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Special Feature

Utilizing ICT to Stabilize Usage of Electricity

Optimizing Power Supply Stability through ICT Utilization in Power Systems

Utilizing ICT to Stabilize Energy Use
— Comprehensive optimization of the entire factory through visualization —

Research and Development of Autonomous Distributed Power System and Contribution to Regional Decarbonization

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About ITU-AJ

The ITU Association of Japan (ITU-AJ) was founded on September 1, 1971, to coordinate Japanese activities in the telecommunication and broadcasting sectors with international activities. Today, the principle activities of the ITU-AJ are to cooperate in various activities of international organizations such as the ITU and to disseminate information about them. The Association also aims to help developing countries by supporting technical assistance, as well as by taking part in general international cooperation, mainly through the Asia-Pacific Telecommunity (APT), so as to contribute to the advance of the telecommunications and broadcasting throughout the world.

Optimizing Power Supply Stability through ICT Utilization in Power Systems

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1. Introduction

Electricity is an essential energy for daily life and industry, and sound operation of power systems for electricity supply to consumers is directly related to stable supply of electricity. To operate a power system in a sound state, the following requirements must be satisfied: (i) match the amount of electricity generated with demand constantly (supply-and-demand balance), (ii) maintain power quality such as frequency and voltage (quality maintenance), (iii) promptly locate and isolate a fault section of the power grid (fault clearance), and (iv) maintain continuation of power supply to sound areas that are not affected by the fault (security of the electricity supply). Various ICT-based systems are in operation to satisfy these requirements concerning power systems.

In the meantime, to achieve carbon neutrality by 2050, it will be increasingly necessary to promote renewable energy and utilization of facilities and equipment that demand electricity such as electric vehicles (EVs). The utilization of ICT will be a crucial factor in achieving the goal.

Considering the background, this paper describes the usage of ICT in power systems currently in operation as well as the future vision of such usage of ICT and expectations for it.

2. Utilizing ICT for power systems

This section focuses on the utilization of ICT for stabilizing electric power supply. So it describes the following systems and technologies as representative examples in the following sub-sections: a "transmission line protection relay system" in subsection 2.1 and an "online pre-calculating system stabilizing controller (OPCSSC)" in subsection 2.2, which are responsible for adjustment of supply and demand to maintain the supply-and-demand balance during normal times in subsection 2.3; control of output for non-firm power sources to achieve both effective use of transmission and substation facilities and stable power supply and quality control on the consumer side in subsection 2.4; and a "distribution feeder automation system" in subsection 2.5.

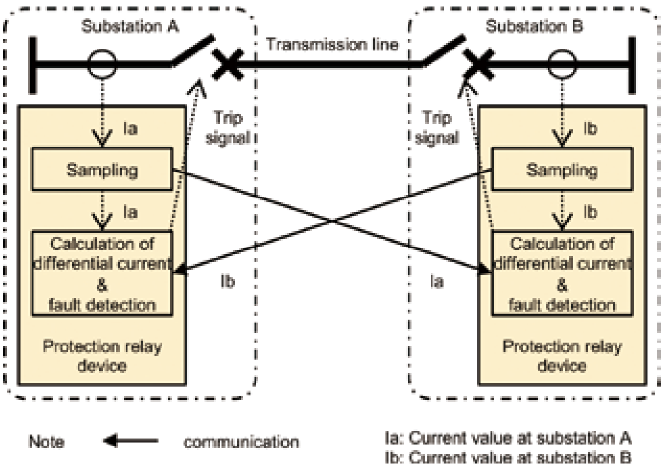
Smart meter systems also utilize various types of communications. However, this paper focuses on power supply stability. So please refer to other literature for communications for smart meter systems, if necessary.

2.1 Transmission line protection relay system

A transmission line protection relay system—consisting of a main protection relay and a back-up protection relay—eliminates short circuits or earth faults that occur on transmission lines. The main protection relay uses communication/transmission for sampled values of current and voltage, and pulse-code-modulation (PCM) current differential relays are used as the main protection relays in 500 and 275 kV bulk power systems.

The basic configuration and operation of the PCM current differential relay is shown in Figure 1. Protection-relay devices are installed at substations located at both ends of the transmission line to be protected, and sampled values of the current flowing in each phase of the transmission line are constantly transmitted to the other end of the line. The protection relay devices calculate the difference of current by using the current values sampled at its own end and those transmitted from the other end. In the case where the difference exceeds the setting criteria, they judge that a fault has occurred on the transmission line, and dispatch trip signals to the circuit breaker to isolate the fault section.

Figure 1: Configuration of PCM current differential relay system



Communication systems used for the PCM current differential relays must have low latency (i.e., 5 ms for 50 Hz power systems and 4 ms for 60 Hz power systems) and high reliability (i.e., system-wide failure rate to operate of 1.0 × 10^{-7})[1]. To meet those requirements, microwave radio[2] and optical ground wires (OPGW)[3] are used as communication media, which are connected by dedicated multiplex equipment (CR-MUX). Microwave radio has two key features as a communication technology for the PCM current differential relays: (i) ease of assuring low-latency transmission because the transmitting and receiving points are connected over the shortest possible distance and (ii) reliability even in the event of large-scale disasters because physical media are not used (only robust towers are used)[4].

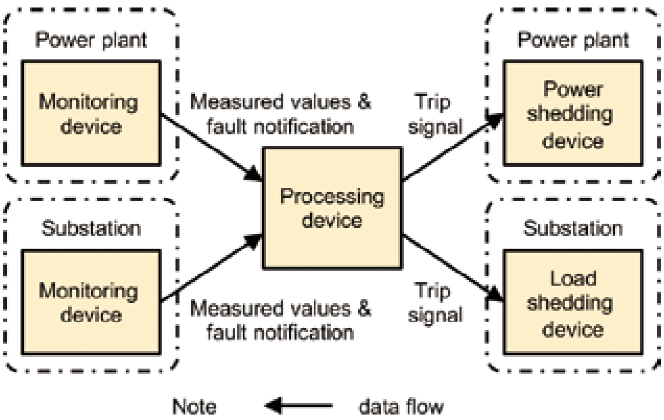
2.2 Online pre-calculation system stabilizing controller

Online pre-calculation system stabilizing controllers (OPSSCs) are operated for purposes such as maintenance of frequency during severe accidents, and they play a role in preventing fault cascading[5]. During the large-scale power outages that occurred in recent years, they also operated to prevent blackouts from occurring[6].

Figure 2 shows a basic configuration of OPSSC —[7]. The processing device constantly receives measured values related to power flows at important points within the power system, and it repeatedly identifies circuit breakers to be tripped for all patterns related to transmission route faults in a bulk power system, loss of generation, etc. at regular intervals. In the event of a fault causing a system disturbance, the relevant monitoring devices notify the fault occurrence to the processing device, which then sends trip signals to the power/load shedding devices responsible for the control target at that time. The power/load shedding devices receiving the trip signals, they trip the designated circuit breakers.

The transmissions of fault notifications and trip signals necessitates ICT that achieves low latency and high reliability; therefore, as in the case of PCM current differential relays, microwave radio, OPGW, etc. are used as the communication media.

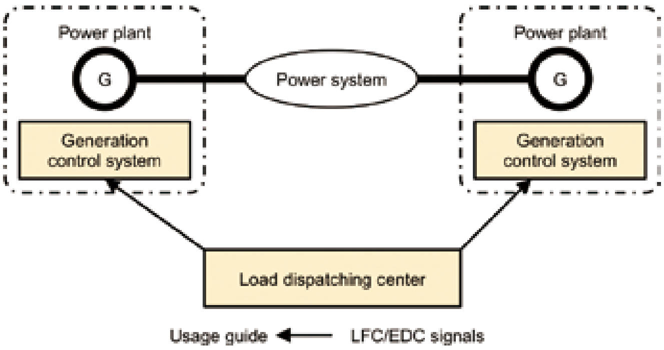
■ **Figure 2: A basic configuration of OPSSC**



2.3 Supply and demand balance control

To maintain the balance between power supply and demand, the output of generators and other equipment is controlled by "load frequency control" (LFC) and "economic load dispatching control" (EDC). Figure 3 illustrates the basic configuration of the system used for LFC and EDC. The load dispatching center system receives measured values such as output and current flow and status values such as breaker open/close status from power plants, etc., and it sends control signals for LFC and EDC to the target power plants every few seconds and every few minutes, respectively. Since the communication used for LFC and EDC (especially in the case of the LFC command) requires low latency and high reliability, microwave-radio and OPGW are mainly used for the transmission path.

