Hitachi Review

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HITACHI
Inspire the Next

Information and Control Systems

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From the Editor

Infrastructure Systems Company, Hitachi, Ltd. has formulated a vision of "becoming the best solutions partner by providing answers to business challenges faced by global customers." In April 2014, the company reorganized its business into four domains: Urban & Energy Solutions, Water & Environment Solutions, Industrial Plant Solutions, and Components Business. This issue of *Hitachi Review* focuses on the Urban & Energy Solutions domain, presenting example systems used in typical applications, and describing the components they use, which include power electronics, surveillance cameras, and information and control platforms. This issue's Expert Insights, meanwhile, carries an article contributed by Dr. Aidan Rhodes of Imperial College London in the UK about that nation's latest power systems and the environment in which they operate.

In Technotalk, Infrastructure Systems Company staff working in the electric power, railways, and platform fields, as well as R&D staff working on information services and energy give their respective perspectives on developments in technology and the role of research laboratories in relation to information and control systems.

The Overview section describes the three forms of value provided by Hitachi's information and control systems, namely (1) eliminating what is "unreasonable, wasteful, and uneven" (smart & smooth), (2) building a social infrastructure that can continue to grow (sustainable growth), and (3) ensuring that infrastructure is safe, secure, and resilient (security & resiliency).

Articles on the "smart & smooth" theme describe an island smart grid model, a smart grid demonstration project that uses photovoltaic power generation, energy management systems for condominiums, power conditioners for renewable energy, and video surveillance systems. Articles on "sustainable growth" cover the upgrade of the Tokyo region railway train management system for the JR Chuo Line, a system for planning, operation and maintenance of water supply and sewage, and steel industry control systems.

Our aim at Hitachi is to combine the knowledge we have built up through the application of the latest information technologies, including big data and cloud computing, in areas such as railways, electric power, water, and the steel industry in order to continue delivering new forms of value to our customers. We also look forward to delivering improvements in the future that use advances in information and control technology to coordinate the operation of multiple systems rather than just optimizing each system on its own.

I hope this issue will provide you with a better understanding of Hitachi's efforts to drive social innovation.

Editorial Coordinator,
Information and Control Systems Issue

Takashi Hotta, Dr. Eng.

Chief Engineer
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Information and Control Systems

Along with the growth of the global economy, the construction of new infrastructure in emerging economies is taking place against a background of population increase and industrialization, while developed economies face urgent societal issues in the form of infrastructure obsolescence, aging populations, declining birthrates, and the need to reduce the load on the environment.
Having reorganized its operations into four business divisions in April 2014, Infrastructure Systems Company of Hitachi, Ltd. is taking steps to strengthen its ability to offer and implement solutions to the problems faced by its customers and by society at large.
By building efficient and sustainable social infrastructure that combines advanced IT with its accumulated technologies and know-how, Hitachi aims to help regions around the world overcome the challenges they face.

Urban & Energy Solutions

Hitachi is helping establish a dependable and comfortable society by supplying traffic management and control systems, passenger services, and other products for rail and road transportation, as well as monitoring and control technologies for power generation and distribution, smart grids, and energy management systems.

Transportation (image)

Source: Mitsui Fudosan Co., Ltd.

Electric power

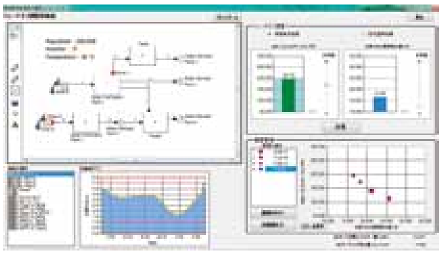
Energy management (image)

Water & Environment Solutions

Hitachi is helping ensure the safety and security of water by developing the equipment and systems needed for everything from water use and waterway management through to water and sewage treatment, seawater desalination and other water making techniques, operation and management, and business management and services (maintenance and support).

Water and sewage treatment plant systems (image)

Monitoring and control system



IT solutions for water

Equipment for chemical and pharmaceutical plants

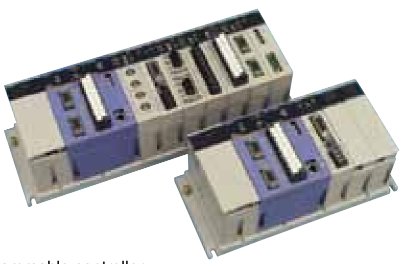
Factory automation system

Plant for oil and gas production facility

Industrial Plant Solutions

In addition to supporting the supply of high-quality products in a wide range of industrial sectors, including steel, chemicals, food, pharmaceuticals, and automotives, Hitachi also supplies plant, power electronics, and other components for oil and gas production facilities.

Control server



Programmable controller

Security equipment

HF-W6500 Model 45/40

Components

Along with supplying apparatus for information and control platforms such as industrial computers, control servers, and others, Hitachi also supports the production of next-generation social infrastructure systems by improving the security of their control systems.

Expert Insights

The Trends toward Greater ICT Control and Integration into the Grid

Underlying Policies and Market Drivers

Dr Aidan Rhodes

Research Fellow, RCUK Energy Strategy Fellowship,
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Dr Rhodes holds a PhD in analytical electrochemistry and is currently Research Fellow at the Centre for Environmental Policy at Imperial College London. His research interests are in energy policy, market design, and regulation, with a particular focus on smart grids and future networks. He has authored several substantive pieces of work in this field, including two reviews of the UK's smart grid capabilities for the Technology Strategy Board, and has contributed to fostering collaboration between the UK and Japan by leading a substantive mission of UK smart grid experts and industry stakeholders to Japan to discuss joint interests. Currently, Dr Rhodes is working on a large research project comparing and benchmarking the energy innovation systems of different countries, with an emphasis on smart grid technologies in the UK and the Asia-Pacific region.

Electricity networks have long been characterised as mature and conservative technologies, relying on proven concepts of power engineering and electrical design dating from the late 1800s. Power flows from large-scale generating plant through high-voltage transmission and lower-voltage distribution networks before being delivered to consumers. This system is used throughout the world with great success, and is an essential enabler of modern living.

Recently however, both government policies and market forces have produced drivers that challenge the notion of an electricity grid being a simple unidirectional series of wires and transformers and make the case for a 'smart grid,' in which information and communication technologies (ICT) are integrated directly into the electricity networks. These advances have the potential to transform the way customers and supply companies interact with electricity, and provide significant new commercial opportunities for communications, monitoring, control, and data aggregation technologies throughout the electricity system, from generation through to the consumer.

European governments have heavily invested in large-scale demonstration and development projects to trial smart grid and metering technologies, with current investments totalling approximately €5 billion. These projects are being driven by:

(1) Policies to decarbonise national electricity systems being led by governments
(2) Concerns regarding security of energy supply and the resilience of electricity networks to extreme events
(3) Moves towards greater competition, choice, and innovation in the energy supply market
(4) The integration of electric vehicles, electric heating, and distributed generation
(5) The development of 'smart' meters and home appliances

Decarbonisation policies and incentives are the first key set of drivers towards a smart grid, and have far-reaching consequences for the energy system. The UK, for example, has a legally-binding target of an 80% reduction in carbon emissions by 2050, which most models suggest would require a virtually decarbonised electricity sector by 2030 in order to meet. The European Union has set a target for 20% of EU primary energy to come from renewable sources by 2020. Due to the difficulty of providing economical renewable heating and transport, a large majority of this energy will need to come from renewable electricity generation. The UK's share of this primary energy target has been set at 15%, which will require renewable generation providing 30% or more of total electricity supply in the UK on a regular basis. The integration of this quantity of renewable generation into an existing electricity system leads to some significant challenges.

In a traditional electricity system, supply is adjusted to match current demand. This becomes an issue with large proportions of renewables and other low-carbon forms of generation due to their particular characteristics. Low-carbon generation can generally be divided into two major forms. Firstly there are those, such as nuclear power or carbon capture and storage (CCS), which provide base-load electricity but are inflexible, meaning it is uneconomic or technically infeasible to change their output levels. Secondly, renewable energy generation sources such as wind and solar are intermittent, providing variable levels of power based on the strength of the energy source.

Large quantities of expensive and polluting fossil fuel-based backup generation would be required to meet shortfalls and balance the system in a traditional electricity network. However, advances in network monitoring and control technology will make it possible to use the network in a more efficient manner, allowing electricity to flow multi-directionally through the grid from energy storage units and distributed generation sources to nearby centres of demand. This more advanced network would save money on backup generation by efficiently allocating low-carbon electricity and actively managing demand. Several European nations, notably Denmark, Germany, and Spain, are already managing large quantities of renewable generation (Denmark generated over 100% of its electricity demand from wind several times in late 2013), and are aggressively exploring smart grid technologies to manage this supply.

Two other major drivers seen in Europe are the cost and security of electricity. The cost of electricity has increased substantially in response to higher fossil fuel costs, subsidies for low-carbon generation, and from major shocks such as the Fukushima incident and the resulting suspension of nuclear power in many nations. High energy prices are both politically unpopular and have the effect of increasing costs, and therefore decreasing competitiveness, in energy-intensive industries. An average of 10% of generated electricity is lost in the networks before consumption, and improving this figure through new, more efficient network assets combined with improved network control and routing is an important economic driver for utility companies.

Electricity access is essential for developed countries' economies and the cost of brown- and black- outs, even for short periods, are very high. New monitoring and control technologies in networks can automatically sense faults when and where they occur and reroute power via different routes to minimise disruption to supply, making the grid more resilient to significant weather disruption and extreme events. The recent extreme flooding and resultant power cuts in the UK have made network resilience a significant political issue for example, with consumers more aware of the reliability of their electricity supply. Technologies that can dramatically reduce grid maintenance costs and penalty charges for supply disruption while increasing reliability are therefore of great and increasing value to network operators.

The consumer end of the electricity system is where some of the most significant advances could be seen from the integration of ICT into the grid. The role of the consumer is constantly changing as new technologies and demand patterns are adopted. The rise of portable electronic devices has increased electricity consumption over the past decade, for example, while improved insulation and more efficient lighting technologies have decreased heating and lighting costs. In the future, a predicted mass adoption of electric vehicles combined with a switch from gas to electric heating in many countries could increase peak consumer electric demand dramatically. This will have significant consequences for traditional electricity networks, as major physical reinforcement to the grid as well as substantial extra generation would be needed. If no demand-side management (DSM) systems are put in place to spread the load of electric vehicles and heating systems throughout the day, the peak load on the system would increase dramatically – models for the UK system suggest that peak electricity demand with the addition of vehicles and heating could reach up to 10 times that of off-peak demand. This extreme variation provides a significant business case for smart demand management systems, as the cost of the needed physical reinforcement in a conventional system would be very high.

The rise of distributed generation will also require dramatic changes to the grid in years to come. Distribution networks have historically been designed to move electricity in one direction, from the generation plant and transmission networks to the consumer. If consumers themselves are feeding electricity into the grid from solar photovoltaic (PV) systems and other forms of distributed generation, major changes will need to be made to the structure and control systems of the distribution networks in order to maintain the stability and efficiency of the electricity system. More localised control of distribution networks, allowing electricity to be brought, sold, and transmitted across a local community, is a natural response to this challenge. Although more difficult to control, these decentralised microgrids can allow communities to own and control their own electricity production and aggregate many individual sources of distributed generation into a 'virtual power plant' able to sell their generated electricity on the open national market. Domestic energy storage units could also participate in the market, storing electricity at times of low demand and selling it back to the grid at peak times. These developments would mark a dramatic shift in the relationship between consumers and the electricity system, moving them from passive consumption to active ‘prosumers,’ engaging with the energy market on their own terms and taking ownership of their own generation sources. Test projects in communities in the UK and the Netherlands, as well as the Danish island of Bornholm, aim to test consumer-facing systems and local grid balancing technologies.

Future consumers would also be able to participate in DSM programmes, shifting or curtailing their energy use in response to signals from the grid. Although many large industrial users participate in such programmes today, smaller users and the domestic market currently cannot. As seen above, demand response and DSM will become increasingly important in order to balance an increasingly complex electricity system. These services have a great deal of value potential as the flexibility of supply becomes more constrained, especially on islanded systems such as the UK network that have limited interconnection with other national grids.

The first step in enabling DSM across the domestic sector is to install smart meters. These meters can automatically transmit electricity usage back to suppliers, but can also receive pricing and control signals from the grid. In response, the meters can communicate with household appliances – refrigerators, dishwashers, washing machines, and heating systems, to give some examples. These appliances can be temporarily stopped, or have their start times delayed until a period of low electricity demand, in order to help balance the grid in times of constrained supply. A successful DSM system would need to have nearly invisible effects to the end consumer, and be easily and transparently operable. This will require careful research into consumer behaviour and attitudes, as well as high-quality ICT products that are secure, stable, and simple to operate. The potential commercial market in this area, however, is extremely large. The EU has mandated that member states roll out smart meters in their countries by 2020, assuming a positive cost-benefit analysis. Approximately half of EU member states have currently decided to install smart meters by this date, totalling 170-180 million installed meters and a cost of approximately €30 billion.

Finally, an ICT-enabled smart grid provides a platform for new technologies, business models, and services. Energy suppliers, through smart meters, will be able to offer their customers a wide range of time-of-use and flexible tariffs, opening up new opportunities for innovative energy service models and personalised tariffs. New technologies such as energy storage and electric vehicle-to-grid systems provide new business models and significant potential value in providing grid balancing and resilience services. It is best to think of a smart grid as analogous to a 3G mobile network – it is an enabling technology, allowing new technologies, innovations, and models to be developed to use its services.

Policies to enable the rollout of smart grid technologies differ by nation due to diverse local electricity market and regulatory structures. In the UK, the regulator Office of Gas and Electricity Markets (Ofgem) oversees new network technologies, and has put into place several policies to accelerate uptake. Regulatory mechanisms for the network operating companies have been changed to incentivise spending on innovation and an annual competition, the Low Carbon Networks Fund, has been established with a budget of £500 million between 2010-2015. Consortia of companies and researchers, led by network operators, bid for funding to conduct demonstrations of new network technologies in communities across the UK, with the results of these projects made publically available.

The development of new monitoring, control, communication, and aggregation technologies for future electricity networks requires knowledge of both ICT development and power systems engineering, two disciplines which traditionally house different characteristics. While ICT development is fast-moving, with horizons of only a couple of years, power systems engineering is a slow-moving, conservative discipline that prizes security and stability. In addition, knowledge of consumer behaviour and acceptance will be necessary for developing consumer-facing devices. A successful player in the future networks market will be a company that can successfully manage and intermarry these differing disciplines to create secure, stable, and technologically advanced products. Future networks and smart technologies provide a significant and sustainable business opportunity for the future, and we are only at the beginning of a long and exciting road ahead.

Technotalk

Creating New Value in Social Infrastructure Systems through Fusion of Control, Information, and Components

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Takashi Hotta, Dr. Eng. Chief Engineer, Infrastructure Systems Company, Hitachi, Ltd.

The demands on social infrastructure have become greater and more sophisticated in recent years. In emerging economies experiencing rapid urbanization and population growth, the requirement is to provide and operate infrastructure at low cost and in harmony with the environment. In developed economies with decreasing birth rates and aging populations, on the other hand, the requirements include further measures for dealing with the environment, more efficient equipment operation, and the upgrading of obsolete equipment. Hitachi has been involved in the provision of reliable, high-quality social infrastructure systems for many years, primarily in Japan. By combining advanced IT with control technologies built up through this work, Hitachi aims to deliver new value to social infrastructure throughout the world.

Responding to Needed System Innovations and Cutting Operating Costs

Hotta: The circumstances surrounding social infrastructure are undergoing major transformations prompted by environmental changes in Japan and elsewhere. To begin with, can you explain the recent trends and issues in electric power and railway infrastructure?

Seiji: In the field of electric power infrastructure, there has been growing interest in grid stabilization technologies in response to ongoing power system reform and measures aimed at expanding the use of renewable energy. While this period of change can be seen as an opportunity, price competition and compliance with international standards have become issues as more overseas supplies enter the market. Meanwhile, it is essential that we maintain those characteristics that are recognized as strengths of Hitachi by our customers, including our attention to detail and ability to see jobs through. Having been personally involved in information systems such as electricity and gas billing, primarily business systems for the electric power sector, I believe it is important that we consider what form future systems should take, and in doing so, that we develop a broad vision of all aspects of social infrastructure, including water and gas as well as electric power.

Ide: Since wider use of home photovoltaic power generation and other small renewable energy systems will result in a large number of generators being connected to the grid, it will make control techniques for electric power distribution even more important than before. And, since accurate purchasing mechanisms will be needed if generators in the home or elsewhere are to be able to sell their excess electric power, there will be a need for infrastructure capable of reliably performing this function. My background is in the development of generators. At the Energy and Environment Research Center where I now work, we are involved with a wide range of technologies, including renewable energy, nuclear power technology, proton beam therapy systems (an application of nuclear technology), high-voltage power electronics, information and control systems for the electric power industry, heat and energy management, wireless communications, and security. We have recently been working to develop technologies that will provide new value in the era of electricity deregulation, including operating techniques that utilize numerical analysis to predict the future state of systems such as those used for electric power distribution.

Kurokawa: In the case of railway infrastructure, reducing the cost of maintaining fixed assets remains a major challenge. While the practice in the railway industry to date has been to replace parts or perform inspection before reaching a fixed length of service or number of kilometers, companies are looking at using status monitoring and predictive diagnosis as a way to reduce costs. I have been involved in the railway business outside Japan. In the UK, we have built our first overseas plant for maintaining rolling stock to establish the capabilities to handle everything from production to maintenance. Taking advantage of this business environment, we have implemented an online monitoring solution that provides continuous remote monitoring of the fleet status at any location by utilizing sensors and other techniques. Currently, we are collecting and analyzing data with the aim of establishing predictive diagnostic techniques. This work has attracted the interest of railway companies because of its potential for cutting costs while also maintaining reliability and safety.

Meanwhile, people around the world are working on the concept of electric trains driven by on-board rechargeable batteries. Hitachi has already commercialized hybrid rolling stock, and this interoperation and fusion of transportation and electric power systems will become even more important in the future. I believe that accurate and precise control of both electric power generation and usage, including the components that make up these systems, will make possible infrastructure systems that maximize energy efficiency.

Fusion of Information and Control Technologies Key to Innovation

Hotta: At Hitachi, we are striving to provide three "values" that we see as being essential for future social infrastructure systems. These values are: making systems "smart & smooth" by eliminating inefficiencies, ensuring that they can maintain "sustainable growth," and providing them with "security & resiliency." Making systems "smart & smooth" involves using information technology (IT) to control infrastructure efficiently, reducing social costs through measures such as improving energy efficiency or minimizing congestion, and seeking to optimize total lifecycle costs by providing operations, maintenance, and other services. Please tell us about the specific initiatives you have embarked on to achieve these.

Akatsu: "Smart & smooth" can also be thought of as an initiative aimed at combining IT and operations technology (OT) to deliver innovations in social infrastructure. A key point in this context is the use of big data. Our aim is to combine big data analysis techniques with practical business know-how so that we can deliver unique solutions that draw on the distinctive aspects of Hitachi to deliver new value. Specifically, by analyzing sensor and other operational data collected from control systems in sectors such as railway and electric power, we can determine what is happening in the field, predict what will happen next, and identify the best actions to take. The aim is to optimize activities by supplying this as feedback to operations.

For example, in January 2014, we embarked on a demonstration project of a cloud-based operation management system for mining machinery in partnership with Wenco International Mining Systems Ltd. of Canada. In addition to the future full-scale rollout of mining industry systems based on cloud services, we also intend to help make customer operations more sophisticated and cost-competitive by deploying services that run on cloud platforms supplied by Hitachi, and that incorporate industry know-how in infrastructure and in the industries that underpin society.

Ide: There is also scope for use of IT in relation to technologies for optimizing grids and making them more stable. I believe we can further improve performance by collecting and using realtime data.

Kurokawa: While the use of big data for operations and maintenance (O&M) is clearly important, there are even greater expectations for its potential to create new value through cross-industry applications that allow collected

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Joined Hitachi, Ltd. in 1988. Having previously worked on the research and development of motor-generators for adjustable-speed pumped storage hydro power plants and gas turbine generators, he is currently engaged in the management of research and development for energy management, power transmission and distribution systems, power generation systems, and other technologies. Dr. Ide is Vice President of the Industry Applications Society of The Institute of Electrical Engineers of Japan (IEEJ), a senior member of The IEEJ, a member of The Magnetics Society of Japan, and a senior member of the IEEE.

data to be utilized in other industries. I feel Hitachi is expected to act as a facilitator for this value creation.

Ohashi: What has become important in recent years has been to work with a diverse range of partners to resolve societal problems, and to establish the frameworks and architectures needed to achieve this. My division has been developing and supplying equipment such as control servers, networks, controllers, protection relays for power systems, and the operating systems that run on these devices. We also undertake development work to create new value with our partners, developing control platforms that can be used to introduce new services and integrate with information systems. Taking on the role of linking customers' businesses together, what we call "with HITACHI," is also one of the important aspects of achieving society-wide optimization.

Achieving Flexible and Sustainable Growth of Social Infrastructure Systems

Hotta: Because social infrastructure systems need to remain in service for decades or more, they require the flexibility, expandability, and ease of upgrading to cope with changes in society that cannot be anticipated when the systems are installed. They also need to provide a platform that can grow along with the development of the city in which they are located. This is what we mean by "sustainable growth," the second of the values described above.

Ohashi: The hardware used in control system components typically uses a lot of semiconductor devices. Since the life cycle of semiconductor devices has become shorter and more rapid these days than that of the era of mainframe computers, the rapid obsolescence of hardware is an issue for infrastructure systems that, by their nature, need to operate continuously for long periods of time. To solve this, we have adopted virtualization, the technology pioneered in the IT sector, to provide realtime virtualization for information and control servers. By extending this technology, we believe we can manage the hardware upgrade cycle effectively and protect customer assets such as their proven application software.

Seiji: Ensuring that system migrations proceed smoothly without having to make modifications to applications that need to remain unchanged is essential to maintaining long-term reliability. With uninterrupted operation being one of the prerequisites of social infrastructure systems, even more important in the future will be techniques and other know-how for making upgrades without requiring a system shutdown, just as we are able to do with railway traffic management systems.

Akatsu: Hitachi has proposed a new approach to social infrastructure systems it calls the "symbiosis-autonomous decentralized systems concept," a development of the existing idea of autonomous decentralized systems. The flexibility and high levels of extensibility of sub-systems in past autonomous decentralized systems have contributed to the provision of social infrastructure that can grow sustainably. The objective of the symbiosis-autonomous decentralized systems concept is to develop this further by getting autonomous systems that fulfill different purposes to coexist flexibly and operate harmoniously. We want to build systems that help each other, such as an arrangement between electric power and railway systems for managing energy whereby railway services are trimmed during times of peak electricity demand. Since infrastructure systems are designed autonomously to optimize operation under their own particular circumstances, having them take account of each other's requirements requires such things as a common language and the solution of complex and sophisticated computational problems. We want to turn this concept for providing sustainable social infrastructure systems into reality by utilizing Hitachi's strengths in

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Joined Hitachi, Ltd. in 1987. Having previously worked as manager of the Information Service Research Center at the Yokohama Research Laboratory, he is currently engaged in strategy formulation for the smart systems business. Dr. Akatsu is a fellow of the IEEJ, and a member of the Information Processing Society of Japan (IPSJ), Society for Serviceology, and The Japan Society for Management Information.

diverse infrastructure system technologies for services such as electric power, railways, and water.

Building Stronger Social Infrastructure Systems

Hotta: The third value of "security & resiliency" seeks to ensure the reliability to operate continuously 365 days a year, to maintain security and privacy, and to recover rapidly from major damage caused by a terrorist attack or other disaster while continuing to deliver essential functions.
Seiji: Since data on someone's use of utilities, such as electric power and gas, provides an indication of their way of life, the protection of security and privacy will also be essential in control systems as more use is made of smart meters in the future.
Akatsu: Because control systems have been making greater use of networking and general-purpose operating systems in recent times, they need to be equipped to deal with the same sort of attacks as those faced by information systems. Also, control security must cope with more stringent performance requirements than those for information systems. Key ways of achieving this include lightweight encryption techniques and the use of whitelist methods such as only permitting access by or execution of authorized software.

With new threats appearing all the time, another approach that has been adopted, this time from the defense sector, is the "observe, orient, decide, act" (OODA) loop for ensuring that an immediate response can be mounted to a cyberattack in the event that security is breached. This seeks to minimize damage and expedite recovery by quickly observing and analyzing the situation, and then deciding on and implementing the response.

Privacy protection measures are essential to the use of big data. We are working on the development of a privacy-preserving analysis technique that can analyze encrypted data without decryption. Hitachi has succeeded in performing operations such as exact-match searches, collation of frequency statistics, and analysis of correlation rules without compromising privacy and with realistic computing times. Because the data remains encrypted at all steps, this reduces the risk of information leaks due to data being eavesdropped or stolen by the agency performing the analysis.

Since data analysis does not necessarily require raw data, anonymizing techniques are also useful. Simply anonymizing people's names is not enough to prevent them from being identified from other data. For this purpose, Hitachi uses the k-anonymization technique, which deletes or generalizes data to ensure that a minimum of *k* records with the same data exist. We have developed algorithms that reduce the amount of information lost by anonymization to utilize big data in ways that take account of privacy.
Ohashi: The CSSC (Control System Security Center) was established as a joint industry-academia-government initiative. Hitachi has worked with the CSSC since its inception, including involvement in security training and joint research into control system security. Since the control system security field, both here and overseas, is going through a period in which compliance with certification systems and other standards is becoming more widespread, I believe awareness is growing.
Hotta: What about improving resilience against disasters and accidents?
Ohashi: Management functions are essential for maintaining "lifelines" such as the use of distributed power sources during emergencies. Since enhancements are also needed for individual components, Hitachi provides not only security functions but also functional safety mechanisms into its controller products, both comply

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Takashi Hotta, Dr. Eng.

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Infrastructure Systems Company, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1983. He has previously been engaged in the management of research into information and control systems and power electronics systems at the Hitachi Research Laboratory. Prior to taking up his current appointment in 2013, he was manager of the Yokohama Research Laboratory.
Dr. Hotta is a member of the IEEE, IEEJ, The Institute of Electronics, Information and Communication Engineers, IPSJ, and The Society of Project Management.

with international standards. Moreover, Hitachi supports maintaining control functions in a safe manner during a fault which allows control to be performed safely and flexibly.

Ide: In the future, large numbers of wind, photovoltaic, and other forms of electric power generation with fluctuating output will be connected to distribution grids. Also, the existence of power electronics equipment with the intelligence to perform active control will allow operations to be performed with response times that have never been seen on power grids before. This represents a major change. Since Hitachi has built up expertise in power electronics equipment and power system control over many years, I believe we are well placed to contribute through the fusion of these technologies.

Seiji: Power electronics equipment plays an important role in the power system infrastructure. Arrangements for sharing electric power between regions are important, not only during disasters but also in applications such as smart cities. Converters that use power electronics are a key component of such systems. I believe that possessing the core component, control, and information technologies will be a major strength for us in providing effective support for these foundations.

Kurokawa: Even globally, there are very few companies that combine all of these capabilities. Our mission is to utilize these strengths to enhance further the value of social infrastructure systems.

Hotta: To fulfill our duty to provide ongoing support for social infrastructure systems, I hope we can continue striving to develop and supply technologies that create new value.

Overview

Information and Control Systems and Component Technologies for Social Infrastructure

Naohiko Irie, Dr. Eng.
Akitoshi Shimura, Dr. Eng.
Minoru Koizumi, Dr. Eng.
Takayuki Takezawa

CHALLENGES FACING SOCIAL INFRASTRUCTURE

THE challenges facing social infrastructure, including population growth, urbanization, and environmental problems, continue to grow year after year. The United Nations estimates that the global population will reach 8.3 billion in 2030, of which 60% will live in cities. Supporting this growth will require the provision of energy (including electric power and gas), transportation (including roads and railways), and other social infrastructure (such as water supply and sewage systems). As the expansion of social infrastructure places an increasing load on the global environment, including environmental degradation and warming, there is a need for the efficient construction and operation of social infrastructure that can reduce the resulting social costs. Against this background, total investment in social infrastructure was approximately $US2 trillion in 2010, and is forecast to rise by a factor of about 1.5 by 2020 (see Fig. 1).

The construction of new social infrastructure is anticipated in emerging economies as their populations grow and as they become more industrialized and urbanized. In the energy sector, for example, there is growing demand for liquefied natural gas (LNG), oil synthesis, gas-based chemical plant, resource development, and power systems[1]. Also needed are the provision of transportation systems to relieve congestion, and water supply and sewage systems to alleviate water shortages and resolve sanitation problems. Issues associated with this rapid provision of infrastructure, including how to reduce investment and operating costs and give proper consideration to the environment, are a concern for all parts of society.

Developed economies, meanwhile, need to deal with a growing awareness of environmental problems, aging infrastructure, and societal problems such as aging populations and falling birth rates. In the energy sector, the generation and supply of electric power from renewable energy is expected to grow at an annual rate of about 8%[1], posing challenges that include the construction of reliable power grids and the establishment and operation of flexible billing schemes. In the transportation sector, the important issues include not only ensuring reliable transportation services but also providing efficient passenger and freight transportation by utilizing data such as that from commuter smartcards. In the industrial sector, the needs are for the use of information to make production more efficient and for the optimization of logistics, including global supply chains, as recommended by Germany's Industrie 4.0[a][2] project.

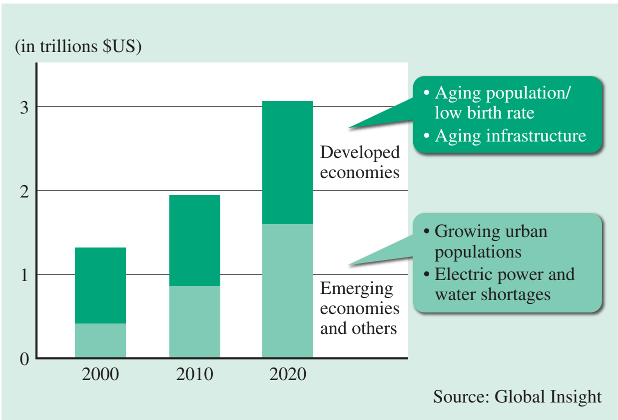

Fig. 1—Forecast of Global Investment in Infrastructure.
Investment in social infrastructure is growing, especially in emerging economies, and is expected to expand by about 1.5 times between 2010 and 2020.

In Japan, meanwhile, a plan for national resilience that incorporates lessons learned from the Great East Japan Earthquake and the selection of Tokyo to host the 2020 Olympic and Paralympic Games have helped prompt moves to upgrade the aging infrastructure. However, the need to balance these against financial considerations means that efficiency is essential for both upgrades and operation.

With reference to these trends, this issue of *Hitachi Review* describes information and control platforms and component technologies for extolling and realizing value in social infrastructure, and also Hitachi's work on building advanced social infrastructure for the energy, transportation, water, industrial, and other sectors.

