTURE

DR and Water Supply Operation Plan

DR is seen as a way of ensuring security of supply by controlling electric power during times of peak demand (see Fig. 2). Under DR, consumers of electric power receive requests specifying when and by how much to reduce their power consumption from an aggregator (a business that consolidates adjustments in power consumption made by other businesses) who deals directly with the power company to determine the amount and timing of power use reductions (negawatts).

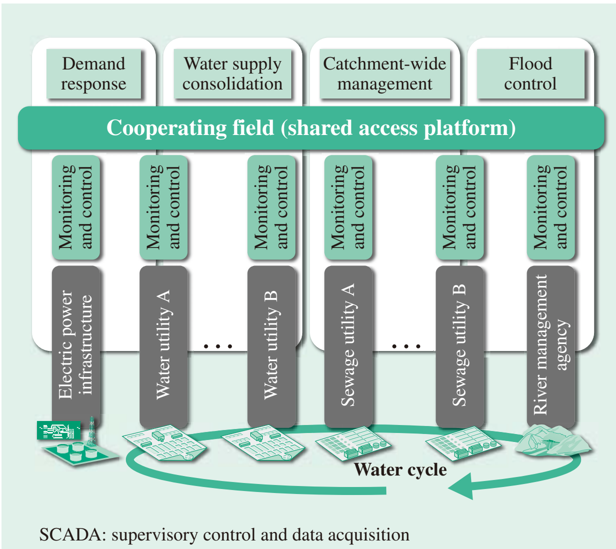

Fig. 1—Application of Symbiotic Autonomous Decentralization Concept to SCADA System for Water Supply and Sewage.
The aim is to create new value through interconnection and interoperation via a shared access platform between electric power infrastructure and the systems involved in the water cycle (water supply, sewage, and waterways).

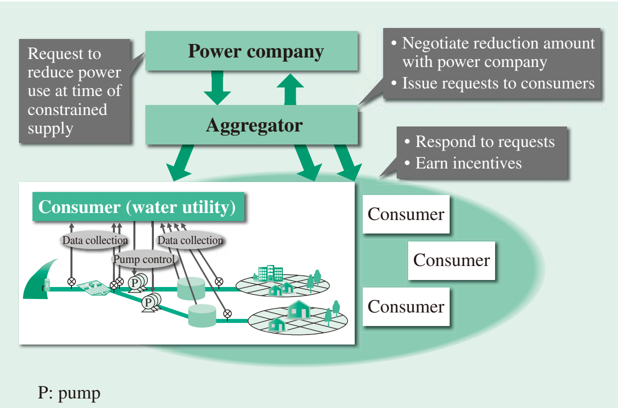

Fig. 2—Overview of Demand Response for Electric Power.
By reducing their power consumption in response to requests issued from power companies via an aggregator, water utilities and other consumers of electric power can earn incentives based on the amount of reduction.

Consumers also receive incentive payments based on their reduction in power use(4). Being major consumers of electric power, water utilities are in a position to participate in such schemes. When they do, because they must prioritize security of water supply, they need to look at how they can participate in DR without compromising this obligation.

The water supply operation planning systems used by the industry are a way to achieve this(5) (see Fig. 3). These systems predict the constantly changing daily demand for water and plan the flow rates at which the utility's purification plants and water intake and conveyance pumping stations need to operate. By adding a function for responding to DR requests to reduce power use, the systems can generate plans in such a way that the utility can earn incentive income without compromising security of supply.

Demonstration Project

To verify the potential for using water supply operation planning system technology to incorporate DR into water supply infrastructure and to determine the benefits, the Hitachi City Enterprise Bureau participated as a consumer in the FY2014 Next Generation Energy and Social System Demonstration Project of the New Energy Promotion Council. Because it was a demonstration project, requests from the aggregator were sent via e-mail and operational plans were produced on a personal computer (PC) that was independent of the SCADA system. These operational plans were checked manually and then operators used the SCADA system to manually shut down pumps as required.

The demonstration project was based on fast DR whereby the reduction requests were issued 15 minutes prior to the commencement of DR. Four separate trials were conducted and the reductions in power use were made via six different Hitachi City Enterprise Bureau facilities (18 pumps with a total contracted capacity of 2,901 kW). Fig. 4 shows the results for a DR trial conducted in the summer. Peak demand for electric power was reduced by 54% in response to DR requests between 13:00 and 17:00 and water storage levels of 80% or more were maintained during and after the DR period.

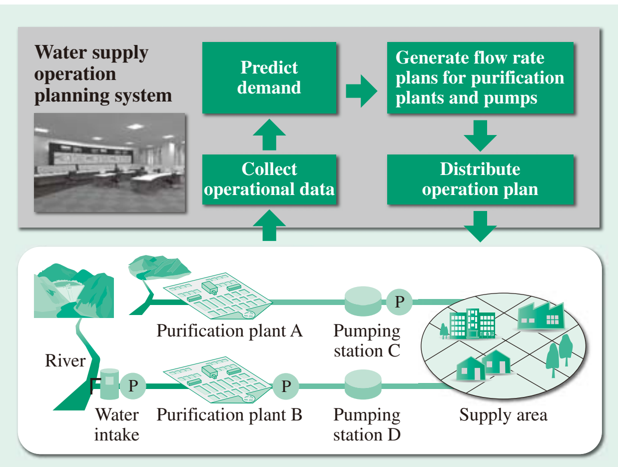

Fig. 3—Overview of Water Supply Operation Planning System.
The system predicts daily water demand and generate and distribute an operating plan for the flow rates at which the water utility's purification plants and pumping stations need to operate.

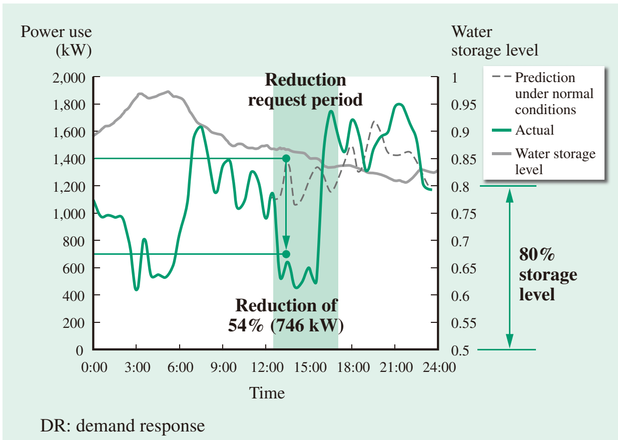

Fig. 4—Results of DR Demonstration Project.
The graph shows the results of a fast DR demonstration project conducted during the summer. This example shows the results for power use reduction requests issued between 13:00 and 17:00, during which time the reduction requests were satisfied while reliably maintaining water storage levels at 80% or more.

Based on this demonstration project, it was concluded that water supply operation systems technology can deliver both security of water supply and reductions in electricity costs through coordination with the electric power infrastructure.

INITIATIVE TOWARD INTEROPERATION BETWEEN UTILITIES

In a new initiative, Hitachi is developing solutions for system-wide optimization through interoperation between water supply and sewage utilities. The following describes one such example, a support tool for coordinating water supply operation that delivers a high level of DR income through coordination across a number of utilities (see Fig. 5).

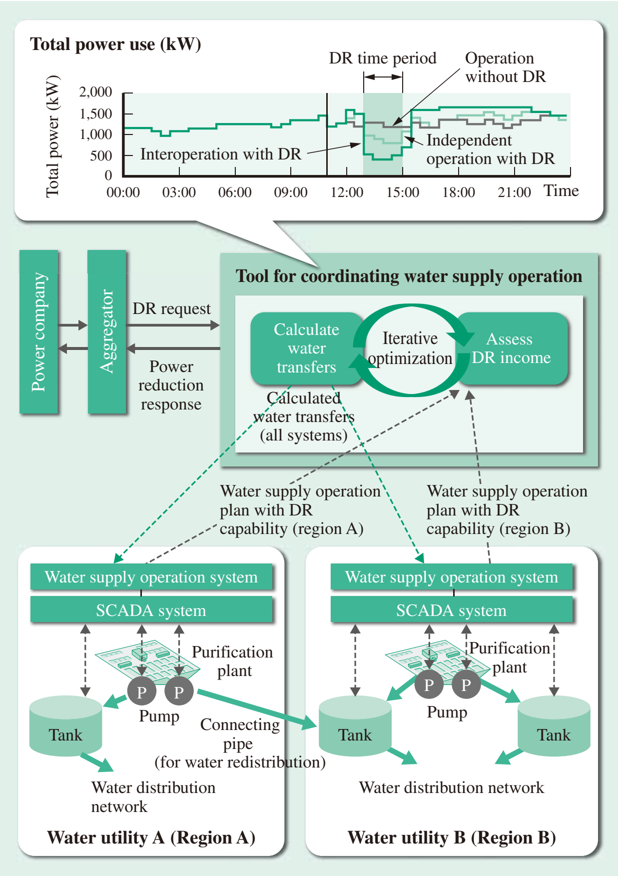

Fig. 5—How Support Tool for Coordinating Water Supply Operation Works and Reductions in Power Use in Response to DR Requests.
The tool utilizes interoperation between each utility's water supply operation system to enable them to maximize DR income by iteratively calculating the DR income for the entire catchment and determining the inter-utility water transfers that will improve this result based on operational blueprints generated for each utility's water supply operation plan, which include a DR function.

The tool is intended for water utilities that are able to transfer water to each other via connecting pipes or other means. It can generate operational plans that provide system-wide optimization (maximize DR income across the entire region) by implementing water supply operation plans with a DR function like that described above over a wider area. These operational plans are generated by solving the mathematical programming problem in a way that treats multiple utilities as a single water conveyance network, including connecting pipes, which means they pose a technological challenge because the larger problem size makes it more difficult to calculate a solution in a short time. Furthermore, the establishment of an integrated system is also typically complicated by the fact that the individual water utilities implement their water supply operation plans as independent business entities.

The support tool for coordinating water supply operation resolves these challenges by interoperating with the water supply operation system of each utility. That is, the support tool iteratively adjusts the boundary conditions (quantity of water transferred via connecting pipes) to progressively improve the overall DR income. The individual utilities then continually solve their respective water supply operation mathematical programming problems (including DR) using these adjusted boundary conditions.

Use of this algorithm shortens the time required to calculate operating plans that maximize (strictly speaking, approximately maximize) the DR income, while preventing the problem size from increasing and keeping the respective water supply operation systems independent of one another.

Fig. 5 shows an example calculation that simulates a water conveyance network covering four cities with interconnecting pipes. The results show that the four city utilities working together achieved a total reduction in electric power use during the DR period that is roughly twice the reduction achieved when the utilities operate independently.

In parallel with this, Hitachi has been developing NEXPERIENCE / Cyber-Proof of Concept (Cyber-PoC)[6] for conducting preliminary cost-benefit analyses of social infrastructure investments. Because the support tool for coordinating water supply operation can be used to make predictive estimates of the energy savings from consolidating the operations of water utilities, there is potential for creating a version of NEXPERIENCE / Cyber-PoC for the water industry.

ENERGY-EFFICIENT CONTROL OF SEWAGE TREATMENT

Prompted by amendments to the Comprehensive Basin-Wide Planning of Sewerage Systems[3], there is growing demand from sewage utilities for advanced control techniques that can save energy and enable interoperation between utilities as well as achieving and maintaining environmental standards for water quality in public basins.

Ibaraki Prefecture and Hitachi have undertaken research trials into "Demonstration of Efficient Nitrification Control with ICT," which is seen as a core technology for saving energy at the catchment level. The research is being conducted under contract to the National Institute for Land and Infrastructure Management of the Ministry of Land, Infrastructure, Transport and Tourism as part of that ministry's Breakthrough by Dynamic Approach in Sewage High Technology (B-DASH) project, and has been in progress since FY2014 on water treatment lines at Ibaraki Prefecture's Kasumigaura Sewage Treatment Plant.

Features of the Control Technique

The technique provides a way to manage the operation of the nitrification process commonly used in biological treatments (in which ammonia is removed by oxidation) by controlling the rate of blower air flow into the biological reactors. It reduces energy use by minimizing excessive blower operation once the target ammonium concentration has been achieved while also providing consistent water quality and more efficient operation and maintenance.

Fig. 6 shows an overview of the control system[7] used in the trials. The system uses a dissolved oxygen (DO) sensor located downstream from the aerobic tank of the biological reactor, ammonium sensors (1) and (2) located respectively upstream from and mid-way through the aerobic tank, and a flow meter. The control system is made up of a feedforward (FF) loop that uses the ammonium concentrations from ammonium sensors (1) and (2) as its input and a feedback (FB) loop that uses ammonium sensor (2).

FF control first predicts the ammonium concentration mid-way through the aerobic tank based on the concentration measured by ammonium sensor (1) and the target effluent ammonium concentration. Next, it uses the newly developed treatment model to determine the blower air flow rate based on the difference between these two values, which represents the ammonium concentration to be treated in the process upstream from the mid-way point.

Similarly, FB control feeds back the difference between the predicted value of ammonium concentration at the mid-way point of the aerobic tank and the concentration measured by ammonium sensor (2) and determines the blower air flow rate.

Using FF control as well as FB control improves the ability of the system to track changes in the incoming sewage while also keeping the treatment process stable with an appropriate air flow rate.

The treatment model used by FF control was implemented using measurements from the two ammonium sensors and actual blower air flow rates. The model is also designed for more efficient operation and maintenance, being auto-calibrated on a daily

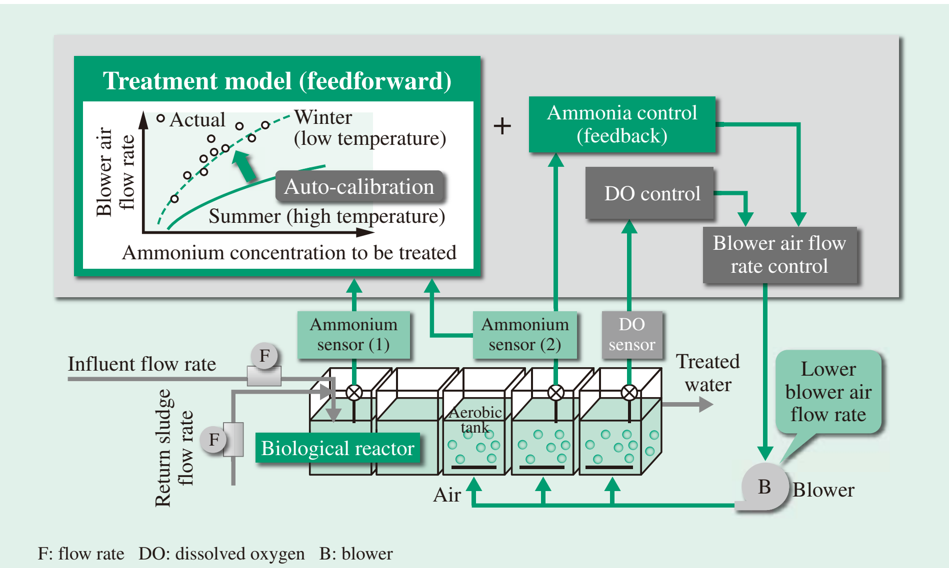

Fig. 6—Overview of Energy-efficient Control of Nitrification.
The technique uses two ammonium sensors located respectively mid-way through and upstream from the aerobic tank to maintain water quality and reduce blower use, with a control function that utilizes actual values and values predicted by the treatment model, an auto-calibration function for the treatment model, and a function for displaying the treatment characteristics.

basis using the latest measurements so that it can adapt to changes in the characteristics of the sewage treatment process.

Demonstration Project

A demonstration project was conducted with the No. 5 and No. 6 nitrification/denitrification process reactors at the Kasumigaura Sewage Treatment Plant. The No. 5 reactor was used as the experimental system, and was fitted with the newly developed air flow rate control system, while the No. 6 reactor was used as the reference system, and was operated using the existing constant DO control system (which works by maintaining a constant DO level in the third and final aerobic tank). The target DO setting for the reference system was left at its current level of 2.0 mg/L, while the experimental system was operated so as to target the same degree of nitrification promotion as the existing system, with a mean effluent ammonium concentration of 1.0 mg-N/L or less.

Fig. 7 shows how the aeration flow rates for the two reactors varied over time. This shows that the aeration air flow in the new control system was consistently lower than the reference system. Meanwhile, the effluent ammonium concentrations were 0.3 mg-N/L in the experimental system and 0.1 mg-N/L in the reference system, indicating that both systems achieved the target of maintaining a mean concentration of 1.0 mg-N/L or less to promote nitrification.