■ **Figure 3: Basic configuration of the system for balancing supply and demand**



2.4 Curtailing the output from non-firm connected power supplies

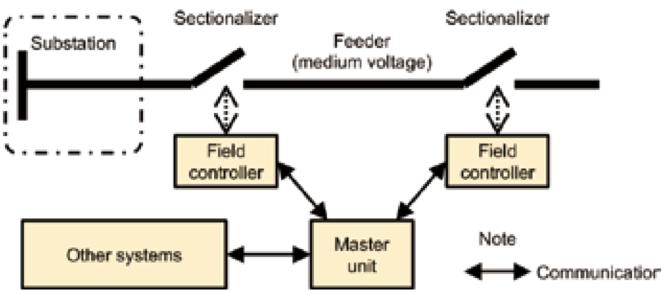
Non-firm connection is a method of connecting the power supply with the upper limit of the available capacity of transmission and substation facilities, and the output of the power supply is controlled according to the available capacity. Specifically, this control is achieved by transmitting the upper-output-limit schedule for each 30-minute time frame as a percentage of the generator's rating in advance via communication. In some cases, the upper output limit value in the 30-minute frame during operation is changed on demand according to the situation.

Two different systems are operated for this output curtailment, and the one chosen depends on the voltage level with which the power supply is interconnected. For power supplies connected to medium- and low-voltage (less than 66 kV) grids, a system based on the Internet and HTTP is used. As for this system, a server is installed on the side of the distribution system operator, and the output-upper-limit schedule is periodically obtained from the generator side via HTTP and Internet VPN. On the contrary, for power supplies connected to high-voltage (66 kV or higher) grids, the output-upper-limit schedule is distributed by cyclic digital transfer (CDT) via a dedicated communication network. Via the dedicated network, commands can be issued at any time, so output can be controlled in real time according to the actual supply and demand of the day.

2.5 Feeder automation system

A feeder automation system in Japan is mainly for medium-voltage feeders (6.6 kV), and they are responsible for distribution grid switching, regulating voltage, and quick restoration of sound sections by isolating a trouble section[8]. This system is almost 100% adopted in Japan, where it is contributing to optimizing voltage and shortening power-outage times. Figure 4 illustrates the basic configuration of a feeder automation system. The system consists of a master unit which is responsible for monitoring and control as well as fault location, isolation, and service restoration, and field controllers. Some of the field controllers are responsible for control of sectionalizer and measurement of current and voltage, and others are used to monitor and control voltage-control equipment (e.g. a step voltage regulator) installed on the medium-voltage feeders. The master unit is also linked to other system such as distribution management systems and control and protection systems for transmission power systems. For communication between the master unit and field controllers, power line communication, metal cables, and optical cables are used as dedicated communication paths. Whichever is used, they are basically mounted to distribution poles and laid along medium-voltage feeders.

■ Figure 4: Basic configuration of feeder automation system



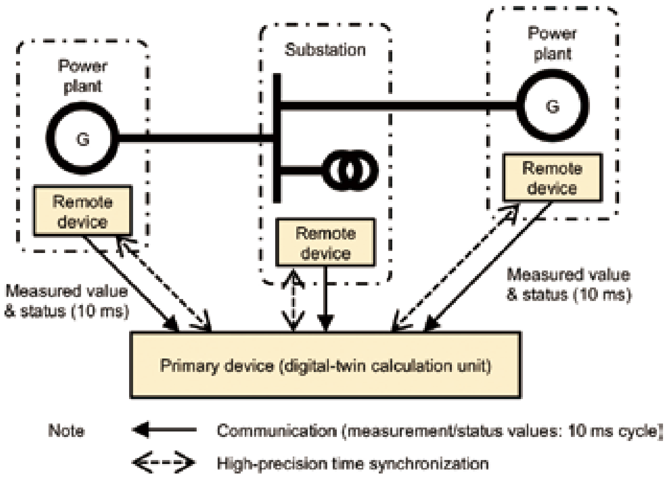
3. Future vision of utilizing ICT in power systems

Four future visions of the use of ICT that are considered to differ significantly from the conventional use of ICT in power systems are described in this section.

3.1 Utilization of ICT for digital twins

Utilizing ICT is essential to create a digital twin. As for the "real-time smart digital twin" (RSDT) proposed by the Central Research Institute of Electric Power Industry as one kind of digital twin, as shown in Figure 5, remote devices installed in power plants and substations synchronize their times with high precision and transmit measured values with time stamp to the primary device at 10 ms intervals. The primary device ascertains the degree of system stability in a few minutes according to the received values measured at the same time, and it could perform preventive control, as necessary[9].

■ Figure 5: Illustration of communication relationship in RSDT (transmission of measurement and status values only)



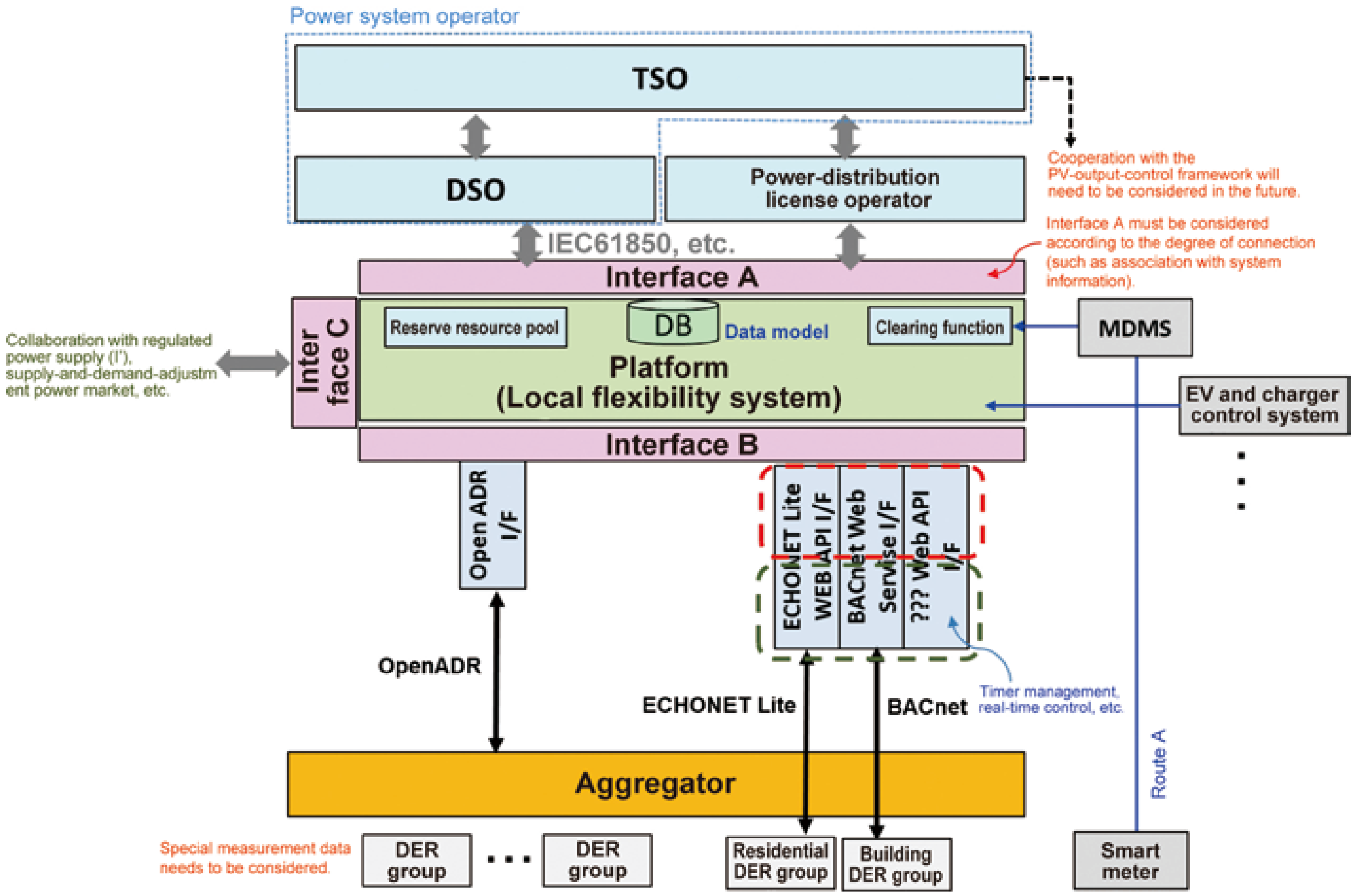
3.2 Cooperation between power system and EVs

EVs are one of the major changes in future electricity usage compared to today's one. Numerous projects are already conducting field trials to utilize the charging and discharging functions of EV storage batteries as a service for operation of power systems[10]. These field trials include transmitting control setpoints to EVs to supply services for replacement reserve for feed-in-tariff. In the future, the utilization of telematics data is anticipated to foster a synergy between the power system and EVs, serving as a key component of a broader range of services tailored to EVs.