SOCIAL INFRASTRUCTURE SYSTEMS THAT HITACHI SEEKS TO PROVIDE

Hitachi has extensive experience and system implementation technologies that it draws on to support highly reliable, high-quality large-scale systems, particularly in Japan. In addition to this track record, Hitachi also aims to deliver new value by utilizing the latest information technology (IT) to overcome the challenges facing social infrastructure throughout the world. Accordingly, in FY2014, Hitachi reorganized its infrastructure systems business domains into urban & energy solutions, water & environment solutions, industrial plant solutions, and components in order to establish a framework that can deliver one-stop solutions for societal challenges.

The social infrastructure systems like those for the sectors mentioned above have many different stakeholders, including the end users of the infrastructure; the operators who build, run, and maintain it; and the governments that impose regulatory oversight. In the future, Hitachi intends to deliver the values of social infrastructure to these stakeholders in three forms, namely "smart & smooth," "sustainable growth," and "security & resiliency" (see Fig. 2). The following sections explain what each of these values mean.

(1) Smart & smooth: Eliminating what is "unreasonable, wasteful, and uneven"[(3)]

This means the efficient control of social infrastructure using IT through improving the efficiency of energy use and relieving congestion, and reducing the overall cost to society including the environmental load, while also improving convenience for end users. It also means reducing the total life cycle cost to operators by analyzing operational data to optimize operation and maintenance, and by providing new services that enhance the convenience of social infrastructure for end users.

(2) Sustainable growth: Social infrastructure that can continue to grow

Social infrastructure that needs to remain in service for decades or more requires the flexibility, expandability, and ease of improvement to adapt to changes in society that cannot be foreseen at the time of its construction. In addition to expanding along with the development of the city, it should also provide a platform for growth that increases capital value for end users, operators, and others.

(3) Security & resiliency: Ensuring that infrastructure is safe, secure, and resilient

In addition to being reliable enough to operate continuously, 365 days a year, infrastructure must also maintain security and privacy; these issues have also become concerns for control systems in recent years. Infrastructure must also have the resiliency to continue delivering essential functions even in the event of extensive damage caused by unforeseen incidents such as faults or disasters, and to be able to recover quickly.

(a) Industrie 4.0
A high-tech strategy of the German government that anticipates the fourth industrial revolution. It aims to make all aspects of wide-scale industrial processes smarter, including logistics, through the use of information and communication technology (ICT), including machine-to-machine (M2M), big data analytics, and the integration of industrial and business systems.

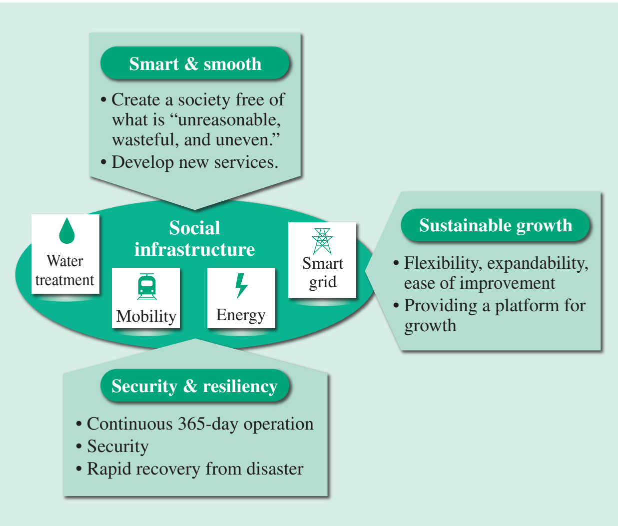

Fig. 2—Values that Hitachi Seeks to Provide to Social Infrastructure.
Hitachi seeks to provide "smart & smooth" infrastructure systems that are capable of "sustainable growth" and "security & resiliency."

INFORMATION AND CONTROL PLATFORMS THAT DELIVER NEW VALUE FOR SOCIAL INFRASTRUCTURE

Social infrastructure consists of the equipment installed at energy, transportation, water, industrial, and other sites; the information and control platforms that control these plants; and the information platforms that handle operation and management at a supervisory level. Hitachi supplies the functions needed for each of these platforms in order to deliver value for social infrastructure in terms of "smart & smooth," "sustainable growth," and "security & resiliency" (see Fig. 3).

Information Platforms

Information platforms play an important role in making social infrastructure "smart & smooth." This includes supporting the formulation of optimal operating plans for control systems and the development of new services by collecting sensor and other operational data from control systems and by utilizing big data analytics, modeling, and simulation for analysis and prediction. Hitachi offers information platforms as the "Intelligent Operations Suite." This includes IT platforms, various industry-specific "vertical services," and early-stage consulting. The IT platforms consist of applications for big data, highly reliable clouds, and security platforms developed in fields such as finance, the public sector, and industry[4].

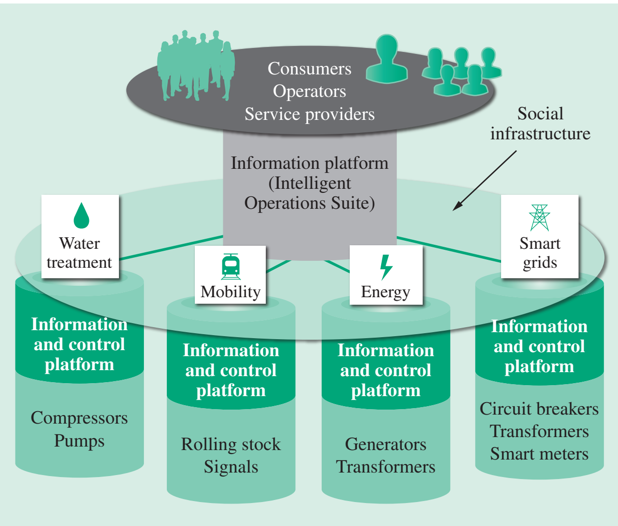

Fig. 3—Platforms that Support Social Infrastructure.
Social infrastructure is underpinned by information platforms that link the infrastructure with consumers and businesses, key plant machinery, and the information and control platforms that control them.

Information and Control Platforms

Information and control platforms are implemented with information and control systems that seamlessly comprise components like control servers and controllers. The various technologies incorporated into these components help deliver the social infrastructure value described earlier in this article (see Fig. 4).

Another article on page 71 of this issue describes the latest work on these platforms.

(1) Smart & smooth

The interoperation of control systems and information platforms is critical to making infrastructure "smart & smooth." To achieve this, Hitachi supplies functions that support the flexible collection of data from information platforms while also ensuring the realtime performance and reliability demanded of control systems.

In the case of social infrastructure, the development of new services also requires greater "intelligence" so that the outputs of information platforms can be utilized as feedback to the infrastructure. Power system monitoring control devices designed for outdoor use and used in smart grids are one example. To satisfy these needs, Hitachi is developing small computers suitable for long-term operation in harsh environments, while also ensuring that applications are expandable.

(2) Sustainable growth

Hitachi proposed the concept of an "autonomous decentralized" system for achieving sustainable growth in social infrastructure in 1977, and has been involved in the implementation of control systems with excellent expandability. In the case of information and control platforms, Hitachi supports the implementation of systems based on the autonomous decentralized systems concept by supplying autonomous decentralized communications middleware for devices such as information and control servers and controllers. Autonomous decentralized communication is incorporated into international standards such as ISO 15745[b] to improve interoperability between systems from different vendors.

Achieving sustainable growth requires that all of the components used in information and control platforms are themselves capable of long-term operation. However, hardware devices such as processors and microcontrollers are becoming commodities, and

(b) ISO 15745
An international standard for industrial automation networks. It specifies standardized rules for describing specifications and takes the form of an application framework for devices that are connected to a network.

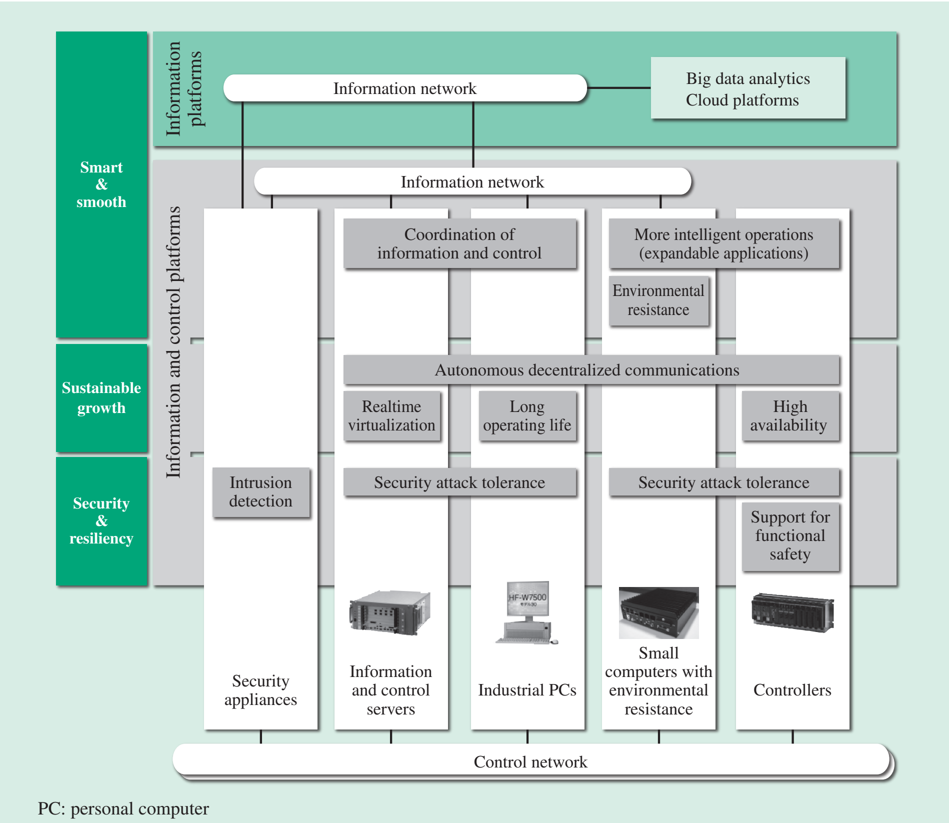

Fig. 4—Overview of Information and Control Platforms.
The three values are underpinned by the distinctive technologies incorporated into the information and control servers, controllers, and other components of information and control platforms.

increasing year-on-year pace of technical innovation in software and services. To combine this situation with long-term operation of social infrastructure is a challenge. In response, Hitachi is using virtualization technology on information and control servers to ensure that proven operating systems (OSs) and applications can have a long operating life. While virtualization is already commonplace in information systems, Hitachi is seeking to deploy it on information and control servers in ways that also satisfy control system requirements for realtime performance, high availability, and ease of on-site maintenance.

(3) Security & Resiliency

While interoperation with information platforms is essential to making social infrastructure smart & smooth, this raises concerns about the resulting increase in security vulnerabilities. Furthermore, the increasing risk of attacks specifically targeted at control systems, such as the Stuxnet[(c)] incident, has created a need for the strengthening of cybersecurity in information and control platforms. Internationally, development of security standards for control quipment and systems, such as IEC 62443, is now ongoing, and vendors need to supply platforms that comply with these standards. Hitachi has been involved with the Control System Security Center since its formation and participated in activities such as security drills and joint research into enhancing control system security.

The first step in strengthening control system security is to raise the attack tolerance of the individual components. Hitachi is developing controllers that comply with international standards for certifying the security of control equipment, particularly ISASecure* EDSA (Embedded Device Security Assurance). Meanwhile, maintaining security at the system level requires the ability to detect intrusions such as unauthorized connections or access. Hitachi has released a node monitoring server for detecting unauthorized network connections. In addition to supplying appliance products that are designed to perform intrusion detection under a wide range of circumstances, Hitachi is also seeking to build more robust security systems through interoperation with security monitoring services that have been developed for information systems.

(c) Stuxnet
A form of targeted attack malware. Stuxnet attacks the control systems of industrial equipment and is known to have been responsible for attacks on control systems at Iranian nuclear facilities. Part of its threat is that, as well as spreading via the Internet, it can infect standalone networks via devices such as universal serial bus (USB) flash memory.

* ISASecure is a Trademark of ASCI.

Support for functional safety is a requirement for information and control platforms so that they can provide public systems with the resiliency needed to cope with unexpected events. Hitachi develops and supplies R800FS/HSC800FS functional safety controllers that comply with the IEC 61508 standard for functional safety. These controllers can operate two types of applications: functional safety applications ensuring safety for equipment and general applications used for ordinary control systems and information processing. These two types of applications can provide highly flexible control functions by complementing each other. They also contribute to greater resiliency in control systems by providing mechanisms that allow control to continue functioning safely when a fault occurs, rather than simply shutting down control outputs.

ACTIVITIES AIMED AT BUILDING ADVANCED SOCIAL INFRASTRUCTURE

The following section describes the work Hitachi is undertaking to build advanced systems that can deliver the three forms of social infrastructure value described above in the energy, transportation, urban development, water infrastructure, and industrial sectors.

Smart & Smooth

(1) Island smart grid model

A smart grid demonstration project is being run on the island of Maui under the leadership of the New Energy and Industrial Technology Development Organization (NEDO) to encourage the use of renewable energy in the state of Hawaii in the USA. The system, which commenced operation in December 2013, controls electric vehicle (EV) charging to resolve problems such as frequency fluctuations caused by the variable output of renewable energy. In the future, we are planning to extend this system by using EVs as virtual power plants[d], whereby they operate as a distributed generation system (see p. 23).

(2) Smart grid demonstration project using PV power generation

Installations of large amounts of photovoltaic (PV) power generation will require more considerations, for example, power quality, efficient operations of existing equipment, PV output prediction, and battery utilization. Hitachi has been working with Kyushu Electric Power Co., Inc. since March 2013 on joint research into developing and testing power system control technology using a demonstration smart grid. In the case of supply and demand control, the project will test the coordination of consolidated and region-specific supply and demand plans and optimal methods for battery control based on these plans. In the case of voltage regulation, the project will identify the issues associated with voltage management on distribution grids and test optimal voltage control techniques by using test load systems to induce fluctuations in the grid load and by collecting and analyzing transmission line voltage, current and other data (see p. 28).

(3) Condominium energy management systems

Since the Great East Japan Earthquake in 2011, electric power consumers in Japan have been installing energy management systems (EMSs) to achieve more energy efficiency, save power consumption, and ensure sufficient amounts of energy during periods of tight supply. However, small-scale consumers and others on low-voltage supplies are not motivated to install the EMSs because of small economic benefit. Condominiums represent one category of such consumers, and Hitachi has developed a "condominium energy management system" (condominium EMS) that consolidates management of each residence in the building. The condominium EMS helps encourage energy efficiency and power saving by presenting information on energy use, remotely controlling appliances and other equipment, and providing notification of times when electric power is in short supply (see p. 41).

(4) Power conditioners for renewable energy

Grid instability is recognized as a problem that results from the installation of renewable energy sources such as PV modules and wind power. These grid instabilities can be broadly divided into two categories, namely the instability caused by a large number of power conditioners disconnecting at the same time in response to a grid fault, and variations in the grid voltage and frequency due to fluctuating output caused by changing weather conditions. Hitachi is developing power conditioners that can deal with these problems, along with control techniques for using these systems (see p. 35).

(5) Video surveillance systems

With the spread of digital technology and broadband networks, application of video surveillance is now

(d) Virtual power plant (VPP)
A networked system of distributed power sources, the technology for which is being commercialized in the USA. The system performs integrated control and management via a communication network of multiple distributed power sources, which may include companies' in-house power generators, home-generated renewable energy, and EV batteries as well as power plants operated by power companies.

expanding beyond crime prevention to business uses such as monitoring what is happening at remote sites or using and analyzing images to support customer operations and business management. Hitachi currently supplies the video surveillance solution to business users and has plans for deploying cloud services that use image analysis techniques combined with high-resolution image transmission and image enhancement to support customer operations and monitor equipment operation (see p. 66).

Sustainable Growth

(1) ATOS Chuo Line upgrade

The purpose of the Autonomous Decentralized Transport Operation Control System (ATOS), which was installed by the East Japan Railway Company (JR-East) and commenced operation in 1996, is to provide optimal railway traffic management throughout the Tokyo region. Taking advantage of its autonomous decentralized architecture, JR-East has been progressively rolling out ATOS to additional lines over time, with the system now covering 20 lines with a combined length of about 1,270 km. The requirements for railway systems have been changing in recent years. This includes the need to adapt to operational changes such as the increase in train operations over multiple lines, minimize the duration of timetable disruption, and utilize IT to improve passenger services. To satisfy these requirements, Hitachi is supporting the sustainable growth of railway systems by upgrading to optimal system configurations, providing efficient command infrastructure, expanding information services, and ensuring seamless system upgrades (see p. 45).

(2) System for planning, operation, and maintenance of water supply and sewage

Water supply and sewage are core parts of the social infrastructure and need to satisfy a diverse range of requirements, including not only safe, secure, and trouble-free use, but also sustainable operation and awareness of biodiversity and other water-related environmental considerations. Hitachi considers the entire water supply and sewage lifecycle, supplying information and control system technologies that help operate services over wider areas, operate in ways that take account of energy and the water ecosystem, and build maintenance and upgrade schedules (see p. 52).

(3) Steel industry control systems

Steel industry control systems tend to be large, comprising motors, drives, programmable logic controllers (PLCs), and process computers among other components. In addition to reliability, they require the quick responsiveness to perform realtime electrical and mechanical control. They also need to satisfy demands for efficient equipment operation and improvement in the quality of steel strip. Hitachi is addressing these needs by adopting the latest computing technology and IT, and by working on innovations in control technologies and system technologies. To satisfy the demands of the global market, Hitachi is also actively adopting standard technologies and is developing operational support techniques and remote maintenance techniques that can be used to supply added-value after-sales services (see p. 60).

Security & Resiliency

Hitachi focuses on the concepts of adaptiveness, responsiveness, and cooperativeness to supply solutions to cities and companies. These encompass solutions for disaster prevention, physical security, and cybersecurity. The July 2014 issue of *Hitachi Review*, entitled "Social Infrastructure Security," contains articles on all aspects of Hitachi's work in security[5].

BUILDING SMART SOCIETIES AND SMART INFRASTRUCTURE

This article has looked at current trends in social infrastructure, Hitachi's business environment and the value it provides, developments in the information and control platforms that help deliver this value, and leading-edge initiatives in the field of social infrastructure.

While current work is limited to delivering value to specific sectors such as energy and transportation, the requirement for the future will be to achieve optimization across these sectors and to deliver value to cities, societies, and the entire world. This will require further advances in information platforms and information and control platforms, and the establishment of business models that include a wide range of stakeholders.

Hitachi is working steadfastly to satisfy the increasingly diverse requirements of social infrastructure and is contributing to overcoming a variety of challenges that exist on a global scale.

REFERENCES

(1) International Energy Agency, "World Energy Outlook 2013," (Nov. 2013), http://www.worldenergyoutlook.org

(2) S. Dais et al., "Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0," National Academy of Science and Engineering (Apr. 2013) in German, http://www.acatech.de
(3) Y. Tani et al., "Convergence of Information Technology and Control Systems to Achieve "Smart & Smooth" Infrastructure," Hitachi Hyoron **92**, pp. 574–579 (Aug. 2010) in Japanese.
(4) "Information as a Resource—Intelligent Operations Combining Big Data and the Cloud—," Hitachi Review **63**, pp. 6–11 (Mar. 2014).
(5) "Social Infrastructure Security," Hitachi Review **63** (Jul. 2014).

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Featured Articles

Island Smart Grid Model in Hawaii Incorporating EVs

Koichi Hiraoka
Sunao Masunaga
Yutaka Matsunobu
Naoya Wajima

OVERVIEW: Having set a target of replacing 40% of its electric power generation capacity with renewable energy by 2030, the state of Hawaii in the USA is proceeding with the installation of wind and PV power generation. To aid this work, a smart grid demonstration project is being conducted on the Hawaiian island of Maui under the leadership of NEDO. The aim of the project is to solve the problem of how to use EVs to stabilize the supply of electric power despite the fluctuating output of renewable energy. Hitachi commenced operation of the EV Energy Control Center for controlling EV charging in December 2013. It is now working on the development of VPPs, with advanced technology for using EVs as a distributed generation system.

INTRODUCTION

AGAINST the background of worsening global environmental problems, trials of smart communities and smart grids are taking place around the world in a variety of forms with the aim of moving to a low-carbon society. One example is the state of Hawaii in the USA, which has set a target of replacing 40% of its electric power generation capacity with renewable energy by 2030, and which is proceeding with the installation of wind and photovoltaic (PV) power generation.

A smart grid demonstration project on the island of Maui in Hawaii (the "JUMPSmartMaui" project, formally titled the "Japan-U.S. Island Grid Project") is being run jointly by the New Energy and Industrial Technology Development Organization (NEDO), Hitachi, Mizuho Bank, Ltd., and Cyber Defense Institute, Inc. Operation of trial sites commenced in December 2013.

This article gives an overview of the island smart grid model, which uses electric vehicles (EVs) and is one of the parts of the Japan-U.S. Island Grid Project handled by Hitachi, describes some of the results of analyzing the data collected since testing commenced, and looks at technology enhancements that can be expected in the future.

SYSTEM OVERVIEW

The project aims to improve the convenience of using EVs in order to encourage their adoption by installing EV direct-current fast chargers (EV DCFCs), initially at five sites around Maui, and subsequently at an additional 15 sites. The sites were selected based on an analysis of traffic patterns and distances from homes, offices, and tourist sites. To provide the island with an energy infrastructure that does not depend solely on fossil fuels, it will also use the EVs as batteries to absorb excess energy and to stabilize a grid that has a large installed capacity of renewable energy.

Fig. 1 shows an overview of the project.

In addition to installing EV DCFCs, the project will also include systems for the home (standard EV chargers, water heaters, and PV power generation) and large grid batteries.

In particular, the EV Energy Control Center (EVECC) described in this article provides integrated energy management for the island and exchanges information with an integrated distributed management system (DMS) and energy management system (EMS) located in the control room at the Maui Electric. The EMS controls the island-wide balancing of supply and demand on the Maui Electric Company grid.

SYSTEM FUNCTIONS

EV Chargers and EV Charging Management System

EVs require an EV charging management solution that enables multiple vehicles to charge simultaneously and controls charging output to reduce power use.

(1) EV DCFCs

Hitachi supplied variable-output EV DCFCs that were adapted for use on Maui by incorporating a

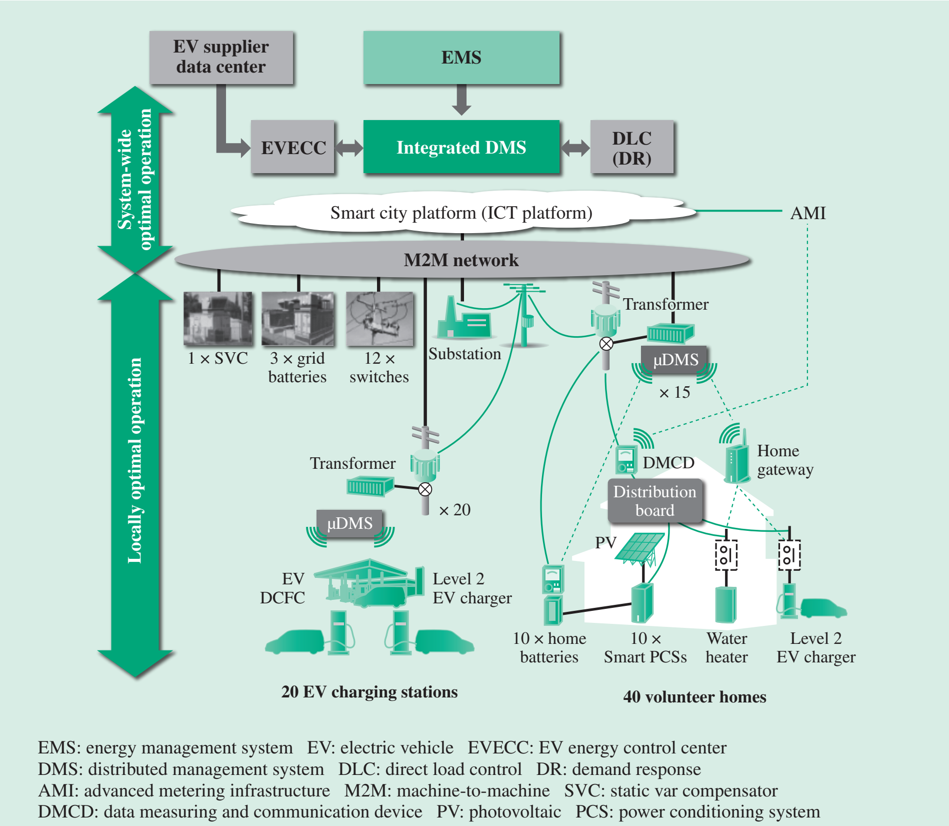

Fig. 1—Overview of Smart Grid Demonstration Project.
In addition to its network of EV DCFCs, the Smart Grid Demonstration Project on the Island of Maui in Hawaii also includes systems for the home and large grid batteries.

direct load control (DLC) function and the ability to be coordinated with existing generation plants. Hitachi also supplied a charging management system that supports the EV DCFCs. The charging management system for Maui uses EV DCFCs that can be expanded from one to four units. A number of EVs can be connected simultaneously. The charging management system allocates a total output capacity of 60 kW between the vehicles, with the precedence for charging being determined by the order in which they were connected. Once the charging of one vehicle is complete, the charging of the next vehicle commences.

Fig. 2 shows a photograph of an EV charging station.

The EV DCFCs at the five sites currently in operation are characterized by the following types of use.

(a) Site A: Located at a large shopping complex at a major center on the island
(b) Site B: Located at a medium-sized shopping center
(c) Site C: Located near a tourist site (aquarium)
(d) Site D: Located near a tourist site (plantation)
(e) Site E: Located at a hotel

To cover a wide area, the EV DCFCs were installed at five sites around Maui, with a further 15 sites planned. The sites were selected based on an analysis of traffic patterns and distances from homes, offices, and tourist sites.

(2) EV charging management system

The charging management system, which performs integrated management of the chargers via a machine-to-machine (M2M) network, has functions to collect information on charger operation and to provide information via web screens to EV users. Information technology (IT) is also used to verify user membership. Users can choose an appropriate time to charge their EV by accessing the web screens to check whether sites are in use or undergoing maintenance.

Fig. 2—EV Charging Station.
EV DCFCs are in use at five sites.

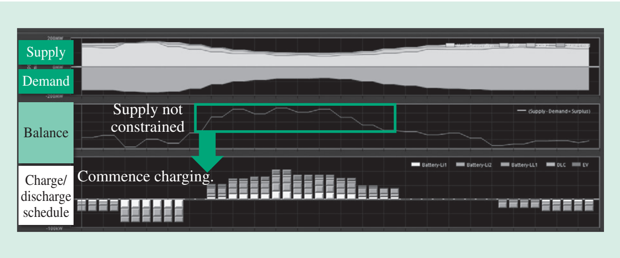

Fig. 3—Load Shifting.
Charging is scheduled to be performed at times when the supply of electric power is not constrained.

EV Energy Management

To put excess energy to good use, the EVECC has a function for scheduling when home chargers commence charging. It acquires information from the integrated DMS about the balance of supply and demand on the grid, and state of charge (SOC) information (how much power remains in the EV batteries) from the EV supplier's data center. It also performs EV energy management by coordinating control of charging with the information from the grid.

Fig. 3 shows an example of load shifting to balance supply and demand for electric power. First the integrated DMS obtains information about the supply and demand for electric power, including renewable energy, from the EMS at the power company's control center, then it uses this to produce a schedule of when excess energy is likely to be available. Next, the integrated DMS and EVECC exchange information about the supply and demand balance and EV charging schedule so that the EVECC can revise this schedule. Finally, the EVECC controls when EV charging starts to utilize the excess energy.

Grid Stabilization

Micro distribution management systems (μDMSs) installed on low-voltage transformers monitor the voltage on the low-voltage grid. When a μDMS detects a fault, such as a voltage rise caused by a reverse power flow from a PV power generation system or overloading caused by several EVs charging at the same time, the initial response to protect the pole-top transformer is to issue reactive power control commands to smart power conditioning systems or to turn off EV charging to avoid voltage deviations.

The integrated DMS monitors fluctuations in the power distribution network caused by the varying output of renewable energy. In this demonstration project, sensors installed on the grid are used to monitor the supply and demand balance on the distribution network. In emergencies, the supply and demand balance is maintained by using the DLC function to disconnect consumer loads such as water heating or EV charging.

In particular, the challenges for the DLC are to disconnect sufficient load to stabilize the grid frequency while avoiding disruption to consumers caused by these disconnections. The constraints are as follows:

(1) Minimize excessive disconnections to maintain supply and demand balance.
(2) Complete control operations within a fixed time to prevent them from continuing for a long time.
(3) Minimize disruption to consumers caused by restricting power demand.

Grid stability is maintained without causing disruptions to consumers by issuing multiple disconnection commands to deal with the uncertainty of their outcomes, and by optimizing the choice of devices to be disconnected so as to complete control operation within a fixed time and to minimize the disruption this causes.

DEMONSTRATION PROJECT

Data on the use of electric power, EV DCFCs, and other systems have been collected since the project commenced in December 2013. This section describes the data collected to date and what it implies about how well the system can be expected to work.

Energy Management

This section describes the results of charging control at the EV charging stations.

Fig. 4 shows an indicative graph of current flow data from the μDMSs installed on the transformer at the site A EV charging station. Fig. 5 shows the EV DCFC usage at the charging station over the same time period.

Fig. 5 shows how heavy use is being made of the EV chargers at those times when Fig. 4 indicates a high load on the transformer secondary. Limiting the EV DCFC output when the transformer becomes overloaded helps with grid stabilization because it provides an adjustment margin that can be used without affecting other loads.

EV Charging Infrastructure

This section presents data on the use of EV charging stations, and what this data indicates about how they will be operated in the future.

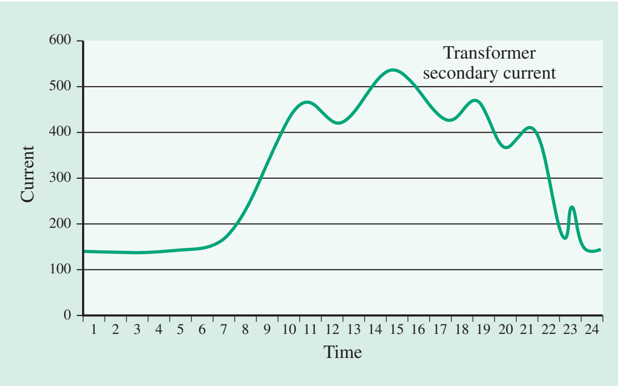

Fig. 4—Data Collected from μDMS.
This graph shows an approximation of the current flow data from the μDMS installed on the transformer at the site A EV charging station.