The aeration air flow ratio with respect to the new control system was 77.7% that of the reference system. An investigation was conducted into an adjustment method that takes account of the required oxygen amount and diffusion efficiency, with the No. 5 reactor (experimental system) tending to require less aeration air flow than the No. 6 reactor (reference system) for the same concentration of ammonia[8]. The investigation found that the adjusted aeration air flow ratio was 85.9%, indicating that the newly developed control system reduced the aeration air flow by 14.1% compared to the previous constant-DO control system.

The demonstration project has continued through FY2015 and proved the long-term stability of the new control system.

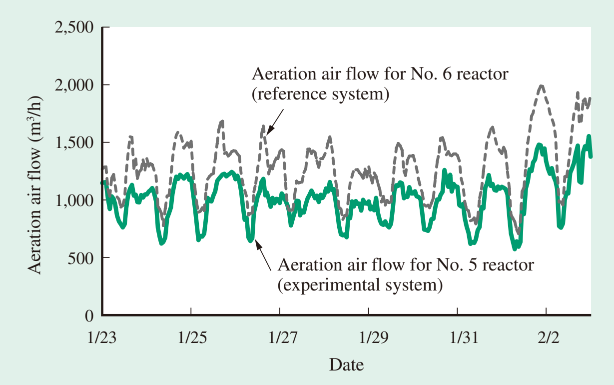

Fig. 7—Aeration Air Flow in Demonstration Project.
The adjusted aeration air flow ratio of 85.9% means that the newly developed control system (experimental system) reduced the aeration air flow by 14.1% compared to the previous constant-DO control system (reference system).

CONCLUSIONS

This article has described work on system-wide optimization of water supply and sewage through the interconnection and interoperation of utilities based on the symbiotic autonomous decentralization concept, including the energy management and energy efficiency benefits that provide examples of the technologies used.

Hitachi intends to continue developing future solutions under this concept to sustain a safe, secure, and comfortable water cycle.

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Featured Articles

Advances in Steel Industry Control Systems in Era of IoT

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OVERVIEW: Hitachi has long taken advantage of the benefits and expandability of autonomous decentralization to build control systems for steel industry equipment that is subject to frequent retrofitting and modification(1). The current practice is to work on advances in control by utilizing ICT to include extensive data collection and analysis functions and provide feedback to control systems. Specific work by Hitachi includes a new thickness control system and an IoT drive system. In the future, Hitachi intends to extend the use of the PDCA cycle by expanding the scope of information use and providing feedback to control systems based on the symbiotic autonomous decentralization concept.

INTRODUCTION

STEEL prices are currently depressed due to global production of raw steel exceeding demand. The challenges for producers in such an environment include how to improve revenue by producing higher-added-value products, and how to boost cost-competitiveness and reduce business risks (see Fig. 1). Examples of business risks include problems with product quality, unanticipated equipment outages caused by faults or accidents, and missing sales opportunities. These challenges, especially things like producing higher-added-value products and reducing business risks, need to be addressed by making further advances in production and control systems.

To meet these needs, Hitachi is utilizing information and communication technology (ICT) to develop new product functions in terms of both hardware and software based on the concept of autonomous decentralization. In particular, it is establishing practices for generating new added value by utilizing a wide variety of plant data in control systems.

This article describes autonomous decentralized systems in the steel industry, examples of ICT use, and the outlook for steel industry control systems.

AUTONOMOUS DECENTRALIZED SYSTEMS

Hitachi has promoted the use of the autonomous decentralized system as the architecture of control systems. This architecture results in distributed systems in which the network is treated as a data field by sharing plant data between nodes so that the control servers, controllers, and other nodes connected to the

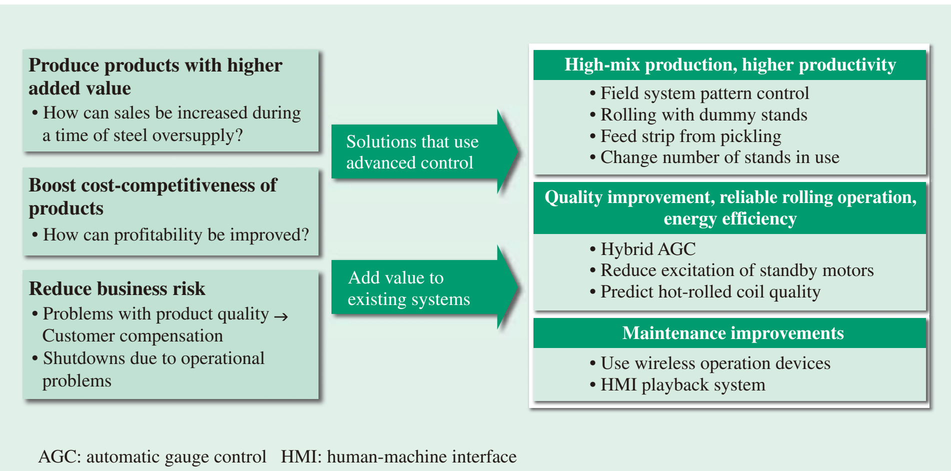

Fig. 1—Challenges Facing Steel Industry and What Hitachi is Doing.
Hitachi has commercialized numerous solutions for the challenges facing the steel industry as they have changed over time.

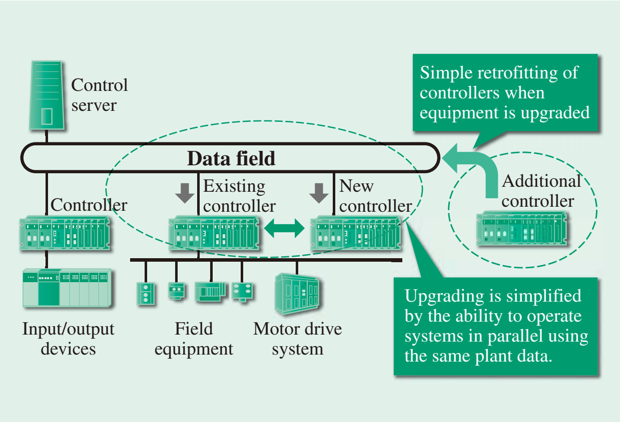

Fig. 2—Autonomous Decentralized Systems and Their Characteristics.
The autonomous decentralized system architecture has played an important role over many years in retrofit and modification projects at steel mills.

network can function autonomously by accessing this shared data to perform their roles. This autonomous decentralized system architecture has the following benefits for steel industry control systems used in production processes that are subject to frequent modifications (see Fig. 2).

The first is that, when software changes or the retrofitting or modification of hardware is considered, use of an autonomous decentralized system that shares data across nodes means that existing data can still be retrieved without difficulty even by components that have been added or modified. Another benefit is that, while testing upgrades to existing equipment, it simplifies the process of operating systems in parallel* by providing shared access to data in the data field. It also facilitates redundancy by allowing a single standby controller to serve as a backup to multiple in-service controllers. In this way, the features of autonomous decentralized systems make them ideal for steel industry control systems.

APPLICATION OF ADVANCES IN ICT

Example Uses of Data at Steel Mills

An autonomous decentralized system is made up of plant machinery, control servers, controllers, and a data field for shared access to plant data. The sequence of data use involves first accessing data in the data field ("sensing"), using the data to consider how to resolve issues ("thinking"), and then making improvements to the actual control systems ("acting"). Control systems can be improved by working through this loop.

The following describes the specific sequence of data use at a steel mill (see Fig. 3).

The sensing step makes the plant data in the data field visible. The plant data that flows through the data field is collected by a process data analysis (PDA) data acquisition system, and the detailed internal control data from the controllers is collected by a trace function. The collected data is stored in a plant database and can be displayed simultaneously using a single tool.

* The verification of updates by inputting the same data into an operational node and a new node and operating them in parallel.

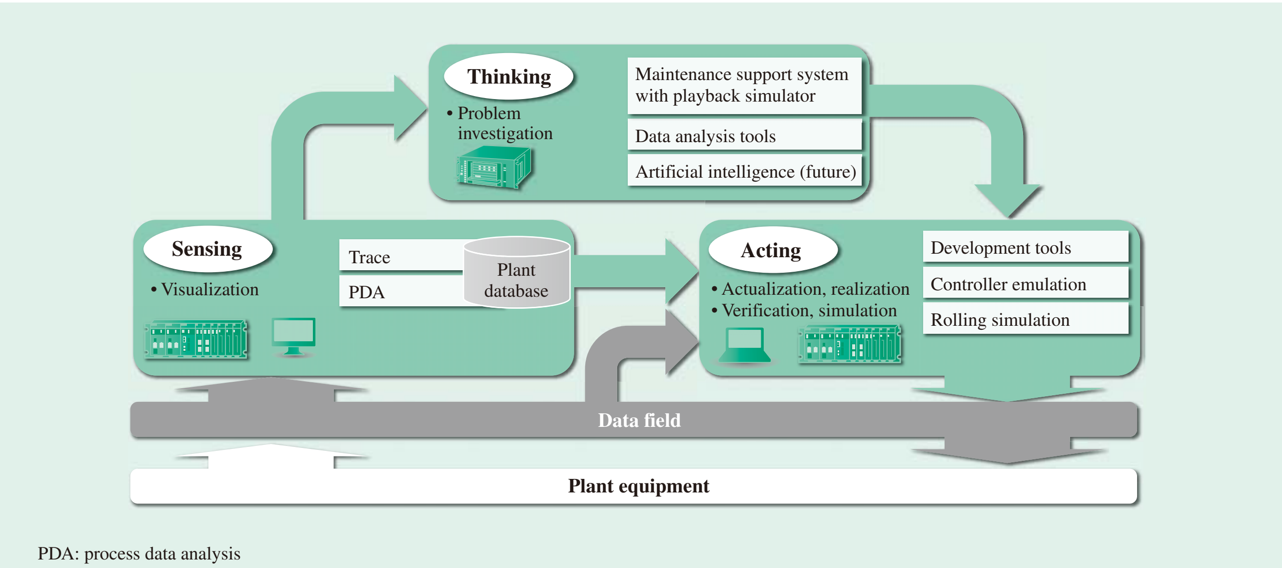

Fig. 3—Use of Data to Improve Product Quality.
Ways of making ongoing use of data from plant equipment are essential for improving the quality of steel products.

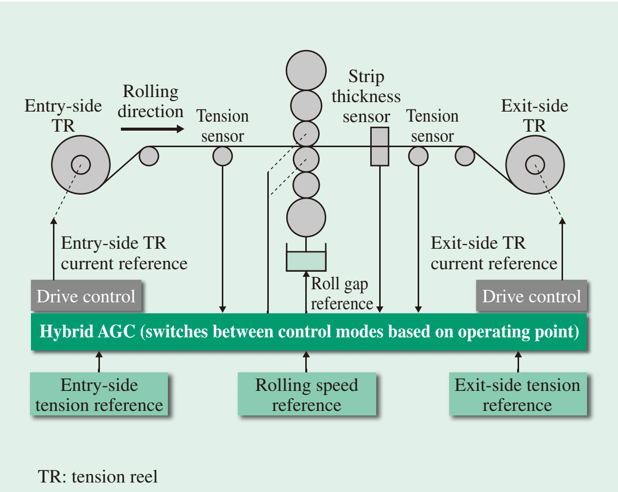

Fig. 4—Control Structure for Hybrid AGC (Single-stand Mill).
Hybrid AGC is a control technique that significantly improves the accuracy of strip delivery thickness by switching between the roll gap and TR current reference, as appropriate, based on actual rolling data.

The thinking step involves using resources such as the Hitachi maintenance support system with playback simulator and proprietary Hitachi data analysis tools to investigate problems and their solutions based on the collected data. This system can also use video camera recordings, with simultaneous playback of data and video so that problems can be investigated from a wider range of perspectives. These features are also available at remote sites away from the plant.

The acting step involves testing on control systems based on the solution hypotheses formulated in the thinking step. The development of algorithms, models, etc. is performed by importing data from the plant database or actual data field data into a development tool. The efficacy of an algorithm is verified by using tools such as a controller emulator or rolling simulator that run on a personal computer (PC) together with data from the data field (or plant database). Once the algorithm has been shown to work, the changes can be quickly incorporated into the control system using the controller's online logic modification function.

Accordingly, autonomous decentralized systems are also suitable for use in terms of facilitating the ongoing development of a steel mill based on the plan, do, check, act (PDCA) cycle, and Hitachi has been working on innovations in system technology and control techniques that incorporate the latest ICT[2]. The following section describes two initiatives Hitachi has undertaken in recent years: the implementation of a hybrid automatic gauge control (AGC) and an Internet of things (IoT) drive system.

Hybrid AGC

A hybrid AGC for a single-stand rolling mill provides an example of acting on the data that has been collected and analyzed in the sensing and thinking steps (see Fig. 4).

The previous control system used the roll gap to control strip thickness and tension reel current to control strip tension. Unfortunately, the system had a problem with long fluctuations from several seconds to ten or more seconds on the exit side of the mill due to interference between thickness and tension control when rolling thin strip at high speed.

In response, a new control technique called hybrid AGC was used to minimize these fluctuations by switching between use of roll gap or tension reel current based on factors including past rolling performance and the current operating point, making it possible to produce higher-quality products (with higher added value).

The first step in the development of this control technique was to collect and analyze data about the problem using the sensing and thinking tools previously developed by Hitachi to determine the changes described above in the degree of influence due to rolling conditions. Next, the benefits of incorporating the technique into the control system were demonstrated through simulation using a rolling model (an acting tool) and by testing on the actual mill.

IoT Drive System

This section describes an IoT drive system that provides another example of data use. The converter panels for motor drive systems used in the steel industry consist of control boards that control the motors that drive the rolling mill and a main drive unit that performs electrical conversion. Hitachi has made progress over time on downsizing these components. In addition to combining cell units (blocks of capacity) to enable flexible configuration of the main drive unit to deliver the capacity required by the customer, Hitachi has also used them to build large and medium-sized panels for the steel industry by increasing the capacity of the individual cell units and making them smaller to reduce the overall size of the panel[3], [4], [5].

Hitachi is also continuing to develop the control boards and is planning reliability, availability, and serviceability (RAS) enhancements that utilize the IoT. In addition to the motor drive system, the IoT drive system also includes a control system (controller) and data analysis units that handle various forms of data acquisition. A variety of issues can be investigated

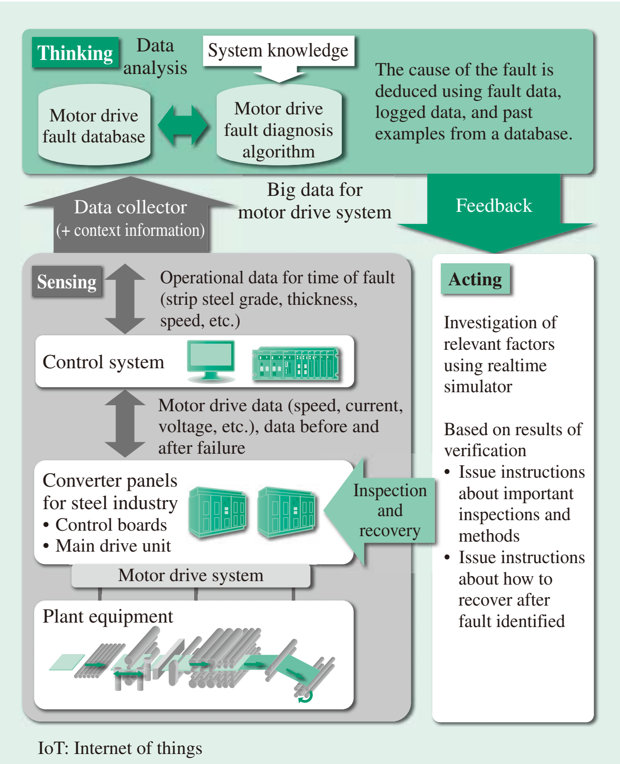

Fig. 5—Fault Analysis Flow for IoT Drive System.
By visualizing associating various types of data when a fault occurs and performing data analysis, the cause of the fault can be deduced and checked to achieve a quick recovery.

by linking information relating to motor control held by the motor drive system (speeds, current, voltage, and so on) to operational data held by the supervisory control system (strip steel grade, thickness, speed, and so on), and the results can be incorporated into the motor drive system.

Fig. 5 shows the flow of fault analysis that was conducted in a case where the motor drive system shut down for some reason during plant operation.