3.3 Utilization of flexibility

Alongside the synergy between power systems and EVs outlined in the previous section, there is increasing focus on power system operations – such as congestion management and voltage regulation – that capitalize on the flexibility provided by distributed energy resources (DERs), including controllable loads, to adapt power output or demand.[11]. When utilizing flexibility, power system operators and aggregators exchange data related to

■ **Figure 6: Platform for utilizing flexibility (cited from reference[11])**



service transactions and operations of DERs through a platform such as that shown in Figure 6.

3.4 Collection of equipment-maintenance data

To stabilize power supply, it is necessary to maintain not only the operation and protection of the power system as described above but also the soundness of facilities such as transformers and transmission lines. Until now, the soundness of facilities has basically been maintained through periodic inspections; however, in the future, methods that actively utilize ICT for appropriate inspections and repairs while monitoring the condition of facilities are expected to become mainstream[12]. That is, in addition to temperature, liquid level, vibration, and other data that are widely used in other fields, data characteristic of the electric-power field (such as partial discharge) is expected to be collected through the Internet of Things (IoT) and other means, and the state of the system will be analyzed by using AI and other methods.

4. Expectations for ICT

Expectations for ICT are described hereafter from the perspective of realizing the above-described future vision of ICT utilization and enabling the stable power supply in the future.

4.1 Ensuring openness through international standards

As for coordination with EVs and utilization of flexibility, parties outside of the electric-power sector are involved in the operations of the power system. And as for ICT used in such environments, "openness" is expected to be ensured. One way to ensure openness is to create international standards for coordination between the electric-power field and other fields. That standardization should be led by the International Electrotechnical Commission (IEC), which creates international standards for electric power-related communications. For example, regarding IEC 61850, the international standard for communications for monitoring and controlling power systems, the IEC has published a technical report for communications related to the sector coupling between power systems and thermal energy systems. In addition, another document for "power to gas" (P2G) technology is under development.

4.2 Expanding the scope of wireless communications

Wireless communications are already used in the PCM current differential relays for transmission line protection and smart meters. In addition, it is anticipated that its application in collecting facility-maintenance data will increase. At that time, it is expected that the power supply for wireless-communication terminals will also become wireless or independent. Moreover, the applications of wireless communication in fields such as protection and control are expected to simplify removal of communication cables and testing at substations.

4.3 Utilization of all-photonic communication network

To create digital twins, it is necessary to implement high-speed broadband communications. As one of the communication networks to meet that need, the "all-photonic communication network" is expected to be used in combination with high-speed wireless communication. It has already been presented by NTT in the form of their concept known as the "Innovative Optical and Wireless Network" (IOWN), and domestic and international companies are participating in the IOWN forum[13]. It is hoped that IOWN technologies will contribute to the realization of digital twins.

4.4 Assuring cybersecurity

Assuring cybersecurity is required in all fields. The design of cybersecurity measures for ICT in power systems should ensure the uninterrupted continuity of power system operations. For example, if communication is cut off immediately when a security certificate expires, the power system may be unable to operate, and a large-scale power outage may occur. For that reason, it is expected that an appropriate security policy—tailored to the characteristics of the electric-power sector—will be established, and that power systems will be operated in accordance with the policy.

5. Conclusion

This article has described how various ICTs are utilized in power systems and contribute to stable power supply. It also outlines future visions for ICT utilization in power systems, including digital twins, EV integration, flexibility use, and facility maintenance data collection, along with the expected role of ICT in achieving these visions.

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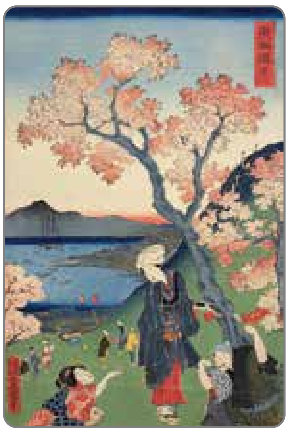

Shinagawa, Tokaido

Utagawa Toyokuni(III) (1786-1864)

Source: National Diet Library, NDL Image Bank (https://rnavi.ndl.go.jp/imagebank/)

Utilizing ICT to Stabilize Energy Use

— Comprehensive optimization of the entire factory through visualization —

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1. Introduction

Concern about countermeasures against global warming is growing globally, and many countries are moving toward achieving carbon neutrality in 2050. In October 2020, Japan also declared that it aims to achieve carbon neutrality in 2050. As a medium-term goal before 2050, Japan also announced that it aims to reduce greenhouse-gas emissions in 2030 by 46% compared to 2013 levels and that it will further strive to reach an even higher reduction of 50%. Moreover, fossil fuels (mainly oil, coal, and natural gas) account for approximately 90% of Japan's primary energy supply (as of 2020), and most of Japan's supply of mineral resources (i.e., raw materials) relies on overseas sources (according to the Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, Energy White Paper 2022).

To achieve carbon neutrality and stabilize energy use, it is necessary to further promote energy conservation in the future. In recent years, it has become essential to promote not only the conventional rationalization of energy use but also further energy conservation through (i) energy management that considers the balance between electricity supply and demand and (ii) implementation of "factory energy-management systems" (FEMS) that utilize the Internet of Things (IoT).

At Fukuyama Works, we have deployed a system that incorporates part of a concept called "e-F@ctory" (our IoT technology) as a FEMS to implement energy management in the factory. The efforts that Fukuyama Works has been comprehensively undertaking to optimize energy saving in the entire factory using FEMS are introduced hereafter.

2. Mitsubishi FA integrated solution: e-F@ctory

As Mitsubishi's factory-automation (FA) integrated solution, e-F@ctory visualizes sensor-collected data by linking FA and information technology (IT) in a way that reduces TCO (total cost of ownership) by repeating the plan-do-check-act (PDCA) cycle at several stages. At the Fukuyama Works, e-F@ctory is being used to save energy and improve productivity (Figure 1). The architecture of e-F@ctory is divided into three main layers: "shop floor," "IT system," and a middle layer ("edge computing") that links them.

On the "shop floor" layer, FA-manufactured products such as sequencers, various devices, and sensors, which are the brains of production equipment, are connected by FA networks, and various data are collected in real time. The data are then seamlessly linked to the IT system for analysis, and the analysis results are fed back for utilization on the shop floor. However, data obtained on the shop-floor layer cannot be fully analyzed because it contains special know-how, circumstances, and other causal relationships that cannot be understood if sent directly to the IT system. Therefore, primary processing, namely, edge computing, is needed to associate causal relationships to the data and make the data informative. One of the key features of e-F@ctory is that the middle (edge-computing) layer between the FA and IT layers is responsible for not only seamless linkage but also optimization of the entire FEMS.

■ Figure 1: Conceptual diagram of e-F@ctory

3. Efforts concerning energy saving at Fukuyama Works

3.1 Background of energy-saving activities

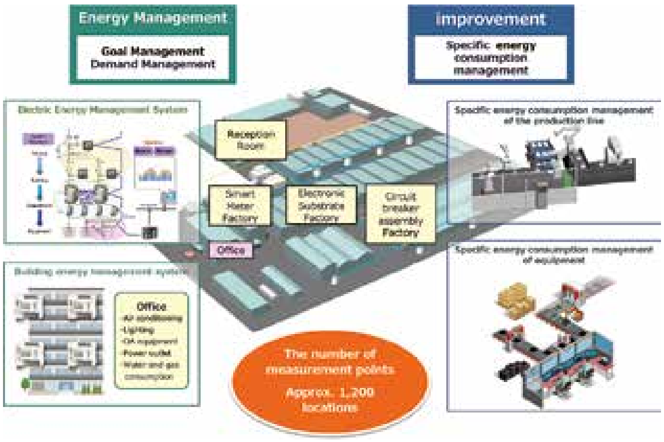
While energy-saving activities have been promoted to comply with the Japan's "Act on the Rational Use of Energy" (i.e., "Energy Conservation Act"), recently, companies are required to continue even more long-term efforts to solve global environmental issues. We have also positioned environmental contribution as an important management issue and formulated "Environmental Vision 2050" to take the initiative in solving environmental issues.