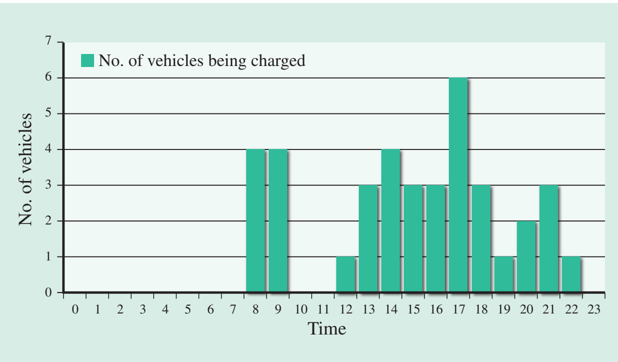

Fig. 5—EV DCFC Use.
The DCFC is heavily used at times of high load on the transformer secondary.

Table 1 lists the number of charges, total power use for charging, and total charging time for the five sites that have already commenced operation. It is assumed that site A has the highest usage because it is located in a public place (a shopping complex) where users can make use of the time taken for charging.

Similarly, Fig. 6 shows a graph of total charger use across all sites at different times of the day. The heaviest use comes in the afternoon (from 3 to 5 PM),

TABLE 1. Actual Use of EV Charging Stations
The highest usage is at site A, which is located at a shopping complex.

Site	No. of uses	Charging power (MWh)	Charging time (min)
A	2,995	22.4	1,203
B	1,780	13.9	656.1
C	304	2.5	90.7
D	330	3.2	97.1
E	285	3.5	108.3

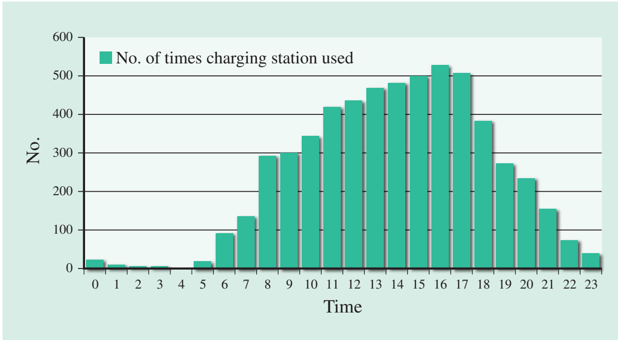

Fig. 6—Charging Station Use at Different Times of Day.
That the most frequent use of the chargers occurs in the afternoon is believed to be influenced by the habits of Maui residents.

which is believed to be because this is the time when many Maui residents are returning home from work.

In the case of Maui, where demand for charging is concentrated at particular locations and times, the EV DCFCs selected for the project help reduce congestion because they are able to charge a number of vehicles at a time, and select the best order in which to start charging each vehicle. Hitachi also plans to monitor the effects of scheduling when to charge EVs at home.

FUTURE TECHNOLOGY ENHANCEMENTS

This section describes virtual power plants (VPPs), a technology for the future.

In the context of this article, a VPP is a group of EVs that can be operated as a power plant, treating the EV batteries as a mobile form of power storage that can be discharged as well as charged. One way this function can be utilized is to charge EVs during the

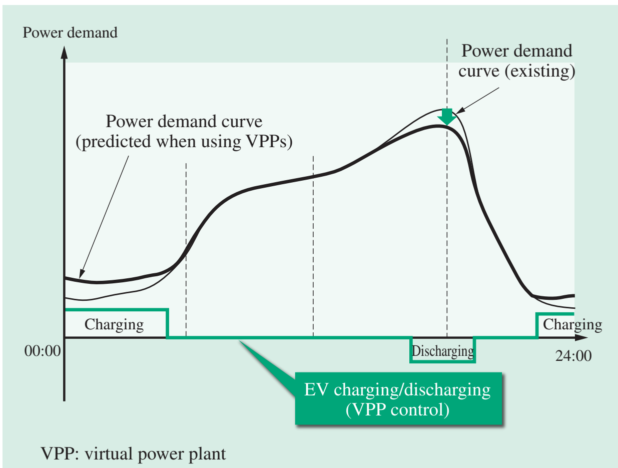

Fig. 7—Power Demand Scenario Using VPPs.
VPPs have the potential to reduce peak power demand.

night, when the level of power generation is low and electricity tariffs are cheap, and to discharge EVs that have returned home for the day at times when power demand is high (especially in the evening). This has the potential benefit of reducing peak demand for electric power (see Fig. 7).

Because this can cut the cost of generation by having the system that manages EVs perform group control of charging and discharging for a number of EVs that are clustered geographically in order to reduce peak demand, it is also potentially of benefit to electric power companies. Since the equipment used in this demonstration project includes EV chargers, systems for the home (standard EV chargers, water heaters, and PV power generation), and large grid batteries, the VPP concept can be applied not only to EVs but also to other consumer equipment.

CONCLUSIONS

This article has described an island smart grid model in Hawaii that uses EVs, and has reviewed data collected from a demonstration project to show how it can be applied to the smart grid model. The article has also described VPPs, a technology that is expected to be developed further in the future.

The demonstration project commenced test operation in December 2013, with evaluation of the benefits of installing the demonstration system scheduled to continue for two years. Hitachi plans to continue reviewing the project and working to improve energy management by analyzing data collected during this time. Hitachi also plans to utilize future technology enhancements in its work on assessing the benefits of smart grid models that use EVs.

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Featured Articles

Smart Grid Demonstration Project at Kyushu Electric Power

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Yuji Saotome
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OVERVIEW: Given the likely future installation of large amounts of renewable energy capacity, the balancing of supply and demand will rely heavily on supply and demand planning and control technologies for predicting power output, and the effective utilization of batteries to cope with the excess power or fluctuating outputs that result when renewable energy is connected to the grid. Grid operation, meanwhile, will require optimal voltage control techniques to maintain power quality and ensure that existing equipment continues to operate efficiently. Hitachi is developing supply and demand planning and control techniques and optimal voltage control techniques that will contribute to maintaining an efficient power supply with high quality and reliability even under future scenarios involving widespread use of distributed renewable energy sources with variable output, such as PV power generation.

INTRODUCTION

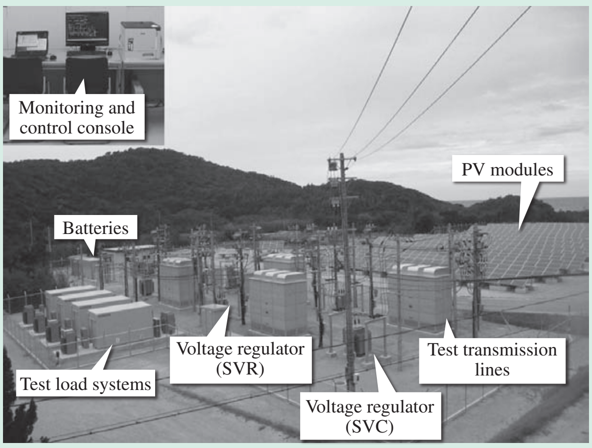
INCREASED demand for reductions in carbon dioxide (CO_2) emissions as a countermeasure to global warming has seen growing momentum in recent years behind moves to make greater use of renewable energy sources such as photovoltaic (PV) power generation. This has led to concerns about voltage deviation on the grid due to reverse power flows from PV power plants. At Kyushu Electric Power Co., Inc. in particular, which has a high proportion of PV capacity, there will be a need for measures to deal with voltage rises on transmission lines and complications to future supply and demand planning caused by the use of large amounts of PV power. In response, Kyushu Electric Power has embarked on a smart grid demonstration project whereby it has installed test equipment, including PV modules and batteries, at Genkai Town in Saga Prefecture and at Satsumasendai City in Kagoshima Prefecture. The aim of the project is to verify the effectiveness of the smart grid in practice, and to identify the associated challenges, the technologies needed, and the operational requirements.

Hitachi is participating in joint research with Kyushu Electric Power and has been running the demonstration project at Satsumasendai since October 2013.

This article describes the progress to date of this demonstration project.

OVERVIEW OF SMART GRID DEMONSTRATION PROJECT EQUIPMENT

The demonstration project equipment installed at Satsumasendai commenced operation in October 2013. It consists of a PV power plant, batteries, and a test transmission line system (see Fig. 1), as well as an energy management system for the measurement, monitoring, and control of voltage, current, and other equipment output parameters.



SVR: step voltage regulator SVC: static var compensator

Fig. 1—Demonstration Project Equipment at Satsumasendai.
The demonstration project was configured using equipment from the Kyushu Electric Power Co., Inc. grid.

TABLE 1. Components of Test Transmission Line System
The table lists the specifications of the main components of the test transmission line system.

Component	Specifications
Test LRT	2,000 kVA × 1, short-circuit impedance: 3%
Static voltage regulators	SVR × 3, SVC × 2, ShR × 1
Test transmission lines	4 × 10 km of 6.6-kV distribution lines (400 sq/200 sq) Line length: 0, 2.5, 5, 7.5, 10 km
Test load systems	525 kVA × 4, active and reactive power control, with bidirectional operability
PV modules	Connected to high-voltage system (simulating a commercial-scale system): 250 kW × 1 Connected to low-voltage system (simulating a household system): 4 kW × 7
Batteries	Connected to high-voltage system (simulating grid use): 100 kW (70 kWh) × 1 Connected to low-voltage system (simulating a household system): 3 kW (10 kWh) × 6

LRT: load ratio control transformer ShR: shunt reactor

Table 1 lists the components of the test transmission line system. The test load ratio control transformer (LRT) has 11 taps, with voltage settings that range from 6,180 V to 7,020 V in increments of 84 V. It is controlled from a static voltage regulator panel that is part of the operating grid. Each of the four test transmission lines has the same impedance (R + jX) as the cable sizes used by Kyushu Electric Power, and can be configured to have a length of between 0 and 10 km, in increments of 2.5 km. That is, it is possible to simulate a long-distance transmission line of up to 40 km by connecting the lines together in a series. The four test load systems can be configured to act as either loads or generators, and are able to provide an output of up to 500 kW (active power) with a response time of 1 s. This means the systems can regenerate a power flow of up to 2,000 kW, and simulate a reverse power flow. The voltage regulators consist of step voltage regulators (SVRs), static var compensators (SVCs), and other components that are the same as those used on the Kyushu Electric Power grid. Also included in the equipment are PV modules and batteries.

Fig. 2 shows the system configuration. A feature of the Satsumasendai project site is that it can configure a

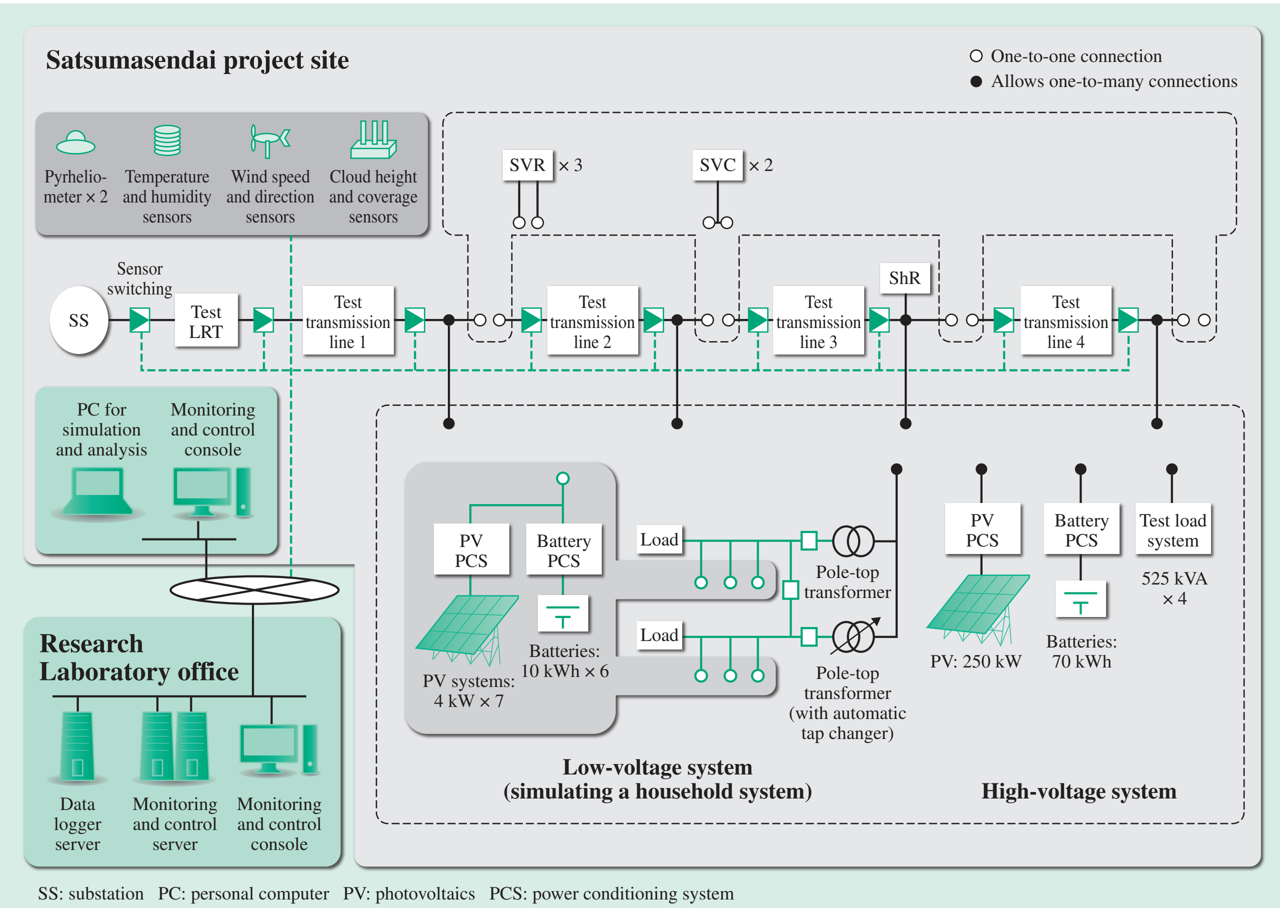


Fig. 2—Demonstration Project Equipment Configuration.
Testing can be conducted under a wide variety of conditions by swapping in and out the various components at the demonstration project site (areas enclosed by black dotted lines).

wide variety of different grid conditions. This is done using the 35 section switches that can swap in and out the various components of the system (including PV modules, batteries, test load systems, and voltage regulators). Measurement data from around the site is collected on a data logger server or monitoring and control server to allow realtime monitoring of parameters such as transmission line voltages and currents or outputs from PV modules and batteries. Functions such as PV output prediction and battery charging and discharging control are performed from monitoring and control consoles. A supply and demand planning function that uses these systems is also included.

The demonstration project is using this equipment to test techniques for supply and demand planning and control, and for optimal voltage control.

TESTING OF SUPPLY AND DEMAND PLANNING AND CONTROL TECHNIQUES

Demonstration Project Overview

With the aim of overcoming the challenges associated with techniques for planning and control of supply and demand on grids with a large PV capacity, the project will test methods for optimal battery control using PV modules and batteries. The objective of optimal battery control is to make effective use of the power generated by PV modules and to minimize the battery capacity needed to achieve this. This includes two types of tests, a long-term fluctuation suppression test and a short-term fluctuation suppression test. The following section describes the supply and demand planning and control techniques used to test the suppression of long-term fluctuations.

Verification of Supply and Demand Planning and Control Techniques

Hitachi has previously developed energy management systems (EMSs) for the planning and control of supply and demand across entire grids or parts thereof. The EMS used by the demonstration project is one designed to manage a specific region, with additional functions that incorporate know-how built up from past experience.

Supply and demand planning functions generate output schedules for generation plants by calculating the balance between supply and demand in the area being managed. Because it is intended for use with PV modules and batteries, the supply and demand planning function in the demonstration project system includes both a PV module output prediction function and a planning function for battery charging and discharging.

The demonstration project is based on the possibility that EMSs for specific regions will be installed in the future, and that the batteries in each of these regions will be operated independently. Accordingly, two new functions have been added to allow independent energy management of a number of regions using the demonstration project system on its own.

The first of these is a function that allows supply and demand plans to be generated for designated equipment only. Past EMSs for specific regions have only considered their own region, and have not had to deal with more than one region at a time. In contrast, the concept of dividing the equipment to be managed by region was introduced in the demonstration project system to allow the generation of multiple independent plans. Fig. 3 shows the equipment covered by a

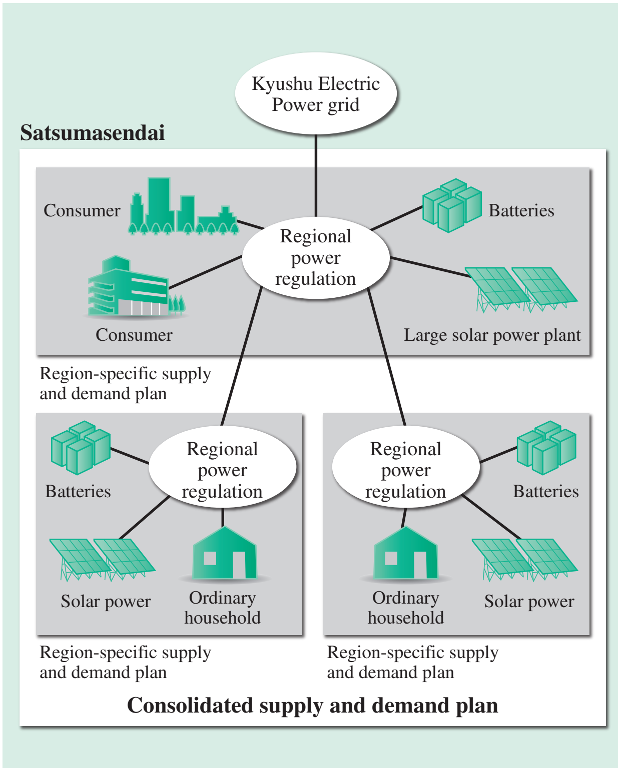


Fig. 3—Example of Equipment Covered by Consolidated and Region-specific Supply and Demand Plans.
The white box encloses the equipment covered by the consolidated supply and demand plan, and the grey boxes enclose the equipment covered by the respective region-specific supply and demand plans. Whereas the consolidated plan covers all equipment, the region-specific plans only cover equipment from their region.

consolidated supply and demand plan, and the equipment covered by the region-specific plans. Whereas the consolidated plan provides for integrated operation of all of the equipment managed by the demonstration project system, the region-specific plans only specify the operation of equipment from their own region. This function allows optimal battery control techniques to be verified under both scenarios in which energy management is consolidated across regions and scenarios in which it is handled within each region.

The other function is the coordination of consolidated and region-specific supply and demand plans. This allows for the case in which some regions use region-specific operation while operation of the remainder is consolidated. This updates the supply and demand plan for the consolidated regions so that their operation is coordinated with the supply and demand plans for those regions operating independently. This function allows optimal battery control techniques to be verified under scenarios in which region-specific and consolidated operation occurs at the same time.

These additional functions provide the flexibility to generate a wide range of different supply and demand plans. Based on the generated supply and demand plan, the demonstration project system sends instructions to the test equipment via the control functions. Fig. 4 shows an example control screen. The screen is used to display a list of equipment setting values and to issue control instructions.

The demonstration project will record and collect the results of supply and demand planning and control, and analyze and verify how these influence load patterns, optimal battery control, and where batteries are installed.

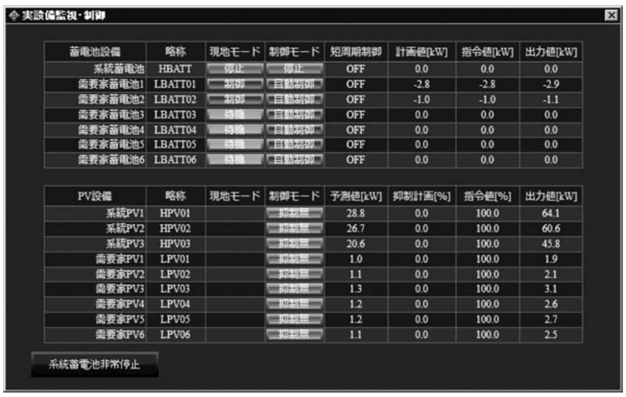


Fig. 4—Equipment Operation Screen.
Control settings are sent to the batteries and PV systems based on a plan generated by the supply and demand planning function.

TESTING OF OPTIMAL VOLTAGE CONTROL TECHNIQUES

Demonstration Project Overview

With the aim of overcoming the challenges associated with optimal voltage control techniques on grids with a large PV capacity, the project includes a variety of testing using the test transmission lines. The project is focusing on the following two types of testing in particular.

(1) Use of test transmission lines for operational verification of voltage regulators

Determine the limit on installed PV capacity, operational limits of voltage regulators, and the benefits of upgrades to grid equipment and the installation of voltage regulators on the transmission line model.

(2) Study optimal voltage control techniques

Determine the benefits of optimal settings for voltage regulators and consider the potential for use of technologies such as advanced techniques for autonomous and distributed control.

The following section provides an overview of this testing, which will start with the type (1) tests.

Evaluation Using Simulations and Test Transmission Lines

The power system and load curve settings (for heavy loads and light loads) for the demonstration project use four average model power systems representing the actual Kyushu grid and loads at a macro level. The testing assumptions cover both distributed (throughout an entire region) and centralized (distributed between transmission start, intermediate, and end points) PV and load distributions, and different combinations of connected capacity and connection points for PV modules.

Because of time and equipment-related constraints, the project has been set up to allow digital analyses of the test cases for the test transmission lines to be performed beforehand using a voltage analysis simulation tool. Because the test transmission lines have fewer nodes than the model grid used for simulation, the test grid needs to be replaced with an equivalent circuit that can be replicated using the test transmission lines. To assess issues such as rises or fluctuations in the voltage on the test transmission lines when a PV module is connected to the grid, the equivalent circuit for the test was configured by adjusting the line impedances on the respective transmission lines and the outputs of the

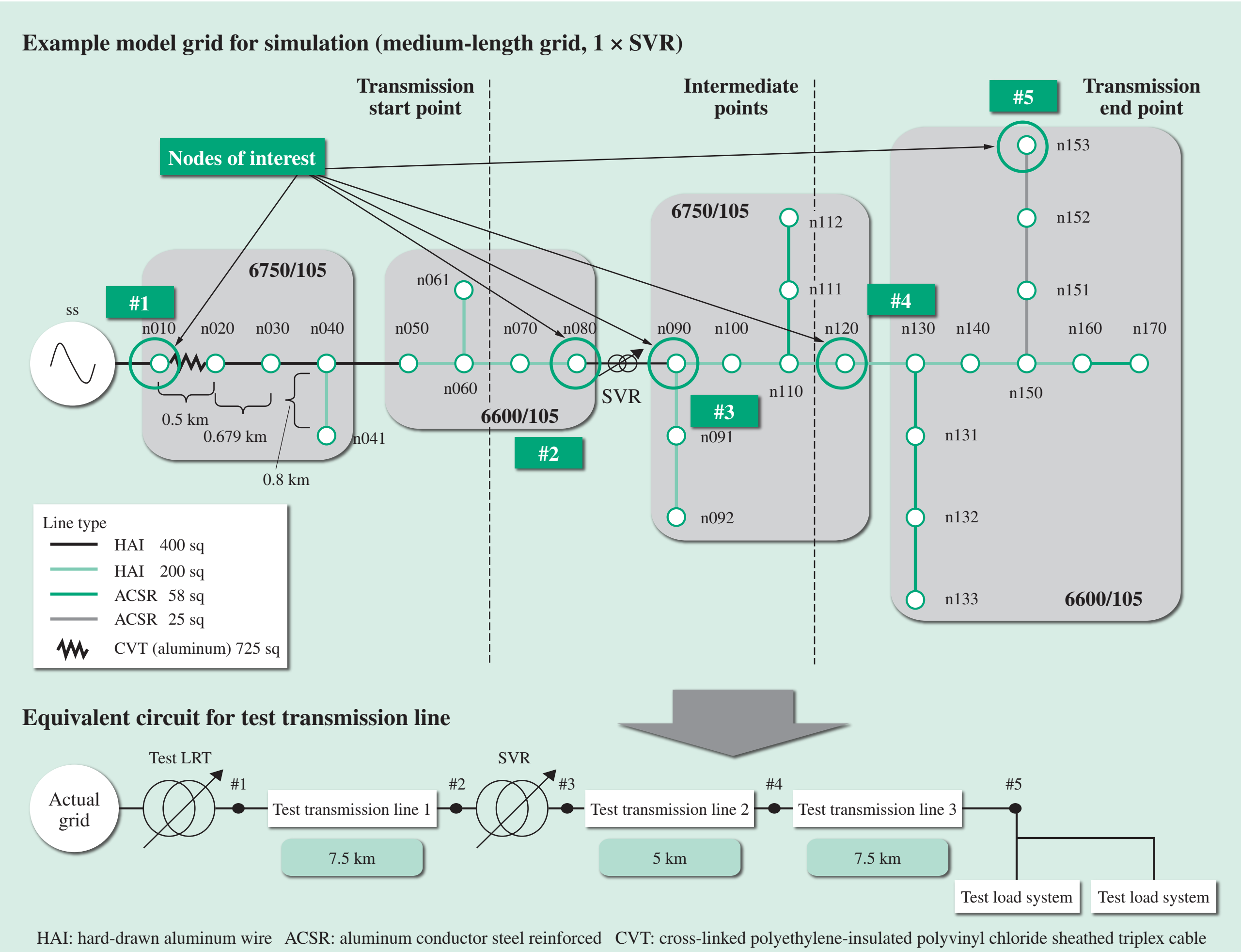


Fig. 5—Equivalent Circuit for Model Grid and Test Transmission Lines.
Because of constraints on the load capacity, number of loads, number of nodes, and length of the test transmission lines, they were replaced by a simulation equivalent circuit for preliminary testing.

test load systems so that the amplitudes of the voltage fluctuations at the equivalent circuit nodes on the transmission lines matched the amplitudes of the fluctuations at each node on the model grid used for simulation shown in Fig. 5 (see Fig. 6).

Issues to be Studied during Testing

When a large amount of PV capacity is connected to a transmission line, reverse power flows occur at times of low load causing the voltage on the transmission line to rise. Meanwhile, because existing voltage regulators were not designed to cope with reverse power flows and PV output fluctuations, there is a need to identify and verify the issues associated with these situations. There is also a need to clarify the issues associated with having a number of different voltage regulators with different operation time limits connected to the same transmission line, and the effectiveness of such configurations.

The demonstration project will determine the operational limits of existing voltage regulators (their adjustment limits and interference with other equipment) by including testing of extreme cases involving reverse power flows and transient output fluctuations caused by PV modules, and cases in which a number of different voltage regulators are installed.

Study of Optimal Voltage Control Techniques

With reference to the results of testing to ascertain the limit on PV module installation capacity when using existing methods on existing voltage regulators, Hitachi investigated ways of calculating the optimal settings for these methods. The test transmission lines were also used to check how well voltage regulators worked when operated using these optimal settings. The next step is a plan to verify the potential for increasing the limit on PV module installation capacity

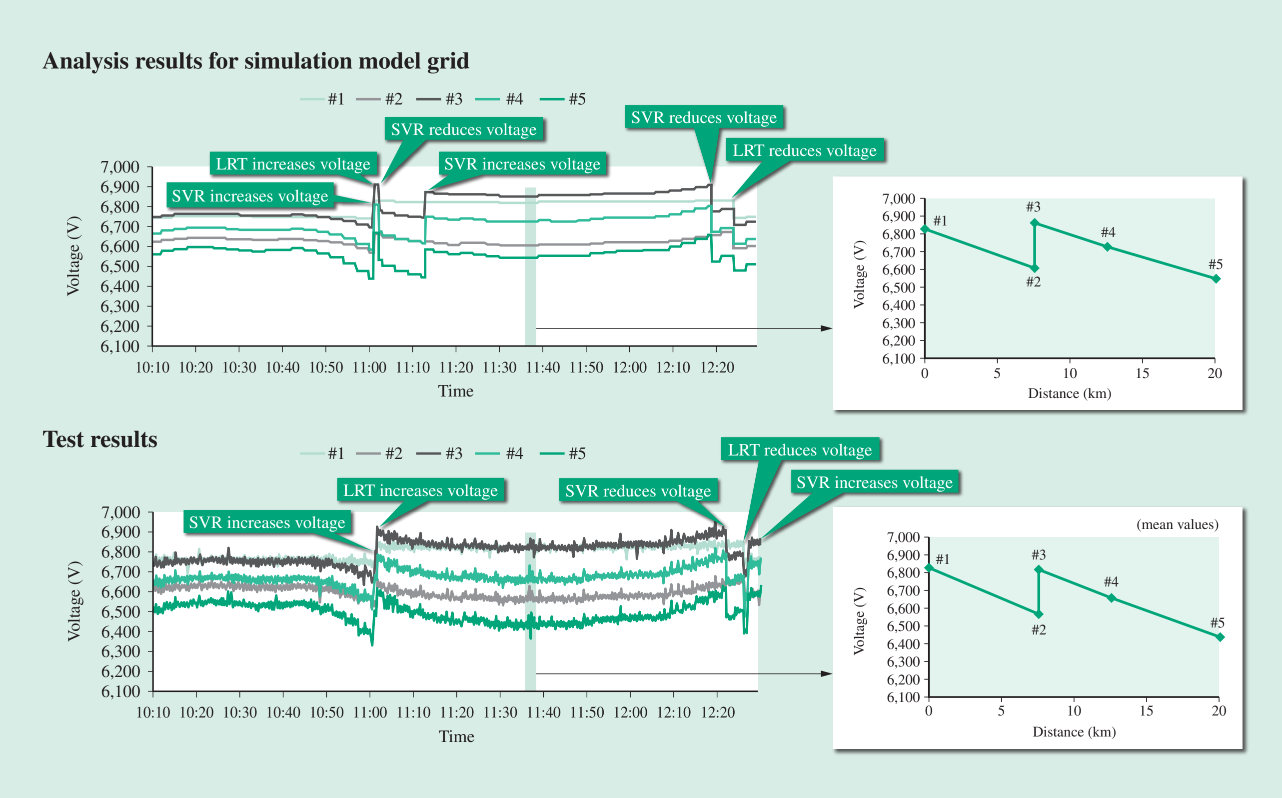


Fig. 6—Analysis Results for Model Grid and Test Transmission Lines.
The validity of the equivalent circuit used in testing was confirmed by adjusting the amplitude of the voltage fluctuations on the simulation model grid and test transmission lines to be the same.

when using existing methods by using different settings at different times, for example.

Based on the results of the above testing, Hitachi also plans to investigate the use of control methods that use communication links and advanced techniques for autonomous distributed control that are currently under development.

CONCLUSIONS

This article has described the testing conducted to date for Kyushu Electric Power's smart grid demonstration project, and its plans for the future.

To support the greater use of renewable energy and help establish a low-carbon society, Hitachi plans to continue with the verification and development of optimal battery control and optimal grid voltage control techniques.

REFERENCES

(1) "Commencement of Smart Grid Demonstration Project," Kyushu Electric Power Co., Inc. Press Release (Oct. 2013) in Japanese.