Sensing functions include a function in the control board for recording fault data such as overcurrent or overvoltage when a fault or shutdown occurs, and a function for recording data from before and after a fault in memory. Insights into the conditions associated with the fault are obtained by linking this data with operational data held by the controller. The data analysis unit that provides the thinking functions performs high-speed retrieval of this data via the Internet or other means, and determines the cause of the fault using diagnostic algorithms based on system knowledge and a database of past fault histories. The acting step involves verifying this cause on a realtime simulator. Faults that have occurred during plant operation can be replicated and tested in realtime by building a model (simulator) to replicate the fault cause identified by the thinking step and running this in parallel with the same control board as used in the plant where the fault occurred, including the control programs and parameters held for the plant by the control board. Based on the results of testing, the plant can also be informed of what checks to perform or how to recover from the fault.

By utilizing IoT technology in the motor drive system this way, it is possible to achieve rapid fault diagnosis and recovery, and to minimize plant downtime. Moreover, it is also possible to prevent unanticipated plant shutdowns due to equipment faults by working through the analysis cycle described above on a regular basis.

OUTLOOK FOR STEEL INDUSTRY CONTROL SYSTEMS

Two potential developments for steel industry control systems based on the autonomous decentralization concept are as follows (see Fig. 6).

(1) Fusion of information and control using the IoT

This development involves using the IoT for the collection and analysis on information systems of large quantities of big data (strain, vibration, and so on) from equipment and processes, as well as human data (people's actions, audio, and so on) that conventional control systems find difficult to utilize. It will be utilized in approaches for further developing steel industry control systems that combine both information and control, including the resolution of problems for which the causes were previously unknown and the generation of know-how from new insights.

(2) Adoption of symbiotic autonomous decentralization, which extends the concept of autonomous decentralization throughout the business.

This involves establishing cooperating fields (shared access platforms) that provide for the coexistence of stakeholders, who represent a system in their own right, with head office and other business systems as well as the control and information systems at the steel mill. By using these cooperating fields to share data, and by providing a view of overall efficiency based on the situation at particular factories or external changes in the business environment obtained by considering the entire supply chain, it becomes possible to devise solutions that optimize this efficiency. This results in the maximization of business efficiency and enables participants to achieve a high level of profitability.

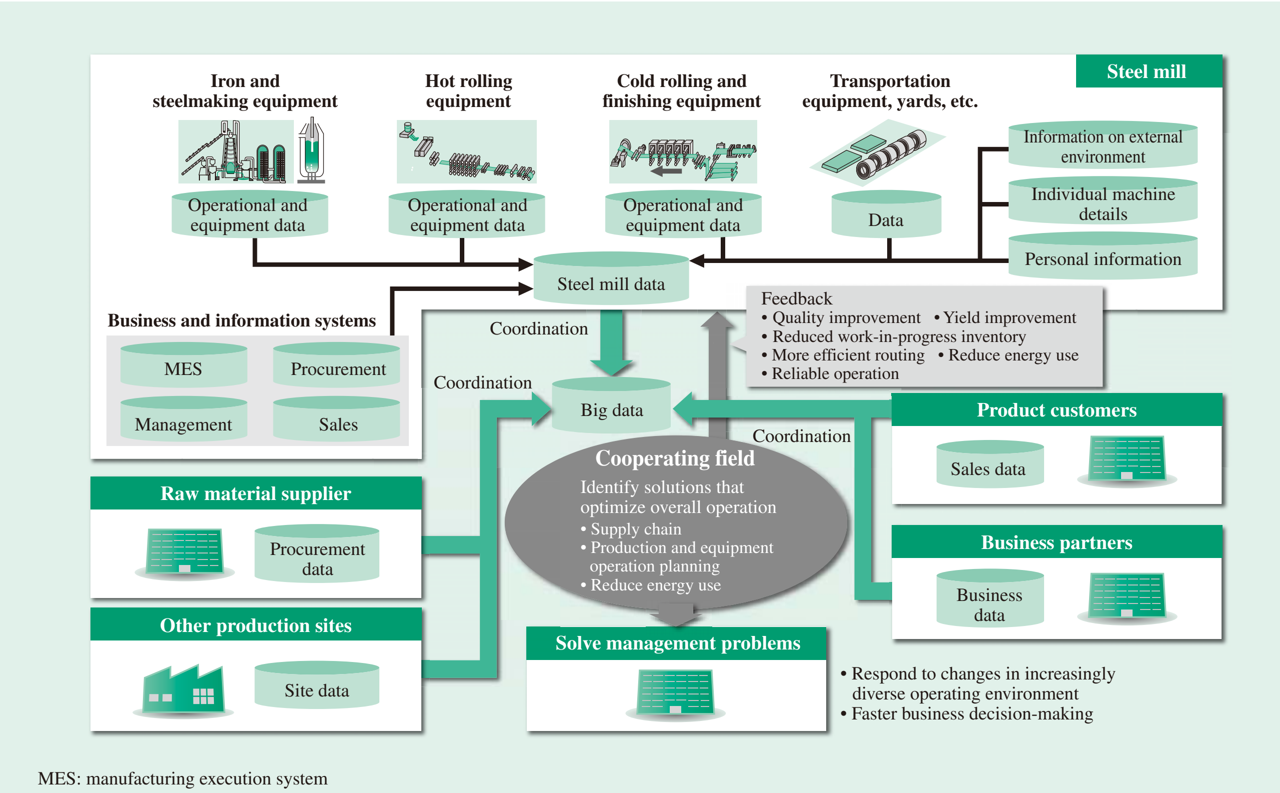

Fig. 6—Further Development of Steel Industry Control Systems.
Solutions that optimize all activities at a customer's company are devised by adopting cooperating fields (shared access platforms). This makes it possible to maximize business efficiency for the purpose of improving profitability.

CONCLUSIONS

Recent years have seen changes in such global trends as the use of the IoT and other forms of ICT for industrial restructuring aimed at more advanced manufacturing. It is anticipated that there will be increasing demand for and momentum behind a shift from the optimization of individual systems to the optimization of overall efficiency, including in the case of steel industry control systems that have undergone ongoing development in the past through the independent implementation of systems for production and control.

Hitachi intends to continue supplying control systems that contribute to the ongoing development of the steel industry and to resolving its problems by pursuing the latest technology with reference to technical developments.

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Featured Articles

Next Generation of Global Production Management Using Sensing and Analysis Technology

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Hiroshi Yoshikawa
Toshihiro Yamada
Nobuhiro Kakeno

OVERVIEW: Hitachi is working on the development of a next-generation production management system that uses IoT technology and cloud services in accordance with a roadmap of functional enhancements based on maturity metrics. Recognizing that cameras provide a new sensing technique for visualization, Hitachi is utilizing image analysis techniques and integration with production results data to achieve quality and productivity improvements in the short term, and to generate improvement suggestions and perform optimization throughout the supply chain by combining these techniques and results data with big data analytics over the long term. Hitachi undertook an analysis of machining and assembly production sites from a 3M perspective to identify applications where image analysis techniques can be beneficial. Furthermore, Hitachi has developed a technique for detecting deviations from standard operation by extracting feature values representing worker operations from images captured on motion cameras, and demonstrated their effectiveness through a trial conducted using actual images from a manufacturing workplace in a customer co-creation project.

INTRODUCTION

ADVANCES in telecommunications and sensing technologies, and reductions in their costs have fostered interest from different industries in uses for the Internet of things (IoT). Germany proposed its Industrie 4.0 project[1] for integrating the IoT and services into manufacturing processes in 2011, with anticipated benefits that include improved productivity, the ability to deal flexibly with specific requirements, and reduced energy use[2]. Similarly, General Electric Company put forward its Industrial Internet concept for connecting industrial equipment to the cloud and using big data analytics to improve speed and efficiency in various industries[3].

In Japan, meanwhile, numerous companies in the manufacturing industry have devised production systems and manufacturing improvement methods that have demonstrated quality and productivity improvements, utilizing improvement activities in which they have been engaged for some time, including the Toyota Production System (TPS), cell production system, and Production Innovations the Daicel Way[4]. Furthermore, to improve productivity, the questions of which IoT technologies or cloud services it is best to develop and install, and what form the next generation of production systems should take, are recognized as major topics for study by industry moving forward.

Meanwhile, there have been notable instances of major recalls by the automotive industry in recent years due to defective parts, and these have reinforced the importance of collecting and managing production results data (meaning actual data from the production process, such as component lot numbers, in-process inspection results, and machining conditions) in order to be able to identify the cause of product defects and take remedial steps.

Currently, manufacturing execution systems (MESs) are used to achieve traceability by collecting actual data such as component lot numbers, process data from production equipment, inspection data, and the results of visual inspections by workers, and by linking this production results data to product serial numbers (IDs identifying individual products).

However, when the completeness of this production results data is looked at in terms of the “man, machine, material” (3M) factors of production, there are instances where current data is considered to be inadequate for identifying the causes of problems (see Table 1). For example, even if a deviation from

TABLE 1. Cases in which Adequate Production Results Data is Not Available (at Machining or Assembly Production Sites)
It was found that, in certain cases, the production results data currently collected at manufacturing plants is inadequate for identifying cases of defects.

Category	Type of information	Management method (current)	Completeness evaluation (reasons)
Man	Manual measurements, interventions	Instrument data	△ (unable to identify defective parts, contaminants, etc.)
	Assembly, machining	Inspection by supervisor	× (unable to monitor all work, no quantitative data)
	Visual inspection	Results recorded on a paper form, etc.	△ (variations between workers, potential for data entry errors)
Machine	Gripping of workpiece	Machining center	△ (unable to detect minor abnormalities)
Material	Type of supplied materials, lot numbers	Label check, etc.	△ (potential for reading wrong label or skipping filling ports)

standard operation procedures (SOPs) is identified as the reason for a defective product, it will still be necessary to recall a wide range of products because it is not possible to determine which lots used the same faulty procedure.

There have been many cases in the past where this data has not been managed by a system and there is scope for new improvements in terms of quality and productivity.

The challenge for MESs is to strengthen traceability by widening the scope of production results data that is managed while also seeking to improve productivity.

NEXT-GENERATION GLOBAL PRODUCTION MANAGEMENT SYSTEM

Basic Concepts

To overcome these challenges, Hitachi is developing a next-generation global production management system for machining and assembly production sites. The system uses on-site cameras as a means of sensing to augment the production results data collected by the existing MESs. In addition to integrating this data, which includes video based on 3M considerations, it also uses big data analytics to suggest improvements and incorporate them into "methods" (+M) at each site. Ultimately, the aim is to consolidate and analyze data from manufacturing sites around the world to achieve inter-site coordination and supply chain optimization at a global level. The system is built on a symbiotic autonomous decentralized platform, improving the quality and productivity at each site in the short term, and management efficiency in the long term (see Fig. 1).

Roadmap Based on Maturity Model

To build its production management system for improving management efficiency, Hitachi recognized the need to add additional functions in accordance with the maturity level of its existing systems. To this end, Hitachi analyzed the production management systems at its own factories and devised a maturity model that classifies production systems in terms of six maturity levels, using this as a basis for developing

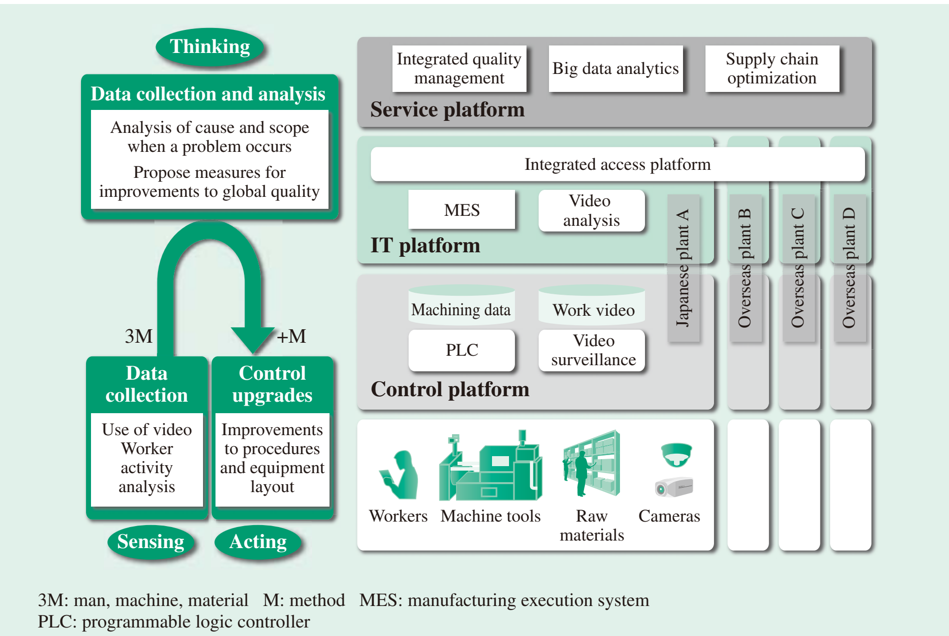

Fig. 1—Basic Architecture of Next-generation Global Production Management System. In addition to collecting information from manufacturing sites around the world based on 3M considerations, the system also uses big data analytics to suggest quality or other improvements and provide these to the manufacturing sites as feedback.

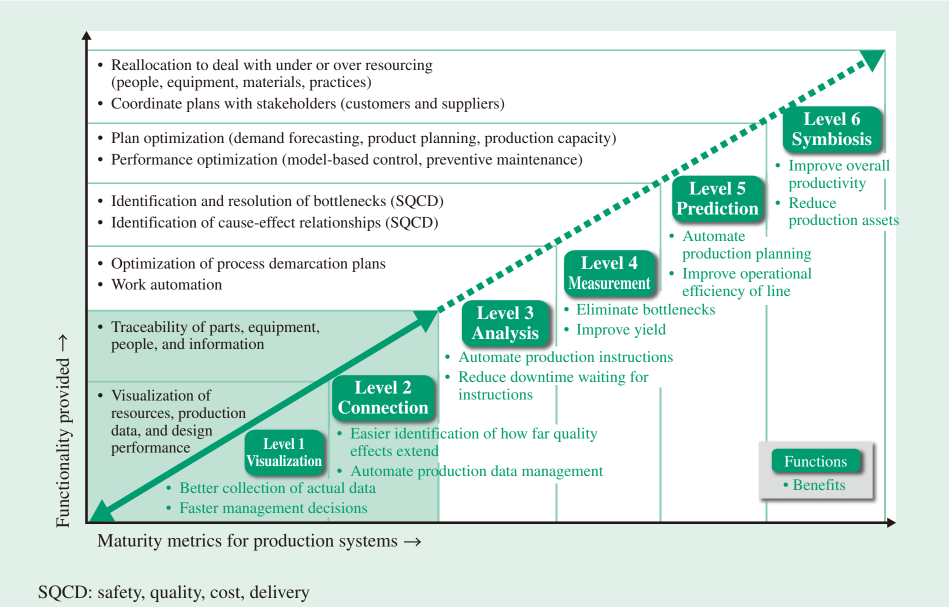

Fig. 2—Maturity Metrics for Production Systems, and the Functions and Value they Provide.
A production management system that can help improve management efficiency can be created by providing additional functions based on the production system's maturity.

a roadmap for system enhancements based on maturity level (see Fig. 2).

Based on site information made available at maturity level 1 (Visualization), actual data is linked together at level 2 (Connection) to achieve traceability. Next, instructions are automated at level 3 (Analysis) and bottlenecks are eliminated at level 4 (Measurement). Plans are optimized at level 5 (Prediction) and system-wide optimization covering multiple sites and stakeholders is the objective at level 6 (Symbiosis).

Primarily, maturity levels up to level 2 contribute to quality improvement, up to level 4 contribute to productivity improvement, and up to level 6 contribute to management efficiency improvement. The next-generation global production management is being achieved by expanding functions based on these production system maturity metrics.

In a co-creation project with Daicel Corporation, Hitachi is currently engaged in functional development and demonstration testing to implement all functions up to level 2 (Connection).

The following section uses the example of a demonstration testing being conducted by Hitachi and Daicel to show how integration of video analysis and MES is being used to improve quality.

VIDEO ANALYSIS

Role of Video Analysis

Video analysis is a technique seen as having great potential for the visualization level of the system maturity model shown in Fig. 2. Hitachi has been building up technology in the field of video analysis for a wide range of applications, including security and factory automation (FA), for nearly 50 years[5]. The intention is to use these techniques to extract meaningful information from quantities of video that are too large to be viewed by people in order to identify defects at an early stage and to make improvements to quality and productivity.