Under these circumstances, aiming to achieve virtually zero CO_2 emissions in 2050, we will respect international trends toward the creation of a decarbonized society and promote the reduction of greenhouse-gas emissions throughout the entire value chain—from design and development to raw material procurement, manufacturing, sales, distribution, use, and disposal. To achieve the goal, the Fukuyama Plant is promoting energy conservation by replacing aging facilities with high-efficiency equipment, using renewable energy sources such as solar-power generation, and implementing EM ("energy-loss minimum") activities to detect and reduce energy loss in production activities through the use of FEMS.

3.2 Overview of energy saving

The Fukuyama Works aims to both improve productivity and save energy by utilizing control technology from the production-equipment field and measurement technology developed in the field of power distribution and reception. The products that we manufacture are circuit breakers, meters and gauges, smart meters, uninterruptible power supplies (UPS), and energy-saving support equipment, which is installed at various locations around the factory and utilized in energy-saving activities through visualization of sensor data (Figure 2).

Figure 2: Overall diagram of the energy-management system at Fukuyama Works



Our energy-saving activities are twofold. The first activity is "target management" (i.e., "demand management") that uses measured energy usage to set and manage target values. As for the second activity, we set production lines as role models for energy-saving activities. We then collect their production volumes and measure their energy consumptions and determine their specific consumptions from that data. These activities are then constantly managed by using specific consumption. Moreover, the automatic assembly line for circuit breakers measures energy consumption of each individual facility, collects the production volumes, and correlates production-related data (such as product quality, errors, and results) as an indicator for managing energy consumption. Energy saving through specific consumption management involves four steps: "measuring," "visualizing," "reducing," and "managing." When measuring energy consumption, it is important not only to collect energy-use data on the shop floor but also to collect data in conjunction with production information such as production volume.

In the visualizing step, the measured energy and production information is visualized by using IT, the data is analyzed, points at which energy loss occurs are identified, and those points are handled in the reducing step. In the reducing step, for example, operations are improved by utilizing energy-saving drive products such as inverters and high-efficiency motors, stopping idling of equipment on standby, and optimizing the startup and shutdown of equipment.

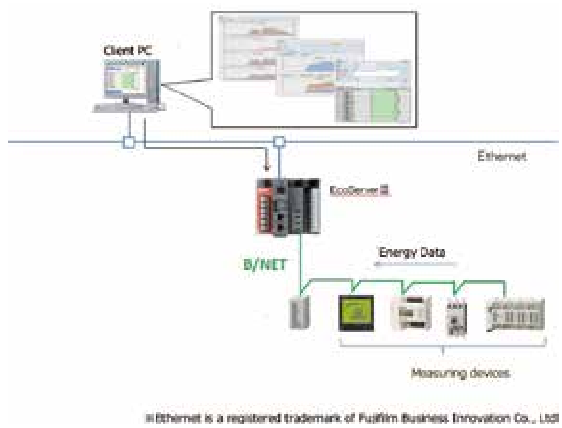
In the managing step, energy usage and specific consumption of lines and equipment are monitored in real time, and those actual values are managed so that they do not exceed the target values. To improve in terms of productivity and energy saving, four consecutive steps, "measuring", "visualizing", "reducing", and "managing," are repeated multiple times along with each PDCA cycle.

Recently, focusing on five key points for energy saving (equipment-start-up time loss, equipment-shutdown time loss, utility time loss, production intensity, and production-loss time ratio), we are utilizing one of our products, "EcoAdviser", an energy-saving analysis-and-diagnosis application equipped with our AI technology, "Maisart" to extract notices of energy loss automatically from data on power consumption and production volume measured and collected at the transformer production line. The insights that we gained from this process have led to energy-saving improvements.

3.3 Energy saving through target management (demand management)

Fukuyama Works received ISO14001 "Environmental Management System" certification in 1997, and we started energy-saving activities from that time. Utilizing the ISO 14001 organizational structure, each department manages electricity-consumption targets to ensure that actual results do not exceed the targets. The amount of electricity used at each location is measured by a measuring device at that location, and the measurement information is transmitted to an energy-saving data-collection server (one of our products, EcoServerIII) via B/NET transmission (a field network for power distribution and control of equipment) for data collection. The web-server function of EcoServer III connects to the Fukuyama Work's network system and discloses the collected data on the web server. In this way, we

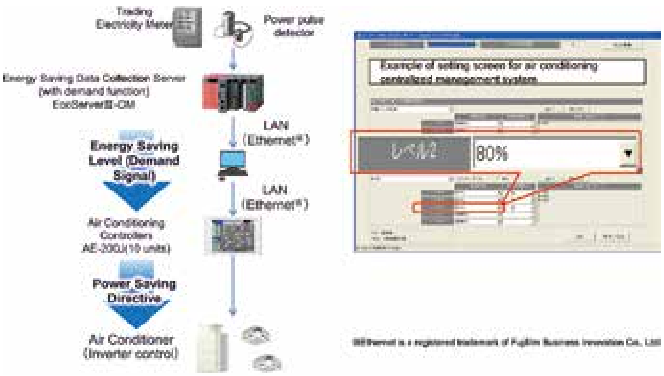
Figure 3: Energy-management system



have created an environment in which workers can monitor their energy use (Figure 3).

As for management of power demand, electric-power pulses supplied from transactional watt-hour meters of the electricity utility providing our electricity are used, and the number of pulses is imported into EcoServer III, which uses its demand-monitoring function to monitor demand. When the demand reaches the energy-saving level, the energy-saving level is sent as a “demand signal” to AE-200J centralized air-conditioning controllers, which send a “power-saving-operation signal” to inverter-type air-conditioners installed in the factory and offices to achieve automatic energy-saving operation (Figure 4).

■ Figure 4: Energy-saving control of air-conditioners based on energy-saving level

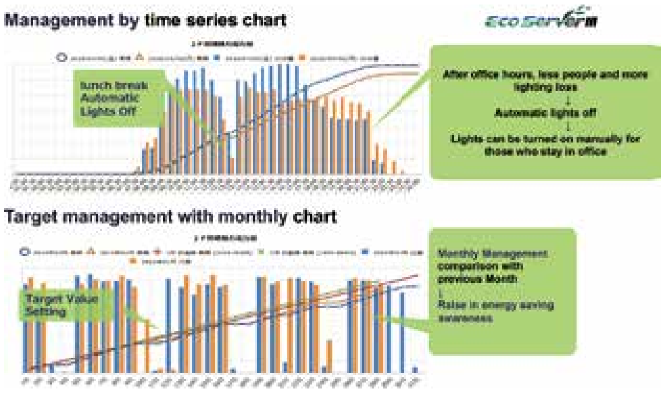


In our five-story office building (General Administration Building), where general affairs, sales, and design staff work, electricity consumption for air-conditioning, lighting, office automation (OA), and outlet circuits on each floor is measured. This measurement information is collected by EcoServerⅢ and can be checked on the web, so it is possible to manage targets based on the measurement data. Energy-conservation measures cover lighting and air-conditioning; as for the former, lights are turned off before the start of work and during lunch breaks. As for the latter, we are working to ensure “schedule management” (e.g., shutting down operations before and after work hours) and “temperature management” (28°C is the target for air conditioning and 20°C is the target for heating). To avoid going back to the previous energy-conservation (energy saving) measures, the compliance status of the countermeasure-applied operations is checked with the measurement data collected by EcoServer III (Figure 5).