(2) K. Kawahara et al., "Effect on Voltage Regulation of Power Distribution Systems of Connecting Large Amounts of Photovoltaic Power Generation Capacity – Effects of Output Fluctuation and Smoothing –," 2012 IEEJ Transactions B, No. 125 in Japanese.

(3) H. Shiki et al., "Equipment Overview of Smart Grid Demonstration Project and Some Results of Testing of 6.6-kV Test Transmission Line," 2014 IEEJ Annual Meeting, 6-214 in Japanese.

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Featured Articles

Robust Control Technique for Grid-connected Power Conditioner

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Masaya Ichinose
Tomomichi Ito
Akira Kikuchi

OVERVIEW: In response to global environmental problems, mass introduction of variable renewable energy sources such as photovoltaic generation systems and wind turbine generation systems are spreading all over the world. On the other hand, the instability of power systems caused by large-scale integration of variable renewable energy sources (RESs) has come to be recognized. The two problems are, respectively, instability caused by disconnection of large numbers of RESs in response to grid faults, and variations in the grid voltage and frequency due to RESs' intermittent nature caused by weather conditions. For those problems, Hitachi is developing a fault-ride-through function to avoid disconnection from the grid, and unique control techniques to contribute to the stability of grid voltage and frequency.

INTRODUCTION

INTRODUCTION of renewable energy sources to the grid is now strongly expected to become a solution against global warming and reduction of carbon dioxide (CO_2) emission. In particular, the introduction of photovoltaic generation systems (PV systems) and wind power generation systems (WT systems) is increasing throughout the world as the equipment cost declines. The amount of installed capacity is growing dramatically, with PV system capacity reaching 63,610 MW[1] in 2011 and WT systems capacity reaching 282,480 MW[1] in 2012.

However, there are concerns about degradation of power quality from the grid with a high penetration ratio of RES. This degradation can be brought about by a) large numbers of RESs disconnecting from the grid triggered by voltage drop, b) voltage variation, and c) frequency fluctuations[2]. The disconnection from the grid in cases of grid fault is due to the technical constraints of power conditioning systems (PCSs). And the voltage variation and the frequency fluctuations are due to the intermittent nature of RESs.

This article describes technical countermeasures for PCSs to deal with the requirements to stay connected to the grid in case of grid fault (fault-ride-through function), and to stabilize grid voltage and frequency.

Parameter		Specification
AC output (grid connection)	Circuit	Three-level inverter
	Rated capacity	690 kVA/660 kW
	Rated voltage	AC 360 V
DC input (battery connection)	Voltage range	DC 520 V–900 V DC 1,000 V (max.)
Reverse conversion efficiency		98.8% (DC 520 V, AC 360 V, power factor: 1.0)
Operating temperature range		0°C–40°C

PV: photovoltaic generation PCS: power conditioning system
AC: alternating current DC: direct current

Fig. 1—Photograph and Main Specifications of PV PCS.
The table lists sample specifications for this 1,000-V DC PCS for PV systems.

CHARACTERISTICS OF PV SYSTEMS AND WIND TURBINE GENERATION SYSTEMS

PV Systems

Fig. 1 shows one of the PCSs for PV systems and its specifications.

This PCS for mega-solar power plants can operate with a direct-current (DC) voltage up to 1,000 V. The inverter has an advanced three-level topology with high efficiency and the maximum system efficiency of 98.8 % (at DC 520 V). The grid stabilization function provided as standard features include optimum power factor control, voltage rise suppression control, and constant power factor and other reactive power control functions. It also has a fault-ride-through (FRT) capability(3).

Wind Turbine Generation Systems

Fig. 2 shows one of the PCSs for wind turbine generation systems and its specifications.

It can withstand very severe conditions (ambient temperature of −20°C, 0.1 s of 130% over voltage, 0.2 s of 50±10 Hz frequency variation), and its standard features include active and reactive power control functions as well as FRT function(3). It uses serial communications via PROFIBUS*1 and CANopen*2 to interface with the wind turbine system controller.

*1 PROFIBUS is a registered trademark of PROFIBUS Nutzerorganisation e.V.
*2 CANopen is a registered Community Trademark of CAN in Automation e.V.

Parameter	Specification
Generator type	DFG
Rated capacity	2,300 kVA/2,070 kW
Rated voltage	AC 690 V
Over-voltage rating	130% 0.1 s
Rotor voltage	AC 0 V–735 V
Circuit	Two-level inverter
Operating temperature range	−20°C–+50°C

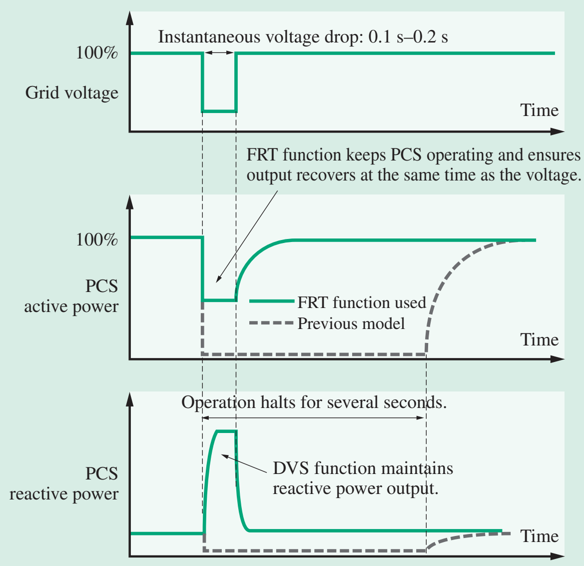
DFG: doubly-fed generator

Fig. 2—Photograph and Main Specifications of Wind Turbine Generation System PCS.
The table lists sample specifications for this DFG wind turbine generation system PCS.

FRT TECHNIQUES (PREVENTING LARGE-SCALE DISCONNECTION)

Instability resulting from the large-scale disconnection of wind turbine generation systems from the large-scale disconnection of wind turbine generation systems during the wide-area blackout in Europe in November 2006 led to revisions to national and regional grid codes and the formalizing of FRT specifications(4).

As indicated by the solid line in Fig. 3, wind turbine generation systems where PCSs are installed are required to be connected to the grid and keep operating in the event of a voltage dip caused by a grid fault, provided the depth and duration of voltage dip are within the stipulated limits. Some



FRT: fault ride-through DVS: dynamic voltage support

Fig. 3—FRT and DVS Operation of PCS during Grid Fault.
The top graph shows the variation of grid voltage with time, including an instantaneous voltage drop. The middle graph shows the active power output of the PCS. The solid line represents the case when the FRT function is used, showing how the PCS continues to operate and output active power through the instantaneous voltage drop. The dotted line shows the case without an FRT function (previous model). In this case, the PCS shuts down and the active power output falls to zero for a time after the instantaneous voltage drop. The bottom graph shows the reactive power output from the PCS. The solid line representing the case when the FRT function is used shows how the DVS function increases reactive power output in response to the instantaneous voltage drop. The dotted line representing the case without an FRT function (previous model) shows how the PCS shuts down in response to the instantaneous voltage drop, as in the active power graph.

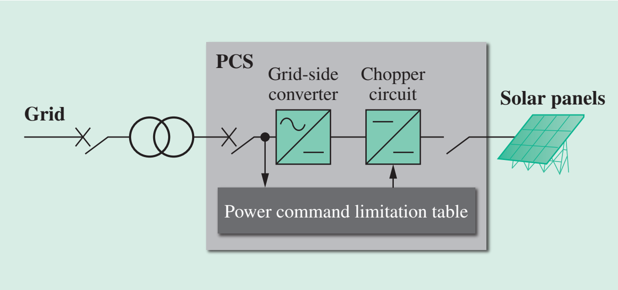


Fig. 4—Block Diagram of PV System.
The Hitachi PCS uses a power command limitation table.

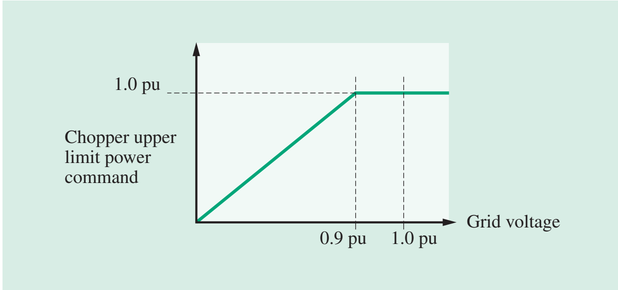


Fig. 5—Power Command Limitation Table[6]*.*
The graph shows the form of the power command limitation table (function).

countries and regions also stipulate dynamic voltage support (DVS)[5] functions, which require wind turbine generation systems to inject reactive power during faults. FRT and DVS functions improve grid stability by preventing large-scale disconnections. The following sections describe specific FRT techniques.

FRT Capabilities of PV PCS

Fig. 4 shows the configuration of a PV system.

The voltage generated by the solar panels is boosted by the chopper circuit and the generated DC power is converted into alternating current (AC) power by the grid-side converter and fed to the grid. In the case of a voltage dip, the output power from the converter is rapidly reduced. So the generated power from the solar panels loses its path and that causes over voltage at the DC-link circuit, which makes the PCS trip to protect the PCS itself.

To prevent this, the generated power from the solar panels is regulated by the chopper circuit based on the residual grid voltage to minimize the rise at the DC-link voltage. The FRT capability is achieved by using a power command limitation table based on the grid voltage to limit the rise in DC-link voltage, thereby improving the ability of the PCS to continue operation[6] (see Fig. 5).

FRT Capabilities of Wind Turbine Generation Systems PCS

In wind turbine generation systems that equip doubly-fed generators (DFGs), power flows from the grid-side converter to the rotor-side converter and the excitation current is supplied from the rotor-side converter to the rotor windings in the DFG (see Fig. 6). With this excitation current, output voltage can be induced from the DFG and that realizes power flow from stator windings to the grid. The following describes the FRT technique mounted in the WT system illustrated in Fig. 6.

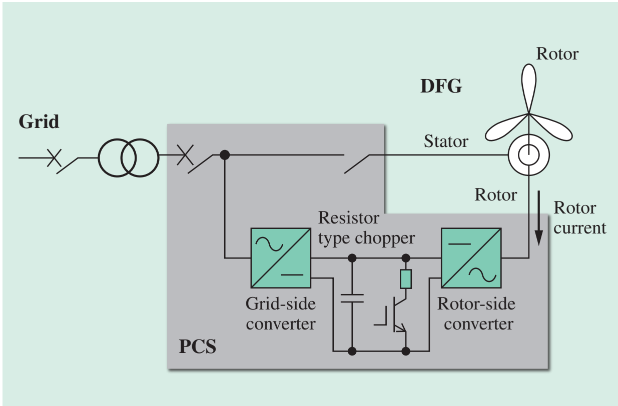


Fig. 6—Block Diagram of DFG Wind Turbine Generation System.
The diagram shows the configuration of Hitachi's PCS for wind turbine generation systems.

Because large current flows in the DFG's stator winding and rotor winding in the case of a voltage dip on the grid side, the PCS has to be able to handle the large current and to output active and reactive power at the same time. The PCS in the wind turbine generation system satisfies this requirement by the following two methods:

(1) Selecting the optimum duty ratio of IGBTs in the rotor-side converter[7]

(2) Stabilizing DC-link voltage using a chopper circuit connected to the discharging resistor

For (1), the large current flow in the rotor that results from the voltage dip on the grid side can be handled by changing the duty ratios of the rotor-side converter's IGBTs, as shown in Fig. 7. This duty ratio selection function allows power to be output from the WT system immediately after the grid voltage dip. For (2), the energy flowing into the PCS during the voltage dip at grid side is absorbed by the resistor and it leads to better FRT capability of WT system. The control method (1) also reduces the load of the discharging resistor, allowing it to be made smaller. Fig. 8 shows

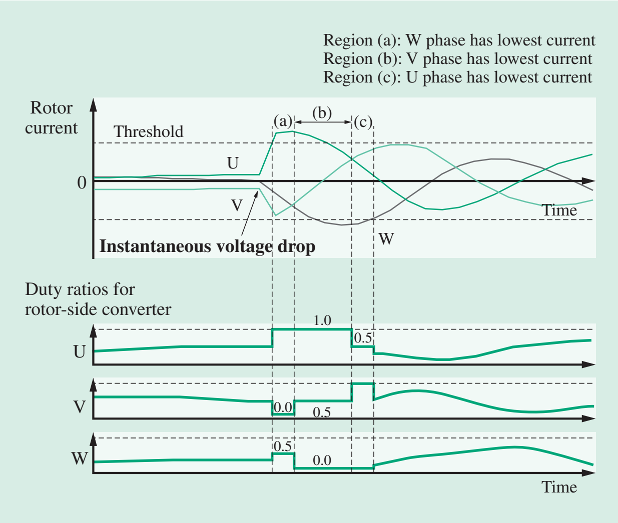


Fig. 7—Duty Ratios for Rotor-side Converter during Instantaneous Voltage Drop[7].
Because a large current flows in the rotor when an instantaneous voltage drop occurs, the duty ratios for the rotor-side converter are set to either 0.0, 0.5, or 1.0 to withstand and limit this excess rotor current.

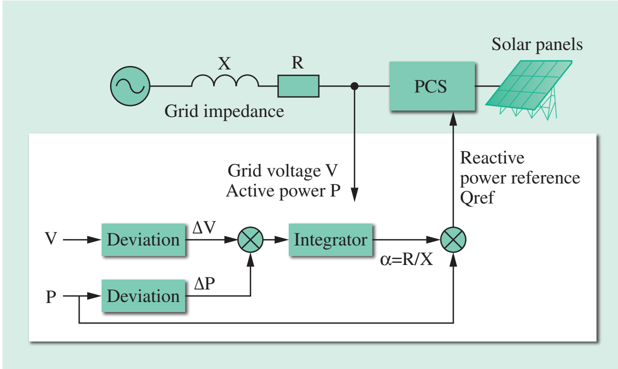


Fig. 9—Block Diagram of Reactive Power Auto-tuning[8].
The optimal reactive power reference (Qref) is calculated from the grid voltage (V) and active power (P). The area inside the white box is the block diagram of reactive power auto-tuning.

measured waveforms during FRT operation using methods (1) and (2). This demonstrates the stable power control of the WT system and continuous operation of the PCS.

GRID VOLTAGE STABILIZATION TECHNIQUES

The following sections describe stabilization techniques for grid voltage and frequency that are incorporated into PV and WT systems' PCSs.

Grid Voltage Stabilization Techniques

Because of grid impedance, when the output power, strictly speaking, the output current from an RES changes, the voltage drop on the grid side also changes. Generated power from an RES changes depending on weather conditions. So the grid voltage changes and the power quality supplied to other consumers deteriorates. Because grid voltage can be controlled by changing injected reactive power from PV system, it is possible to stabilize the grid voltage by injecting optimal reactive power to the grid.

Fig. 9 shows an example of a PV PCS. For a grid impedance with resistance (R) and (X) in Ohm, the PCS automatically estimates α (=R/X) from changes in grid voltage (V) and active power (P), and minimizes the variation in grid voltage by setting

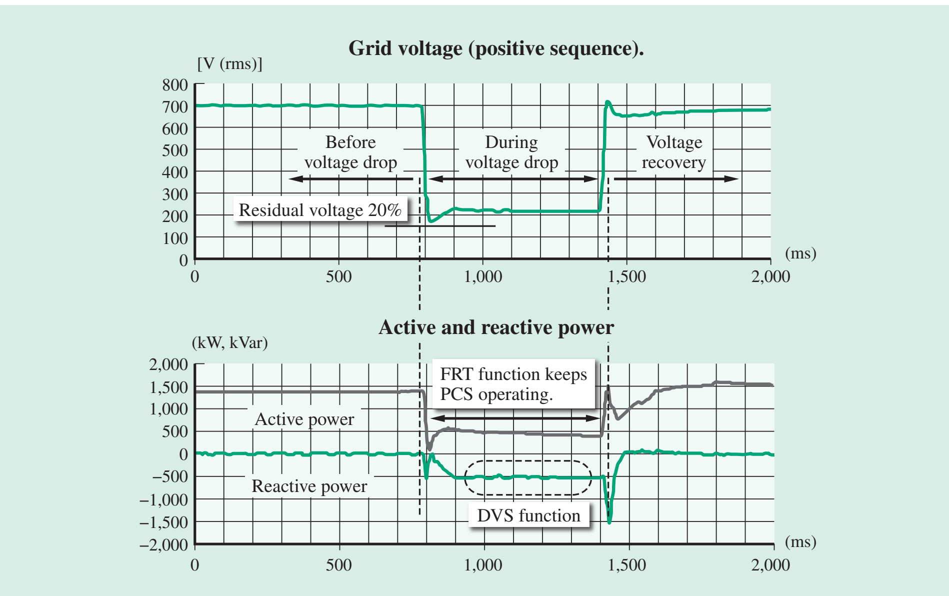


Fig. 8—FRT Waveforms (Three-phase Grounding Fault, 20% Residual Voltage, 1.5-MW Capacity).
The graphs show actual FRT waveforms from a Hitachi wind turbine generation system PCS. The top graph shows how the grid voltage varies with time, including the instantaneous voltage drop. The bottom graph shows the active and reactive power output by the PCS. The FRT function keeps the PCS operating and the DVS function increases the output of reactive power during the instantaneous voltage drop.

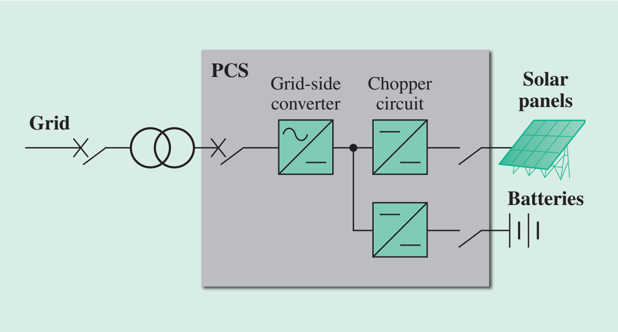


Fig. 10—Hybrid PCS[9].
The figure shows a block diagram of a hybrid PCS that combines solar panels and batteries.

the reference for reactive power output by the PCS (Qref) to P*α. This function is called reactive power auto-tuning[8].

Frequency Stabilization Techniques

Because the demand and supply of active power have to be balanced, short-duration excesses or shortfalls are absorbed by the rotational energy of conventional generators and appear as deviations in the grid frequency. Fluctuations in the output power from the PV and WT systems due to their intermittent nature degrade power quality by causing variations in the grid frequency.

Fig. 10 shows a hybrid PCS for PV systems that combines both solar panels and batteries. The hybrid PCS can contribute to grid frequency stabilization by charging or discharging the batteries to smoothen output power from the PCS.

CONCLUSIONS

This article has described how the impact on grid stability from renewable energy sources such as PV and WT systems is now recognized because of the mass introduction of renewables. And Hitachi is developing technical countermeasures such as the FRT function, reactive power auto-tuning control, and hybrid PCS, to solve the problem.

As the higher penetration rate of RES systems creates a bigger impact on grid stability, it will become difficult to maintain grid stability by relying only on the standalone control function of PCSs. What will be required in the future will be total control involving interoperation between the grid and PCSs, and between battery systems and PCSs, and also the utilization of "electric power accommodation" (power sharing arrangements).

To ensure the reliable supply of electric power, Hitachi continues delivering highly flexible power solutions that fuse technologies from power systems, batteries, and power electronics.

REFERENCES

(1) Agency for Natural Resources and Energy, "FY2012 Annual Report on Energy (Energy White Paper 2013)," http://www.enecho.meti.go.jp/about/whitepaper/2013html/ (Jun. 2013) in Japanese.
(2) New Energy and Industrial Technology Development Organization (NEDO), "Renewable Energy Technology Whitepaper," http://www.nedo.go.jp/library/ne_hakusyo_index.html (Dec. 2013) in Japanese.
(3) Japan Electrotechnical Standards and Codes Committee, JEAC9701-2012 Grid Inter-connection Code (Mar. 2013) in Japanese.
(4) "Mapping of Grid Faults and Grid Codes," Risø-R-Report, Risø National Laboratory, Denmark, http://www.risoe.dk/rispubl/reports/ris-r-1617.pdf (July 2007).
(5) N. Kanao, "Research into FRT•DVS for Wind Power Generation," Hokuriku Electric Power Company Annual R&D Report, No. 45 (Feb. 2011) in Japanese.
(6) T. Aihara et al., "Power Converter and Generation Converter System," Hitachi, Ltd., Patent 5260092 in Japanese.
(7) A. Bando et al., "Doubly-fed Generator and Doubly-fed Variable-speed Motor-Generator," Hitachi, Ltd., Patent 5401213 in Japanese.
(8) S. Ohara et al., "Distributed Power Supply System and Grid Stabilization Method," Hitachi, Ltd., Patent 4575272 in Japanese.
(9) Hitachi Battery Solutions, Product Catalog (Oct. 2012) in Japanese.

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Featured Articles

Condominium EMS Based on Information and Control Technology

Tomotaka Shimojo
Yukiteru Kato
Hiroaki Sato
Hiroyuki Hatsuzawa
Yasuhiro Masuda

OVERVIEW: Since the Great East Japan Earthquake of March 2011, electric power consumers in Japan have been installing EMSs in recognition of the need for energy efficiency and power saving, and for ensuring sufficient energy during periods of tight supply. However, one of the obstacles to the wider adoption of these EMSs is that it is difficult for small-scale consumers and others on low-voltage supplies to gain an economic benefit from their installation. Condominiums represent one category of such consumers. To reduce their power use and encourage energy efficiency, Hitachi has developed an EMS for condominiums that consolidates management of each residence in the building.

INTRODUCTION

AS part of its business supplying energy management systems (EMSs) to various different types of electric power consumers, Hitachi has released an integrated xEMS for facilities such as buildings or factories, and a "condominium energy management system" (condominium EMS) that covers both private and communal areas in the condominium.

Among the features of these EMSs is the integrated xEMS that provides equipment and applications to suit the objectives and purposes of building or factory managers, whereas the condominium EMS is designed to provide services to condominium residents (ordinary consumers).

This article describes an condominium EMS jointly developed by Hitachi, Ltd. and Hitachi Building Systems Co., Ltd., and looks at the issues associated with the wider adoption of condominium EMSs and the outlook for the future.

WORK ON SYSTEMS FOR CONDOMINIUMS

Hitachi, Ltd. commenced sale of a security management system for condominiums in 2001. To date it has supplied access control services for both the communal and private areas of condominiums, including the use of smartcard authentication for entering the premises, to more than 60,000 residences. In collaboration with Hitachi Building Systems, Hitachi, Ltd. also operates a continuous 365-day service infrastructure, having established two customer centers and more than 350 maintenance sites around the country.

Since the Great East Japan Earthquake of March 2011, policies for ensuring energy supplies have required efforts to be made not only by suppliers of electric power, but also by consumers. There has also been a public sector initiative relating to systems for condominiums, in the form of a project that commenced in FY2013 run by the Ministry of Economy, Trade and Industry to promote the installation of condominium EMSs (a project to accelerate implementation of smart mansions). By managing energy in ways that link residences together, the condominium EMS installation business not only encourages energy savings across entire condominiums, but it can also be expected to provide added value to residents, including the benefits of saving electricity.

Given this background, Hitachi's condominium EMS development included integrating with the existing security management system and expanding its services to encompass systems for condominiums.

SYSTEM IMPLEMENTATION UTILIZING INFORMATION AND CONTROL TECHNOLOGY

Overview of Condominium EMS Functions

The newly developed system for condominiums combines both energy and security management functions. It is configured in a way that allows services

Energy display screen

Air conditioner screen
(for controlling appliances that support ECHONET Lite)

Fig. 1—Web Screens for Services to Individual Residences.
The service provides screens that allow each residence in a condominium to view its energy use, control home appliances, and so on.

to be selected from among the available functions in order to suit customer budgets and requirements.

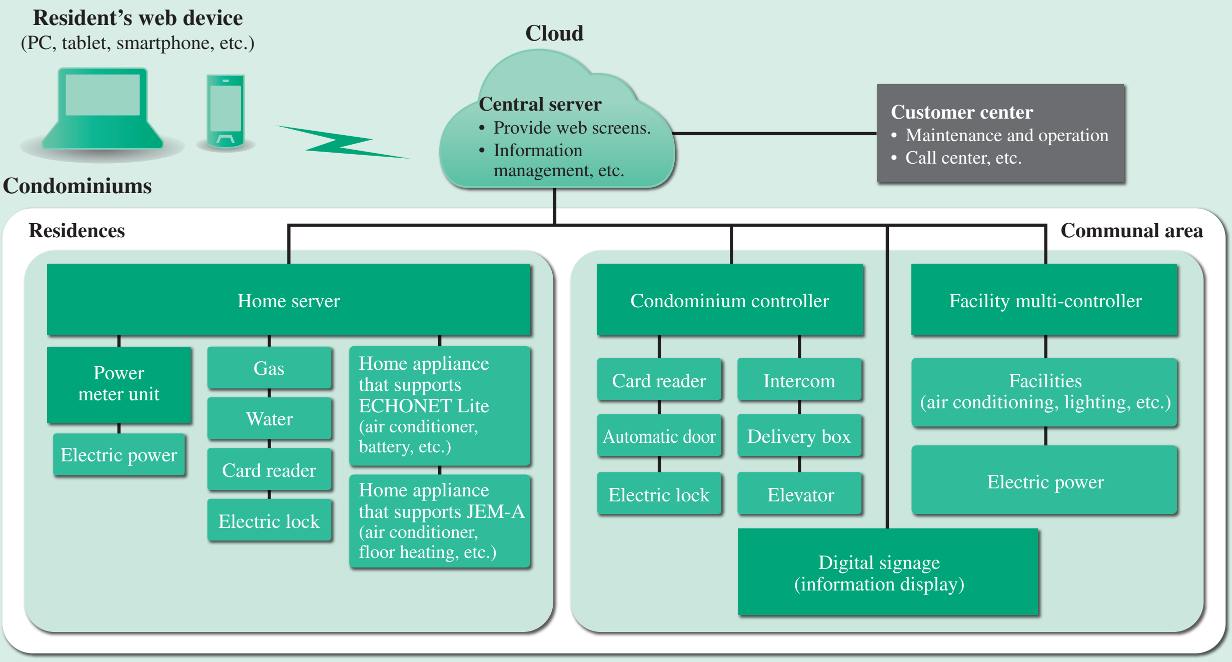
The main energy management functions that the condominium EMS provides for individual residences are as follows (see Fig. 1):

(1) Measurement and presentation of energy use
(2) Remote control of appliances that support ECHONET Lite*1
(3) Setting of energy use targets and alarm notifications
(4) Distribution of e-mails requesting emergency power savings at times of tight supply

The main energy management functions for communal areas are as follows:

(1) Measurement and presentation of energy use
(2) Remote control of air conditioning, lighting, and other utilities

*1 ECHONET Lite is a registered trademark of the ECHONET Consortium.



PC: personal computer

Fig. 2—Block Diagram of Condominium System.
The condominium system has a cloud-based configuration consisting of a central server with residence and communal area devices in the condominium connected via a network. The residence devices consist of a home server and a power meter unit and the devices for communal areas consist of a condominium controller, a facility multi-controller, and an information display for digital signage. The home server combines both energy management and security management functions. The facility multi-controller and condominium controller provide energy management and security management functions, respectively.

(3) Automatic control of equipment during times of tight electric power supply
(4) Use of digital signage to encourage power saving

The system also includes existing security management functions that are not covered here.

Ensuring Reliability of Cloud Service

The condominium system has a cloud-based configuration that consists of a central server with residence and communal area devices in the condominium connected via a network (see Fig. 2).

The functions of the central server that manages the condominiums includes providing web screens for performing actions such as viewing power use or remotely controlling equipment, exchanging information with residence and communal area devices, and various forms of information management. The security of the cloud system is ensured by implementing countermeasures against web application vulnerabilities and by encrypting data such as residents' e-mail addresses or passwords. The system also uses virtualization and redundancy for the central server to ensure fault tolerance. To prevent unauthorized external access when web screens are used for the remote control of equipment connected to residence and communal area devices, these devices are designed to only accept control commands from the central server via encrypted communications.

Configurable Devices to Suit Customer Needs

Whereas past residential devices have only supported security management functions, Hitachi has developed a new home server and power meter unit that also support energy management functions (see Fig. 3).

The exit security management functions included in the home server are a card reader interface (I/F) used for smartcard authentication and an electric lock I/F for door lock control. The energy management functions consist of a local area network (LAN) I/F to the power meter unit that handles power measurement at the distribution board, a pulse input I/F for gas, water, and other meters, and a control adaptor I/F for the control of appliances that support standards such as JEM-A and ECHONET Lite.

Because it incorporates so many I/Fs, the home server allows residences to combine services from a wide range of options. And, integrating both energy and security management functions into the same device saves space and cuts device costs.

The power meter unit, which uses a current transformer installed on the residence's distribution board to measure power use, was developed as a separate device from the home server. To make efficient use of space and to minimize wiring requirements, it has been designed to be small and to offer a choice of either a fixed-wire or wireless LAN connection to the home server. This facilitates installation in existing condominiums where it can be difficult to find space for the unit and install additional wiring.

For communal areas, the system uses a facility multi-controller that is already used as an energy management device in factories and other buildings, and a condominium controller that is already used as a security management device for condominiums.

The facility multi-controller includes a contact output I/F for equipment control, a LonWorks[*2] I/F, and a pulse input I/F for energy meters. It provides functions such as displaying information about energy use and controlling equipment remotely by exchanging information with the central server.

The condominium controller has I/Fs for connecting to card readers, automatic doors, electric locks, intercoms, delivery boxes, elevators, and other condominium facilities. Its functions include using a card reader for smartcard authentication to unlock doors (automatic doors and electric locks), displaying information on the lobby unit of the intercom, and temporarily lifting security to allow use of delivery boxes or elevators.

*2 LonWorks is a registered trademark of Echelon Corporation registered in the United States and other countries.

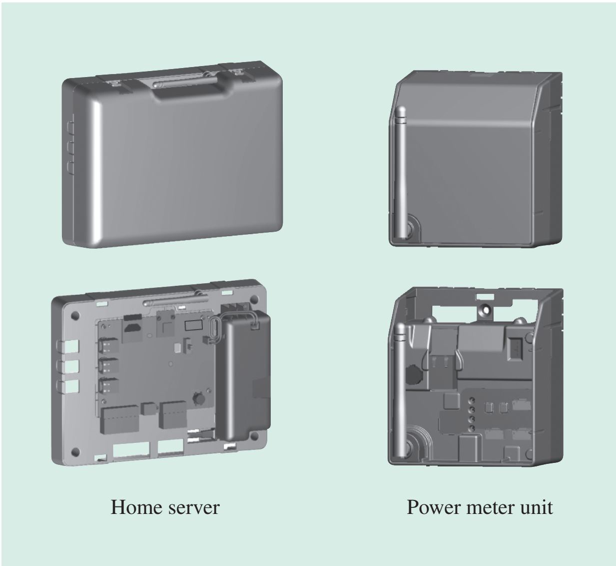


Fig. 3—Home Server and Power Meter Unit.
The home server and power meter unit are designed as separate devices in order to provide flexibility in terms of where they are installed.