The choice of what to analyze in the co-creation project with Daicel was made to enable acquisition of 3M information (see Table 2). To monitor the operations of workers, motion cameras capable of capturing body movements were used. To monitor the movements of supervisory or parts supply staff, panoramic cameras mounted in the ceiling and capable of capturing images over a wide area were used. To capture the progress of parts supply, pan/tilt/zoom (PTZ) cameras capable of homing in on targets with high precision were used. To detect various anomalies in equipment, fixed cameras were used (see Fig. 3).

TABLE 2. Types of Analysis and Sensing Methods
The choice of what to analyze was made based on 3M considerations and sensing methods selected to suit the purpose.

Category	Analysis	Sensing method
Man	Worker activity	Motion camera
	Location of supervisory and parts supply staff	Panoramic camera
Machine	Spills, work-in-progress out of position	Fixed camera
Material	Parts supply	PTZ camera

PTZ: pan, tilt, zoom

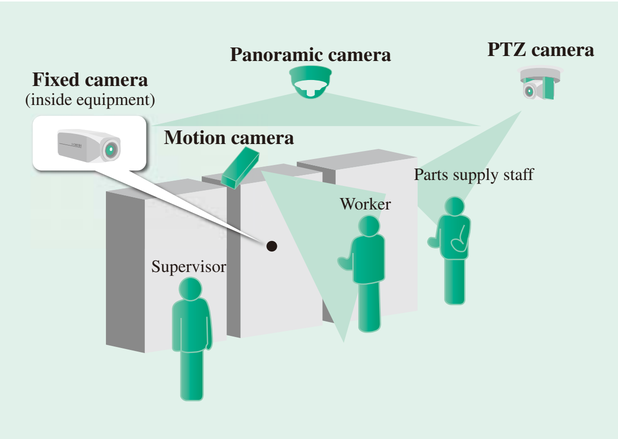

Fig. 3—Camera Locations.
The types of cameras to install at the site were chosen based on the intended analysis.

The following section describes a new initiative in which motion cameras are used to capture worker operations.

Worker Operation Recognition

Motion cameras can capture three-dimensional shapes. In the case of people, it is possible to infer information about the position of joints (such as the wrists, elbows, or shoulders) from these three-dimensional shapes. Hitachi has developed an abnormal operation detection technique that uses this information to detect when worker operations deviate from standard operation.

The basic structure of the algorithms typically used for video analysis can still be used if the input is switched from video to joint position information. This structure is made up of preprocessing to remove noise from the input, feature extraction to identify the information required for interpretation, and a classifier that uses the extracted feature values to make statistical assessments.

Fig. 4 shows a block diagram of the abnormal operation detection algorithm. The preprocessor uses smoothing to remove noise from the joint information and normalization to cancel out information that is not directly relevant to the work, such as arm or leg length. The feature value extractor extracts information (feature values) representing worker movements. These feature values are determined through consultation and on-site observation. That is, the bodily movements to be detected are determined from the results of consultation about which operations represent a deviation and knowledge of what constitutes standard operation acquired through site observation, and this is used as the basis for determining the feature values. The classifier selects the combination of feature values to consider based on the type of work being monitored, and identifies whether there are deviations by performing a statistical comparison with the standard operation model.

Cameras had already been installed at Daicel's Harima plant. To verify the efficacy of the new technique, the abnormal operation detection process was applied to actual data from the plant. This produced examples of visual inspection performed over a long period of time and of the removal of identified products. This demonstrated that the technique can be used to detect deviations from standard operation. In the future, Hitachi intends to devise ways of identifying problematic deviations by combining the technique with production log data.

FUTURE OUTLOOK

The image analysis technique described above is primarily intended as a "connection" function for quality improvement. Along with the comprehensive adoption of connection technologies at manufacturing

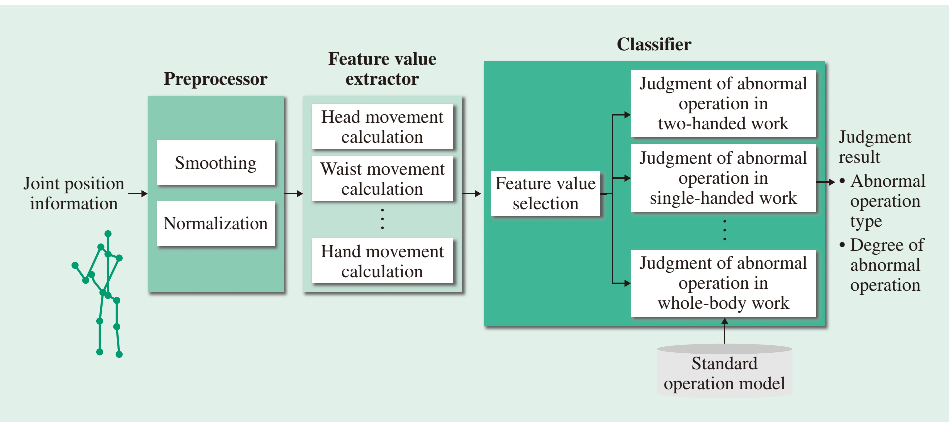

Fig. 4—Block Diagram of Abnormal Operation Detection Algorithm.
The algorithm is modeled on those used for video analysis and has the same overall structure. The individual parts, however, use newly developed techniques.

sites around the world, Hitachi intends to provide capabilities for combining and "analyzing" information collected from different sites to "measure" problems. It anticipates that the following three technologies will be important to achieving this.

The first is edge cognition technology. When using the image analysis technique as a sensing technique at a plant, it is not practical in terms of cost to collect, consolidate, and analyze large amounts of video data in one location. Accordingly, there will be an important role for technology that performs video analysis in realtime at a location close to the manufacturing site, namely within the camera that is the source of the data. The second is ultra-high compression & super-resolution technology. Even when edge cognition is used, there will still be cases, such as when problems occur, where there is a need to forward video data from the site to the company headquarters, a mother factory, or some other remote location. Such cases require the ability to transmit data with high quality and at low cost. The third technology is big data analytics. This is used to generate improvement suggestions by consolidating and analyzing information such as production data collected by the MES or the results of video analysis from manufacturing sites around the world together with actual data on quality or productivity. One example might be to identify differences between quality or productivity at different plants and determine the reasons. These improvement suggestions can then be sent back to the plants as feedback, such as proposals for globally standardized SOPs (methods) or quality standards.

From here, the next level involves automating the optimization of practices at each plant through "prediction." Key technologies include planning optimization based on demand forecasting or production capacity prediction, and performance optimization by preventive maintenance and model-based control.

The ultimate objective is to go beyond the optimization of individual sites to create "symbiotic" production systems that achieve system-wide optimization through measures such as the sharing of resources between different plants or the coordination of planning across the entire supply chain.

CONCLUSIONS

This article has described work on the development of a next-generation global production management system for improving management efficiency at machining and assembly production sites.

A roadmap of the functions required in terms of the 3M factors of production was formulated on the basis of a system maturity model. The article also described work on abnormal operation detection using motion cameras to interpret worker operations and demonstration testing at a customer factory to provide an example of image analysis that uses camera images as a new form of production results data.

ACKNOWLEDGMENTS

In writing this article, the authors received considerable advice and assistance from the staff of Daicel Corporation and everyone else involved regarding the use of worker operation recognition to detect deviations from standard operation, which was used as an example in this article. We would like to take this opportunity to sincerely thank everyone for all the help they provided.

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Featured Articles

Image Sensing Techniques for Analysis and Interpretation of Surveillance Video

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OVERVIEW: Video surveillance systems, which have been heading for digital formats and higher image quality along with a switch from analog cameras to network ones for the purposes of crime prevention, disaster response, anti-terrorist measures, and tighter internal control are expanding in terms of their introduction and use at enterprises and public facilities[1), 2)]*. They are also spreading into a wide range of other business areas through the utilization of video content analysis and various databases. Moreover, activity involving the solving of management issues, such as operational efficiency or quality of product improvement, has been initiated recently in the industrial field with the progress of IoT technology, accordingly. In addition to security purposes, Hitachi is also proposing plant surveillance video for things such as product quality improvement and plant safety by making use of image sensing for analyzing and recognizing humans, vehicles, and other objects from surveillance video.*

INTRODUCTION

THERE have been two changes in the video surveillance systems field in the context of a transition from analog cameras to network ones in recent years: higher resolutions and larger-scale camera networks that connect a central data center with hundreds of cameras. Under such circumstances, video content analysis technology for identifying humans, vehicles, and other objects in video images acquired by surveillance cameras has become practical to use. In addition, the demand for automatic monitoring systems with multiple cameras to supersede human monitoring is increasing.

Meanwhile, in the field of industry, the German Industrie 4.0 project, representing the fourth industrial revolution, and the Internet of things (IoT) are becoming more popular and more familiar. Consequently, there is a growing need for video content analysis functions such as surveillance cameras with sensors that are able to recognize and collect needed pieces of information when humans are present on video, for example. Such information can be utilized to increase productivity or improve quality, efficient allocation of manufacturing equipment, or optimal posting of workers in a factory, by analyzing them together with big data coming from the production management systems.

This article describes the technological direction of image sensing that can recognize and analyze humans, vehicles, and other objects on surveillance video and Hitachi's activity in this field, as well as the problem posed by analysis processing load for the implementation of surveillance video systems and its solution.

FROM IMAGE PROCESSING TO VIDEO CONTENT ANALYSIS

Hitachi started researching image processing in 1968, and has been turning its research results into commercial and industrial applications on dedicated hardware for positioning objects and checking the shape of components mounted on circuit boards, or wafer inspection by large-scale integration (LSI) production equipment. These technologies have developed into video content analysis techniques that are used for realtime detection of road conditions through in-vehicle cameras through the evolution of information technology (IT) and embedded technology.

Meanwhile, in the video surveillance sector, the speed of networks and central processing units (CPUs) has been increasing in recent years since analog cameras have begun to be replaced with network ones. As a result, the way image processing algorithms are implemented has changed from dedicated hardware to software, high-speed searching of scenes from large amounts of video recorded on hard disks, and realtime video content analysis of live video have become possible on personal computers (PC) and servers.

IMAGE SENSING TECHNIQUES

Trends in Technology for Video Content Analysis

The technology for measuring and identifying humans, vehicles, and objects from cameras or sensors is defined as "image sensing" technology in this article. Video content analysis techniques using cameras will be mainly explained in the following two sections.

Video content analysis has been subjected to extensive research and using video surveillance systems for security purposes is the most widespread use in this research field. The typical applications of the system are intrusion detection for finding humans that enter into a specific area, facial recognition, measuring traffic volumes of vehicles, recognizing vehicle license plates, and so on. The flow of technical development in these applications can be broadly divided into the three steps described below (see Fig. 1).

The first step is "presence sensing." At the beginning, it is necessary to recognize the presence of human bodies or faces, and vehicles, determine their locations, or count the number of them in video images in order to perform analysis. Applications such as detection for finding humans intruders and measurement of traffic volumes can be handled in this step.

The second step is "status and attribution recognition." Information gathered by status, type, or attribution is classified or checked against pre-registered information. Applications such as facial recognition and recognizing vehicle license plates can be handled in this step.

The last step, which, unlike the first and second steps, has not established sufficient technologies, and is expected to be a subject of further study, is "behavior understanding and prediction." This step features the recognition of interactions or contexts, including temporal and circumstantial changes between detected objects and the prediction of their future statuses by means of analysis using a large amount of data.

Details of Hitachi's techniques in the three steps will be introduced in the following section.

Hitachi's Video Content Analysis Techniques

(1) Presence sensing

Hitachi has developed a technique that enables the identification of congested situations by analyzing existing surveillance camera video (see Fig. 2). Additional sensors or other equipment are not needed for the technique because it only requires rough information.

If the technique was introduced into surveillance cameras at a manufacturing factory, it could be utilized for being notified of the high possibility that an accident has occurred, for example, in places that are not usually crowded with people.

Compared to the previous purpose of surveillance cameras, to record what happened in the past, this

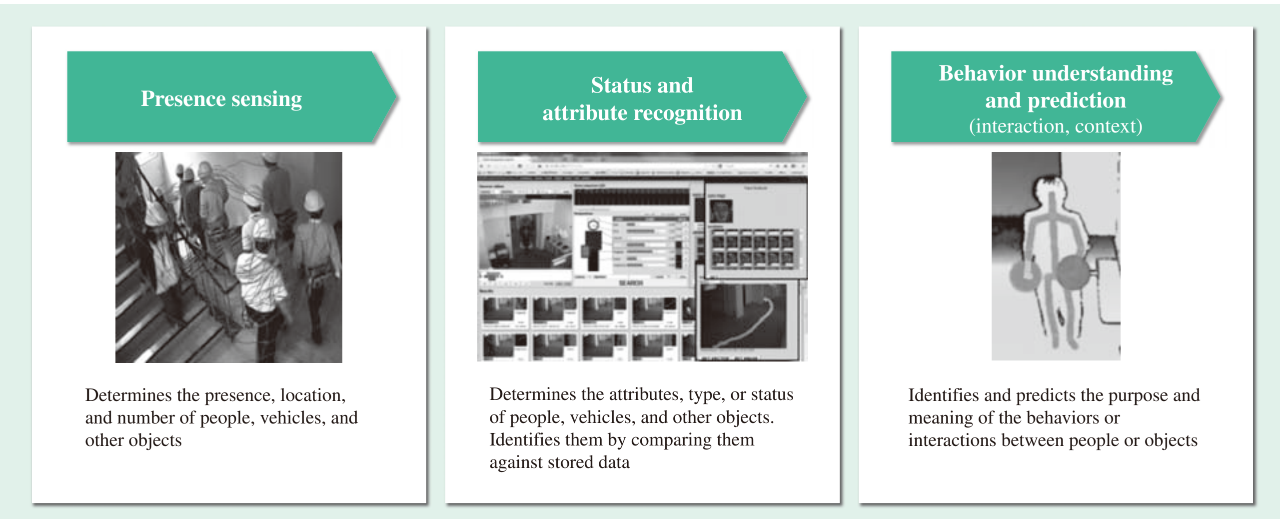

Fig. 1—Classification of Video Content Analysis Techniques.
The sequence of video content analysis can be explained in three steps: "presence sensing," "status and attribution recognition," and "behavior understanding and prediction."

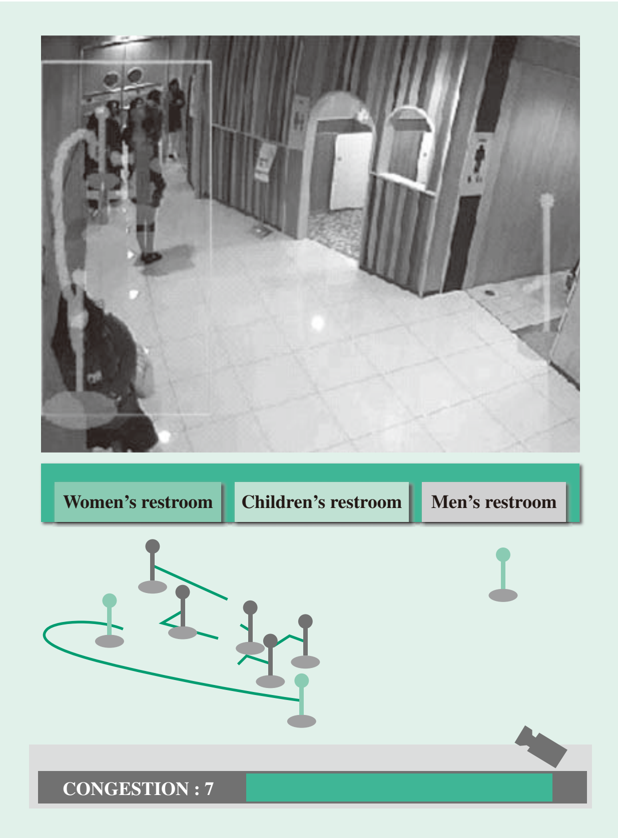

Fig. 2—Example Analysis of Congested Situations in Restrooms.
The system can identify the congested situation in the white rectangle by detecting the presence of humans on existing surveillance camera video.

Fig. 3—Multi-perspective Search Technique.
The technique can search for a specific individual on video from among a large number of surveillance cameras based on the person's clothes and objects the person is carrying.

Fig. 4—Realtime processing.
The technique can detect people who are walking erratically or carrying prohibited hazardous objects.

technique adds new value by providing timely and prompt notification of accidents or other incidents.