3.4 Energy saving through production-intensity management

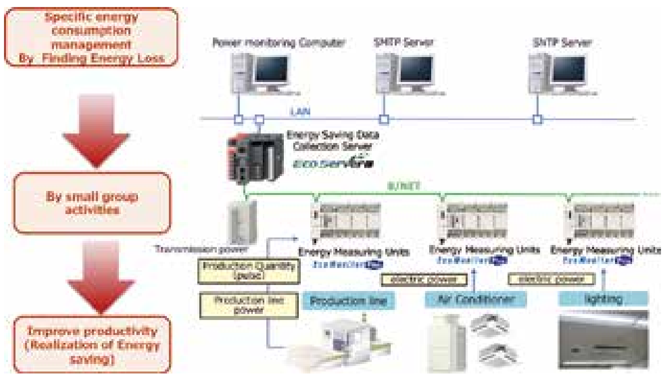
Energy use on production lines increases in proportion with production volume. Managing energy usage only is insufficient to determine whether energy is being used efficiently, so it is necessary to manage trends in energy usage while comparing it with production information. At the Fukuyama Works, we link production volume to energy consumption and practice production-intensity management. On performing production-

■ Figure 5: Energy management of the office building



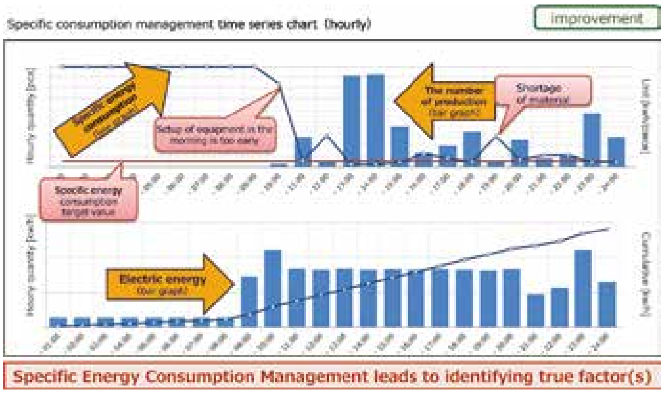
intensity management, we construct energy-saving model lines by targeting lines that are likely to be effective when improvements are made. The targeted lines include lines that consume a lot of energy, lines that can be expected to be expanded laterally after being improved, and lines with significantly fluctuating production volume due to changes in types of products manufactured. A case study of one of these energy-saving model lines, namely, a production line for printed circuit boards in our electronic-module factory, is introduced hereafter. An EcoServer III, the above-described energy-saving data-collection server, is connected to the line, measurement devices are installed at the switchboards of the production line and used to measure the electricity consumption of the entire line, and sensors are installed along the production line and used to collect production figures and visualize production intensity (Figure 6).

■ Figure 6: Energy-management system for electronic-module factory



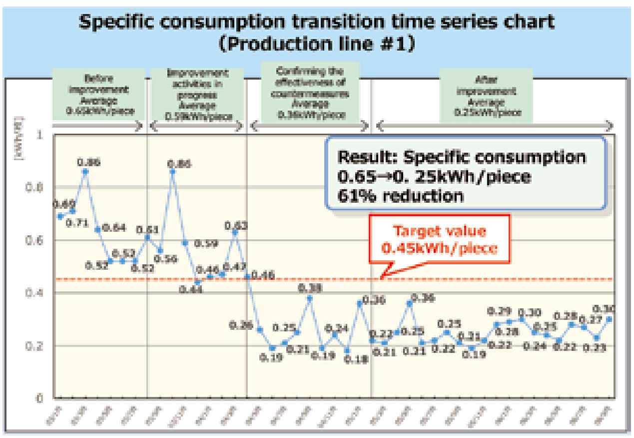
By linking the amount of electricity used on the line with the number of products produced, the energy-management system for our electric-module factory (as shown in Figure 6) manages specific consumption by using the amount of electricity consumed to produce one product (kWh/item) as an index. In small group activities, which are improvement activities undertaken at production sites, we check the temporal fluctuations in production intensity, analyze the factors that exaggerate the points along the line at which the production intensity exceeds the target value, and discover points at which production intensity can be reduced. As shown in Figure 7, items for improvement were hidden at points where specific consumption exceeded the target value, and specific consumption was improved through small group improvement activities.

■ **Figure 7: Example of analysis using production intensity graph**



To reduce specific consumption, it is effective to improve and increase productivity as well as to reduce energy consumption, and by promoting these activities in conjunction with improvement activities at production sites, the efficiency of production lines can be improved. By accumulating improvement activities to address the identified improvement points, we reduced production intensity by 61% compared to before we implemented the small group activities (Figure 8).

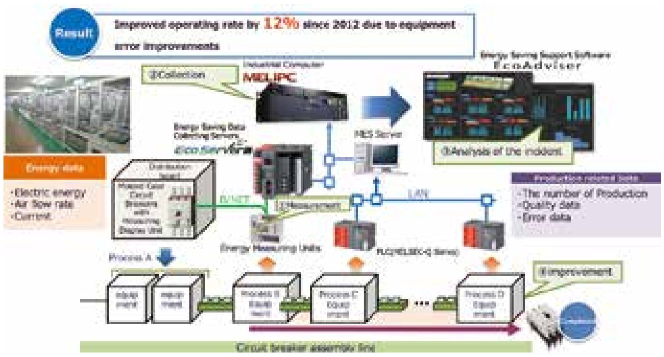
■ **Figure 8: Improvement effect through production-intensity management**



Moreover, by building a system that visualizes energy and production information for each manufacturing facility, we were able to make more detailed improvements in specific consumption, improve productivity, and achieve optimal use of energy. In the above-mentioned case study (as shown in Figures 6 and 7), we implemented production-intensity management on a production line basis, and factors that worsened the consumption rate and improvement measures were identified through small group activities. However, in the case of production intensity management for each line, only rough production information and energy information was available, so it took a huge amount of time and effort to analyze the factors that worsened the production intensity. And it was difficult to identify which piece of equipment in the line was making the production intensity worse (i.e., increasing it).

In 2010, when the automatic-circuit-breaker assembly line was upgraded, we introduced production-intensity management for each piece of equipment comprising the line (as shown in Figure 9). This upgrade allowed us to (i) identify the equipment that was causing the energy-consumption rate to increase immediately and (ii) collect information on production, quality, and equipment errors (short stoppages) from the sequencers used to control that equipment. Then, by comparing the collected data with the production-intensity data, it is possible to analyze the causes of the increase in the production-intensity. As for the features of the energy-management system, energy consumption and production information for each unit comprising the production line is measured. Data on energy consumption is collected and integrated by EcoServer III, and production information collected via the sequencers is collected and integrated by EcoAdviser, an energy-saving support application installed on MELIPC (our industrial computer).

■ **Figure 9: System for collecting energy and production-information from automatic-circuit-breaker assembly line**



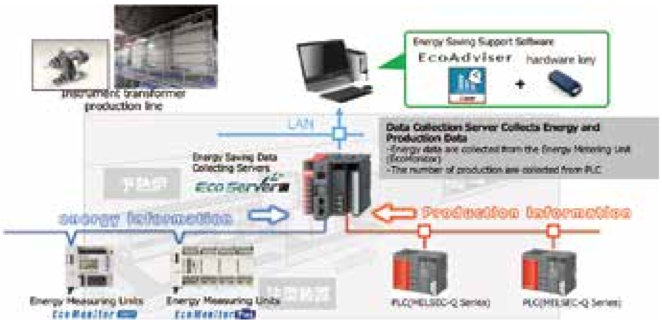
The collected data is displayed as energy and production information on a dashboard, one of EcoAdviser's functions, on a large monitor that is set up on the shop floor, as shown in Figure 10, and the monitor is used to share information with the shop-floor workers. To manage productivity, a ranking of first-pass yield by process and number of "pass" or "failed" products for each process is displayed in a manner that makes it possible to identify bottleneck processes easily. The number of equipment errors and cycle time are also managed, so it is easy to link awareness of processes that need to be improved to improvement actions. As a result of daily improvement activities, production intensity (kW/unit) was reduced by approximately 30% (compared to 2012 figure).

As for a recent initiative, on our transformer production line, as shown in Figure 11, EcoAdviser, the energy-saving analysis and diagnosis application equipped with our AI technology Maisart,

■ Figure 10: Dashboard of EcoAdviser on the circuit-breaker automatic assembly line

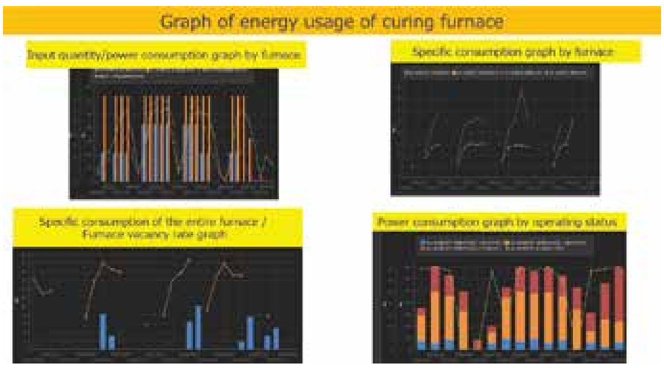
is being used to measure and collect electricity consumption and production volume for each piece of equipment on the production line, automatically diagnose energy loss, and make improvements based on the insights gained from these measurements.