Since the amount of communal equipment differs depending on the size of the condominium, the facility multi-controller and condominium controller do not share common hardware. Instead, their design allows a choice of how many units to install depending on factors such as the type and quantity of facilities. They also support a digital signage service for communal areas. Using a display installed at the condominium entrance or other location, this can be used for applications such as encouraging awareness of power saving among residents or providing them with information such as news and weather reports.

ISSUES WITH WIDER USE OF CONDOMINIUM EMSS

As property developers become more concerned about issues such as energy and the environment, the number of condominiums that proactively install condominium EMSs is increasing.

If condominium EMSs are to be used more widely, there is a need to go beyond simply saving power through equipment control or by presenting information on energy use, to providing added value that will contribute to the saleability of condominiums. Furthermore, with electricity deregulation anticipated to expand the number of choices for residents and lead to more intense competition, other important factors will include the establishment of regulatory frameworks and the development of services that lighten the burden on residents and deliver the benefits of system installation.

FUTURE OUTLOOK

Hitachi aims to raise awareness of power saving among residents through measures such as setting targets for energy use and integrating these with digital signage, and to improve the benefits to residents of installing these systems by, for example, working with service providers (electric power consolidators) who can supply power to an entire condominium at lower cost via a shared high-voltage connection. Hitachi also intends to offer incentives to encourage power saving so that services will continue to be used after the system is installed, and to offer additional welfare services, particularly for the elderly.

CONCLUSIONS

This article has described Hitachi systems for condominiums, particularly condominium EMS functions.

In the future, Hitachi intends to continue adding value to condominium systems to offer convenient services that are safe, secure, and trouble-free.

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Featured Articles

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

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Ryuji Yamagiwa
Hideki Osumi
Mitsunori Okada
Kiyosumi Fukui

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

INTRODUCTION

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

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

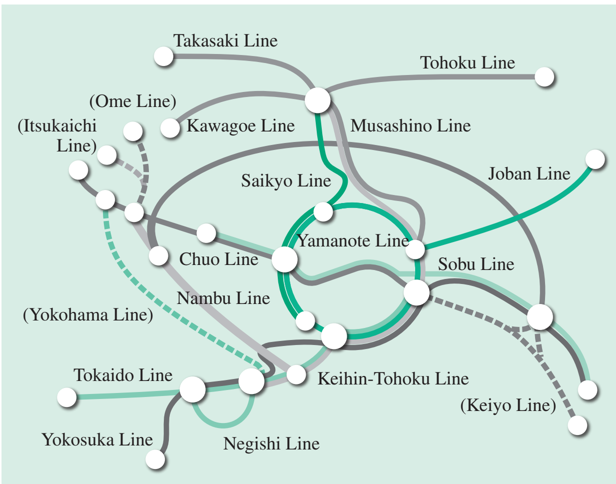

Fig. 1—Railway Lines Managed by ATOS.
Since first entering service on the Chuo Line in 1996, ATOS has been progressively deployed across the major railway lines in the Tokyo region. This deployment is scheduled to be expanded to include the Yokohama Line, Keiyo Line, Ome Line, and Itsukaichi Line in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

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

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

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

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

CHALLENGES CURRENTLY FACING ATOS

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

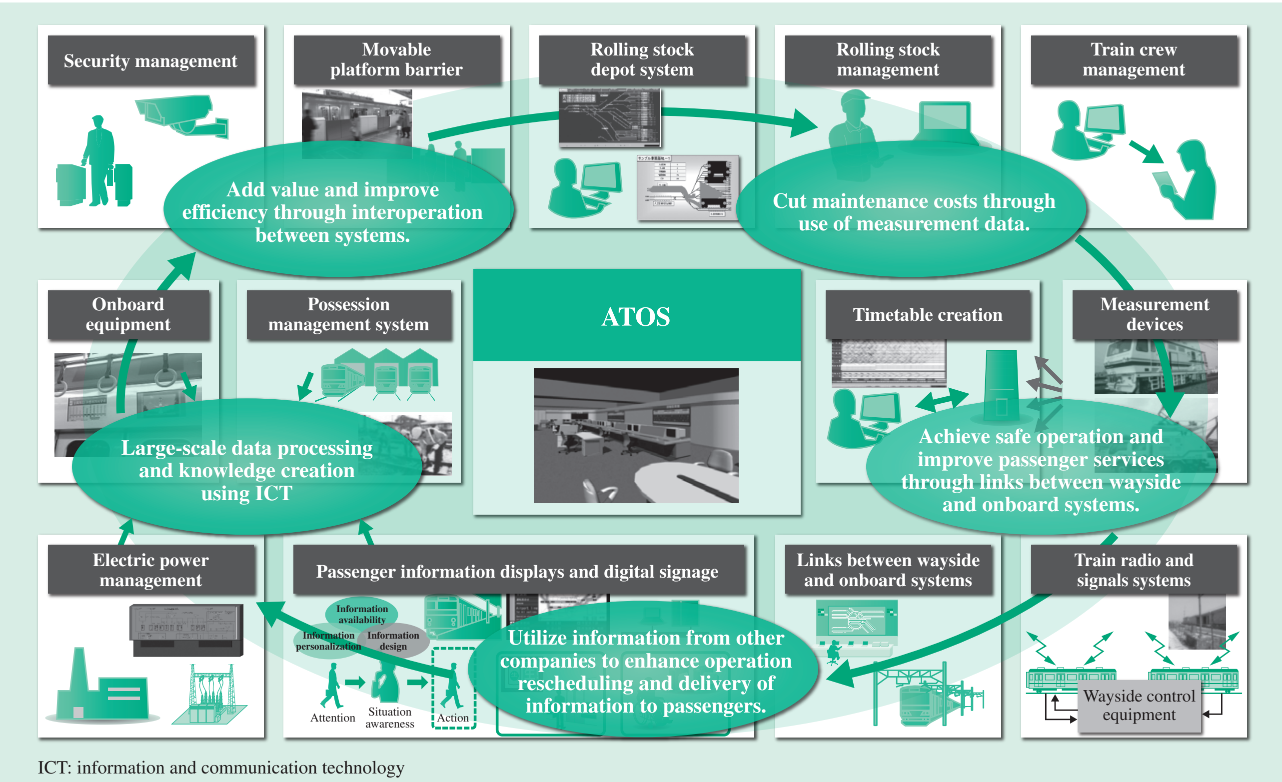

Fig. 2—Overview of Services Made Possible by Fusion of Information and Control.
Hitachi uses advances in information and control to improve services to railway users, station staff, train crew, and others, and to create railway systems that take account of the environment.

Architecture Obsolescence

(1) Establishing a data network environment for expanding services

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

(2) Optimization of equipment configuration to improve maintenance efficiency

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

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

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

Faster Recovery from Timetable Disruptions

(1) Enhancements to functions that support operation rescheduling

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

(2) Support for networking of railway traffic

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

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

(3) Better provision of information for control functions

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

Growing Demand for Information Services

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

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

TECHNOLOGIES THAT FUSE INFORMATION AND CONTROL TO SOLVE PROBLEMS

Upgrade to Optimal System Configuration

(1) Network

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

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

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

(2) Optimization of equipment configuration

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

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

(3) HMI upgrades

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

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

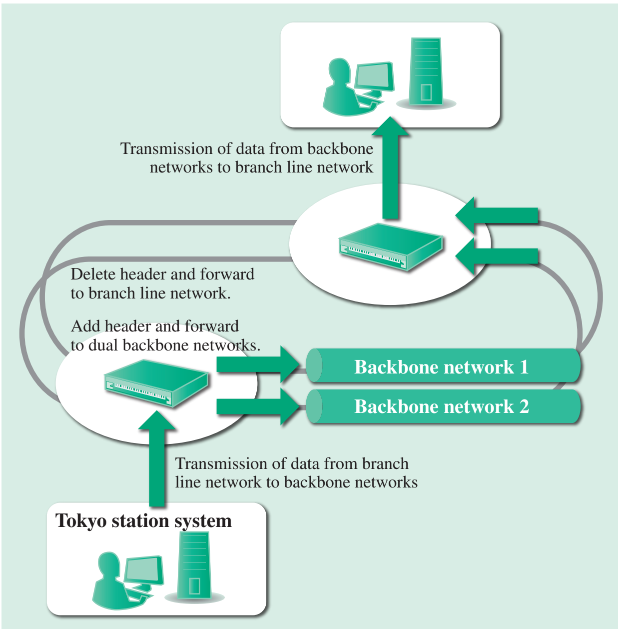

Fig. 3—Highly Reliable Network Communications Using TN-1000.
Because of the large number of networked devices, waiting for performance upgrades to these devices would raise problems of obsolescence on the current network. Accordingly, Hitachi opted for communicating via dual networks, avoiding having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

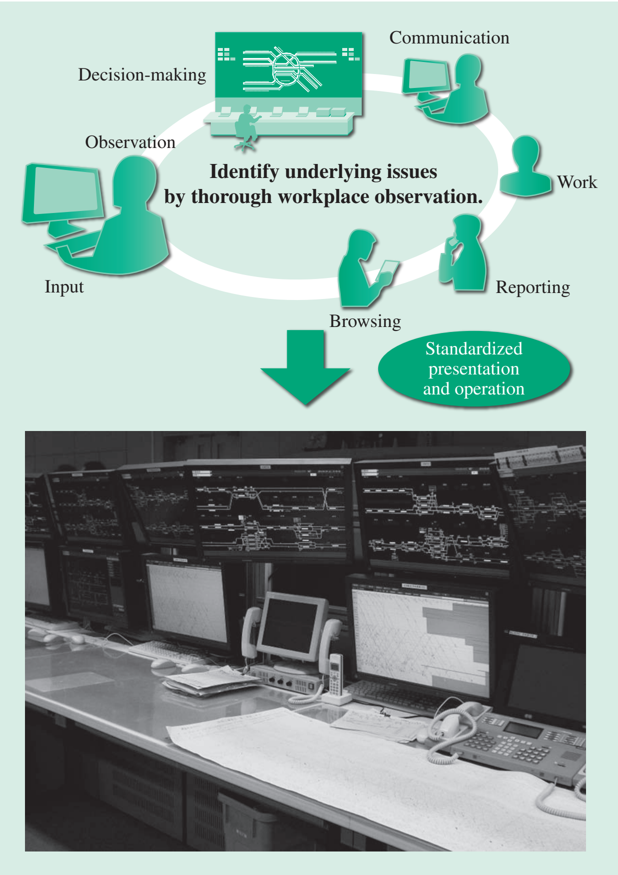

Fig. 4—Standardized Presentation and Operation.
Hitachi improved the "experience value" of screen interfaces by conducting workplace observations and other work to identify the issues faced by operators in order to determine their latent needs.

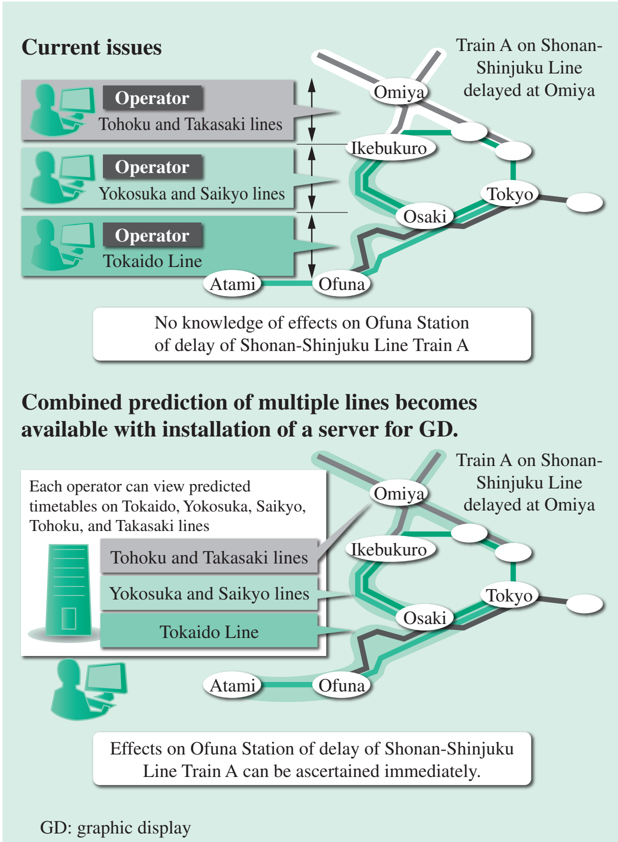

Fig. 5—Overview of Multi-line Prediction by Server for GD.
Currently, details of delays on other lines are conveyed by communication between people. When the new server is installed for GD, it will be possible to obtain predictions about line status that take account of delays on other lines.

Provision of Ideal Environment for Traffic Management

(1) Predicted timetables

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

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

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

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

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

(3) Improving provision of information for control functions

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

Expansion of Information Services

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

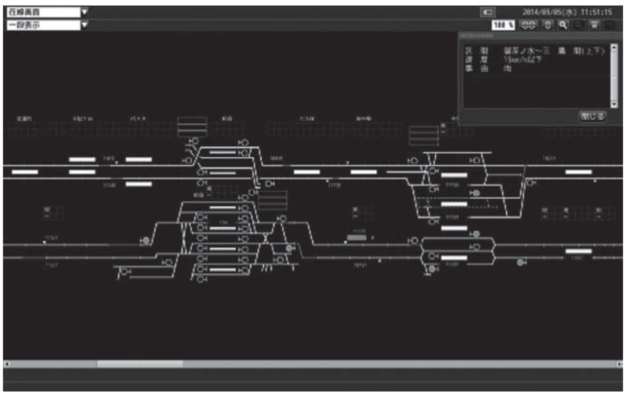

Fig. 6—Display of Restrictions on CRT Screen.
This implements the concept of incorporating restriction notifications into the screen. These were previously posted at the top of the track diagram frame.

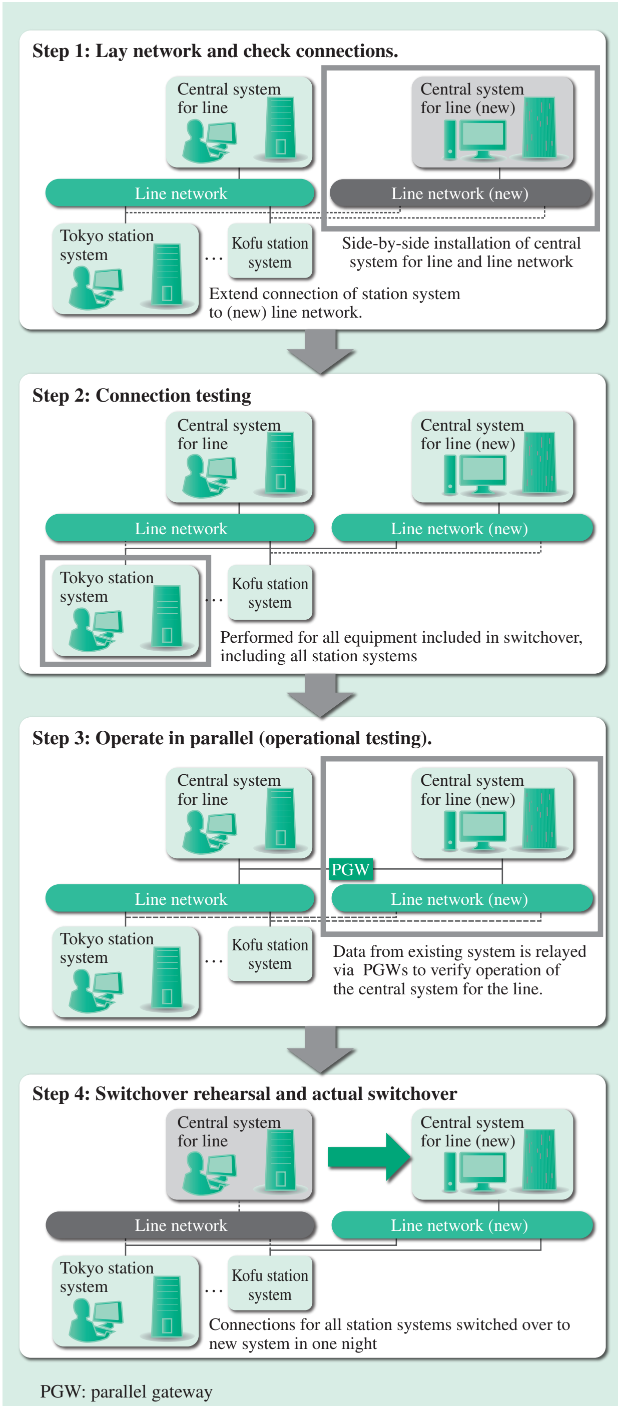

Fig. 7—Switchover Steps.
By verifying the operation of new equipment beforehand, the switchover was able to proceed quickly during the window of opportunity when passenger services were not running.

Seamless System Upgrades

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

WORK OUTCOMES

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

CONCLUSIONS

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

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

REFERENCES

(1) H. Miyajima, “Innovation in Traffic Management Systems—Achieving Safe and Reliable Transportation,” JR-East Technical Review, No. 05 (2003) in Japanese.

(2) T. Sano et al., “A Method of Train Rescheduling Operations Using a Train Prediction in High-density Train Traffic,” IEEJ Papers of Technical Meeting on ITS (Nov. 2010) in Japanese.

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Featured Articles

Information and Control Systems to Support Planning, Operation, and Maintenance Activities for Sustainability of Water Supply and Sewage Facilities

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OVERVIEW: Water supply and sewage are the parts of the social infrastructure that deal with the water that is essential to life. In addition to providing safe, secure, and trouble-free access to water, these systems are part of the water cycle and need to take account of water's role in the environment, including biodiversity. To satisfy these diverse needs, Hitachi has a track record of supplying systems and solutions for water supply and sewage that are based on information and control technology. In addition to the monitoring and control functions associated with routine equipment operation, Hitachi is also utilizing operational data accumulated by the systems and pursuing the ongoing development of technologies that contribute to water supply and sewage infrastructure throughout its life cycle, including equipment planning and maintenance.

INTRODUCTION

WATER supply and sewage systems are essential parts of the infrastructure for maintaining life and social activity, as well as for protecting water ecosystems. In Japan, meanwhile, where a large amount of infrastructure installed during the country's period of rapid growth is coming due for replacement, there is a need for planned upgrades to keep water supply and sewage services operating. Also, more effort is needed to ensure the actual and perceived safety of water in the environment, with recent threats to the environment including the Great East Japan Earthquake of 2011 and the detection of formaldehyde in the Tone River system in 2012, which led to water supplies being shut down. On the other hand, water supply and sewage services need to proceed with a variety of initiatives in the face of a difficult business environment, with pressure on finances arising from the prospect of a falling population and the diminishing availability of experienced staff.

With reference to these circumstances, the Ministry of Health, Labour and Welfare published its "New Water Supply Vision" in March 2013, summarizing the directions to be followed by the water supply industry in the future in terms of safety, resilience, and sustainability[1]. The Ministry of Land, Infrastructure, Transport and Tourism meanwhile published a document on sewage, entitled "New Sewerage Vision," in the summer of 2014.

Hitachi has been supplying systems that utilize control and information technologies, and the fusion of the two, to meet these evolving requirements[2],[3],[4].

This article describes the component technologies for information and control and the latest activities relating to system technologies that improve the efficiency of water supply and sewage services through each phase of their life cycle, from planning to operation and maintenance, and that maintain the health of water ecosystems.

In component technologies, this includes a review of the technologies used in Hitachi's information and control systems, particularly those for extending services over wider areas. For the operational phase, the article describes a water supply operation system, water distribution control system, and a nitrification control system for sewage treatment. These system technologies are implemented on an information and control system platform and provide control techniques to satisfy requirements for saving energy, cutting peak power demand, and reducing the environmental load. For the maintenance phase, the article describes an asset management system and the pipe network management system. These provide techniques for utilizing information collected during maintenance in the planning phase (see Fig. 1).

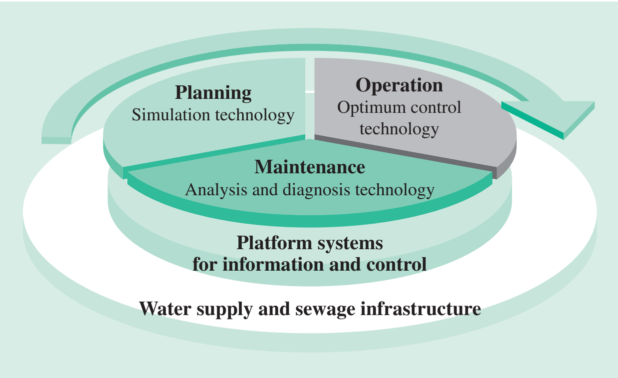

Fig. 1—Information and Control Systems to Support Planning, Operation, and Maintenance.
Hitachi deploys a wide variety of system technologies for use in planning, operation, and maintenance based around component technologies for information and control.

PLATFORM SYSTEMS FOR INFORMATION AND CONTROL WITH WIDE-AREA COVERAGE

Based on the underlying concepts of scalable architecture, seamless operation, and human-machine interfaces (HMI) that support operations, Hitachi has made ongoing functional enhancements to its information and control systems. The following sections describe two of these technologies that help extend services over wider areas. The first of these is the use of the domains concept by platform systems, the second is platform system for web services, which uses digital devices to provide ways of sharing information.

Making effective use of information spread over a wide area is essential for the application of system technologies to the operation, maintenance, and planning phases. This is a challenge that information and control systems needed to overcome.

Use of the Domains Concept for Monitoring and Control over Wide Areas

Along with being implemented in stages across a number of fiscal years, monitoring control systems for water supply and sewage require centralized management through the integration of these systems for a variety of different equipment in order to achieve wide-area coverage. In many cases, however, this has proceeded no further than connecting monitoring control systems together via a network and passing process input and output signals between systems, with the sharing of information from monitoring control system databases (message history and trend

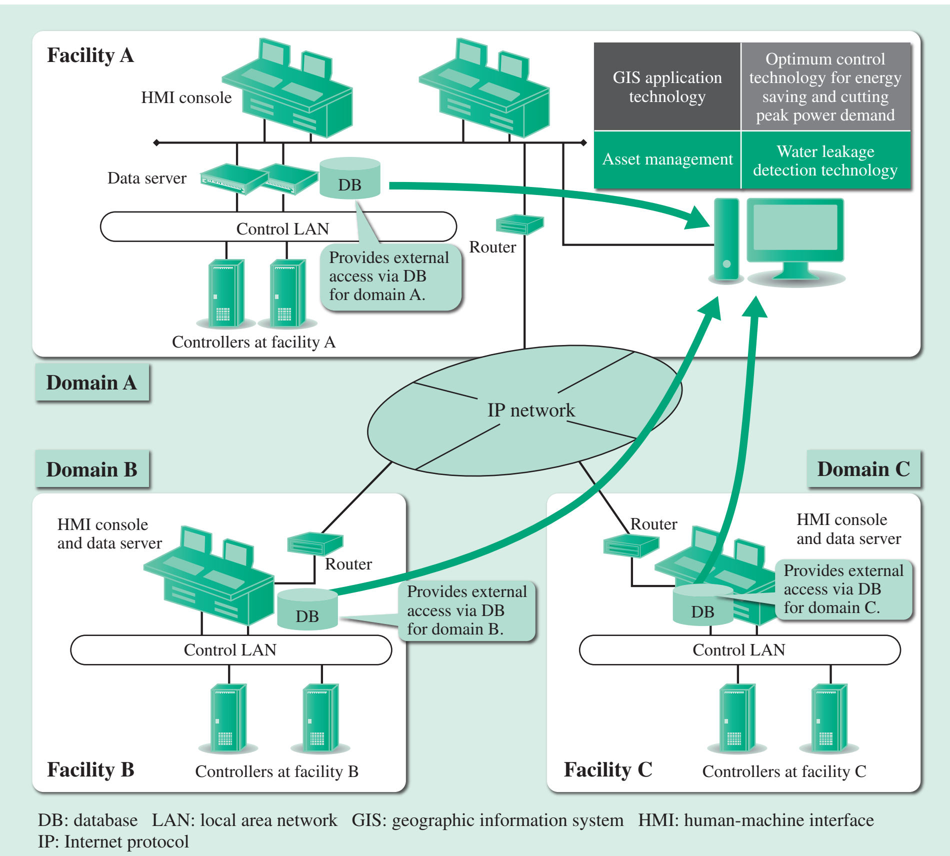

Fig. 2—Use of Domains for Wide-area Monitoring and Control.
Dividing the network into domains makes it possible for systems to access each other's databases. It also provides information systems with efficient access to databases spread over a wide area.

database) having proved difficult. Accordingly, utilizing operation, fault, trend, and other information held by the monitoring control systems for each item of equipment in an integrated system results in inefficient system maintenance because it requires the configuration of separate databases of the same type based on process input and output signals collected via a communications system, and duplication of software administration.

To overcome this problem, Hitachi's platform systems for information and control have adopted the concept of domains in their middleware layers. Here, a domain means a section of the network that is managed as a single entity. By assigning a domain identification number to the monitoring control system for each item of equipment, the equipment monitoring control systems are able to access each other's databases (message history and trend database), including process input and output signals (see Fig. 2).

Use of Digital Devices for Information Sharing

The platform system for web services can distribute operational and management information to a wide variety of devices, including widely used consumer products ranging from desktop personal computers to smart devices such as smartphones and tablets.

When operation and management cover a wide area, geographically dispersed facilities need to be managed efficiently by a limited workforce. Smart devices can be useful monitoring tools for staff who visit sites around the area being managed. Since they include a function for sending e-mail notifications of faults in important equipment, they are also useful in times of emergency when speed is critical. Another feature is their ability to connect to the Internet, which means their use is not restricted just to the intranet of the water supply or sewage service operator. This opens up the potential for a number of operators managing wide-area services to exchange information (see Fig. 3).

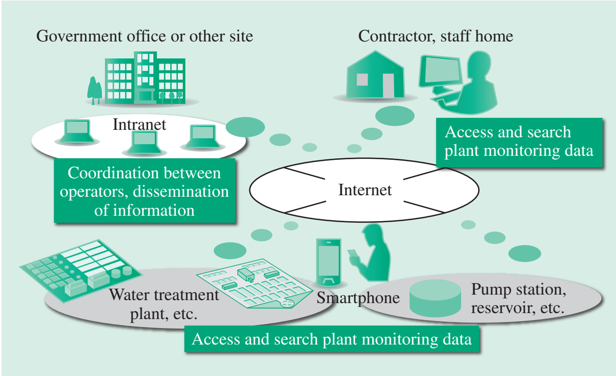

Fig. 3—Use of Smart Devices and the Internet.
This contributes to rapid decision-making by sharing information from monitoring control systems. Mobility is also improved through the use of smart devices.

OPERATIONAL TECHNOLOGIES THAT TAKE ACCOUNT OF ENERGY AND WATER ENVIRONMENT

Water Operating Plan and Water Distribution Control System

Water supply operation systems and water distribution control systems are two solutions that help save energy and ensure reliable water supplies (see Fig. 4).

Water supply operation systems are used by water distribution networks made up of a number of water treatment plants and reservoirs. They produce a daily plan for the water treatment, intake, and distribution volumes needed to satisfy that is forcasted based on information such as weather conditions, the turbidity of incoming water, and equipment condition. They can use multi-objective optimization techniques to generate plans that balance trade-offs such as between ensuring reliable operation and reducing environmental load(5).

Because they can generate operating plans that smooth pump operation by taking advantage of the buffering capabilities of reservoirs while ensuring that they stay within their upper and lower limits, these systems can also help shift or cut peak demand for electric power by water services, which are major consumers of electricity.

Water distribution control systems ensure that the treated water stored in reservoirs is delivered to users efficiently. Water pressure needs to be managed appropriately. If the pressure is too high, it wastes energy and increases leaks, and if the pressure is too low, it reduces the flow rate at the point of delivery. The system uses an online pipe network simulation for the dynamic detection of locations where the pressure is low, and then responds by adjusting valves or pump discharge pressures to restore the required pressure. This keeps water distribution pressures at appropriate levels despite changing demand.

These systems have been installed in waterworks utilities in Japan and are helping ensure reliable supply and energy savings. Functions are also under development for maintaining appropriate operation across the entire process, from water intake to delivery,

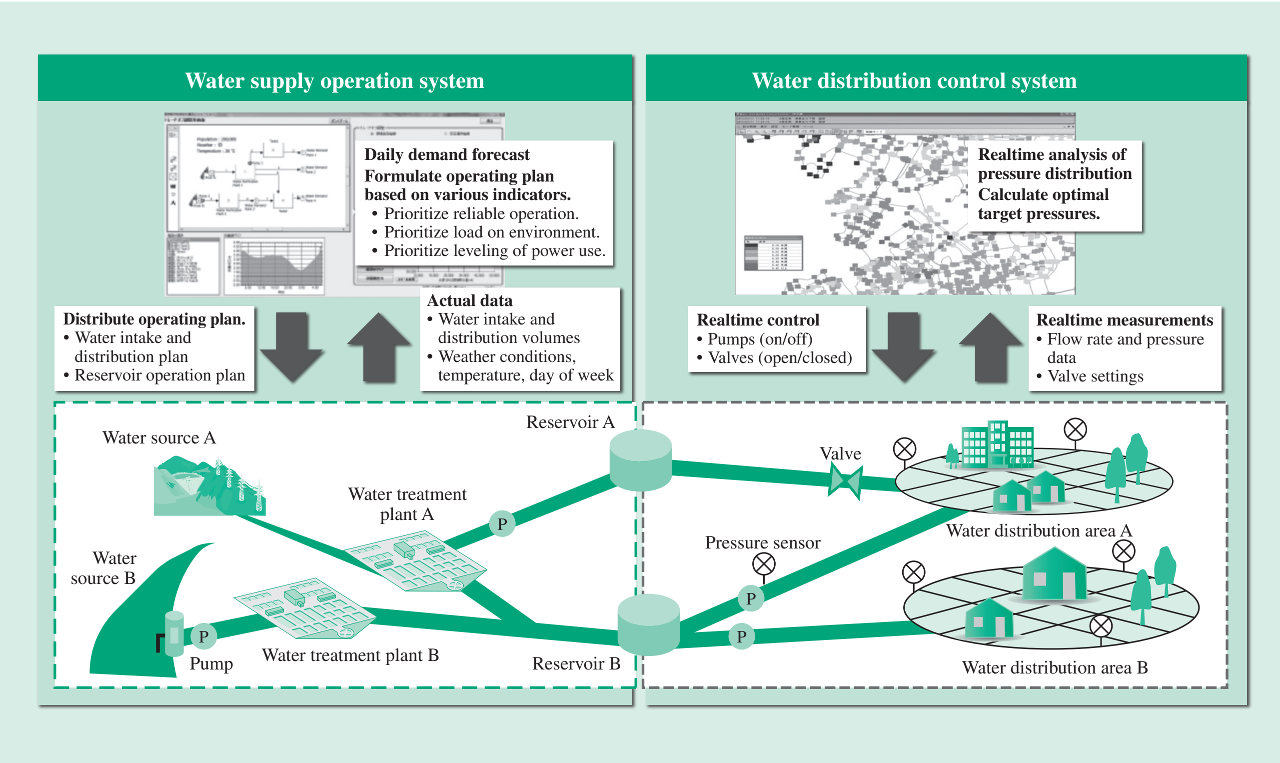

Fig. 4—Water Supply Operation System and Water Distribution Control System.
These systems provide solutions for water distribution networks that contribute to saving energy and to the intake, distribution, and reliable delivery of water.

through the interoperation between the water supply operation and water distribution control systems. These should achieve even higher levels of reliability and energy savings.