(2) Status and attribution recognition

Hitachi has developed a multi-perspective search technique that enables searching for a specific person from among a large number of integrated multi-surveillance video images based on certain clues, including facial appearance, clothes, personal belongings, and route of movement (see Fig. 3).

Hitachi conducted a demonstration experiment and tested its effectiveness at tracking the route of movement of a suspicious person in a building using a group of ten or more surveillance cameras.

(3) Behavior understanding and prediction

Hitachi has a sophisticated and enhanced status recognition technique for recognizing a person's behavior in surveillance camera video images, so that realtime analysis of human behavior and features of the objects they are carrying can be achieved in addition to the existing techniques to obtain human location information through existing surveillance cameras (see Fig. 4).

This technique brings new applications for use in detecting people walking erratically or carrying prohibited hazardous objects such as fuel cans.

Moreover, Hitachi has been further studying human behavior analysis by means of a multi-model processing technique that combines surveillance camera video images and rangefinders in order to accurately analyze physical posture and physical positional relationships, because this cannot be done by using video images only (see Fig. 5).

Hitachi intends to utilize this technique to monitor work or to assist inexperienced workers at factories or site shops in the future.

Outlook for Image Sensing Technique

It is anticipated that image sensing techniques that determine information including the status of humans, vehicles, or objects using cameras, will be expand more into the workplace and continue to develop to a higher level in the future.

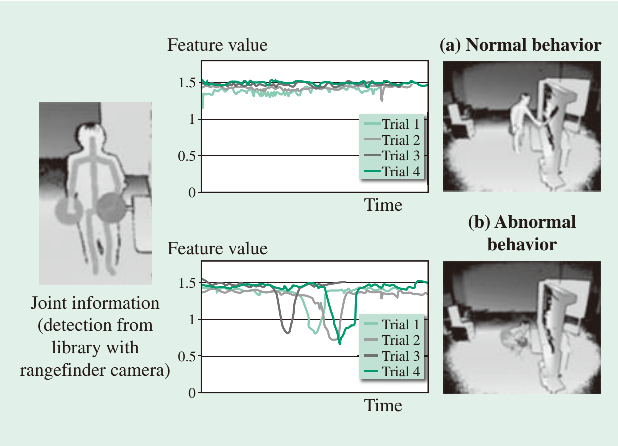

Fig. 5—Detection of Human Behavior Using Rangefinder.
The technique can detect specific human actions such as crouching down based on a measurement of the angles of the person's joints using rangefinder information.

In recent years, cameras, sensors, servers, and other equipment have been spreading throughout the market because of their falling prices. In terms of technological advances, great progress has been made on machine learning techniques, particularly with deep learning, which contributes to improving the accuracy of image recognition. In addition, data analysis and visualization have become easier to performing because of the progress made in big data processing technology and the availability of data processing platforms such as Pentaho*.

Hitachi has been pursuing research and development in this field in order to provide integrated solutions that enable the identification of anomalies or changes in large facilities by combining data collected from many cameras and sensors with cloud-based data processing platforms. These solutions also improve the accuracy of detection through video content analysis techniques using deep learning.

FUTURE ISSUES AND HOW TO OVERCOME THEM

Hitachi has been considering the practical realization of video content analysis not only for purposes of security, but also for all kinds of purposes.

As the scale of facilities becomes larger and the variation of video content analysis becomes greater, so too will the required number of surveillance cameras and volume of video data also increase. Through this, some issues are expected to be come up, including

* An open source business intelligence (BI) tool for professional use.

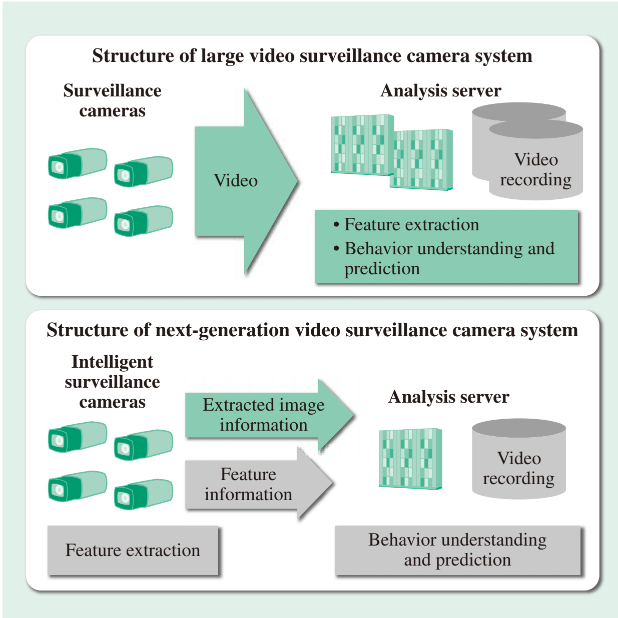

Fig. 6—Structure of Next-generation Video Surveillance Camera System.
The system can reduce the total amount of data with a feature extraction processing function added on to surveillance cameras.

cost increases due to the larger storage capacity of servers that receive video data, cost increases due to increasing analysis processing loads, and increases in network loads due to large volume, high-resolution video (see Fig. 6).

In order to overcome these issues, surveillance cameras should be equipped with "presence sensing" and "status and attribution recognition" functions and steps for extracting feature information from video images alone, because distributed processing and data compression are effective ways of doing that. As a result of this, it will be possible to carry out the final step, "behavior understanding and prediction," with low cost and high speed, based on transferring the minimum amount of feature extraction video data and feature data to the analysis server.

For the practical realization of this, the interoperation of a large number of surveillance cameras for large facilities, realtime processing that enables prompt response, and combination processing techniques using multiple devices for detailed behavior assessment will be required.

With regard to next-generation video surveillance camera systems, a promising approach is to build a system with business intelligence (BI) tools such as Pentaho based on image sensing techniques that combine intelligent surveillance cameras/sensors with analysis servers.

CONCLUSIONS

This article has described the utilization of image sensing techniques in surveillance cameras and sensors, and image sensing techniques for analyzing or recognizing humans or objects in video images for purposes beyond just security purposes.

Hitachi will continue contributing to the realization of a "safe and secure" society and applying image sensing techniques for public facilities and all kinds of fields behind the scenes at an international sports event in Tokyo, in 2020. Hitachi will also continue moving forward to resolve customers' operational efficiency improvement challenges and quality assurance improvement challenges utilizing these technologies.

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Featured Articles

Next-generation IoT-based Production System for High-mix Low-volume Products in an Era of Globalization

—Activities at Hitachi's Omika Works—

Ryo Onizawa
Toshiko Takamura
Masataka Tanaka
Shuichi Motohashi

OVERVIEW: Hitachi's Omika Works supplies information and control systems that underpin the social infrastructure and deals with high-mix low-volume products that are customized to suit specific customer requirements and applications. To ensure that it can continue to supply these high-value-added products in a timely manner and at reasonable cost, the plant is seeking to implement smart manufacturing practices that utilize the IoT. The first step involves making factory information available (visualization) based on the concepts of obtaining a more accurate understanding of production capacity and coordinating production information at the site. Along with RFID and other sensors to track actual production progress, this includes optimizing the overall plant by improving coordination between departments, between processes, and between management and the workplace.

INTRODUCTION

HITACHI'S Omika Works supplies information and control systems that underpin the social infrastructure and deals with high-mix low-volume products that are customized to specific customer requirements. While attention to detail in the design and manufacture of customized products is a strength of Hitachi, market competition in this era of globalization has raised challenges of speed and cost. Hitachi has identified the following three requirements that it must satisfy if it is to succeed in global markets without compromising its strengths, and is currently developing the next generation of its production system.

(1) Respond quickly to fluctuating demand
(2) Supply high-value-added products in accordance with customer requirements
(3) Maintain the same level of cost-competitiveness as products produced in high volumes

This article describes the concepts behind the next-generation production system at Omika Works that uses the Internet of things (IoT), and presents examples of its use.

Level		Function to be established
6	Symbiosis	Symbiotic optimization among stakeholders
5	Prediction	Mfg condition prediction & proactive measures
		Eng condition prediction & proactive measures
4	Measurement	Mfg planning, eng problem-solving
		Eng planning, eng problem-solving
3	Analysis	Mfg bottleneck analysis
		Eng bottleneck analysis
2	Connection	4M resource track & trace
		Eng info track & trace (dwg No. , ID, …)
1	Visualization	4M resource visualization
		Mfg result visualization
		Eng result visualization

4M: man, machine, material, method dwg: drawing
Mfg: manufacturing Eng: engineering info: information
ID: identification

Fig. 1—Process Maturity Metrics for Factory of the Future.
This model has been proposed by Hitachi for measuring the maturity of production systems.

CONCEPTS AND SYSTEM ARCHITECTURE

Concepts

In preparation for the development of its next-generation production system, Omika Works evaluated its current system. Based on a model proposed by Hitachi for measuring the maturity of production systems (see Fig. 1), this analysis and evaluation found that, while individual systems had a high level of maturity, overall the capabilities of levels 1 (visualization) and 2 (connection) were inadequate.

This meant there was insufficient ability to identify the true bottlenecks and a tendency for production improvement activities to focus on individual items.

In response, the first step in the next-generation production system project was the development of a factory visualization system to boost level 1 and level 2 capabilities. The objectives (concepts) were to obtain a more accurate understanding of production capacity and to coordinate production information at the site (both horizontal and vertical coordination). These concepts are described below.

(1) Concept 1: Obtain a more accurate understanding of production capacity

As noted above, Omika Works deals mainly with high-mix low-volume products that are made to order, such that, while there may be a degree of similarity between products in the same category, most are custom designed. The resulting variation in product lead times means that, compared to products produced in high volumes, it is more difficult to determine production capacity in a routine and quantitative manner.

To deal with this difficulty, Hitachi established capabilities for recording (sensing) the 4M (man, machine, material, method) factors of production to provide an accurate view of what is happening in the workplace, including information on the movement of goods and work progress. In addition to analyzing this information to provide an accurate assessment of production capacity, it also identifies which bottlenecks genuinely require action.

(2) Concept 2: Coordinate production information at the site (both horizontal and vertical coordination)

Past production improvement activities at Omika Works have tended to focus on the work systems and other processes associated with individual product ranges, targeting the efficient production of specific high-mix low-volume products. Furthermore, coordination between departments and processes has been impeded by cases where links between different items of information are sporadic, and where information is difficult to collect and use because it is not available in digital form.

These problems were overcome based on the following two vertical and horizontal considerations to identify links between information that facilitate system-wide improvements.

(a) Provide information on how individual workplace activities influence management indicators (vertical coordination)

(b) Share information and updates across departments and processes by linking the 4M flows, from reception of new orders to the actual site (horizontal coordination)

Based on these considerations, Hitachi centralized information that was spread across different departments and processes and linked it to other information to transform it into new and valuable forms. Hitachi also adopted data collection and archiving practices for transforming site information into usable formats without human intervention by converting data on past defects and know-how into digital form.

The following section describes the system architecture used to implement these concepts.

System Architecture

This section describes the approach to collecting and archiving for information use.

First, an IoT approach to information collection was adopted for factory visualization. At Omika Works, the IoT is recognized as a way to generate new added value while also improving overall product quality and efficiency by linking and using digital data collected by existing information systems that were developed and used in the past.

Next, a cooperating field approach was adopted to the collection of information for factory visualization. The conventional practice is to define separate information systems as autonomous entities, to process the digital data they hold based on how it is to be analyzed, and to store this information in shared repositories called “cooperating fields” (see Fig. 2). This data collection requires a matching process of converting between the different coding practices used in each information system and a cleansing process to deal with duplicated or missing data, but allows digital data to be collected without having to modify existing information systems and makes information from the cooperating fields available via visualization screens (views).

DEVELOPMENT METHODS

Rather than the waterfall development process used in the past, the factory visualization screens were developed using lean startup practices that involve working rapidly through a cycle of hypothesis formulation, implementation, and course correction. As requirements change according to the circumstances, it is difficult to specify all of the information that users will want to see in advance. This is because enabling users to see what is actually happening prompts

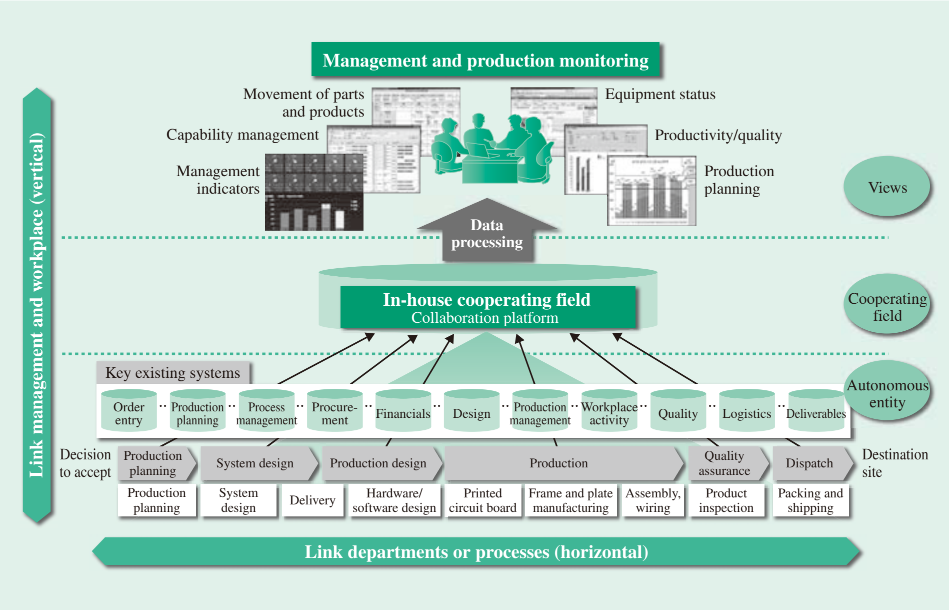

Fig. 2—Architecture for Data Collection Using In-house Cooperating Fields.
The system architecture is intended for the collection of data from in-house systems in data cooperating fields, and the processing and presentation of this data.

additional requirements as users ask for the ability to perform visualization and analysis from different perspectives. Accordingly, the development involved working through a cycle of quickly developing systems with the functions needed for testing hypotheses and obtaining rapid feedback about users' reactions.

The lean startup development process included the adoption of Pentaho, an open source software (OSS) business intelligence (BI) tool. Past in-house system development has tended to design and build systems from scratch based on a requirements specification. This resulted in long development times with upfront investment and ongoing maintenance costs.

Pentaho comes with a screen-builder tool that works by combining information visualization components and the Pentaho Data Integration (PDI) extract/transform/load (ETL) tool for processing digital data. As the source code is available (in accordance with the open source policy), the various plug-ins have considerable scope for expansion. Thanks to these features, using Pentaho enabled development to be completed quickly while minimizing the initial investment and maintenance costs.

Some of the screens developed using Pentaho are described in "Problem Visualization Using Management Information" below.

IMPLEMENTATION EXAMPLES

This section provides examples of factory visualization by describing how the information acquired by sensing and collected by information systems is used. This information, which has not been easy to interlink in the past, is collected in the cooperating fields and presented to users in ways that make it valuable to them. This provides an integrated overview of information that in the past could only be reviewed by accessing a number of different information systems, and enables it to be combined in ways that facilitate different types of analysis.

The following sections provide examples that relate respectively to obtaining a more accurate understanding of production capacity (Concept 1), and to horizontal and vertical coordination of information (Concept 2).

Visualization of On-site Movement

Omika Works has adopted radio-frequency identification (RFID) as a way to obtain a comprehensive overview of the movement of goods at the site. As of October 2015, the plant had approximately 450 RFID scanners and approximately 80,000 RFID chips in use. Attaching RFID tags to the labels and instruction forms that are circulated through the production site provides a mechanical means for collecting progress information. Attaching a label tag to goods shipped to the factory, for example, allows the movement of those goods to be tracked. Similarly, using work instruction card tags and manufacturing instruction card tags ensures the correct work instructions are issued to match the product specifications (see Fig. 3).