■ Figure 11: Energy-management system of production line for transformers



First, from the preheating furnaces, pouring equipment, and curing furnaces on the transformer production line, the curing furnace with the highest electricity usage was selected as the target for improvement. As a step toward improvement, the graph function of EcoAdviser is used to determine the electricity usage of the furnaces from various graphs plotting (1) number of products and energy by furnace, (2) production intensity by furnace, (3) overall production intensity and vacancy rate of the furnace, and (4) energy consumption by operating status as shown in Figure 12.

■ Figure 12: Graphs for energy-saving operation of curing furnaces

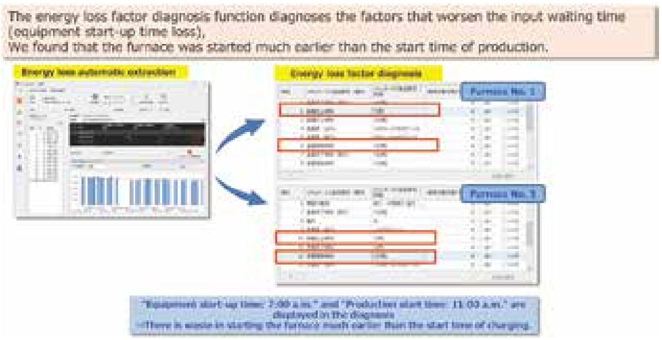


Analyzing the information obtained from the graphs revealed (i) a furnace with poor furnace efficiency (large vacancy rate) and (ii) power loss due to waiting for workpieces to be loaded. These findings have enabled us to improve the efficiency of the production line for transformers.

The "energy-loss automatic-diagnosis function" of EcoAdviser—which focuses on five key energy-saving perspectives (equipment-start-up-time loss, equipment-shutdown-time loss, utility time loss, production intensity, and production-loss time ratio)—is used to automatically extract "energy-loss notices" from the data on amount of energy consumption and production volume for each curing furnace. We focused on two of those perspectives, namely, equipment-start-up-time loss and production intensity, which are the most-common energy losses, and proceeded to understand their current status we determined and analyzed their status as explained hereafter.

As a countermeasure for equipment-start-up-time loss, as shown in Figure 13, we found that the start-up time of the curing furnace was earlier than the production start time. As for production intensity, we found that among several curing furnaces, a particular furnace routinely showed about three-times-higher consumption than that of the others. After checking the on-site curing furnace in question, we found that hot air was leaking from the product-loading door, so we fixed that leak; consequently, we reduced CO_2 emissions by approximately 50 tons per year.

■ Figure 13: Energy-loss diagnosis screen



4. Conclusion

A case study of a factory that uses FEMS to optimize energy use comprehensively throughout the entire factory and reduce energy consumption in the utility and production systems was described. We will continue our efforts as described in this case study to achieve the goal of carbon neutrality by 2050.

*This article is only a case study of Fukuyama Works, which may not necessarily be applicable to our overseas works.

Research and Development of Autonomous Distributed Power System and Contribution to Regional Decarbonization

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1. Introduction

At Sony Computer Science Laboratories (Sony CSL), we are promoting the introduction of renewable energy through research and development of the Open Energy System™ (OES)—namely, a concept that will form the basis of distributed power systems using distributed renewable energy and change the nature of society. The contents of this research and development, examples of demonstration experiments, and future developments are described hereafter.

2. Background of the need for distributed power systems

As reaffirmed in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which is the intergovernmental organization that collects and organizes scientific studies on global warming, climate change is being driven by global warming[1]. Countries are also increasingly moving to counter carbon-dioxide emissions, which are closely related to global warming.

Japan can be taken as an example country. In October 2020, Japan's Prime Minister Suga announced the policy goal of reducing emissions of greenhouse gases such as carbon dioxide to virtually zero (so-called "carbon neutrality") by 2050. To achieve this goal, the energy-conversion sector (primarily power generation by power plants)[2], which emits the largest amount of carbon dioxide by sector, must be decarbonized; that is, power generation must stop depending on burning carbon-dioxide-emitting coal, natural gas, etc. In fact, the Sixth Strategic Energy Plan approved by the Japanese Cabinet in October 2021 clearly states that renewable energy must be introduced to the maximum possible extent.

As pointed out in the Net Zero 2050 report[3] of the International Energy Agency (IEA), which makes policy recommendations on energy issues in general, to achieve decarbonization by 2050, it will be necessary to (i) shift from conventional fossil fuels (which emit CO_2) to renewable-energy sources such as solar and wind power and (ii) make maximum use of those sources. These renewable-energy sources are also called "variable renewable energy" in a way that indicates the amount of electricity generated by them fluctuates with variable weather and other factors. As for electricity systems, it is essential that supply (generation) and demand (consumption) always match. It is therefore necessary to be able to balance the fluctuating amount of electricity generated by renewable-energy sources with demand.

As one renewable-energy source, solar-power generation benefits from ease of introduction, so it will be installed in various places. In conjunction with this trend, the nature of electricity-transmission networks will also change. Conventionally, large-scale power plants were built far from the power-consumption areas. From the power plants, electricity only flowed one-way via transmission lines toward the consumption areas. As stated in the Sixth Strategic Energy Plan, since fewer suitable sites are available for construction of large-scale solar power plants, it is necessary to install solar-power-generation facilities on the roofs of houses, on idle land in municipalities, and in various other locations where solar power has not been introduced before. As a result, power will flow "in" from the extremities of the power network in a manner that was not previously anticipated. Dealing with this new trend will also be a challenge.

3. Our approach

As for transitioning the electricity system to generation from renewable-energy sources and promoting decarbonization, two issues must be addressed: (i) coordinating the ability to balance supply and demand and (ii) managing the new electricity network. Sony CSL has focused on "microgrids" as a mechanism for utilizing distributed renewable energy. A microgrid is a distributed power system that enables control of the balance between demand and consumption in a small, regional (community size) basis, stable operation of the electricity system, and connection with existing power systems. A microgrid is a distributed power system that generates, stores, and distributes the electricity consumed within a certain area while being able to adjust locally. OES is a concept centered on a distributed power system that utilizes this microgrid mechanism to maximize the use of renewable energy and achieves regional energy circulation. As for the core technology of OES, we have developed the "autonomous power interchange system" (APIS), which is a control technology that establishes a microgrid by autonomously matching supply and demand on a one-to-one (peer-to-peer) basis and flexibly adapting

＊1 Kotaro Jinushi's affiliation is as of January 2023.
＊2 Daisuke Kawamoto's affiliation is as of January 2023.

the power supply by utilizing storage batteries connected by DC private lines.

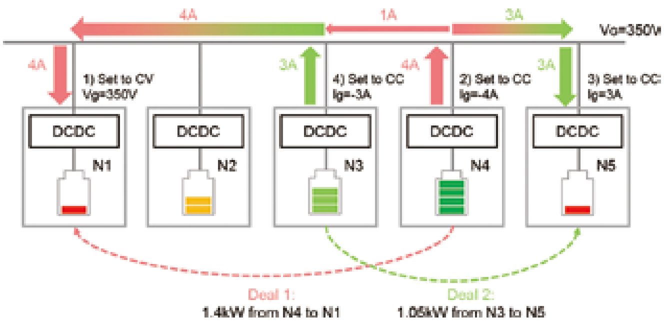
4. Our technology

As explained below, APIS consists of two technologies: (1) physical peer-to-peer power interchange and (2) autonomous distributed cooperative control.

(1) Physical-peer-to-peer (PP2P) power interchange

A feature of this technology is that power is interchanged between storage batteries by using constant-current control to adjust the power balance between the storage batteries. In the case of conventional power interchange using voltage control, it is difficult to achieve quantitative power interchange within a single power network. Constant-current control enables PP2P power interchange through flexible battery combinations such as many-to-many, one-to-many, and many-to-one, so it becomes possible to adjust the balance between demand and supply. PP2P power interchange between five storage batteries in a DC power network is shown schematically in Figure 1.