Sewage Nitrification Control System for Reducing Environmental Load

"New Sewerage Vision" includes references to both reducing the load on the environment by cutting carbon emissions and the need to protect the water environment[6]. This means that there is a need for sewage treatment process technologies that can save energy and cut carbon emissions while also improving water quality.

Nitrogen removal, one of the issues associated with protecting the water environment, consists of nitrification and denitrification. The nitrification process involves oxidizing ammonia nitrogen to nitrate nitrogen in the incoming wastewater. This consumes electric power because it uses blowers for aeration to provide the required oxygen. Accordingly, optimizing nitrification through precise control of the blowers is one way to save energy and improve water quality.

Hitachi has developed a system for determining the appropriate air flow rates. The system calculates separate target air flow rates for the upstream and downstream sides using not only a standard dissolved oxygen (DO) sensor at the end of the aerobic tank, but also two ammonia sensors located respectively at the mid-point of the aerobic tank, and at a further upstream side of the aerobic tank. This system performs nitrification control in a way that considers not only the target for ammonia concentration in the treated water, but also a target for the mid-point of the process. This stabilizes the process and minimizes over- or under-aeration, reducing blower power consumption while also maintaining water quality. The upstream air flow rate is calculated based on the measured upstream ammonia concentration and the target mid-point concentration. The downstream air flow rate is calculated based on the measured mid-point ammonia concentration, flow rate, and DO measurement.

Commissioning time can be shortened by using a sewage water quality simulator to set the initial control parameters for the calculation. Maintainability can also be improved by adding a function for automatically updating the control parameters based on actual measurements, which eliminates the need to tune the parameters again over time (see Fig. 5).

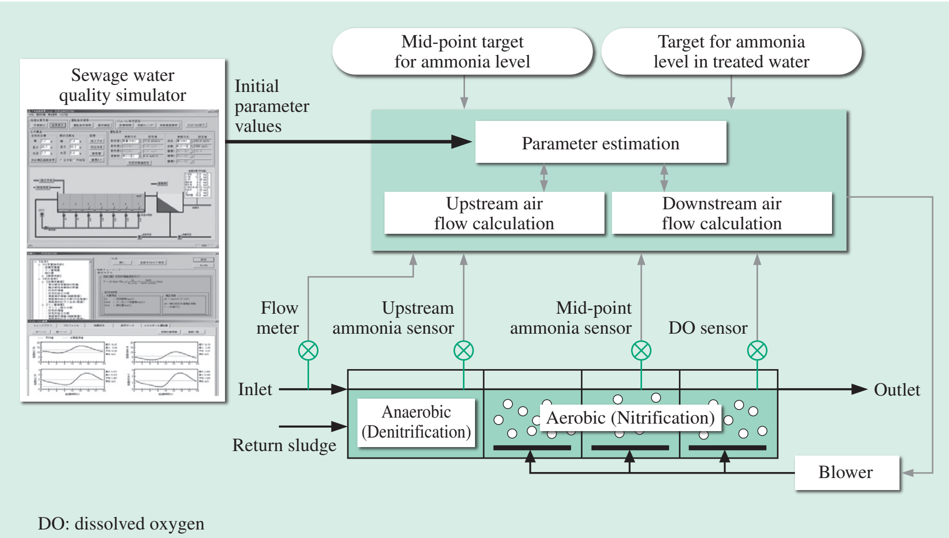

Fig. 5—Sewage Nitrification Control System with Low Environmental Load.
The system controls the air flow to reduce blower energy use. This is done by adding ammonia sensors and calculating the required upstream and downstream air flow rates. Maintainability is also improved by automatically updating parameters based on actual data. To shorten commissioning time, the initial parameter values are obtained using a sewage water quality simulator.

SYSTEM TECHNOLOGIES FOR MAINTENANCE AND REPLACEMENT PLANNING

In Japan, which is entering an infrastructure maintenance phase, replacement planning is also an important part of planning work. This section describes system technologies that make routine maintenance more efficient, and in doing so also make available collected information for use in replacement planning.

Asset Management System

With expenditures on replacements expected to rise as the water supply and sewage infrastructure installed during Japan's era of rapid economic growth approaches the end of its expected service life, its replacement needs to be undertaken in a planned and appropriate manner with limited resources. Accordingly, water supply and sewage service operators need to adopt asset management practices to formulate medium to long-term replacement plans.

Asset management consists of (1) obtaining the necessary information, (2) micromanagement, (3) macromanagement, and (4) utilizing forecasts for replacement demand and financial position.

Micromanagement consists of (1) determining the requirements for existing facilities in terms of factors such as their performance and soundness, (2) inspecting each facility, (3) evaluating the soundness and other facility performance criteria based on the inspection results, (4) predicting future expenditures based on the performance evaluation, and (5) repairing, reinforcing, or replacing equipment and facilities[7]. That is, micromanagement makes it possible to utilize the results of routine maintenance for purposes such as extending facility life or planning replacements. It is recognized as having a key role in working through the plan, do, check, and act (PDCA) cycle for asset management.

In response, Hitachi has developed a system for utilizing equipment management systems, records and other equipment information, operating histories from monitoring control systems, and machinery inspection data for micromanagement (see Fig. 6 and Fig. 7).

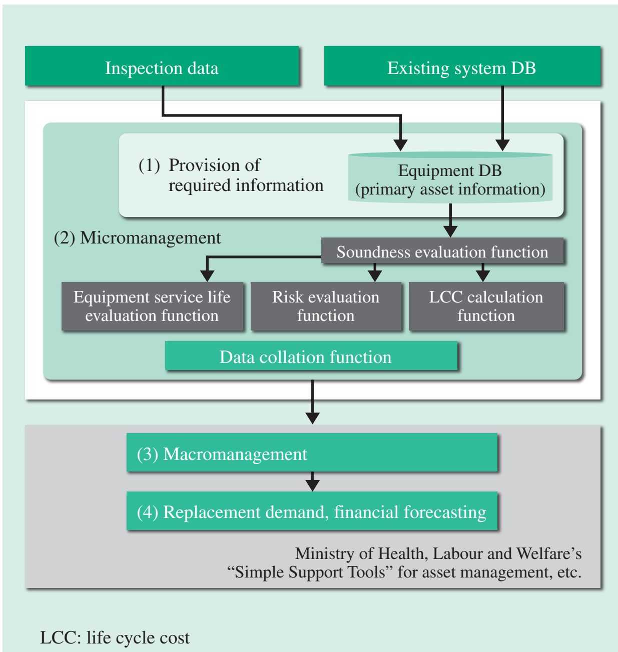

Fig. 6—Overview of Asset Management System.
The system allows micromanagement based on information such as inspection data or operational records from existing equipment.

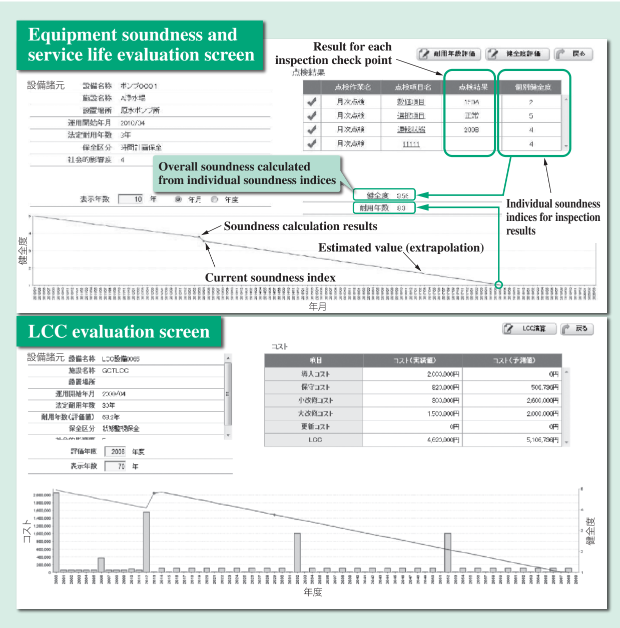

Fig. 7—Asset Management System Screens.
These screens are for equipment soundness and expected service life evaluation, and for LCC evaluation.

(1) Soundness evaluation

This involves calculating equipment soundness based on inspection data, where soundness is an indicator of an item of equipment's current condition. The procedure is to first obtain the individual indices for equipment condition from the results for each inspection check point, and then to use these to calculate an overall soundness index for the machine or item of equipment. The calculation can include not only quantitative inspection data but also qualitative assessments (such as normal/abnormal, or OK/suspect/NG).

The next step is to average the individual soundness indices to obtain the soundness of the entire equipment. The soundness is updated each time an inspection is performed and new data is obtained. Trends in equipment soundness can be assessed by plotting how this information changes over time.

(2) Expected service life evaluation

The expected service life of equipment is obtained by extrapolating how its soundness changes over time to determine when it will reach a level where the equipment needs to be replaced. When repairs are made to improve soundness, the expected life can be updated to take account of the maintenance work by extrapolating from data after the repairs.

(3) Risk evaluation

This evaluates the level of risk associated with an item of equipment by producing a risk matrix of its impact on society versus soundness. The risk level increases when the equipment is degraded due to a decrease in soundness. This risk level is used to prioritize equipment replacements.

(4) Life cycle cost (LCC) evaluation

The LCC is calculated from the sum of actual and predicted costs for installation, maintenance, repair, and replacement.

The system has a function to collate and output collected data. For example, it can produce the input data for the "Simple Support Tools" for asset management[8] published by the Ministry of Health, Labour and Welfare. Evaluations can be performed easily using these tools by inputting the generated information.

Pipe Network Management System

This system uses geographic information system (GIS) technology to manage the locations of the pipe network, water pumping plant, and other equipment spread over a wide area. It also handles attribute information such as dimensions and materials and improves the efficiency of water pipe network equipment management through functions like the examples listed below.

(1) Data statistics function: Uses location data to provide statistics such as supply and demand or incident frequency for different districts.

(2) Supply interruption display function: Uses simulations to determine in advance the effect of water supply interruptions caused by construction work or other incidents.

The functions for evaluating the risks to pipes include displaying the location of water leaks, the frequency of water leaks in each area, which pipes have similar characteristics to a pipe where a leak occurred, and pipes collated according to leak probability estimated from asset data. These functions support pipe replacement plans based on pipe risk.

Also, the various functions provided can utilize unified management of location-linked data such as consumer water use or measurements from monitoring control systems. The water distribution control system described above also utilizes GIS technology for realtime monitoring, with map-based display of analysis results and actual measurements of parameters such as pressures and flow rates.

There is also a system for estimating the distribution of water leaks that works by dividing the area of interest into virtual areas and using pipe network simulations, water pipe attribute data, equipment data,

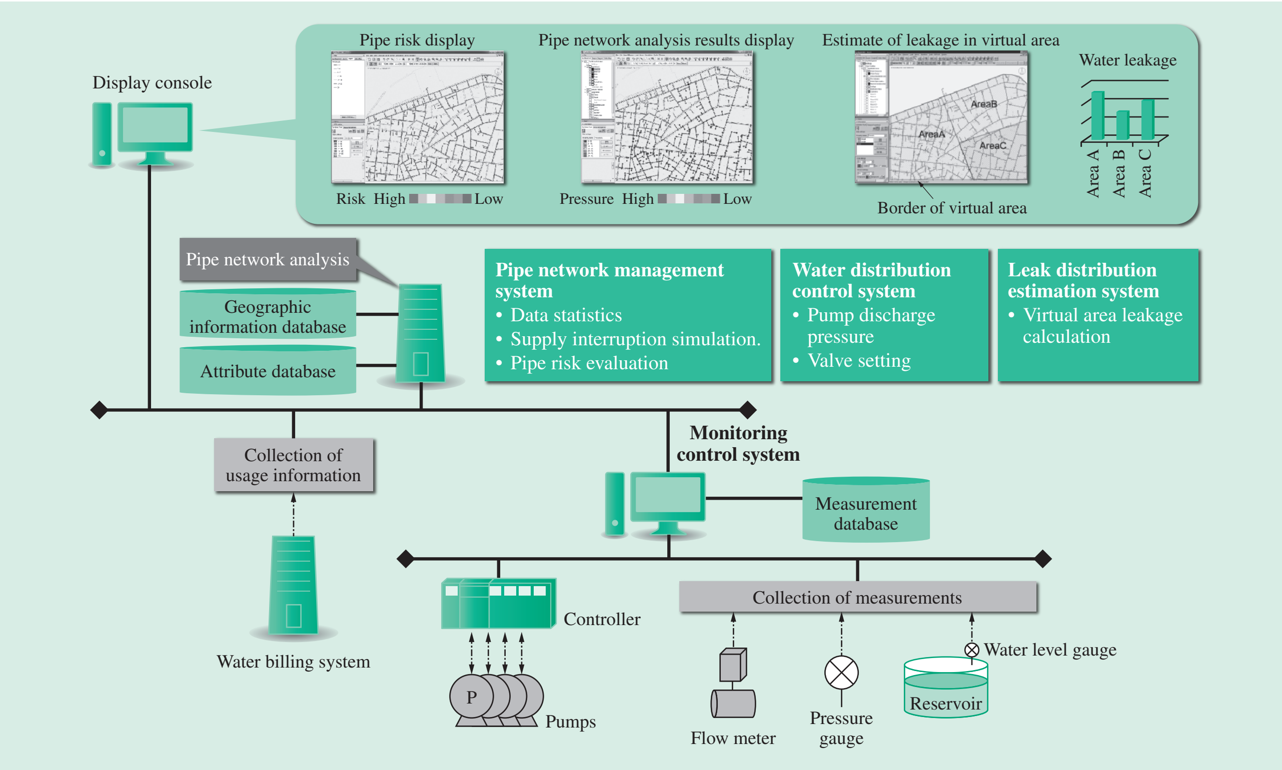

Fig. 8—Example of Integration of Pipe Network Management System with Other Systems.
Energy savings and more efficient maintenance are achieved by analyzing realtime measurements together with pipe network, position, and other data to optimize water distribution and estimate leaks.

and measurements to estimate the volume of water leaks in each of these areas. This can improve the efficiency of water leak investigations by using the amount of leakage in each virtual area to prioritize the order in which they should be investigated (see Fig. 8).

CONCLUSIONS

Hitachi is continuing to work on technical developments that utilize information and control system technologies to overcome the challenges faced by water supply and sewage services. This article has described work on component technologies for extending services over wider areas, and system technologies that include operational technologies for saving energy and reducing the load on the environment, an asset management system that helps smooth capital investment by formulating replacement plans with reference to equipment soundness, and a pipe network management system that provides comprehensive support for maintenance and replacement planning on water distribution networks.

REFERENCES

(1) "New Water Supply Vision," Water Supply Division, Health Service Bureau, Ministry of Health, Labour and Welfare, http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/topics/bukyoku/kenkou/suido/newvision/index.html in Japanese.
(2) H. Tadokoro et al., "Information and Control Systems Contributing to Safety and Security in Water and Sewage Works," Hitachi Hyoron **91**, pp. 638–643 (Aug. 2009) in Japanese.
(3) H. Tadokoro et al., "Information and Control Systems Contributing to Reliable, Secure, and Sustainable Waterworks / Sewerage Systems," Hitachi Hyoron **93**, pp. 606–611 (Sep. 2011) in Japanese.
(4) T. Takemoto et al., "Evolution of Information and Control Systems for Water and Sewerage," Hitachi Hyoron **95**, pp. 528–533 (Aug. 2013) in Japanese.
(5) H. Tadokoro et al., "Development of Water Supply Control System for Energy Saving and Stable Water Supply," IWA Aspire 2013 Daejeon Proceeding 09D1-1 (Sep. 2013).
(6) "New Sewage Vision 2100," Sewage Division, City and Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, http://www.mlit.go.jp/kisha/kisha05/04/040902_2_.html in Japanese.
(7) "Asset Management Handbook for Water Supply Business—Upgrading and Financing of Water Supply Infrastructure from a Medium to Long-term Perspective—," Water Supply Division, Health Service Bureau, Ministry of Health, Labour and Welfare (Jul. 2009) in Japanese.

(8) "'Simple Support Tools' for Asset Management," Ministry of Health, Labour and Welfare, http://www.mhlw.go.jp/topics/bukyoku/kenkou/suido/vision/am/130605-1.html in Japanese.

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Featured Articles

Operation Support and Remote Maintenance Techniques for Steel Industry Control Systems

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Takaaki Ozawa
Hajime Takahashi

OVERVIEW: Steel industry control systems tend to be large, comprising motors, drives, PLCs, and process computers among other components. In addition to reliability, they require the speed of response to perform realtime electrical and mechanical control. To achieve this, Hitachi uses the latest computing and information technology. Hitachi is also working on innovations in control and system technologies to improve the efficiency of equipment operation and the quality of steel strip. Hitachi has supplied numerous control systems to steel companies in Japan and overseas since the era in which steel was considered the mainstay of industry. In addition to making extensive use of universal technologies in recent years to facilitate expansion into global markets, Hitachi has also been developing both operations technology and remote maintenance techniques for delivering added-value after-sales services to meet the needs of emerging economies where new rolling mills continue to be constructed.

INTRODUCTION

ALTHOUGH the market for steel has been subdued in recent years as a result of the global economic downturn, steady growth continues. To succeed in a steel market characterized by intense competition on both technology and cost, Hitachi has been incorporating the latest technologies into the products it supplies for steel industry control systems, which include motors, drives, programmable logic controllers (PLCs), and process computers.

In addition to the conventional requirements for reliable and responsive control systems that can produce high-quality steel products, the shift in the market away from Japan and toward emerging economies in particular has brought with it growing demand for incorporating process know-how into systems to help ensure stable operation. There is also a demand for after-sales operation and maintenance services to assist with the control performance enhancements and troubleshooting required after a rolling mill enters operation.

This article describes new products and technologies that have been incorporated into steel industry control systems in recent years, together with case studies of improvements in operational efficiency, maintenance, and standardization that were developed in response to an increasingly global market.

FEATURES OF STEEL INDUSTRY CONTROL SYSTEMS

System Configuration

Hitachi's steel industry control systems are used in hot rolling mills, cold rolling mills, and processing lines. Steel plant equipment includes mechanical parts (rolling mills and their associated auxiliary systems) and the motors and other electrical systems that drive them. A continuous pickling line and tandem cold mill (PL-TCM), for example, is 300 to 400 m in length and has more than 1,000 actuators and 2,000 sensors. Furthermore, the steel strip, which exits the mill at speeds up to 100 km/h or more, needs to be produced to a thickness accuracy in the order of microns (μm).

To produce high-quality steel strip through high-speed and reliable control of this large process, Hitachi's steel industry control systems use the industrial controllers capable of high-speed computation and the RS90 series process computer running the Linux[*1] operating system. These are connected together by a 1,000-Mbit/s backbone network designed for high-speed control applications. Other equipment, including process input/output (PI/O) stations and insulated-gate bipolar transistor (IGBT) drives, are connected via a universal field

*1 Linux is a registered trademark of Linus Torvalds.

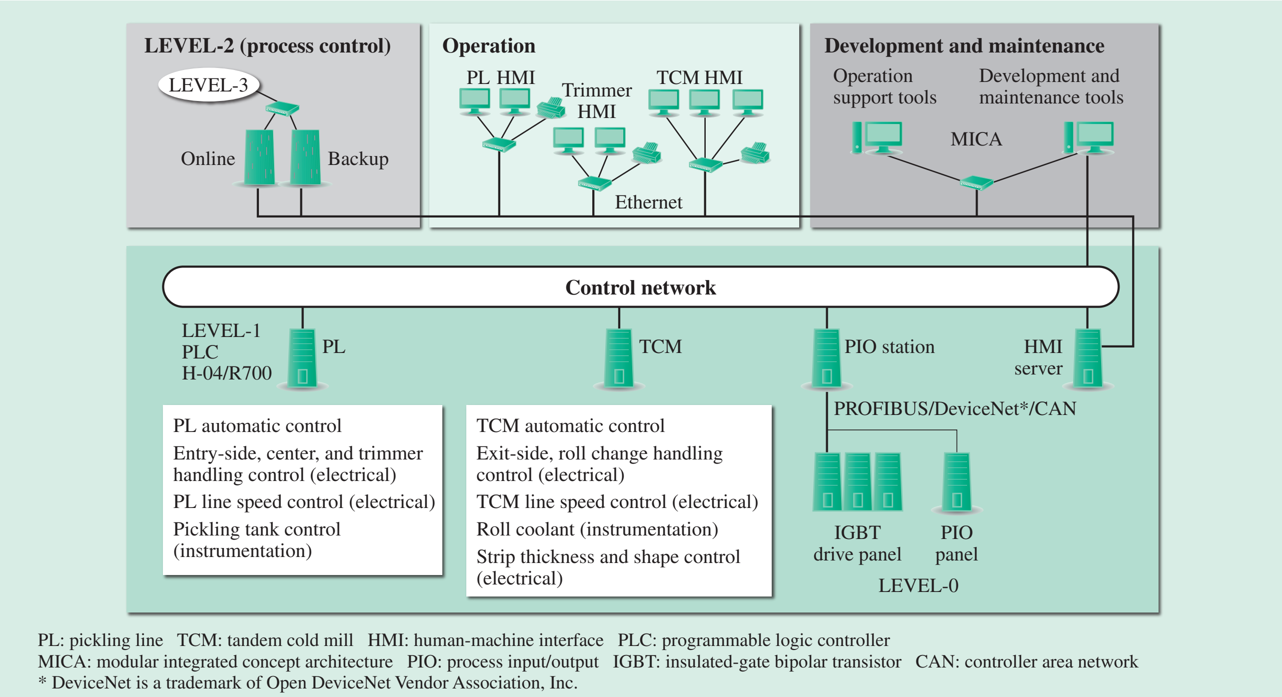


Fig. 1—System Block Diagram of PL-TCM.
A PL-TCM is a common type of steel finishing line. The control system shown here performs reliable and responsive control of a large and complex process.

bus such as PROFIBUS*2. This configuration enables responsive control of the rolling mills and auxiliary equipment (see Fig. 1).

Use of Latest Products in System

The latest model in Hitachi's range of PLCs is the R900 central high-speed processing unit (CHPU) released in February 2014. It has more than 10 times the processing performance of the previous R700 model and features more efficient use of space, and allows up to five central processing unit (CPU), network, or other cards to be installed with each CHPU card. To maintain compatibility and improvements in engineering efficiency, the existing Modular Integrated Concept Architecture (MICA), Process Data Analysis (PDA), and other utility tools for tasks such as programming and data analysis can still be used with the R900 CHPU as easily as before.

The second generation of large-capacity 3.3-kV IGBT inverter drives for the main motors were released in September 2013. Use of global-standard IGBTs not only allows for greater output, but also ensures long-term product availability, a simpler circuit design, and smaller drive size (55% of the previous model). Hitachi has also developed an auto-tuning function for its small-capacity drives that can determine control parameters automatically, facilitating their use with motors for which the specifications are unavailable.

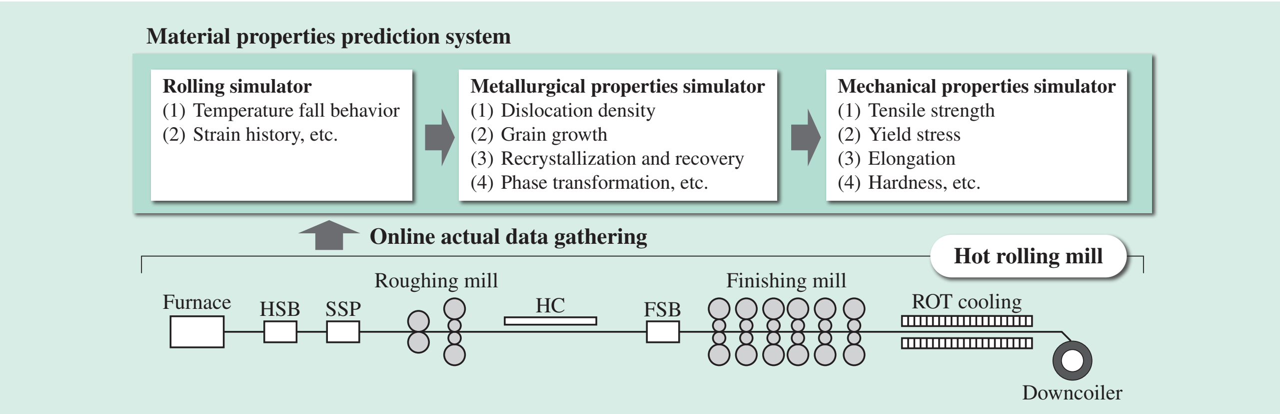
*2 PROFIBUS is a registered trademark of the PROFIBUS Nutzerorganisation e.V.

LATEST TECHNOLOGY FOR STEEL INDUSTRY CONTROL SYSTEMS

Hot Rolling

In the hot rolling field, Hitachi has strengthened its collaboration with Mitsubishi-Hitachi Metals Machinery, Inc., and has completed a large number of projects in recent years that involved the supply of both mechanical and electrical control equipment. In addition to conventional hot rolling mills, this has included supplying overseas customers with control systems for a variety of different types of hot rolling plants, including compact hot strip mills that produce coils by rolling thin slabs or transfer bars directly from a continuous caster, Steckel mills (reverse finishing mills), and aluminum hot rolling mills.

Hitachi has a long history of working on developments that anticipate customer needs. At an aluminum hot rolling mill supplied to a Taiwanese site in 2013, for example, Hitachi achieved more reliable operation and better strip thickness accuracy through the sophisticated mathematical modeling of rolling for a wide variety of product grades, ranging



HSB: hot scale breaker SSP: slab sizing press HC: heat cover FSB: finisher scale breaker ROT: run-out table

Fig. 2—Hot Rolling Mill and Material Properties Prediction System for Steel Strip.
The system uses actual rolling data to estimate changes in the metallurgical properties of hot-rolled coils, and then predicts the mechanical properties to ensure coils are produced with the required strength and formability.

from soft pure aluminum to aluminum alloys that are several times harder, and by using this to optimize control signals such as the rolling load, roll gap, and rolling speed.

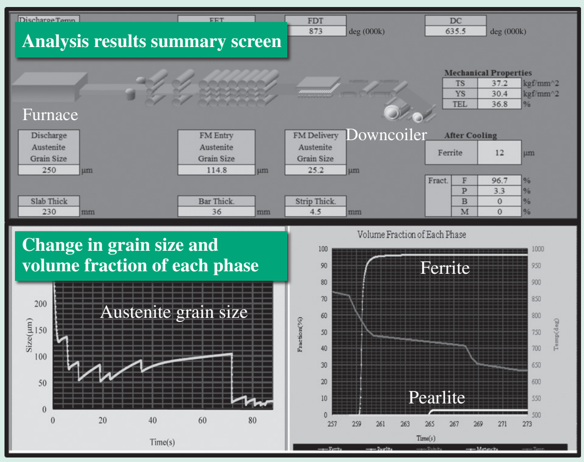
Because of the need to produce steel strip with strength, formability, and other material properties within the required range, there is strong demand from hot rolling plants in emerging economies for the means to predict these properties. To meet this demand, Hitachi has commercialized a material property prediction system (MPPS) for steel strip (see Fig. 2)[1]. MPPS uses an online simulator to calculate the temperature and strain history of the steel strip from the temperature and rolling data collected from the plant. This information is provided to a metallurgical properties simulator to estimate the changes in metallurgical properties (crystalline grain size, volume fraction of each crystalline structure, and dislocation density, etc.) from the time the slab is charged into the furnace until the strip is coiled on the downcoiler. These results are then used by a mechanical properties simulator to predict the mechanical properties (strength, hardness, and elongation, etc.) of the hot-rolled coil (see Fig. 3). A human-machine interface (HMI) is also provided to simulate how varying the parameters for a designated coil, such as its temperature changes and working history or its chemical composition including alloying elements, will change its metallurgical and mechanical properties.

The MPPS is a useful tool for producing quality reports after rolling, for assisting with the production of rolling schedules, and for simplifying steel strip quality inspection.

Cold Rolling

Hot rolling provides the feedstock for cold rolling. Hitachi has for many years maintained a high level of competitiveness in the field of cold rolling, with a large share of the international market for PL-TCMs for the mass production of high-quality steel strip in particular. Recently, Hitachi has been working on improving the quality of steel strip rolled on single-stand mills, and has developed a hybrid automatic gauge control (AGC) for the production of high quality steel strip.

When thin steel strip is rolled at high speed on a single-stand mill, long-period fluctuations in the exit thickness (with a period from several seconds



MPPS: material property prediction system

Fig. 3—Screen Showing Results of MPPS Analysis.
The MPPS uses actual rolling data to estimate changes in the metallurgical properties of hot-rolled coils and predict the mechanical properties.

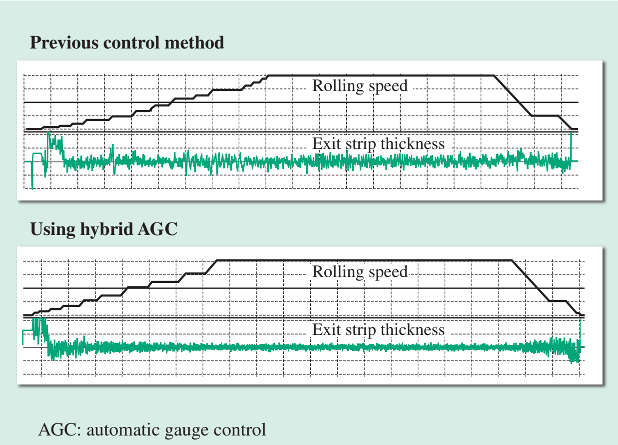


Fig. 4—Improvement in Strip Thickness Accuracy from Use of Hybrid AGC.
A significant improvement in exit strip thickness accuracy was achieved by controlling the roll gap of the rolling mill and the tension reel current based on actual rolling data.

up to 10 or more seconds) can occur for system-related reasons. This has made it difficult in the past to combine improvements in both productivity and quality. The hybrid AGC suppresses these fluctuations by controlling the roll gap and tension reel current based on actual rolling data and the operating point for rolling. This has succeeded in improving the exit thickness accuracy during high-speed rolling (see Fig. 4).

Portable Remote Control

Because the control panels used by operators to operate machinery are positioned at specific locations to suit each item of equipment, they need to be installed at many different places around the plant. The problem is that they can be cumbersome to use because of the restrictions on where they can be located. This means that a number of operators may be required to observe the machinery and operate the controls, or that the operator, having observed the steel strip from up close, then has to walk back to use the operating panel.