This provides accurate information on 4M movement at the plant and makes it possible to determine the production capacity of the overall

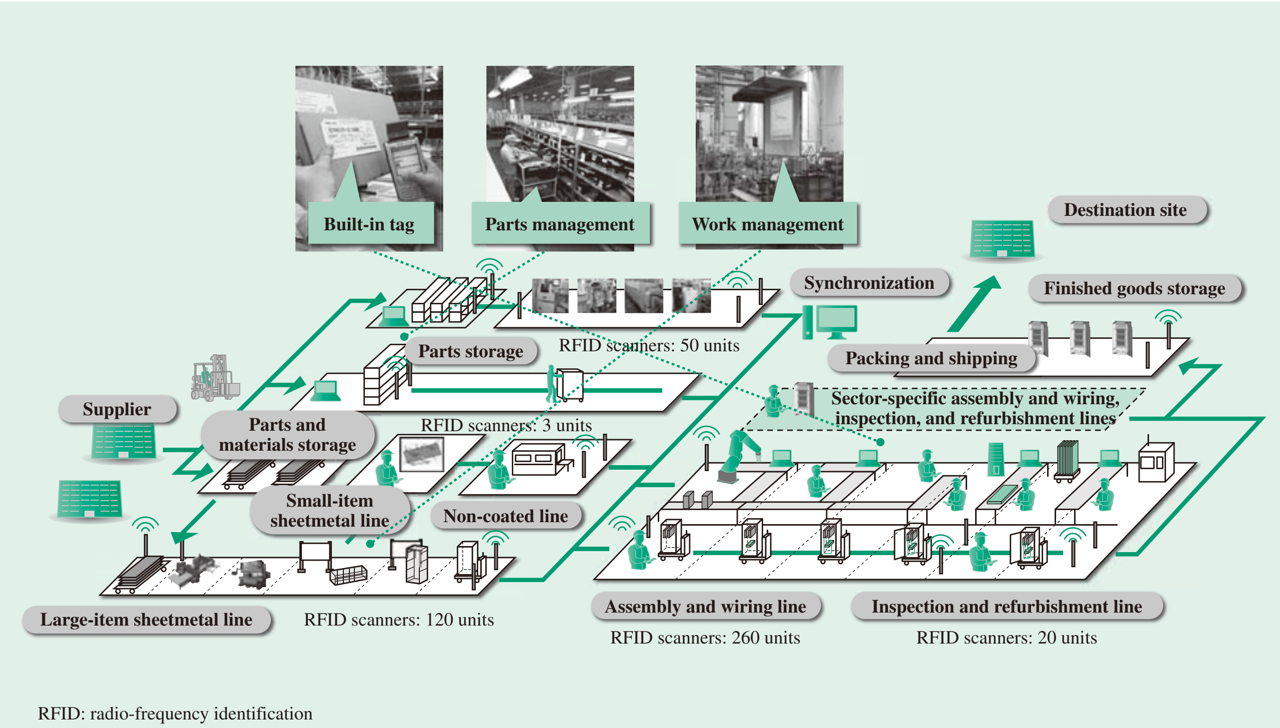

Fig. 3—Use of RFID for On-site Tracking.
Omika Works attaches RFIDs to parts, work instruction cards, and other items to enable the sensing of 4M movement and work progress at the site.

production line with a high degree of accuracy. This accuracy provides the following benefits.
(1) More accurate estimation of product costs and lead times (more accurate cashflow management)
(2) More accurate estimation of work backlogs at the plant (optimization of plant utilization)
(3) Greater ability to judge whether urgent jobs and other work can be accepted or not (increased sales opportunities)

Defect Visualization for Hardware Design

To improve product quality, Omika Works goes to great efforts to prevent product defects from being designed in. However, information on past failures or know-how built up through experience was often held only by individual people or departments, with the resulting lack of experience and knowledge making it difficult to eradicate defects entirely. Other inadequacies included the rotation of staff and transfer of skills between generations.

In response, data on past defects together with tools and other know-how held by the design and production departments were converted to digital form so that they could be shared across departments and processes. Hitachi also established mechanisms for identifying when there is a risk of defects being incorporated at the design stage by making this digital data available in the structural computer-aided design (CAD) system (see Fig. 4).

This enables the production of high-quality products in accordance with individual customer specifications while also minimizing unnecessary costs by preventing rework.

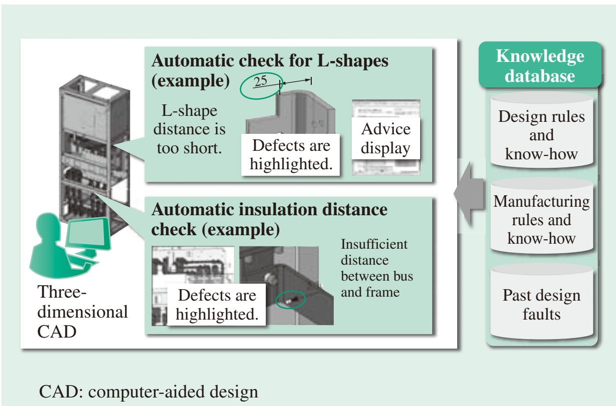

Fig. 4—Automatic Structural Design (Sheetmetal) Checking by CAD System that Supports Designer Awareness.
Checks are performed at the design stage using three-dimensional CAD. Site standards, know-how, and information on past failures are recorded as digital data and used to identify potential design faults.

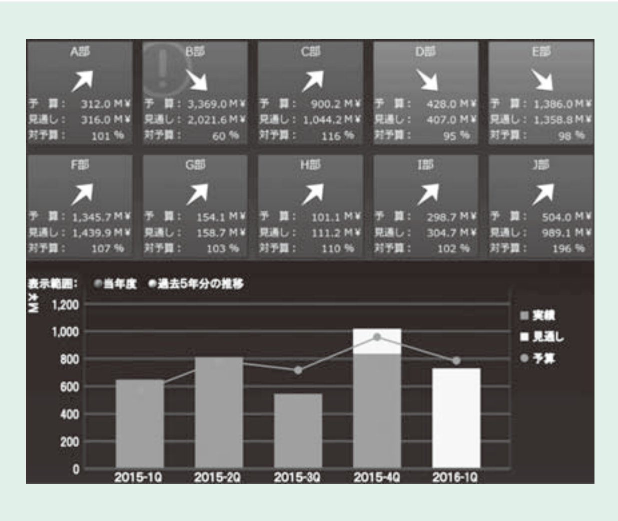

Fig. 5—Screen Showing Departmental Financial Performance.
The screen uses a heat map and cumulative bar chart (developed on Pentaho) to show departmental financial performance. The user interface was designed to suit management use cases.

Problem Visualization Using Management Information

In the past, financial data was collated in the accounting system and used by management to review performance and make decisions. However, it takes time to collate the different types of plant data and this was an impediment to timely situation assessment and decision making. In response, timely preliminary results were made available by collating the production information that serves as the source for financial data and storing it daily in the data cooperating field.

As presentation is an important aspect of data visualization, Hitachi developed user interfaces that follow management decision-making processes. BI tools were used to facilitate rapid implementation, including the use of heat maps, a form of presentation that provides an overview of the full situation, the presentation of detailed data to those departments to which it is of interest, and the ability to switch between displaying different type of information such as quarterly trends or annual trends going back five years (see Fig. 5).

Outcomes

The work has provided the capability to collect site information from existing information systems or through such means as RFID sensing, and to utilize it in data cooperating fields. It has also established a development cycle involving rapid development techniques that minimize up-front investment by using OSS, and verified their performance.

CONCLUSIONS

This article has described the development of a next-generation production system with a focus on on-site use of information.

In the future, Hitachi intends to enhance its production methods that use information obtained from cameras by image processing, or such technologies as augmented reality (AR) and robots designed for manufacturing products in a wide range of variants. Hitachi also plans to extend the use and visualization of information more widely, including at overseas plants, by acquiring experience in Japan and subjecting it to evaluation.

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Featured Articles

International Standardization Activities for Hitachi System Security Concept and Social Infrastructure Security Based on It

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Masashi Sato
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OVERVIEW: The networking of social infrastructure in recent years has led to greater security risks in the systems used in this infrastructure. In response to these increased risks, international standardization bodies and other industry organizations are working on formulating security requirements for systems. Hitachi uses the Hitachi system security concept as a basis for dealing with the requirements demanded of social infrastructure, which include responding to trends in cyber-attacks and long-term operation, and has been engaging in studies at the IEC. These requirements were presented in a whitepaper entitled "Factory of the future" that describes how factories will look in the future and the technology they will require, and are currently being adopted. In the future, advances in the IoT and elsewhere will make security even more important. Hitachi intends to supply security solutions to create secure social infrastructure that everyone can use with confidence.

INTRODUCTION

THE threat of cyber-attacks has become greater and more severe in recent years as social infrastructure has become increasingly networked. Accordingly, diverse security measures to protect against cyber-attacks have become essential for social infrastructure systems.

A major prerequisite for the control systems used in social infrastructure is that they continue operating for a long period of time, and they need to be able to handle a wide variety of system interoperation associated with the evolution of threats and advances such as the Internet of things (IoT) and be able to respond rapidly to any attacks that occur.

Taking note of trends in how to deal with cyber-attacks, the characteristics of social infrastructure such as long-term operation, etc., and developments in open innovation, Hitachi has expressed three new security requirements for social infrastructure systems, namely adaptivity, responsivity, and cooperativity, in the form of the Hitachi system security concept. These requirements were presented by the International Electrotechnical Commission (IEC)[1], an international standardization body, in a whitepaper entitled "Factory of the future"[2] that describes how factories will look in the future and the technology they will require (subjects of study at the IEC), and are currently being adopted.

This article presents an overview of security in social infrastructure systems followed by a description of the Hitachi system security concept[3] in which Hitachi has proposed security requirements for social infrastructure systems, and solutions for implementing this concept.

DEVELOPMENTS IN SECURITY FOR SOCIAL INFRASTRUCTURE SYSTEMS

This section presents an overview of developments relating to the threats, system configurations, and countermeasures required when implementing security for social infrastructure systems (see Fig. 1).

Security threats are continually changing, and along with attacks such as zero day and multi-vector attacks, which have become more diverse in recent years, there are also cases of attacks based on conditions that differ from conventional assumptions, such as malicious activity by insiders. Furthermore, with regard to the prerequisite system configurations, progress is anticipated on the symbiotic autonomous decentralized systems proposed by Hitachi in which system interconnections transcend the boundaries of industries and businesses, such as the IoT, supply chain developments, and the analysis of plant data. For these reasons, it is difficult to accurately predict what

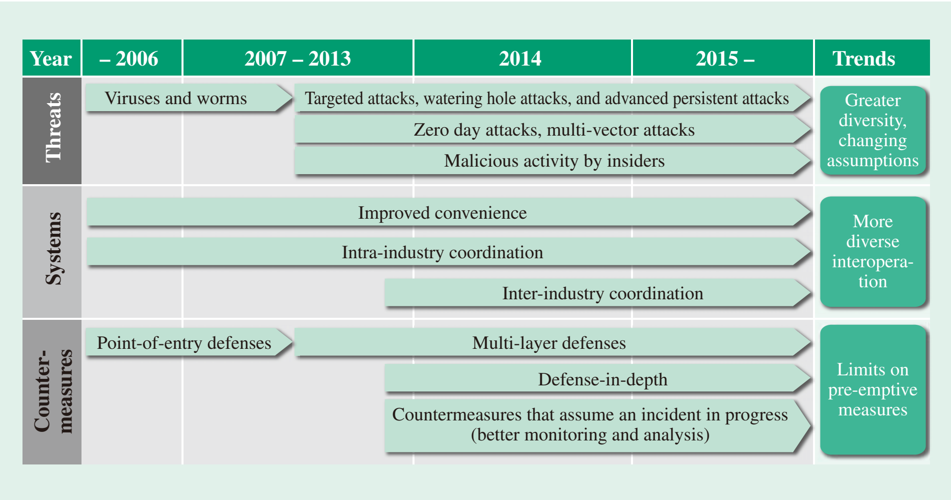

Fig. 1—Security Developments.
Along with security threats becoming more diverse in recent years, social infrastructure systems, too, are adopting various forms of interoperation. This means that countermeasure techniques also require a new approach.

security threats will arise, making it hard to establish countermeasures in advance.

This means that, as a prerequisite, it is essential to have security measures that are based on threats and systems continually changing in these ways.

HITACHI SYSTEM SECURITY CONCEPT

This section describes the Hitachi system security concept proposed by Hitachi (see Fig. 2).

A prerequisite for ensuring the security of a social infrastructure system is to ensure robustness (hardening) with respect to likely threats based on the target system's configuration. On top of this, Hitachi has proposed three new requirements for security: giving security measures the ability to adapt as needed to continually changing threats and system configurations (adaptivity), providing responses that will minimize the impact on the social infrastructure system if a security threat does materialize (responsivity), and having different organizations work together to ensure the early identification of security threats (cooperativity).

Recognizing that these three requirements play an important role in the implementation of social infrastructure or industrial systems and need to be adopted internationally, studies have been undertaken at the IEC, and they have been adopted in a whitepaper entitled "Factory of the future" that describes how factories will look in the future together with the technology required.

The details are described below.

(1) Hardening (see Fig. 3)

This refers to the primary measures used to protect the services and other functions of social infrastructure systems. However, providing complete security against continually changing threats is impractical. Instead,

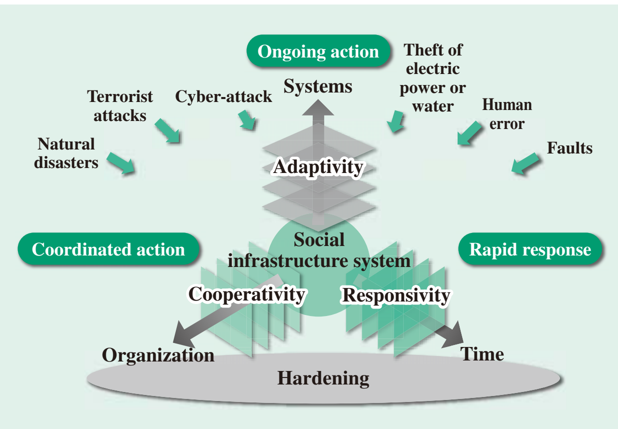

Fig. 2—Hitachi System Security Concept.
Hitachi has presented its views on the requirements for security in social infrastructure systems in the form of the Hitachi system security concept.

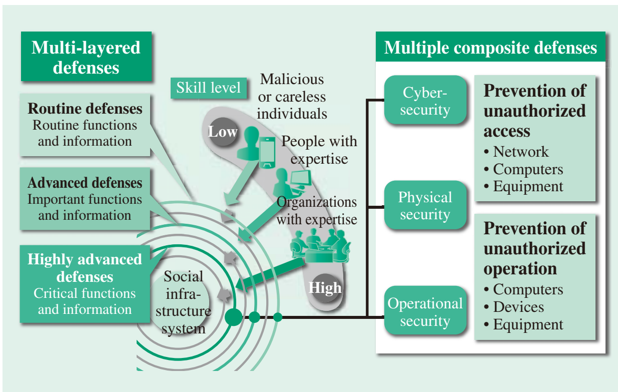

Fig. 3—Ensuring Hardening.
To harden systems against a variety of threats, it is important to implement multiple and multi-layered defenses.

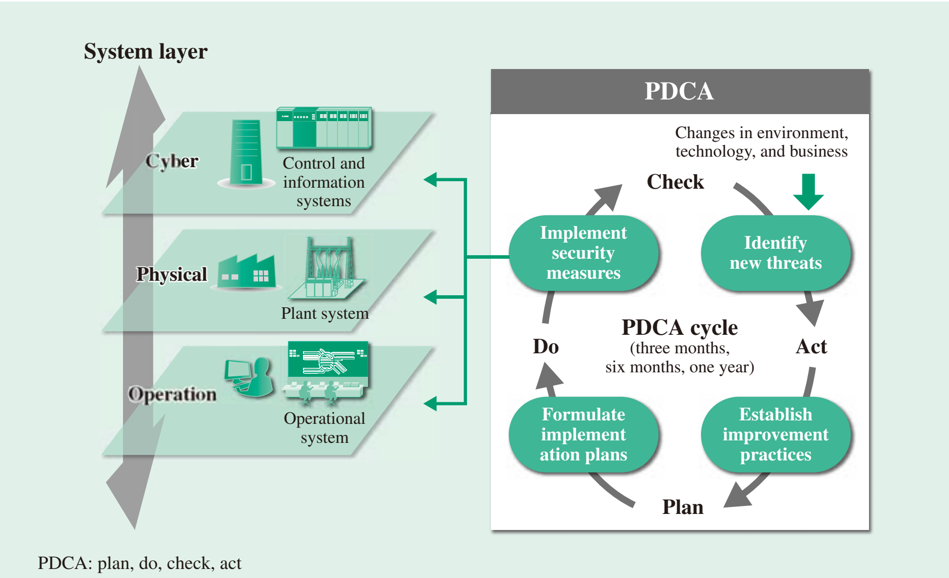

Fig. 4—Ensuring Adaptivity.
The PDCA process plays an important part in adapting quickly to changes in threats and technology.

what is needed is a defense-in-depth approach with a good balance of physical, operational, and other measures. The adoption of defense-in-depth also involves reducing the risk of attacks on systems that provide important functions.