■ **Figure 1: PP2P power interchange**



(2) Autonomous distributed cooperative control

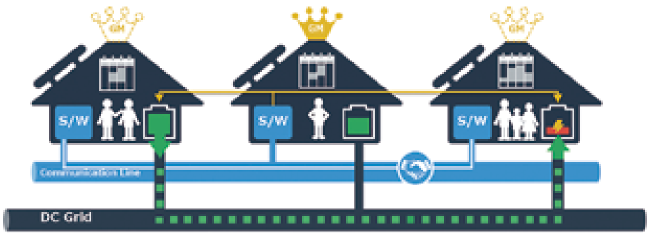
As for APIS, each storage battery is controlled by software with the same functions. The software transfers power according to the trading conditions set for the storage batteries, i.e., target SoC (state of charge) for each time period, amount of electricity to be interchanged, electricity prices, etc. (hereafter, simply "conditions"). Each storage battery periodically compares its "conditions" with the target SoC and offers to interchange power flexibly with the other storage batteries. The battery receiving the offer checks its SoC and other conditions and decides whether to accept the proposal. If it accepts the offer, a deal will be concluded, and power will be interchanged (Figure 2). This conditions for each storage battery can be set in units of time. The conditions can be changed all at once from the server side. While each storage battery can autonomously perform power interchange, it is also possible to control power interchange from the APIS control center side.

Combining these two technologies has the following two benefits.

Effective use of renewable energy: By exchanging power between storage batteries, it is possible to adjust the supply-and-demand balance of renewable energy (the amount of which is generated is expected to fluctuate) and use it effectively.

Regional circulation of energy: Controlling the charging and discharging of individual storage batteries by using APIS makes it possible to collect surplus electricity within a certain region at specific facilities. It will also be possible to transfer surplus electricity to the large batteries of EVs and transport it to the place that it is needed in a manner that achieves "energy circulation" within the region.

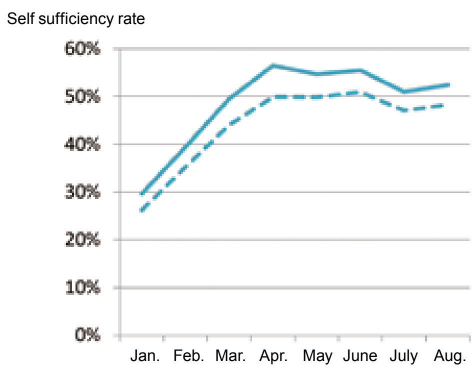
■ **Figure 2: Autonomous distributed control of household power supply by APIS**



5. Example demonstration of OES

We first tested APIS at 19 residences for teachers on the campus of the Okinawa Institute of Science and Technology Graduate University (OIST). Solar panels and storage batteries equipped with APIS were installed at each residence and operated from December 2014 to March 2020. (This demonstration experiment was selected as Okinawa Prefecture's "Subtropical Island-type Energy Basic Technology Research Subsidy Project" and was conducted as a joint venture with OIST, Okisokou Co., Ltd., and Sony Business Operations Corporation). This experiment demonstrated that a new distributed power system can be constructed in parallel with the conventional power system, operate stably, and consume more renewable energy than simply installing solar panels and storage batteries at each home (Figure 3).

■ **Figure 3: Effects of power interchange in Okinawa**



Simulation from OIST's actual data (from 2015)

APIS can be constructed relatively easily by connecting each storage battery with a private DC line. However, installing new private DC lines faces issues such as high installation cost, which limits the locations where they can be installed. With that issue in mind, we are expanding and demonstrating APIS to enable power interchange similar to that described above by utilizing AC distribution lines that are already installed.

The location of the expanded demonstration of APIS is Umaba School Cottage, a "workcation" facility in Shiraji Umaba, Ikeda-cho, Miyoshi City, Tokushima Prefecture (Figure 4). Since October 2021, a power-interchange demonstration experiment using storage batteries (Figure 5) connected to the AC wiring of this building has been conducted in collaboration with the Consortium for the Creation of Environmentally Friendly Workation Models, a consortium of industry, government, and academia.

■ Figure 4: Umaba School Cottage and solar-power generation

■ Figure 5: Installed storage batteries (Murata Manufacturing Co., Ltd.)

At the same time, we are verifying the charging and discharging of fixed amounts of electricity from EV storage batteries via CHAdeMO using ECONET-Lite. In 2023, a battery-storage system and expanded APIS were installed at other facilities in the city. We plan to implement two-way power interchange between multiple points (i.e., those facilities) by using an actual power-distribution network and EVs.

We want to demonstrate that this battery-storage system and expanded APIS can be used to effectively utilize renewable energy, contribute to the decarbonization of the region, and promote the circulation of energy within the region by supplying surplus daytime solar power generated by households in the region to community centers that consume electricity during the daytime.

6. Future developments

Our goal is to implement a new distributed power system, mainly based on renewable energy, to promote decarbonization and increase regional energy independence. To help achieve this goal, APIS was released on an open-source basis in December 2020[4]. We hope that this open-source release will promote open innovation and that we can introduce APIS widely. We are also thinking about redefining APIS for matching surpluses and shortages of various goods and expanding it into a system that combines excess and shortages in the flow of goods and people within a certain area in a way that makes efficient use of them.

For example, when EVs are recharged in areas with electricity surpluses and transported to places with electricity deficiencies, people can be transported in those EVs, thereby contributing to secondary transportation in those areas. We are also considering combining APIS with smart agriculture. When the timing and quantity of agricultural crops to be harvested are estimated, if a surplus of agricultural produce is estimated, it can matched with the demand of organizations within the region and supplied to them. We believe it is possible to expand APIS to such an intra-regional distribution system. Pursing these kind of distributed systems that are not limited to electricity, and their social implementation, cannot be achieved by Sony CSL alone. We therefore strongly desire to promote APIS while co-creating it with various organizations.

(This is a translation of the January 2023 issue of the ITU Journal)

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[4] Sony CSL APIS https://github.com/SonyCSL/APIS

APT Training 2023

— Developing fundamental network planning skills in regional communities to bridge the digital divide —

The ITU Association of Japan
International Cooperation Department

Since FY2017, the ITU Association of Japan has been conducting an Asia-Pacific Telecommunity (APT) training program*1 as a human-resource development support program to teach network planning skills, in an effort to eliminate information disparity in urban and rural areas of developing countries, in the APT.

Over the eight days*2, from October 11 to 20, 2023, we held a face-to-face training program for the first time in four years, since 2018. This year, the training was held approximately one month earlier than most years, so there was only about one month—less than usual—to recruit participants, but with the help of the APT administration, nine trainees were selected from the APT. One was selected from each of Laos, Maldives, Mongolia, Nepal, Palau, Philippines, Sri Lanka, Thailand, and Tuvalu. The trainees stayed at the Hotel Sunroute Plaza Shinjuku, near the south exit of Shinjuku Station in Tokyo, and the training was held in a meeting room on the fourth floor of a building next to the hotel.

In an effort to eliminate information disparity in urban and rural areas of developing countries, trainees gained skills to analyze the state of communication networks in their countries, to use basic network design methods for eliminating information disparity, and to apply those methods designing a communications network optimized for their region. The trainees were given to several tasks. Before the training, each trainee had to submit a country report analyzing the state and issues with communication networks in their own country. Then, at the end of the training period, they had to select an under-populated area in their own country, study what would be the best type of network for that area using the network design skills they had learned, and submit an action plan summarizing the results of their study.

The training proceeded with lectures and drills for practice. Mr. Takayoshi Hamano, formerly of NTT, conducted the "Network Planning" lectures and drills, regarding technical skills for overcoming digital disparity. To complement this, "Optical Fiber" lectures were given by Mr. Kazuhide Nakajima, who is from NTT.

The schedule for the eight-day training program was as follows.

- Day 1 AM Orientation , Opening ceremony
  PM Presentation of trainee country reports, Welcome reception.
- Day 2 AM Presentation of Japan country report
  PM Lectures by Mr. Hamano, Mr. Nakajima.
- Day 3 Visit to Kanagawa Institute of Technology
- Day 4 to Day 6 Practice with various drills
- Day 7 Create an action plan
- Day 8 AM Presentation of action plans by trainees, closing ceremony, farewell lunch meeting

A detailed description of each day follows.