In response to this problem, Hitachi has developed a portable remote control in collaboration with Mitsubishi-Hitachi Metals Machinery, Inc. that operates via a local area network (LAN) to make work more efficient and to simplify the equipment. By adopting a number of different approaches to deal with issues of responsiveness, reliability, and ease-of-use, Mitsubishi-Hitachi Metals Machinery, Inc. has been able to eliminate all of the control panels installed at its experimental mill, and is using the remote control units to operate the rolling mill instead (see Fig. 5).

GLOBALIZATION AND UNIVERSALITY IN STEEL INDUSTRY CONTROL SYSTEMS

Remote Maintenance Services

Because many emerging economies lack experience in plant operation, there is strong demand for operations technology and operational support services after systems are installed. To achieve this, data is shared between the customer site and the remote maintenance system at Hitachi, and used to provide after-sales services that include troubleshooting or parameter tuning for the rolling control systems. The maintenance support system with playback simulator is useful for services like these.

The maintenance support system with playback simulator has multimedia analysis functions for simultaneously replaying process and video data to give the user a sense of what was happening in the plant when they perform analysis. This requires the transmission of process data and large amounts of video data from a server at the plant to the maintenance system (client). For this reason, data is downloaded rather than streamed in order to avoid problems with buffering delays caused by inadequate communications infrastructure. Also included is a function whereby, when the user enters an analysis key (coil number, time, analysis data or segment, etc.) at

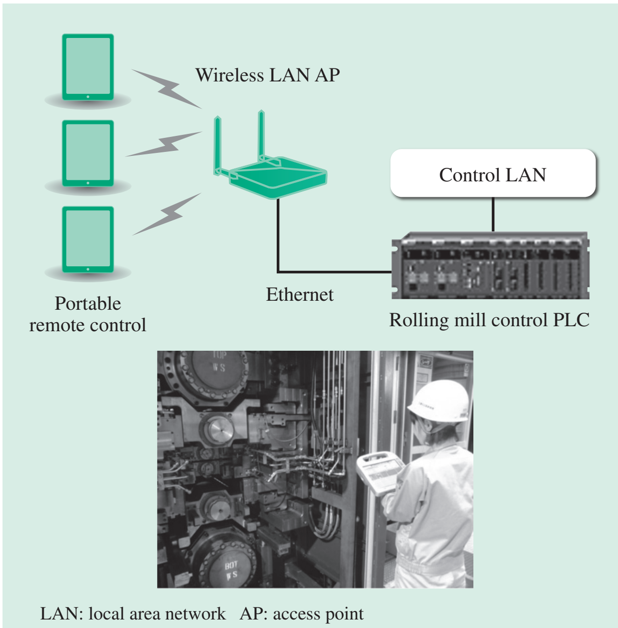


Fig. 5—Block Diagram of Portable Remote Control System, and System in Use.
Instead of being tied to the location of the control panel, the portable remote controls allow operators to view machinery as they operate it.

the client, the system uses predefined relational data to automatically send the client only the data that is required for analysis (see Fig. 6). Remote maintenance services have already been introduced at some sites in China and South Korea(3).

HMI Standardization

The trend in steel industry systems overseas has been toward the use of standardized software to improve maintenance. It is particularly common for customers to specify the use of standardized graphics software for HMIs.

The object linking and embedding for process control (OPC)*3 standard is used to integrate process data with standardized graphics software. Furthermore, Hitachi has developed Human Interface Generator for Web (HumInG-W), a web-based graphics package for operator screens that allows screens to be viewed from a standardized personal computer in an office or other remote location. To ensure the responsiveness of these screens, the package uses a server-controlled realtime push-based technique for updating data. Also, the ability to perform client system configuration from a web browser provides flexibility during upgrades, and facilitates integration with off-the-shelf software(3).

Process Computer Standardization

A common requirement overseas is for process computers to use the open-source Linux operating system (OS) running on standardized server hardware. To overcome the problem that standard Linux implementations cannot run Hitachi's proprietary realtime technology, a virtual machine system is used for virtualization to facilitate the migration of existing applications. This reduces the cost of application software upgrades and ensures that future system upgrades can be performed at low cost and with high quality.

CONCLUSIONS

This article has described the characteristics of steel industry control systems; the latest new technology for product quality, operational efficiency, and other improvements; and remote maintenance services and the use of standardized technology designed to keep pace with ongoing globalization.

The further installation of rolling equipment is anticipated in emerging economies such as India.

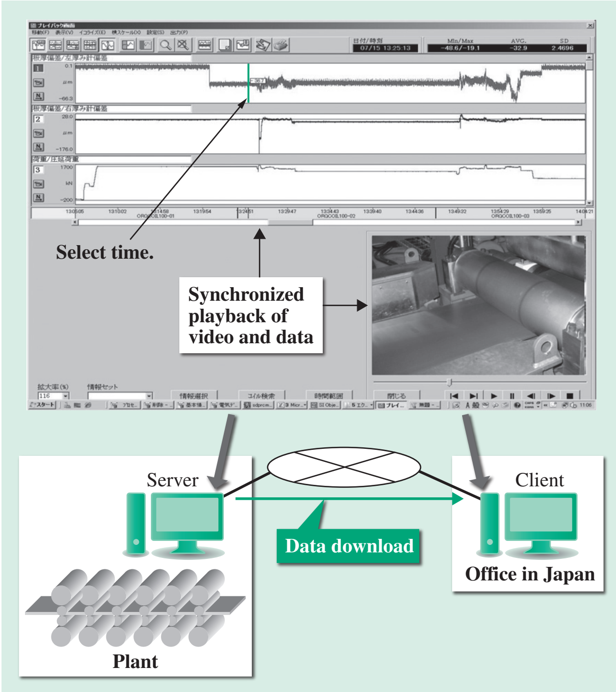


Fig. 6—Maintenance Support System with Playback Simulator Screen.
The system assists with plant analysis by enabling synchronized playback of charts and video.

Along with adding value to after-sales services and developing operations technology that makes this possible, Hitachi intends to continue supplying advanced steel industry control systems that satisfy the ideas and requests of customers around the world.

REFERENCES

(1) M. Park et al., "Through-process Computer Simulation of the Metallurgy in Hot Strip Rolling," Asia Steel International Conference (2012).

(2) T. Minamimura et al., "Advanced Information and Control Systems for Smart Steel Rolling," Hitachi Hyoron **92**, pp. 618–621 (Aug. 2010) in Japanese.

(3) T. Ozawa et al., "WEB Technologies Applied Computer Control System," The Institute of Electrical Engineers of Japan Technical Society MID-09-12, pp. 19–22 (Jun. 2009) in Japanese.

*3 OPC is a registered trademark of the OPC Foundation of the USA.

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Featured Articles

Development and Future Deployment of Cloud-based Video Surveillance Systems

Wataru Ebihara
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Fukuyasu Abe
Shinichiro Hirooka

OVERVIEW: The market for video surveillance systems has been growing, with the technology being seen as essential for preventing unauthorized or criminal activity at logistics or financial services branches, and for quickly resolving violent incidents and similar. With the spread of networks in recent years, there has been growing demand for use of these systems in business. This demand extends beyond existing applications for preventing crime to also include uses such as remote monitoring to keep track of people and equipment, and image analysis to support customer operations and business management. Hitachi has been developing cloud-based video surveillance systems to meet this demand, and has plans to extend this development to future cloud services such as using image analysis for customer business support and equipment operation monitoring.

INTRODUCTION

WITH growing concerns about public safety and security, video surveillance systems are being installed in a variety of different locations, including retail outlets, offices, public places, and factories.

Along with the spread of networks and greater use of digital video, video surveillance systems are increasingly using network cameras with high image quality and definition. The 2012 market for network cameras in Japan and overseas grew by 18% over the previous year, with the number of network camera shipments in Japan being forecast to exceed those of analog cameras in 2015[(1)].

The trend toward networked systems is also leading to increased demand for large, cloud-based systems that perform centralized management of video at a data center or similar. Uses for these systems

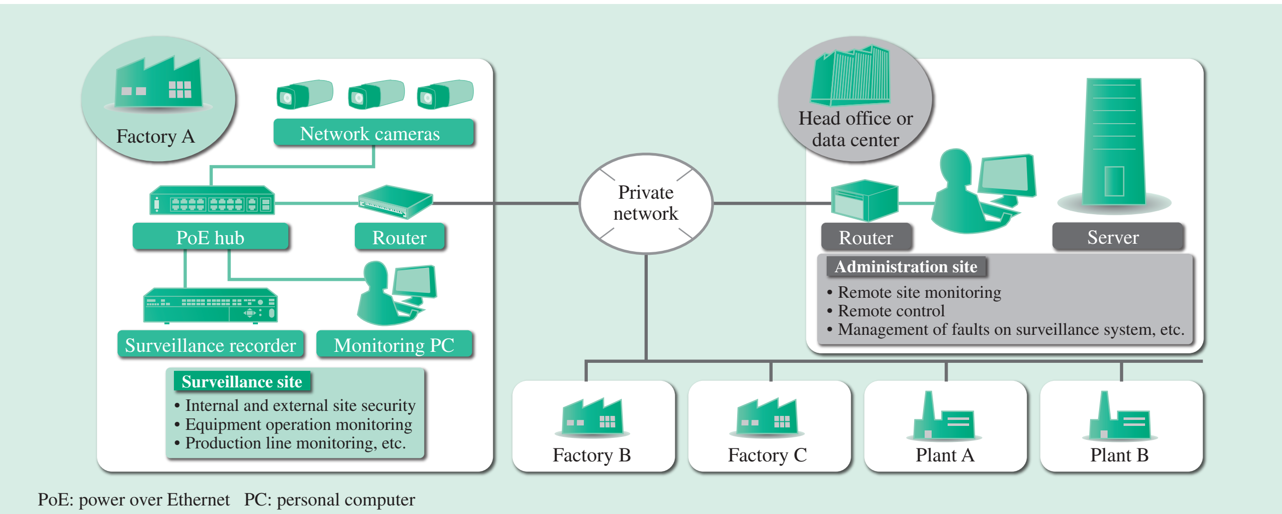

Fig. 1—Example System Block Diagram of Video Surveillance Solution.
Installing the video management system on a server at the customer's head office or data center allows centralized management of an entire surveillance system to be performed remotely, with capabilities that extend from acquiring video from each site to monitoring system operation.

extend beyond crime prevention to include growing demand for business applications such as remote site monitoring, or the use of images and their analysis to support customers' operations and management.

This article describes Hitachi's work on cloud-based video surveillance systems, their future commercialization in applications that utilize image analysis, and camera image enhancement techniques that play an important role in image analysis.

CLOUD-BASED VIDEO SURVEILLANCE SYSTEMS

Video Surveillance Solution

Hitachi developed the integrated video management software for use with video surveillance systems that are becoming larger in scale (see Fig. 1).

Past video management software has been based on a standalone model in which a copy of the software is installed on a personal computer (PC) at each site. As a result, the video surveillance system is split between different sites, making system management and the sharing of video between sites more difficult.

In contrast, the video management system is configured on a client/server model that provides client PCs with a full range of monitoring video display functions and that manages site information centrally on the server. This significantly reduces the amount of work that was previously required at each site because it enables a dedicated department to perform centralized administration via the network of the operation and other settings in the management information at the server. The system runs on an SQL Server* database that provides high-speed data retrieval. This enables the implementation of large video surveillance systems with up to 32,000 network cameras and 2,000 video recorders.

Because the client PCs at each site do not need to handle administration of the video surveillance system, they can be customized for video display. Similarly, because they work by retrieving management data from the server, sophisticated video display operation using the latest management data is made simple, even for large video surveillance systems that add and remove sites frequently.

Deployment of Video Surveillance Service Incorporating Image Analysis

Because the video management system provides interfaces to other applications and systems, it can act as a platform for flexible solution configuration. Accordingly, Hitachi is looking to deploy a cloud-based service that integrates the video management system with an image analysis application to help customers improve the efficiency of their operations and management (see Fig. 2).

This can provide solutions to suit different industries. One possible application for factories or other plants, which have been suffering from a

* SQL Server is either a registered trademark or trademark of Microsoft Corporation in the United States and/or other countries.

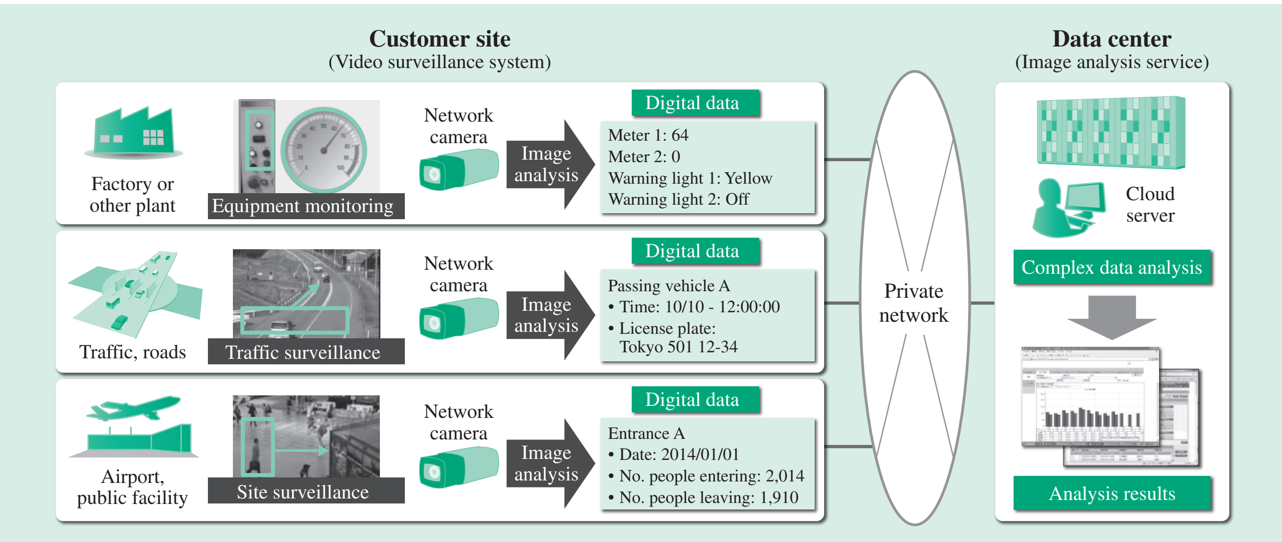

Fig. 2—Conceptual Model of Video Surveillance Service Utilizing Image Analysis.
This involves supplying image analysis services tailored to each customer to improve operational and management efficiency or otherwise help with their business.

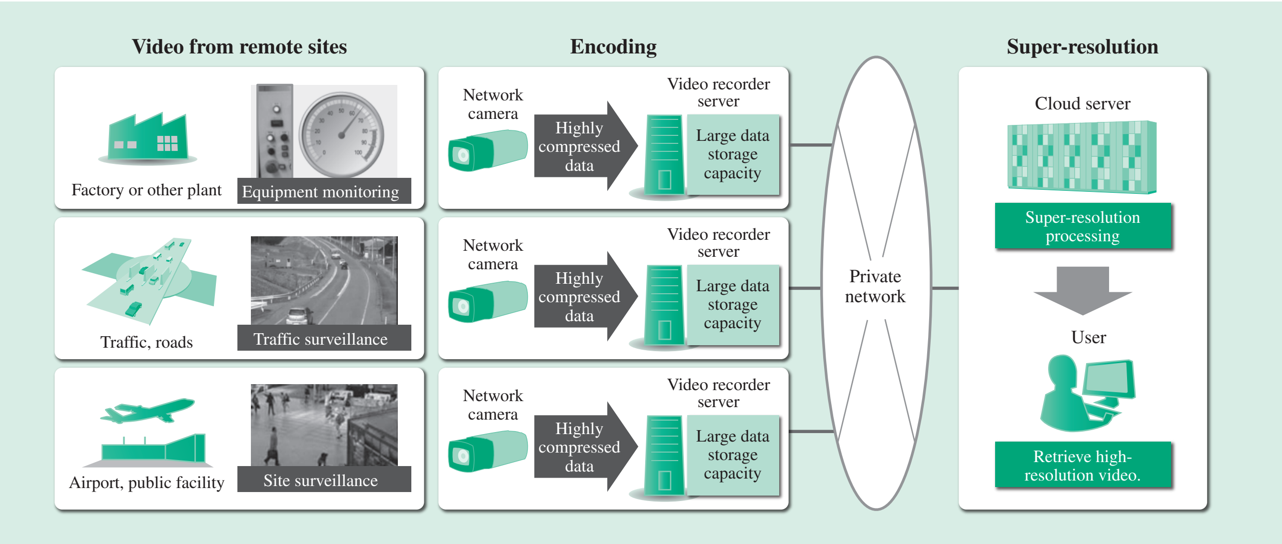

Fig. 3—Flow of Video Data.
Compressing the video data to a high degree at the camera reduces its size and allows large amounts of data to be sent to the cloud server.

shortage of experienced staff in recent years, is to use image analysis to monitor equipment operation in place of visual observation by an operator. A potential traffic application is to build a database using image recognition to read car number plates so that illegal vehicles can be quickly identified.

Hitachi currently provides a solution for retailers that works with an image recognition application to count the number of people passing in front of a video camera in order to automatically determine the number of people entering and exiting a site. The solution is utilized in marketing, such as for adjusting staff shifts to match rises and falls in the number of customers coming to a store, or measuring the effectiveness of promotional activities such as advertising flyers.

IMPROVING ACCURACY OF IMAGE ANALYSIS

Video Transmission Processing

Improving the accuracy of image analysis using video data received remotely from a network camera requires high image quality and definition together with large amounts of image data. However, factors such as the finite capacity of the hard disks on the video recorder server and limited network bandwidth mean that image data needs to be compressed in order to reduce its size. Unfortunately, as well as reducing the use of network bandwidth, image data compression also reduces the image resolution and therefore degrades the analytical accuracy.

In response to the problems due to compression, Hitachi is developing a video surveillance system that performs image data encoding at the camera using a technique that allows images to be decoded with super-resolution. By compressing the image data, this reduces the size of the data stored on the video recorder server and the network bandwidth needed to transmit the video to the cloud. The system provides users with high-resolution video by using a newly developed technique to perform super-resolution processing of the transmitted video data on the cloud servers (see Fig. 3).

This method supports the handling of large amounts of high-quality and high-definition image data and allows a variety of image analyses to be performed.

Camera Image Enhancement Techniques: Improving Camera Image Quality

Better camera functionality is also important for improving the accuracy of image analysis. Along with using network cameras that have adequate sensitivity and resolution, this also means capturing images with good visibility under difficult conditions, such as fog or backlight. In response, Hitachi has developed a new digital signal processor (DSP) to provide cameras with high performance (see Fig. 4).

(1) Development of Hitachi's unique DSP

In addition to noise reduction [brightness signal-to-noise ratio (S/N) improved by 6 dB and color S/N by 12 dB compared to previous model], the new DSP also performs adaptive region-based contrast enhancement. The contrast enhancement unit consists of tone

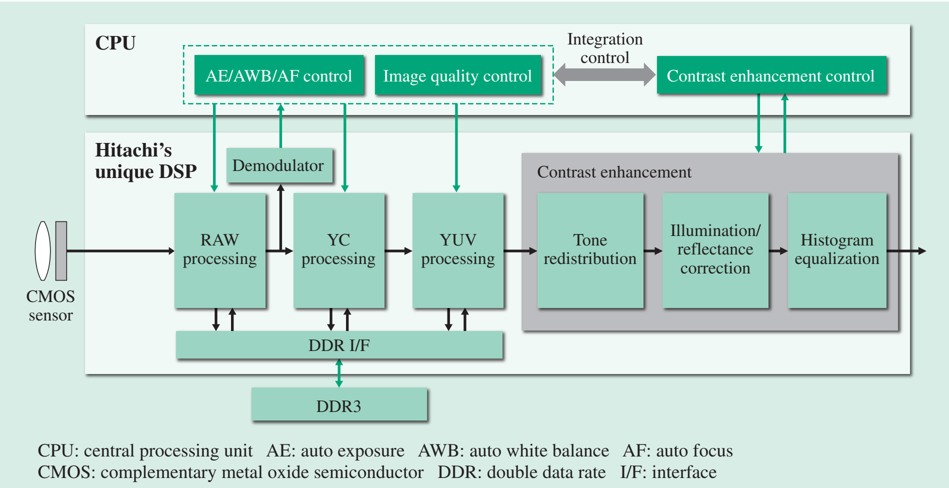

Fig. 4—Functional Block Diagram of Camera System with Hitachi's Unique DSP.
The DSP provides a single-chip solution that works in tandem with a host CPU to perform noise reduction and other camera signal processing, exposure, white balance, and other automatic control, and contrast enhancement for better image visibility.

redistribution, illumination/reflectance correction, and histogram equalization functions. Visibility can be improved under a variety of poor conditions by adjusting the enhancement parameters used by these functions to suit the scene.

(2) Use of contrast enhancement to improve visibility

The following section uses the example of contrast degradation caused by fog to explain how contrast enhancement is performed using Hitachi's unique DSP. The loss of contrast in fog is due to the scattering of light by water vapor droplets in the air. Under these conditions, it is known that the brightness of an object falls asymptotically to the level of ambient light as the distance between camera and object increases[2]. Accordingly, the basic concept behind defogging is to restore the contrast by adjusting the enhancement parameters for each region such that they reverse this process[3]. Based on this premise, enhancement can restore the brightness level by first estimating the level of ambient light in the region of interest in the image, and then widening the brightness distribution around this level (see Fig. 5).

Another form of enhancement is to combine wide dynamic range (WDR) and contrast enhancement to expand the dynamic range of scenes with large variations in light level. Hitachi's unique DSP can also perform Enhanced Intensity processing, a function for enhancing nighttime and other dark scenes to increase the brightness of objects that are difficult to see in the dark. This expands small differences in signal level in dark regions to improve their visibility (see Fig. 6).

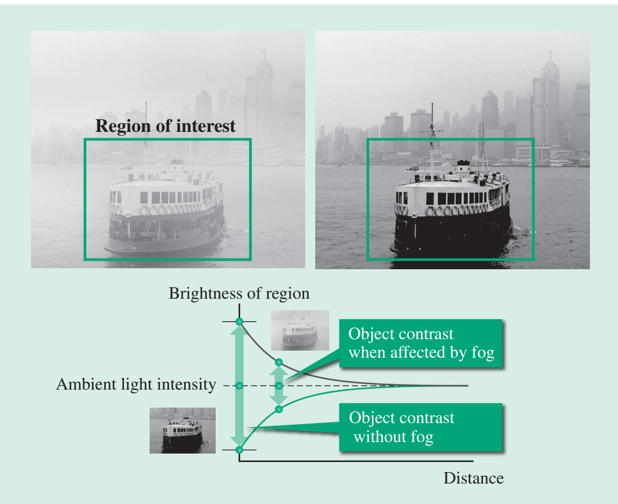

Fig. 5—Defog Function Implementation.
Defogging uses image analysis to estimate the ambient light intensity in each region and then widens the contrast around that intensity.

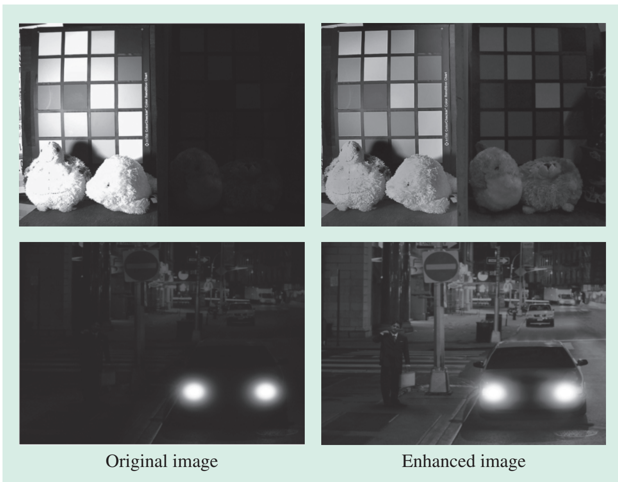

Fig. 6—Examples of Visibility Improvement.
Contrast enhancement can be used with wide dynamic range (WDR) processing to improve the visibility of images that combine both light and dark regions (top), and with the Enhanced Intensity function to improve the visibility of dark images (bottom).

(3) Commercialization of image enhancement techniques

Hitachi led its competitors in commercializing this image enhancement technology by including a defog function based on these techniques in a camera module developed in 2012. The technology was also used to improve the visibility of license plates and vehicle interiors in traffic surveillance cameras, with products released in 2013. Hitachi intends to continue developing techniques for using contrast enhancement to improve visibility, and to use the technology to differentiate itself from its competitors.

CONCLUSIONS

This article has described Hitachi's work on cloud-based video surveillance systems, their future commercialization in applications that utilize image analysis, and camera image enhancement techniques that play an important role in image analysis.

With Tokyo due to host the Olympics in 2020, it is anticipated that there will be growing demand for video surveillance systems to help ensure safety and peace of mind, and to enhance security. Hitachi intends to continue supporting public safety by supplying video surveillance solutions that deliver value to its customers.

REFERENCES

(1) Yano Research Institute Ltd., "Network Camera/VCA System Market: Visual Communications 2013" (May 2013) in Japanese.

(2) H. Koschmieder, "Theorie der horizontalen Sichtweite," Beiträge zur Physik der freien Atmosphäre (1924) in German.

(3) S. Hirooka et al., "Real-time Image Visibility Enhancement Technology under Bad Weather Condition for Video Cameras," IPSJ SIG Technical Reports, Vol. 2013-CDS-8, No. 1, pp. 1–6 (Sep. 2013) in Japanese.

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Featured Articles

Information and Control Platforms for Globalization and Enhancement of Service Extensibility

Katsuhito Shimizu
Eiji Nishijima
Takahiro Ohira
Satoshi Okubo
Takuma Nishimura
Toshiki Shimizu

OVERVIEW: Work on the provision of the social infrastructure that underpins economic development continues in sectors such as urban development, energy, and railways, particularly in emerging economies. In developed economies, meanwhile, there is growing demand for updating the aging social infrastructure. These economies constitute a global market for information and control components and for the implementation of systems, particularly information and control systems, that need to operate reliably over long periods of time. This market is anticipated to grow in both activity and size. On the other hand, providing social infrastructure that imposes a low load on the environment and is efficient in terms of both energy and economics requires that this infrastructure be capable of being expanded in a variety of ways to satisfy demands for a steady stream of new services and functions, such as applications for big data based on information collected from infrastructure field[1]. Achieving this expandability places a high priority on using the latest IT and adopting open communication standards (including in information and control systems), and on making operations more intelligent. Given this background, Hitachi is developing technologies to boost the ability of its information and control platforms to be used globally, and to enhance the scope for expanding services through the use of the latest IT in information and control systems.

INTRODUCTION

HITACHI develops and supplies information and control platforms for use in information and control systems that support high availability and the long-term reliable operation of social infrastructure that needs to run non-stop. In recent years, Hitachi has been working to make its information control components compliant with international standards to improve its ability to satisfy procurement requirements, particularly in global markets.

Information and control systems require expandability and reliable operation that can continue to be supported over the long term. In the case of upgrades to social infrastructure, in particular, there is strong demand for reducing system maintenance costs and extending the life of existing software assets. Hitachi is working on the development of technology for server virtualization[2], which is increasingly being adopted for the information technology (IT) systems used in the latest information systems, to improve realtime performance in control applications.

It is already common practice in conventional information and control systems for operations to be initiated in isolation from the Internet or other external systems, and there has been demand in recent times for diverse service expansion capabilities to support new services and functions that connect to external systems. Hitachi is continuing to develop technologies that can help improve the safety and security of social infrastructure and service expandability. These include enhancements to control system security to counter the threat of cyber-attacks on information and control systems, and the development of small and rugged computers that can help with the adoption of intelligent operations.

CHALLENGES FACING SOCIAL INFRASTRUCTURE SYSTEMS AND HITACHI'S INITIATIVES

As described above, information and control platforms require expandability and reliable system operation that can continue to be supported over the long

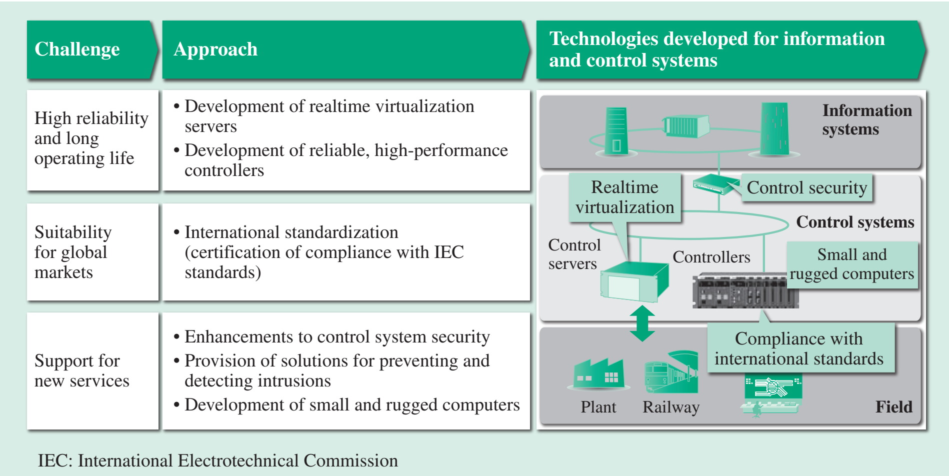


Fig. 1—Technologies being Developed for Information and Control Systems.
In developing technologies and products for information and control systems, Hitachi recognizes three particular challenges associated with satisfying the requirements for these systems and the changes in the circumstances surrounding them.

term. To become better able to satisfy procurement requirements in global markets, and to allow customers to create new services, it is important to strengthen security and enhance the scope for service expansion (see Fig. 1).

This article describes the following four technologies being developed by Hitachi to overcome these challenges.

(1) Realtime virtualization servers for control applications

(2) Certification of controller compliance with international standards

(3) Control system security that maintains control performance

(4) Small and rugged computers for making operations more intelligent

REALTIME VIRTUALIZATION SERVERS FOR CONTROL APPLICATIONS

Trends in Information and Control Servers, and Hitachi's Work on Server Virtualization

Hitachi's RS90 series of information and control servers feature long-term product availability and high reliability. They are used in information and control systems in a variety of industries, such as power generation and steel manufacturing.

Information and control systems have continued to get larger in recent years. Challenges include how to minimize maintenance costs and extend the life of software to keep pace with rapid advances in hardware and OSs. IT systems that feature high-level interoperation between different types of systems have become increasingly common in recent years in applications such as urban development and energy management. To reduce costs, these systems need the ability to grow into large and durable parts of the social infrastructure, being initially installed on a small scale and then progressively expanded. This requires information and control systems with a high degree of flexibility and expandability.

In information systems, meanwhile, server virtualization is widely used to help reduce maintenance costs. Server virtualization is a technique for running a number of virtual machines simultaneously on the same computer hardware (see Fig. 2). By running a proven OS on a virtual machine, virtualization allows the same OS to remain in use for a long period of time, even when the underlying computer hardware is upgraded. It can also cut maintenance costs by consolidating a number of servers with low loads on the same computer hardware.