In addition to supplying security products focusing on control systems that provide reliable long-term operation, Hitachi also builds systems that comply with international and other industry standards and utilize business knowledge.

(2) Adaptivity (see Fig. 4)

Security threats are becoming more ingenious. System architectures, too, are continually changing, including the use of publically available technology through open innovation and interoperation between systems to create new businesses. This means that social infrastructure systems are continually being exposed to new threats. As noted in the section above about hardening, because it is essential to focus on control systems that operate reliably over long periods of time, there is a need to assess how to deal with threats before those threats materialize. In other words, it is important to provide security management for adapting to the changes to which the system is exposed.

To achieve this, management, engineering, operations, and human resources need to come together on an ongoing basis to work through the plan, do, check, act (PDCA) cycle. Specifically, in addition to choosing the improvements to make based on systematically identifying the new threats and other changes to which the system is exposed and assessing the risks they present, there is a need to establish improvement practices in terms of cyberspace, physical space, and operational management, and to formulate implementation plans based on these improvement practices. An important factor in this work is performing an objective risk assessment.

To achieve this adaptivity, Hitachi supplies engineering that draws on its past experience in developing control systems and is based on the Cyber Security Management System (CSMS) for control systems.

(3) Responsivity (see Fig. 5)

Because complete protection against security threats is impractical, the response when an incident does occur is an important aspect of protecting social infrastructure systems and minimizing damage. Along

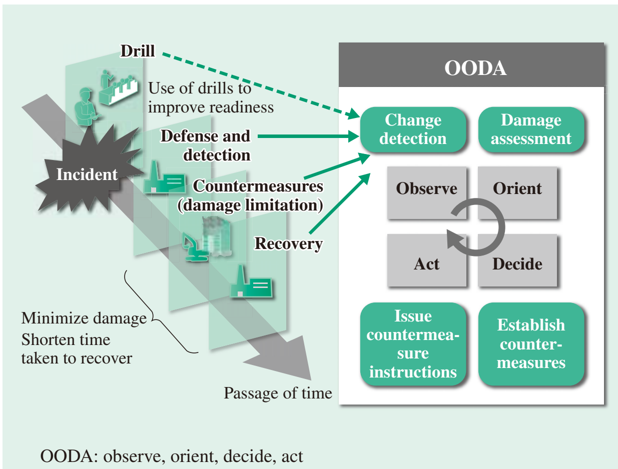

Fig. 5—Achieving Responsivity.
To minimize the impact of security threats on a system, it is important to identify the signs of a threat quickly and to take action against it.

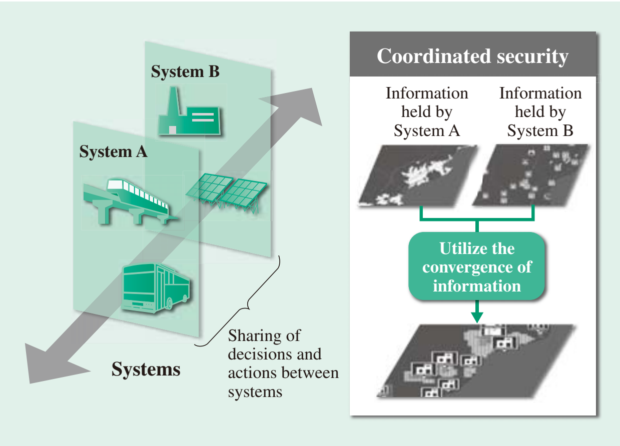

Fig. 6—Achieving Cooperativity.
To protect social infrastructure systems, it is important to establish mechanisms for obtaining timely information about security threats in other related systems.

with continuous monitoring for changes in the state of the system and assessing whether changes are due to security threats, achieving this requires a rapid response based on an assessment of the scope of the security threat and the formulation of responses. In addition to providing systems with ways of identifying system status changes, a dedicated organization for formulating responses and other practices is also essential.

Together with techniques for rapidly detecting changes in the status of a system at the IT level and business level, Hitachi also supplies specialist services such as providing the latest security information to support a dedicated organization and classifying security threats.

(4) Cooperativity (see Fig. 6)

To protect social infrastructure systems against threats, it is important to obtain information about security threats beforehand. Furthermore, when a number of systems are working together, there is the potential for a security threat to a system at one site to spread to the other systems.

Accordingly, not only do social infrastructure systems need to coordinate their security policies and other countermeasures, it is also important that they share security threat information.

To achieve this cooperativity, Hitachi offers a variety of gateway devices and supplies solutions that enable information sharing between organizations.

SECURITY SOLUTIONS

Following the summary of Hitachi system security concept presented above, this section presents examples of security solutions that utilize that concept (see Fig. 7).

Providing security from the perspective of adaptivity involves conducting risk assessments that focus on the assets being protected, and supplying optimal security countermeasures by formulating the cyber-security and physical security measures needed to offer realtime protection. In terms of

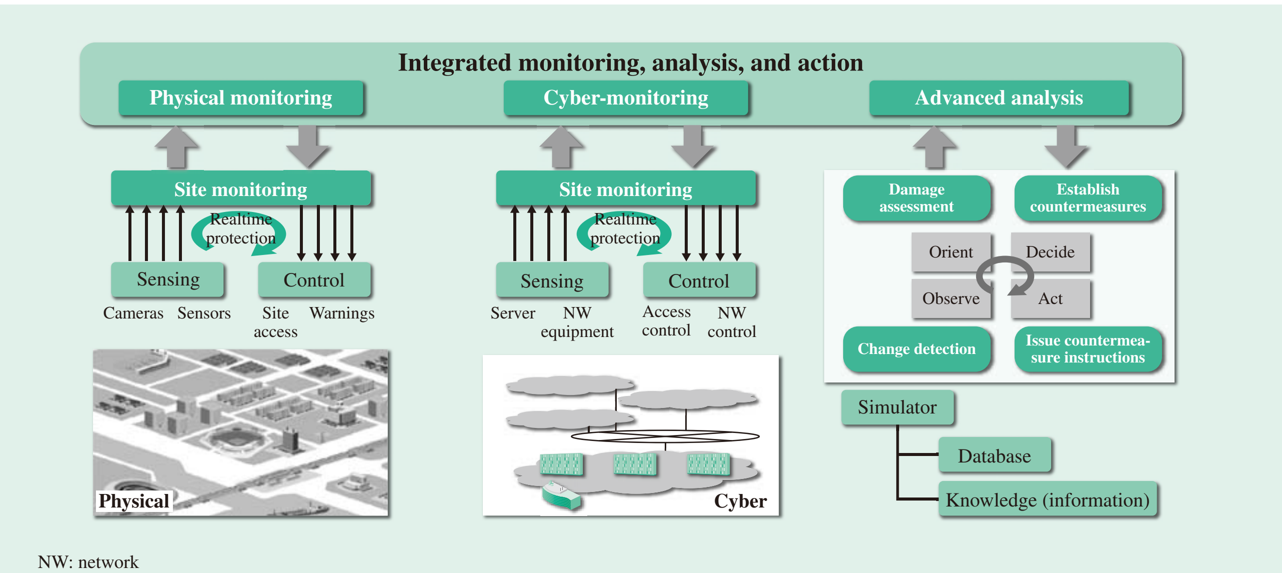

Fig. 7—Example Security Solution that Uses the Hitachi System Security Concept.
The security of social infrastructure systems is maintained by providing realtime protection in terms of both cybersecurity and physical security, with integrated monitoring, analysis, and action.

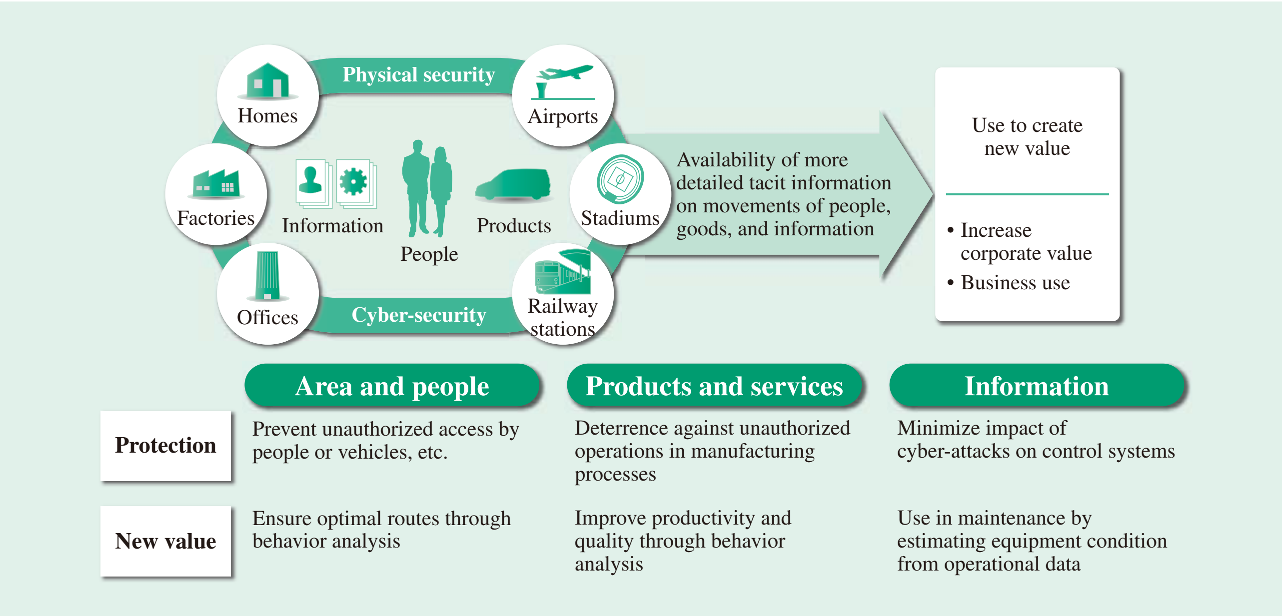

Fig. 8—Add Value through Security.
In addition to offering protection, the shared use of information obtained from security systems can also create new value.

responsivity, it involves providing engineering support for establishing the infrastructure needed to respond quickly to intrusions or new threats, and supplying systems for security threat analysis.

The implementation of security measures, meanwhile, involves obtaining information with even greater precision and granularity than in the past, and identifying the knowledge needed to decide whether or not the information is reliable. Use of this information helps improve corporate value and opens up possibilities in the form of new services. To this end, Hitachi is also promoting ways of making good use of the information obtained by security measures (see Fig. 8).

CONCLUSIONS

This article has described new security requirements for building the control systems that underpin social infrastructure systems.

Security measures for control systems are an important requirement for protecting social infrastructure systems. To build secure social infrastructure that everyone can use with confidence, Hitachi intends to continue cooperating with organizations in Japan and elsewhere and working on the research and development of the technologies needed to protect against increasingly sophisticated threats, and also to supply products that utilize the technology it develops. It also plans to supply total services for social infrastructure systems that extend from security risk analysis to system implementation and operational support.

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Featured Articles

Information and Control Platform for Utilization of Plant Data

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OVERVIEW: Along with the growing adoption of IoT practices for plant devices in recent years, potential is seen for the establishment of business models and the creation of new added value through the use of big data obtained from such devices. To achieve this, it will be important that control systems satisfy new requirements for the collection and use of plant data, flexible interconnection with IoT devices, and the maintenance of security when these permit open execution. Against this background, Hitachi is developing technology for offering new solutions that utilize plant data in control systems based on its symbiotic autonomous decentralization concept.

INTRODUCTION

TO maintain the operation of important social infrastructure that is required to operate non-stop, reliability and expandability are two crucial requirements for the systems that monitor and control such infrastructure equipment. In the past, the ability to build autonomous decentralized control systems with excellent reliability and expandability has been achieved by having the servers, controllers, and other control nodes exchange the information required for these control systems based on the autonomous decentralization concept, and by supplying information and control platforms that operate autonomously based on exchanging this information between individual control nodes(1).

In more recent years, advances in sensing, networks, and big data analytics have led to growing adoption of Internet of things (IoT) practices for the on-site equipment used in control systems. It is anticipated that the plant information made available as a result will not only be used by the control system itself, but also provided for use by management and other stakeholders for the creation of new added value and business models through open innovation(2).

This article describes the development of technology for information and control platforms (platform technology) using the symbiotic autonomous

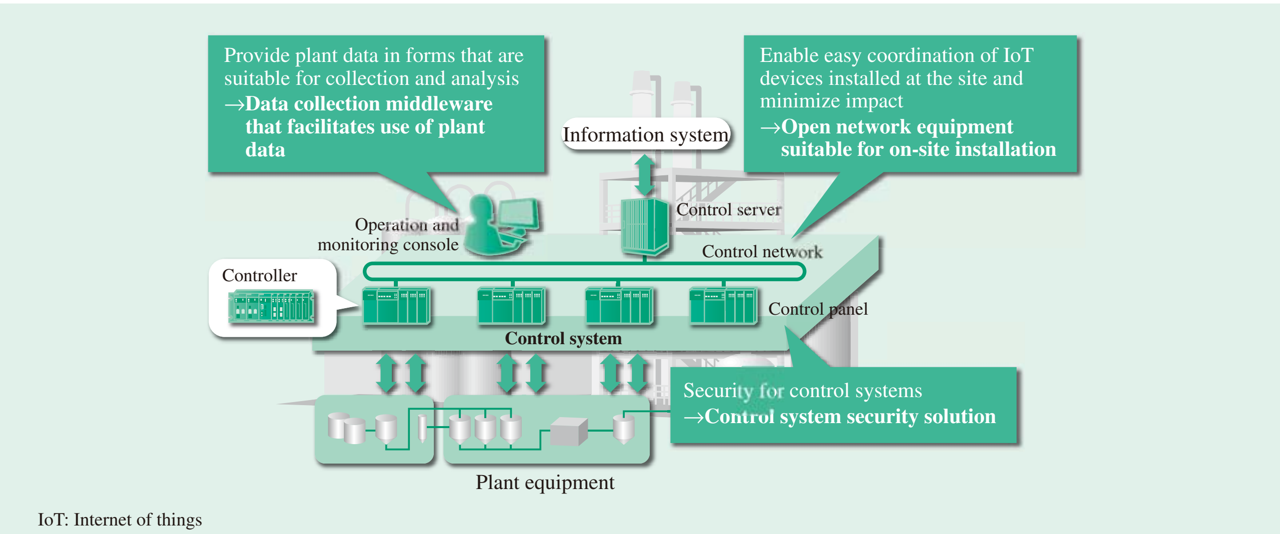

Fig. 1—New Functions Provided by Information and Control Platforms.
Hitachi is developing new functions needed to satisfy the new requirements for information and control platforms associated with implementing the symbiotic autonomous decentralization concept.

decentralization concept, which extends the autonomous decentralization concept at the system level in response to these trends.

WORK ON CONTROL SYSTEMS AND THE CHALLENGES THEY FACE

Control systems are implemented on information and control platforms that are made up of servers running a control operating system (OS), a network, controllers, and the middleware that ties these components together.

The implementation of the symbiotic autonomous decentralization concept described above requires control systems to satisfy new requirements for collecting and using plant data, flexible interconnection with IoT devices, and maintaining security when these functions are executed in an open environment.

To satisfy these requirements, Hitachi is developing new functions that enable information and control platforms to collect plant data and provide it in forms that are suitable for analysis, to enable the easy coordination of IoT devices installed at a site and minimize the impact of doing so, and to maintain control system security (see Fig. 1).

This article describes the following three aspects of these technical developments.

(1) Data collection middleware that facilitates use of plant data

(2) Open network equipment suitable for on-site installation

(3) Control system security solution

DATA COLLECTION MIDDLEWARE THAT FACILITATES USE OF PLANT DATA

Plants are likely to hold data that could potentially be used to improve energy, economic, or other forms of efficiency. Meanwhile, advances in big data analytics have created an environment in which services that utilize this plant data can be provided. To achieve this, these services require many different ways of collecting this plant data, while the collection methods require the expandability to allow users to obtain the data they want to use.

Middleware for "Pull" Information Collection

In a typical control system, the controllers use sensors to obtain information about the process being controlled and use actuators to control actions. This information is processed in the form of monitoring data and transmitted across the control network to be monitored by the control server (monitoring system) (see Fig. 2).