The first day began with an orientation, providing guidance regarding the training program. This included an overview of the schedule and the area surrounding Shinjuku station. An ice-breaker was then held to help diffuse any tension, in which trainees introduced themselves to each other in pairs. An opening ceremony was held in the afternoon, with an opening greeting by Mr. Yujiro Hayashi from the Ministry of Internal Affairs and Communications (MIC) (Figure 1). This was followed by presentations of country reports,

Figure 1: Group photo from the opening ceremony

*1 A training program to convey Japanese technologies and services to communications technologists and government-related people in APT member countries, using funding contributed by the Japanese government.
*2 Excluding the weekend (Saturday, Sunday)

Figure 2: Country report presentation

Figure 4: Group photo from Kanagawa Institute of Technology

which trainees were required to prepare beforehand (Figure 2). The trainees presented the state of telecommunications in their countries, including issues such as the digital divide, with local data such as the various regions, population, geography and the available equipment and facilities.

Through the presentations and Q&A sessions afterward, participants shared the state of the telecommunications environment in their countries with the lecturers and other participants. A welcome reception was held after presentation of the country reports, helping to build closer relations among the trainees and with the lecturers and secretary staff. In the morning on Day 2, the ITU-AJ Secretary General, Kazuhiko Tanaka, gave a presentation on the state of mobile communications in Japan as a country report for Japan. In the afternoon, Mr. Hamano gave a lecture on network planning and wireless technology, which trainees would work on starting on Day 4 (Figure 3). Finally, Mr. Nakajima from NTT gave a lecture on optical fiber, providing the trainees with details of optical fiber technology.

On Day 3, trainees visited Kanagawa Institute of technology, so they could see an advanced technology research facility in Japan (Figure 4). In the morning, trainees learned about smart-house technology in a lecture by Kanagawa Institute of Technology Professor Masao Isshiki. In the afternoon, they visited the university's smart-house experimental building, and learned how smart-house technology is actually being used through explanation and demonstration (Figure 5). This was followed by tours of various other university facilities.

Figure 3: Network planning lecture by Mr. Hamano

From Day 4 to Day 6, trainees studied basic network design methods through practice and discussion, using drills created from different types of geographic data on each of the three days.

During the mornings, the lecturer would explain the drills, and individual students would think about a network plan for that geography. In the afternoon, trainees divided into three groups to discuss the network plan for the geography in that drill. This discussion was repeated two or three times, rearranging the groups, to derive the best network plan. Finally, a representative from each group presented their best network plan, and the lecturer gave comments regarding the presentations to evaluate them (Figure 6, 7).

Figure 5: Tour of smart house test facility at Kanagawa Institute of Technology

Day 7 was for creating presentation materials regarding the action plan. The trainees selected a region in their country, considered concrete aspects of this area

Figure 6: Group discussion for a drill

Figure 7: Presentation after group discussion for a drill

such as population, geography and available facilities, investigated an optimal network plan for eliminating the digital divide, and prepared the materials.

On the last day of the training, trainees presented their action plan (Figure 8). The lecturer and other trainees held Q&As about the presented action plans, which led to lively discussion. After presentation of the action plans there was a closing ceremony, where ITU-AJ General Secretary, Mr. Tanaka, presented each trainee with a certificate for completing the training (Figure 9). This was concluded with each trainee giving their comments regarding the training program. After the ceremony, a farewell luncheon was held at a Japanese restaurant, where they enjoyed a soba and mini-donburi lunch.

Figure 8: Action plan presentation

It has been four years since training was held in-person, so we gave consideration to having a training environment that would encourage active discussion among participants. One effort was to provide drink and snack catering in the training room, to encourage more active communication among trainees and with lecturers and secretary staff. The trainees gathered there during each break and it became a good communication tool. A second effort was to prepare large printed maps showing the regions for each of the drill problems, so that the network plan could be drawn directly on the map. This also encouraged discussion. We arranged the desks into the three groups for group discussions, so that trainees could sit around the map while discussing the problem. We also rearranged group members for several discussions so everyone could hear a range of opinions when studying network plans, to help create more-comprehensive network plans. Each day we had a representative from each group present their network plan, but we also tried to ensure that everyone had a chance to give a presentation. As a result of these efforts, we received action plan reports from all of the trainees on the final day.

Because telecommunications technology advances so quickly, we want to consider selection of lecture content and locations to visit so that participants are exposed to the latest technologies. Although the basic concepts of designing and building communication networks do not change much, we also want to ensure that the content of drills are reviewed appropriately, according to the latest trends in communication technology, so that we can offer a more meaningful training program.

In conclusion, we would like to offer sincere thanks to everyone at the APT and MIC for their guidance and cooperation in offering this training program, to Mr. Hamano for his efforts preparing lecture materials and guiding the trainees, to Mr. Nakajima from NTT for his lecture, to Prof. Isshiki and to all others from Kanagawa Institute of Technology for their help with the lecture and facility visit.

Figure 9: Presenting completion certificates

= A Serial Introduction Part 3 = Winners of ITU-AJ Encouragement Awards 2023

In May every year, The ITU Association of Japan (ITU-AJ) proudly presents ITU-AJ Encouragement Awards to people who have made outstanding contributions in the field of international standardization and have helped in the ongoing development of ICT.
These Awards are also an embodiment of our sincere desire to encourage further contributions from these individuals in the future.
If you happen to run into these winners at another meeting in the future, please say hello to them.
But first, as part of the introductory series of Award Winners, allow us to introduce some of those remarkable winners.

Masamune Nakakita
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Fields of activity: New Business Development in South-East Asia

Providing value-added services and implementing smart city in collaboration with partners in Vietnam

I am very thankful to have received this prestigious Encouragement Award from the ITU Association of Japan. I would like to express sincere thanks to all at ITU-AJ and the many others who have offered their guidance and cooperation in these activities.

During the four years from 2017 to 2021, I worked to provide value-added services at OCG Technology JSC in Hanoi, Vietnam, which is a joint venture between the NTT East Group and the VNPT Group, a national telecommunications provider in Vietnam. After returning to Japan, I worked on new business development in South-East Asia, and mainly on smart-city development projects in the Bình Dương province of Southern Vietnam.

To expand the service platform business that VNPT is providing to the Vietnamese market, I particularly coordinated among various Japan and Vietnam partners in areas where Japan has experience, such as cloud gaming and mind-training content, from localization to preparation for implementation.

I later lead a smart-education solution project for elementary schools in Vietnam, involving tablets, electronic blackboards and a cloud-based classroom support system, from trial to launching a commercial service.

In the most recent two years, I have been studying ways to implement a smart city plan quickly in Southern Vietnam. For example, we are planning a population flow control system that uses camera video and AI analysis to shed light on the behavior of residents, linked to transit and other services. Implementing this will require high-speed connectivity such as Local 5G, conforming to O-RAN, and also applications provided on that platform. I look forward to continuing this work and collaborating more closely with everyone at the ITU active in these various fields.

Yuki Matsumura
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Fields of activity: 3GPP RAN1

Contributions to 3GPP RAN1 standardization

I am very honored to have received this prestigious encouragement award from the ITU Association of Japan. I would like to express my sincere gratitude to all at ITU-AJ and everyone else involved. Since I joined NTT DOCOMO in 2014, I have been working on 3GPP standardization. For the first three years, I worked on simulation of standard techniques. Since 2017, I have attended 3GPP RAN1 meetings.

One interesting practice in 3GPP RAN1 is to continue discussion until none of the companies raises any concerns regarding the proposal. Any delegate in any company attending the RAN1 meeting has a right to speak their views or raise concerns regarding the proposals, which I think is a fair practice that can help avoid overlooking potential issues. On the other hand, sometimes it takes a long time to reconcile companies' views on an argument. In the last stage of Rel. 15 (i.e., the first release of the 5G standard specification) in 2017, the discussion sometimes started in the early morning and ended at midnight. In addition to the official meeting, there were several offline discussions to exchange companies' views in detail. It was very hard work, but I felt a sense of accomplishment when I first read the finalized standard specification for Rel. 15.

Since 2022, I have taken the role of moderator for the topic of Multi-Input-Multi Output (MIMO) in RAN1 for Rel. 18. Although it is not easy to coordinate different views from different companies, I feel it is very interesting when we converge after extensive discussion and reach agreements. I will take this award as encouragement and continue my effort to contribute to 3GPP standardization activities.

通巻百四十二号

定価　一冊　一、六五〇円（本体価格　一、五〇〇円、消費税　一五〇円）　年間購読料　六、六〇〇円（本体価格　六、〇〇〇円、消費税　六〇〇円）

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