Hitachi has implemented realtime virtual servers by developing realtime virtualization platform software for control use that allows virtual servers to satisfy information and control server requirements.

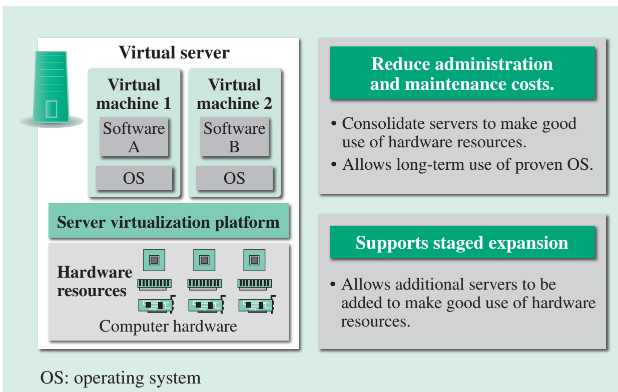


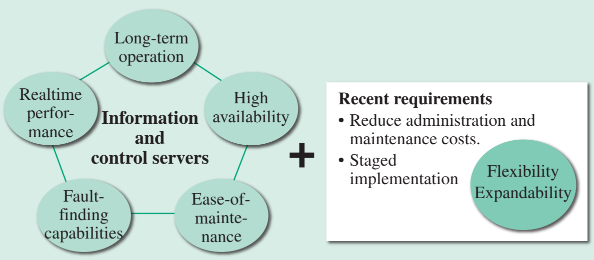
Fig. 2—Server Virtualization.
Virtualization allows a number of virtual machines to run on the same computer hardware.

Because information and control servers are used for the monitoring and control of plants, the conventional requirements include long-term operation (on the order of a decade), the realtime performance necessary for plant control, the ability for processing to continue even if a fault occurs on the server, a high level of availability to ensure reliable plant operation, fault-finding capabilities that can reliably isolate the cause of faults, and quick and reliable maintenance (see Fig. 3). The following sections describe the specific measures that Hitachi's realtime virtualization platforms use to satisfy these requirements.

Ensuring Realtime Control Performance on Virtual Machines

The realtime control performance required of information and control servers includes that processing be executed in a deterministic order, that it produces predictable results, starts at the required time intervals (regularity), and has low latency (meaning a short delay between the request to execute a process and the commencement of its execution). With the server virtualization used for conventional information systems, however, processing conflicts occur when a number of virtual machines are running concurrently. Also, access to physical hardware by software running on a virtual machine is emulated by the server virtualization platform, causing problems with variable latency due to delays in execution of the software on the virtual machine.

Accordingly, the new realtime virtualization platform developed by Hitachi provides a resource partitioning mechanism whereby virtual machines can reserve exclusive access to hardware resources (processors, disks, and network devices). This eliminates processing conflicts when virtual machines are running concurrently. Similarly, the latency of software execution on a virtual machine is kept within a fixed time by having the realtime virtualization platform run on a different processor core than those used to execute software on virtual machines. This overcomes the problem of server virtualization causing variable latency and, together with other measures to ensure predictability and regularity, ensures realtime control performance for the software running on virtual machines (see Fig. 4).



Requirement	Description
Long-term operation	Because servers operate alongside the plant they monitor and control, they need a life of around 10 years.
Realtime performance	High level of (predictable, regular, and low-latency) realtime performance needed to ensure control processing executes reliably on a time scale suitable for the time constant of the plant.
High availability	Switchover to the backup system when a fault causes a shutdown needs to occur on the order of seconds, without interfering with plant monitoring and control.
Fault-finding capabilities	Ability to identify and resolve the causes of faults is needed to maintain reliable operation of field.
Ease-of-maintenance	Ability to perform server maintenance quickly and accurately during short shutdown periods is needed to ensure high plant utilization.
Flexibility, expandability	Flexible server consolidation is needed to reduce server administration and maintenance costs. The expandability to allow staged implementations starting from a small system is needed to minimize initial installation costs.

Fig. 3—Requirements for Information and Control Servers.
In addition to such requirements as long-term operation and high availability, these servers also need better flexibility and expandability.

Ensuring High Availability of Virtual Machines

Information and control systems have achieved improved availability and ensured processing continuity by using redundant configurations for information and control servers so that software execution can rapidly switch over to different computer hardware in the event of a fault. Likewise with virtualization, redundant configurations are used for the computer hardware that hosts the virtual information and control servers to ensure high availability by allowing rapid switchover.

In the past, reliable and rapid switchover has been achieved by using the reset mechanism provided by the computer hardware to shut it down after a fault is detected. Hitachi's realtime virtualization platform also supports use of the reset mechanism for rapid switchover. Furthermore, Hitachi's realtime virtualization platform has a mechanism for resetting a single virtual machine on which a fault has occurred in cases when a number of virtual machines are running on the same physical computer. In this mode, only the faulty virtual machine switches to the backup physical computer, with all other virtual machines continuing to execute without switchover [see Fig. 5 (1)]. This minimizes the impact on execution of the other virtual machines where no fault has occurred.

When information and control servers with a redundant configuration are shutdown to perform

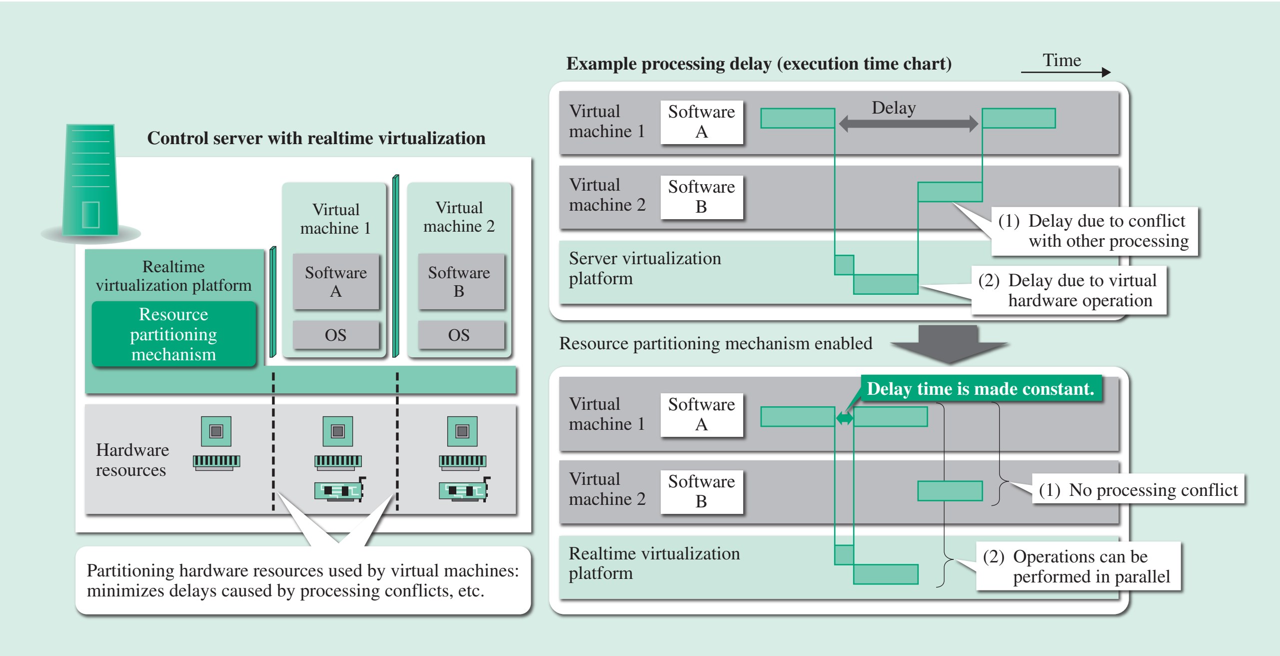


Fig. 4—Ensuring Realtime Control Performance.
The diagram shows the benefits of the resource partitioning mechanism in Hitachi's realtime virtualization platform. In the time chart on the top-right, the completion of software A is delayed for two different reasons [(1) and (2)]. In the time chart on the bottom-right, where the resource partitioning mechanism is used, the processing delay for software A is made constant.

maintenance tasks such as software updates, it is common practice to shut them down one at a time so that there is at least one server operating at all times, preventing any interruption to the operation of the plant. To achieve this, Hitachi's realtime virtualization platform allows individual virtual machines to be shut down manually. On the other hand, when switchover of virtual machines is performed one at a time, maintenance work such as replacing computer hardware parts is made difficult when the same physical computer is running both active and backup virtual machines. Accordingly, to improve operational efficiency, the realtime virtualization platform also has a mode for automatically switching over all virtual machines on a physical computer at the same time.

Improvements to Fault-finding on Virtual Servers

Because server virtualization requires a number of virtual machines to execute concurrently with the virtualization platform software, fault-finding can be made more difficult by problems such as processing delays. Similarly, because each virtual machine, as well as the virtualization platform software, operates on its own time frame, collecting trace logs and reviewing operational information in time sequence can be difficult.

Hitachi's realtime virtualization platform provides an integrated trace mechanism that allows all trace logs to be viewed in time sequence. This provides a common overview of operations in a particular virtual machine, the realtime virtualization platform, and the other virtual machines so that the cause of an execution delay can be identified more quickly [see Fig. 5 (2)].

Quick and Accurate Maintenance on Individual Virtual Machines

It is common practice in information and control systems to use comparatively small servers, with a separate information and control server assigned to each control function or item of the plant being controlled. As a result, software backups are typically performed by making a full system backup of the information and control server. Because virtualization environments consisting of multiple virtual machines will likely require software maintenance to be performed on individual virtual machines, Hitachi's realtime virtualization platform allows system backups to be performed separately for each virtual machine [see Fig. 5 (3)].

Since backups typically involve transferring large amounts of data from the disk to a backup storage device, it is necessary to ensure that this does not interfere with the operation of other virtual machines.

To achieve this, a mode is provided that uses the resource partitioning mechanism described above to limit the processor time, disk access bandwidth, and other resources available for the backup. This allows quick and accurate maintenance to be performed individually for each virtual machine.

CERTIFICATION OF CONTROLLER COMPLIANCE WITH INTERNATIONAL STANDARDS

As safety and security requirements for controllers are becoming stricter, Hitachi has been developing products that comply with the associated international standards.

International standards for the safety and security of controllers certify aspects such as functional safety, electrical safety, electromagnetic compatibility (EMC), and control system security. Hitachi is developing products that comply with these standards.

The following sections describe the development of controllers that comply with functional safety standards.

R800FS Functional Safety Controller

Hitachi has developed the R800FS functional safety controller and functional safety remote input/output (RI/O), which comply with the IEC 61508:2010 Edition 2.0[3] functional safety standard. R800FS Version 1 was certified by TÜV Rheinland Industrie Service GmbH of Germany in 2010.

Functional safety standards require that hardware failure and self-diagnosis rates satisfy the required levels, and certify that development processes guarantee that software will not include design faults that threaten safety. They also require a fail-safe design ensuring that the control output signal to the plant defaults to a safe value when a fault occurs.

Since the R800FS can combine both functional safety programs required by systems such as those used to ensure safety, and general programs used for ordinary control systems and information processing, it can provide highly flexible control functions in which these complement each other. Functional safety programs execute in parallel on the two microprocessors in the R800FS's central processing unit (CPU). Safe computation and control output are

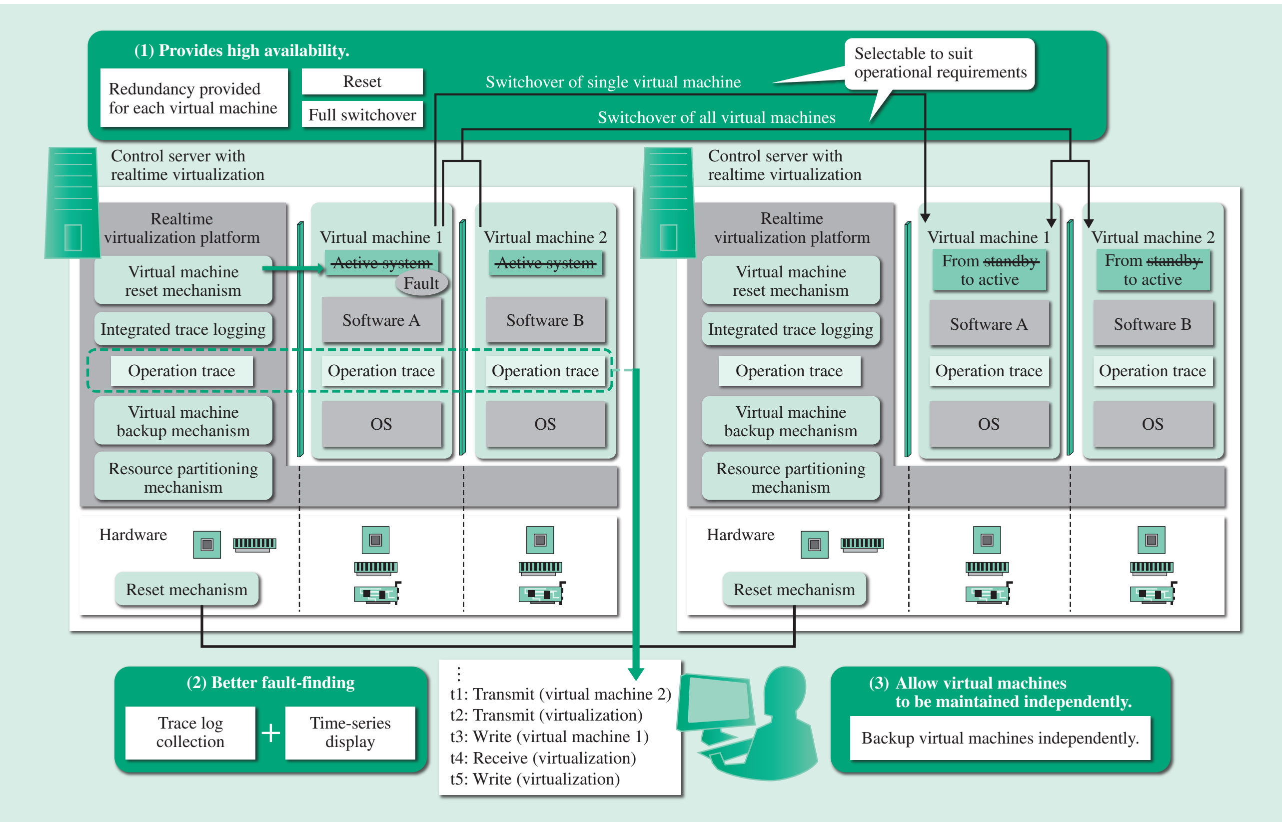


Fig. 5—Improvements to Availability, Fault-finding Capabilities, and Ease-of-maintenance.
The reset mechanism is used to achieve high-speed switchover, the integrated trace mechanism to facilitate analysis, and the resource partitioning mechanism to improve maintenance.

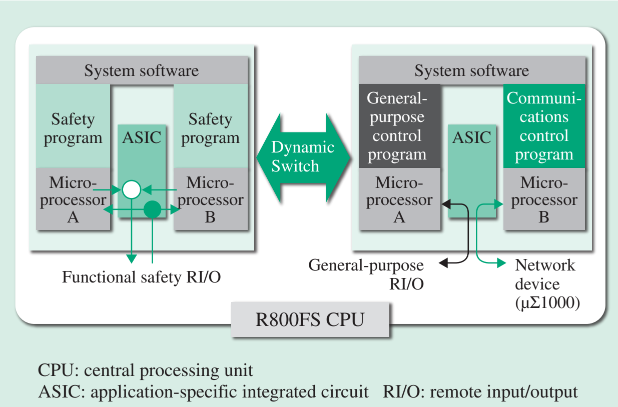


Fig. 6—R800FS CPU Support for Both Functional Safety and General-purpose Control.
Using two microprocessors improves the rate of diagnosis and allows both functional safety control and general-purpose control calculations to coexist.

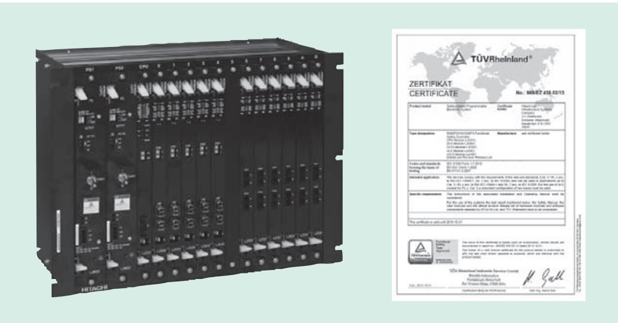


Fig. 7—CPU Unit of R800FS Functional Safety Controller (left) and Certificate from TÜV Rheinland (right).
Version 2 of the R800FS, which features enhanced performance, received updated certification in 2013.

achieved by using a comparison function implemented in an application-specific integrated circuit (ASIC) to check the intermediate values and results of these computations. For general programs, on the other hand, flexible high-speed processing is provided by the multiprocessor. The functional safety RI/O, meanwhile, achieves a high rate of self-diagnosis by using an ASIC with dual internal circuits to compare inputs and outputs (see Fig. 6).

R800FS Version 2 Designed for Better Availability, Maintenance, and Performance

Although halting control outputs when a fault occurs is fundamental to the concept of functional safety, it can result in a loss of plant availability. In response to this problem, Hitachi developed Version 2 of the R800FS to improve availability and ease-of-maintenance by enabling control to continue operating safely in the event of a fault. It received updated certification from TÜV Rheinland in 2013 (see Fig. 7).

The R800FS uses remote communications between the CPU and RI/O, with availability improved by using fully redundant communication paths over a ring topology. To prevent multiple overlapping faults, Version 2 has a function for the early detection of faults that retrieves fault information from all modules, including non-intelligent communication modules. To make maintenance easier, it also has functions to detect incorrectly connected communication lines and the locations of line breaks.

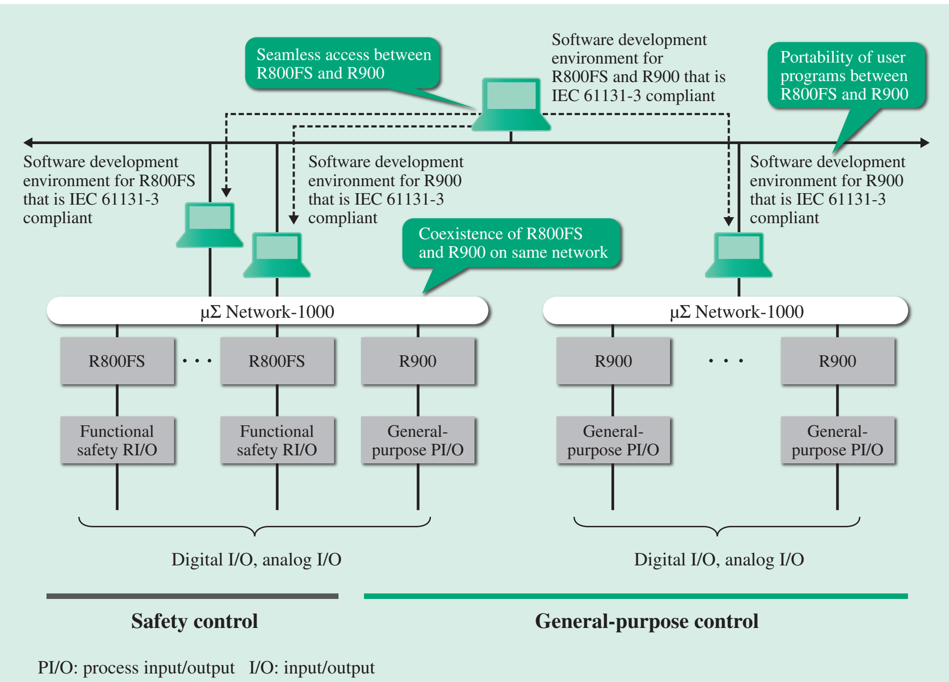


Fig. 8—Unified Architecture.
The architecture allows the seamless incorporation of functional safety and the implementation of highly expandable systems.

Safe communications is used for the remote communications between the CPU and RI/O. Normally, the safety layer of processing used to achieve safe communications is performed by software, involving more processing than conventional communications. To improve performance, Version 2 of the R800FS implements the safety layer in the hardware. This enables parallel processing using both software and hardware, which improves performance by more than 50% over R800FS Version 1.

Certification has also been obtained under the UL 61131-2 and CAN/CSA E61131-2 electrical safety standards, and the product also complies with the environmental and EMC requirements specified in IEC 61131-2, and the functional safety EMC requirements of IEC 61326-3-1.

Unified Architecture Enabling Flexible System Configuration

The R800FS functional safety controller is able to connect to the same control networks as devices such as the R900 general-purpose controller, industrial personal computers (PCs), and information and control servers, and exchange data with these devices. It also supports software portability for user programs, using an integrated software development environment with an IEC 61131-3 compliant programming language. This improves usability and smoothes the adoption of functional safety in information and control systems, supporting the development and operation of safe information and control systems that are also more expandable (see Fig. 8).

CONTROL SYSTEM SECURITY ENSURING CONTROL PERFORMANCE

Concepts and Overview of Control System Security

The vulnerability of information and control systems to cyber-threats has been highlighted in recent years by the Stuxnet incident in which malware was targeted at a control system. This has prompted the expediting of moves to formulate international standards for control system security, with certification under these standards increasingly being stipulated in procurement rules. In Japan, the Embedded Device Security Assurance (EDSA) security certification scheme for control devices has started by the Control System Security Center (CSSC).

Information and control systems need to remain in operation for long periods of time, during which they may be retrofitted with additional equipment or functions. They combine a wide variety of different systems, ranging from controllers to information and control servers, IT servers, and database systems, using system configurations that are optimized for the operation of each in-service system. Accordingly, ensuring the cyber-security of information and control systems requires that they incorporate information security products such as firewalls and intrusion detection systems (IDSs), control security components that comply with international standards and have international certification, and information and control network security products that can support the long-term operation of control systems (see Fig. 9).

EDSA Certification for Control Security Components

EDSA certification is a certification scheme for assuring the security of control components administered by the International Society of Automation Security Compliance Institute (ISCI). It defines the criteria for different levels of security (see Table 1).

The communication robustness test (CRT) is performed on equipment to verify that a predefined list

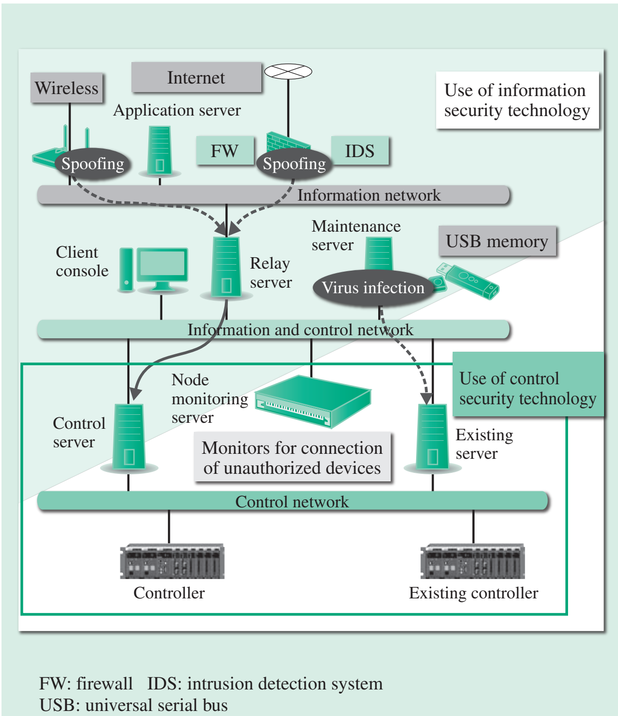


Fig. 9—Example Application in Control System.
The system supports both information security technology and control security technology.

Table 1. EDSA Certification Criteria and Assessment Level
EDSA certification defines the criteria for assessment levels that represent the strength of security.

Test	Description	Assessment level		
		Level 1	Level 2	Level 3
CRT	Communication robustness test	69	69	69
FSA	Functional security assessment	21	50	83
SDSA	Software development security assessment	129	148	169

EDSA: Embedded Device Security Assurance

of essential services (such as the continuity of control calculations) can continue to function either while an attack from a communication link is in progress or after the attack ends. Specifically, the equipment being tested is connected to the network along with human-machine interface (HMI) devices and the continuity of essential services is verified using the data displayed on the HMI and the control outputs from the process input/output (PI/O).

A functional security assessment (FSA) uses equipment testing and documentation to verify whether security function requirements are satisfied at a system level.

A software development security assessment (SDSA) models security threats in terms of the security requirements and uses documentation to verify whether the design and review processes throughout the software development lifecycle cover these threats.

Security Products for Information and Control Networks

Because the equipment used in information and control systems remains in service for a long time and is subject to modifications after the system commences operation, such as upgrades to equipment and functions, it is common for old and new equipment to coexist. This makes it difficult to maintain security simply by installing individual components with standalone security support.

Along with the use of firewalls and IDSs to prevent intrusion by external attacks, other effective techniques include monitoring changes in equipment configuration to identify which devices are permitted to connect to the network, blocking those components that are not needed, and early detection and response to infections or other attacks. For example, Hitachi's node monitoring server continuously monitors the network for the connection of unauthorized devices and issues a warning to the security operation system when one is detected.

SMALL AND RUGGED COMPUTERS FOR MAKING OPERATIONS MORE INTELLIGENT

Requirements for Making Operational Systems More Intelligent, and Hitachi's Initiatives

Social infrastructure systems that require high reliability and availability are creating new requirements with an operational focus, including the provision of a variety of services that are closely integrated with infrastructure operation and the utilization of detailed and up-to-date information from the field. To satisfy these requirements, Hitachi is working on initiatives aimed at making operations more intelligent.

The on-board display systems on trains, for example, need to provide passengers with a wide variety of information, not only accurate realtime service information but also things like news, advertising, and weather reports. This system requires the installation of small computers that process this diversity of display data in the confined space inside a train ceiling. Accordingly, these computers need to be not only small but also capable of operating in harsh environments, including the vibration from the moving train as well as temperature highs and lows, and condensation during wet weather, that occur when the train is out of service.

Similarly, the power monitoring devices used in smart grids may be installed on the tops of power poles where they experience harsh outdoor temperature and humidity conditions, or close to transformers where electrical noise levels are high. The controllers for industrial robots operate in production plants, where they often experience significant vibration, sulfur-containing or other corrosive gases, or high levels of dust. Also, because equipment such as power monitoring devices and industrial robot controllers is located in places where installation and replacement work is difficult, it is important that it operates reliably for long periods of time. As making operations more intelligent results in devices being installed in a wider range of sites, the demands for making them rugged enough to withstand these environments will become more diverse.

Development of Small and Rugged Computers

Hitachi has developed the above-mentioned small computers for train display systems and embedded computers for use in substations in the past. In response to the growing and increasingly diverse

TABLE 2. Small and Rugged Computer Specifications

The table lists the main specifications of the small and rugged computers developed by Hitachi.

Parameter		Specification
Processor (SoC)		Intel*1 Atom*1 processor (1.46 GHz) (1 core, 1 thread)
Memory	Main memory	2 Gbyte DDR3L-SDRAM with ECC
	Non-volatile memory	512 kbyte MRAM
Graphics	Controller	Integrated in SoC
	Graphics memory	Shares main memory.
	Display resolution	2,560 × 1,600 max. (WQXGA)
	Colors	16,700,000 (24 bpp)
File storage	CFast slot	CFast slot × 1 (replaceable from front panel)
I/O interface	Display	1 × display port
	USB port	1 × port (USB 3.0, USB A type connector) 3 × ports (USB 2.0, USB A type connector)
	LAN port	3 × ports (1000 Base-T, Wake-on-LAN)
RAS functions		LED, WDT, etc.
Supported OSs		Hitachi customized Linux*2 (planned)
BIOS		EFI

SoC: system on a chip DDR: double-data-rate
SDRAM: synchronous dynamic random access memory
ECC: error check and correction
MRAM: magnetoresistive random access memory
WQXGA: wide quad extended graphics array bpp: bits per pixel
LAN: local area network RAS: reliability availability and serviceability
LED: light-emitting diode WDT: watchdog timer
BIOS: basic input/output system EFI: extensible firmware interface
*1 Intel and Intel Atom are trademarks of Intel Corporation in the U.S. and/or other countries.
*2 Linux is a registered trademark of Linus Torvalds.

demand for ruggedized devices, Hitachi has embarked on the development of small and rugged computers that satisfy the following seven requirements.

(1) Wide operating temperature range (–10 to +60°C)
(2) Small size: 210 mm (W) × 70 mm (H) × 225 mm (D)
(3) Sealed, environment-proof design
(4) 10-year life with continuous 365-days-a-year operation
(5) Fanless (natural air cooling) design to eliminate need for replacing parts
(6) No hard disk drive (HDD) for better tolerance of vibrations
(7) Use of memory error checking and correction (ECC) for better reliability

For the new small and rugged computer, Hitachi uses small, high-performance system-on-a-chip (SoC) devices with low power consumption that includes a memory ECC function to reduce heat dissipation and allow the use of a sealed design. In addition, using thermal fluid analysis to check the component layout under natural air cooling conditions and minimizing hot spots, Hitachi also optimized the metal housing itself to incorporate measures for dealing with heat that took account of the 10-year product life, including using conduction to dissipate the heat from the SoC. These measures succeeded in achieving a sealed, fanless design with a 10-year life.

Fig. 10—Small and Rugged Computer.
Hitachi's small and rugged computers use a proprietary metal case design with excellent heat dissipation. The connectors and LEDs are located on the front panel for easier maintenance.

To achieve reliable operation in environments with a high level of vibration, these small and rugged computers do not include mechanical components that are vulnerable to vibration or shock. Instead they use a CFast* card for file storage. All plug-in connectors and light-emitting diodes (LEDs), including the CFast slot, are located on the front panel to improve maintenance, such as installation or replacement, unplugging of cables, or checking LED indicators (see Table 2 and Fig. 10).

CONCLUSIONS

This article has described the recent challenges facing the information and control systems that support the reliable, long-term operation and high availability of the social infrastructure, and the associated technological developments. Hitachi draws on its accumulated know-how to overcome the technical challenges of supporting a safe and secure social infrastructure in the face of rapidly changing IT and service expansion requirements, while also taking an active approach to incorporating the latest IT into its information and control systems.

Hitachi intends to continue developing technologies to help achieve a high-quality social infrastructure that is safer and more secure.

* CFast is a registered trademark of CompactFlash Association.

REFERENCES

(1) T. Mizuno, “Statistical Analysis of Socio-Economic Phenomena Using Big-Data- Econophysics,” Research Report Knowledge System (ICS), 2014-ICS-173 (4), 1-3 (Jan. 2014) in Japanese.

(2) K. Seino, “Fundamentals and Technology of Virtualization,” Shoeisha (2011) in Japanese.

(3) “Functional Safety of Electrical/electronic/programmable Electronic Safety-related Systems,” IEC 61508 2nd edition (Apr. 2010).

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