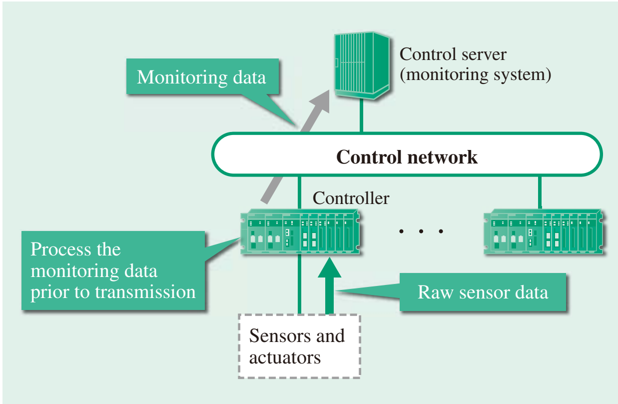

Fig. 2—Flow Chart of Data Acquisition by a Control System.
Rather than raw sensor data, control servers collect monitoring data that has been pre-processed by controllers.

The information is transmitted in the form required for monitoring by the server, not as raw sensor data. When monitoring the flow in a pipe, for example, the flow rate may be calculated from a number of different sensor readings for things like temperature and pressure. Accordingly, a new operation and maintenance (O&M) service for identifying or anticipating faults on individual sensors would need to obtain not only the data transmitted by the controllers but also the sensor readings it holds internally.

Unfortunately, to obtain these values in an existing control system would require modifications to the controller software or settings whenever the data points to be collected are added or changed. The resulting impact on production, such as having to shut down the controller, is a major problem.

To overcome this difficulty, Hitachi has developed middleware for "pull" information collection that can obtain data held inside controllers as required.

The middleware can add or change the data being retrieved without modifying the controller software or settings by having an application that runs on a control server specify which controller data it requires. Furthermore, because the collection of data from the controller uses a request/response ("pull") model, a controller that receives a request can send the requested data to the server at a time that does not interfere with execution of control functions. The middleware also includes a function that specifies the available bandwidth in advance so as to prevent data requests from overloading the controller and interfering with execution of control functions (see Fig. 3).

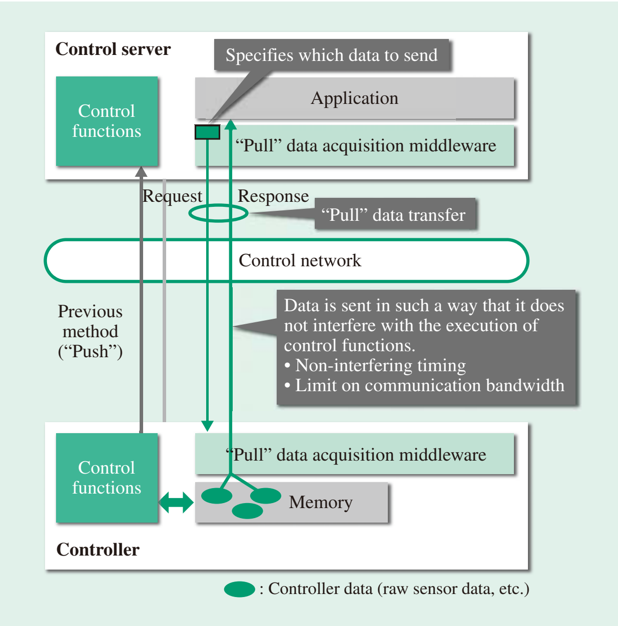

Fig. 3—Overview of Access Functions for "Pull" Data Acquisition Middleware.
Controllers return data in response to requests from control servers in such a way that it does not interfere with the execution of control functions.

In the future, Hitachi plans to add another function for converting the collected data into forms that are suitable for analysis.

Operation Monitoring Middleware

The growing diversity and complexity of social infrastructure systems is increasing the time it takes to identify the location of faults when they occur, and the associated losses are a drain on profits.

While the hardware and software used in control equipment already have the ability to acquire operational data, they are subject to the following problems that limit the use of this data.

(a) An inability to collect information required for investigating causes

Delays in action by operators to collect information can result in necessary data being lost.

(b) Limited availability of staff with skills for log analysis

Because the analysis of information requires specialist knowledge, only certain staff can do this work.

(c) Difficulty narrowing down the scope of investigation

The required information cannot be identified.

Hitachi has developed operation monitoring middleware as a means of solving these problems[3]. The middleware is made up of the following components.

(1) Operation data (fault information) acquisition middleware

Automatic acquisition and storage on a disk of the relevant fault information when a predefined trigger occurs (such as an error message). The middleware also provides batch commands that maintenance staff can use to collect all types of fault information.

(2) Operation data archiving middleware

The collection and archiving on a single computer of information collected by the data acquisition middleware, memory dumps, and network data for devices connected to the system.

(3) Alarm management middleware

Performs the initial analysis of fault information collected by the operation data archiving middleware and outputs the likely fault location on a local console.

(4) Fault information analysis tool

Performs more detailed fault analysis based on information collected by the operation data archiving middleware. Along with combining information from a number of computers or faults and displaying it with a graphical user interface (GUI) in time-series, hierarchical, or other format, the tool also includes a function for learning specialist analysis know-how.

The first three of these components of the operation monitoring middleware are easy to customize for individual systems, including being able to add collection and analysis commands for fault information from specific applications.

The current purpose of operation monitoring software is to reduce loss costs, and Hitachi also plans to adapt it for use by remote maintenance services for which there is growing demand from an increasing number of projects in other countries.

OPEN NETWORK EQUIPMENT SUITABLE FOR ON-SITE INSTALLATION

New requirements are emerging that are important to plants that host social infrastructure systems with high criteria for reliability and availability, such as the requirement to provide a variety of services that work closely with these plants or the requirement to use detailed and up-to-date plant information. The establishment of plant networks for the interconnection of plant equipment and transmission of valuable plant information is essential to satisfying these requirements.

These networks require core components that can operate reliably over long periods of time at sites with harsh environmental conditions and limited space available for installation. These components in turn

Fig. 4—Intelligent L2 Switch.
The switch features improved ruggedness to allow on-site installation. In addition to common network functions, it is also equipped with proprietary functions for high reliability.

need to support Ethernet. Ethernet has spread rapidly in industry over recent years, being a general-purpose open standard, with the standardization of things like quality of service (QoS) and virtualization still ongoing.

An Intelligent L2 Switch for Industrial Use

To provide a platform for implementing site networks that satisfy these requirements, Hitachi has developed its Intelligent L2 Switch, which is a small 10-port intelligent L2 switch for industrial use that features long life (10-year design life) and advanced functions together with excellent reliability and ruggedness (see Fig. 4).

Intelligent L2 Switch supports more than 40 common network functions, including simple network management protocol (SNMP), spanning tree protocol (STP), and virtual local-area network (VLAN).

They also include a proprietary optical ring protocol based on the core technology of a control network that complies with International Electrotechnical Commission (IEC) Publicly Available Specification (PAS) 62953. They are equipped with high-reliability functions, including the ability to recover automatically from a network fault in 500 ms or less in the maximum configuration of 64 nodes, re-routing around intermittent as well as fixed faults, and redundancy of blocking.

They also provide the following three features thanks to a specially optimized metal case and component mounting design.

(1) Able to operate at ambient temperatures from −10°C to 60°C

(2) Better resistance to dust due to having no fan or ventilation slots

(3) 4G seismic tolerance

These features enable the switches to be installed at sites with a harsh environment (see Table 1).

In the future, Hitachi intends to increase the number of Ethernet ports to allow use in large systems.

CONTROL SYSTEM SECURITY SOLUTION

More control system vulnerabilities to cyber threats have become apparent in Japan and elsewhere since the first appearance of the Stuxnet malware that targeted control systems, meaning that security measures for control systems are needed to deal with these threats.

The provision of security measures for control systems involves first dividing the system into zones with different security protection levels, deciding on the level of security measures for each of these zones and the communication links between them, and then reviewing and implementing these (prevention,

TABLE 1. Intelligent L2 Switch Specifications
The table lists the main specifications of the Intelligent L2 Switch.

Ambient temperature	In operation	−10 to 60°C
Fan, vent	Fanless, ventless	
Vibration tolerance	4G	
Standards compliance	Vibration Impact Air pressure EMI standard EMS standard EMC standard Safety certification Environment	JIS E3014 class 1 (0.5 G) JIS E3015 class 1 (10 G) TB/T 1433-1999, KX3 VCCI class A IEC 61000-6-2 IEC 61000-6-4 CE mark CB test report (IEC 60950-1) EU RoHS directive
Network management	SNMP SNMP MIB	SNMPv1, SNMPv2c RFC 1213 MIB II RFC 1215 Traps
Optical ring protocol (based on IEC PAS 62953)	Maximum range Maximum number of nodes Re-routing time	Optical loop: 500 km total 64 500 ms or less
Special functions	• STP extended functions (loop guard) • QoS [priority control, bandwidth control (input policing)] • Port security (restricts access based on MAC address) • Packet filter function (levels L1–L4) • Loop protection • Broadcast storm control • Reset reboot on hardware fault	
Self-diagnostics	WDT, main memory ECC, cache parity, voltage monitoring for all DC power supplies	
External dimensions	300 (W) ×180 (D) ×43.5 (H) mm	
Installation	Vertical, horizontal	
Power supply	Input voltage	AC 90–250 V
Product life	10 years	

JIS: Japanese Industrial Standards VCCI: Voluntary Control Council for Interference by Information Technology Equipment CB: certification body
EU: European Union RoHS: Restriction of Hazardous Substances
IEC: International Electrotechnical Commission
EMI: electromagnetic interference EMS: environmental management system
EMC: electromagnetic compatibility
SNMP: simple network management protocol
RFC: request for comments MIB: management information base
PAS: Publicly Available Specification STP: spanning tree protocol
QoS: quality of service MAC: media access control WDT: watchdog timer
ECC: error checking and correction DC: direct current AC: alternating current

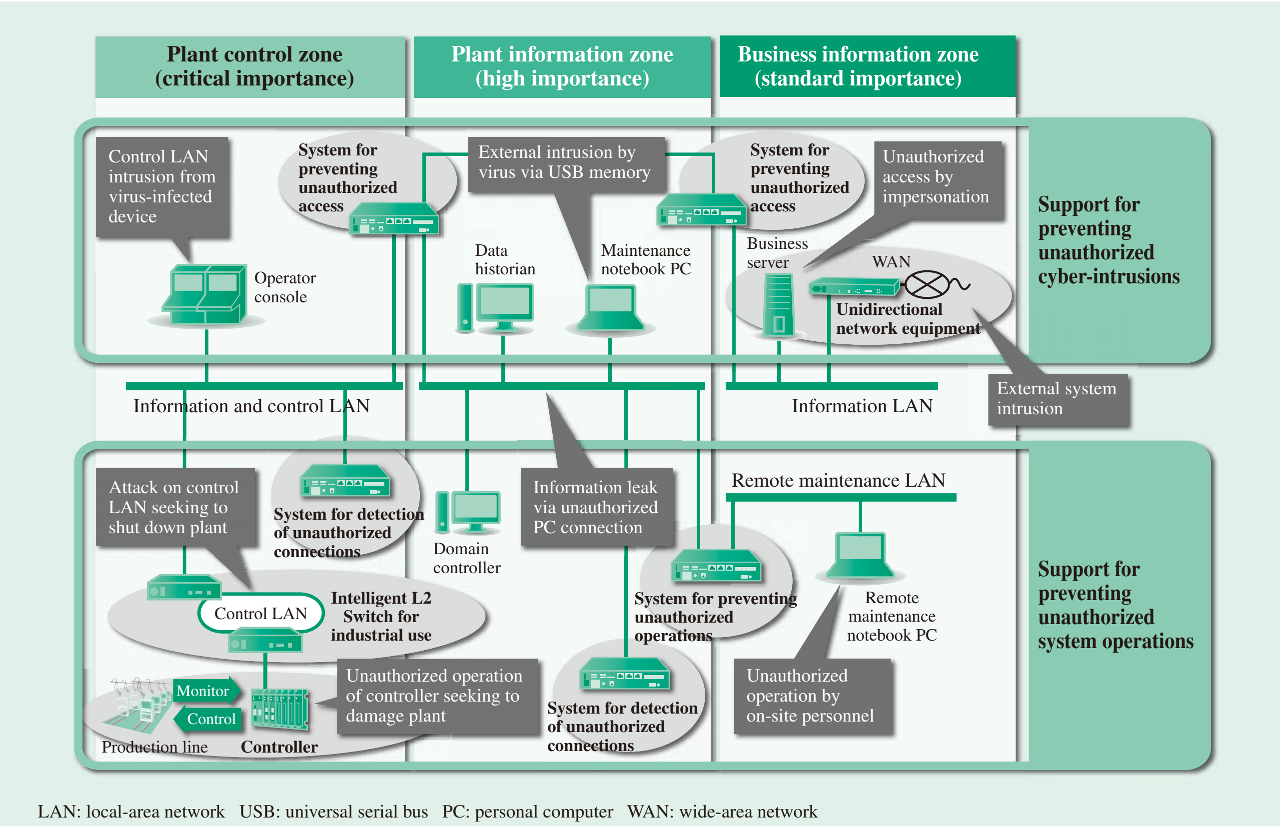

Fig. 5—Control System Security Solution.
Hitachi supplies two different control system security solutions that combine security products for a wide range of control systems.

detection, preventing threats from escalating, and recovery)[4].

Hitachi has extended this approach to develop the Hitachi system security concept for social infrastructure security[5]. For security measures for control systems in particular, the recommended practice is to use measures that focus on resilience by adopting a whitelist approach that forms part of the Hitachi system security concept and only permits pre-approved operations, and Hitachi offers two control system security solutions that support the prevention of unauthorized cyber-access and unauthorized system operations, respectively (see Fig. 5).

Support for Prevention of Unauthorized Cyber-access

Preventing unauthorized access via cyberspace through connections to other systems is important for protecting control systems against external threats and ensuring their availability. Along with preventing unauthorized access, the challenge when installing security measures on a control system is also to minimize the load imposed by their installation and operation.

Accordingly, the installation of control system security is simplified by providing systems for preventing unauthorized access that permit the definition of whitelist security policies with tools to assist with this definition of security policies (see Fig. 6).

Similarly, the features of unidirectional network equipment, which include having a long life without requiring maintenance, reduce the work associated with system operation by acting as a software-less "data diode" (a hardware device that only permits communications in one direction, like a diode) (see Fig. 7).

Fig. 6—System for Preventing Unauthorized Access.
Installation in control systems is simplified by providing a support tool for defining whitelist security policies.

Fig. 7—Unidirectional Network Equipment.
Operational maintenance is minimized by eliminating the use of software. The device itself has a simple design to prevent mistakes.

These technologies improve measures for preventing unauthorized access while being designed for easy installation and operation.

Support for Prevention of Unauthorized System Operations

Before the targeted attacks that have been increasing in recent years, it was necessary to implement countermeasures on the assumption that it is not possible to eliminate unauthorized access entirely. Accordingly, there is a need for ways of limiting the damage that results if unauthorized access is permitted. Behavior detection techniques are widely used to detect cyber-attacks on information systems. They are more difficult to use on control systems, however, because they cannot tolerate misdetection. Accordingly, measures are adopted instead that improve their robustness to an attack.

Systems for preventing unauthorized operations protect critical equipment from denial of service (DoS) and other similar attacks by providing functions that include limiting the bandwidth of communication data and disconnecting the network.

Hitachi has developed a controller that is certified under the Embedded Device Security Assurance (EDSA) certification program for guaranteeing the security of control components run by the Security Compliance Institute (ISCI) of the International Society of Automation (ISA). It offers improved resilience to cyber-attacks by satisfying a predefined set of security requirements[6] (see Fig. 8).

EDSA: Embedded Device Security Assurance

Fig. 8—Controller with EDSA Certification.
The controller offers improved resilience to cyber-attacks by satisfying a predefined set of security requirements.

By building control systems using equipment that has such a high degree of robustness with respect to cyber-attacks, the impact on the plant equipment being controlled can be minimized in the event that an incident does occur.

CONCLUSIONS

This article has described the latest challenges and technical developments for the use of plant data from control systems based on the symbiotic autonomous decentralization concept.

As it can be anticipated that control systems will continue to develop in the future by adopting the latest information technology (IT) in their role as a platform underpinning the social infrastructure, Hitachi intends to continue developing technology for information and control platforms and supplying new solutions.

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