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New Value-Creating Solutions Starting From IoT

Fuji Electric

Innovating Energy Technology

FUJI ELECTRIC
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New Value-Creating Solutions Starting From IoT

The fundamental value of the IoT is in connecting everything to the Internet, gathering data to create new value. Today, a variety of IoT solutions have been launched as key technologies to address various challenges in society, such as enhancing product quality, improving productivity and reforming work style. These are expected to further spread in the future.

Fuji Electric has offered solutions to optimize energy management and operation of facilities and equipment, and it is accelerating its efforts to create higher customer value while putting the IoT into practical use.

In this Issue, we present our new value-creating solutions using the IoT. We also introduce the IoT platforms to efficiently implement them, together with the data analytics that perform analysis, prediction and optimization.

Cover Photo:
A quote from the catalog "Fuji Electric System Solutions"

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Contents

Preface

In the Era When Everything Is Connected

KANO, Manabu*

The word “Internet” takes me back to when I was still a graduate student. It was the early 1990s, and not many people, even in the university, were aware of emails or the worldwide web (WWW). I with my seniors installed yellow cables (10BASE5) in the university building to connect laboratory work stations to the network and browse only a few websites that were available using NCSA MOSAIC (a web browser developed at the University of Illinois). Those days, almost nothing was connected to the Internet, except for those expensive workstations. The current digital native generation may not even be able to imagine such a ridiculously inconvenient world. Certainly, it was hard task to organize work; papers for international conferences arrived by airmail, and we would have to organize them manually. Conversely, if I went on an overseas business trip, I would be free from work-related requests. It was such a slow-paced era.

More than 20 years have passed since then, and various things are connected to the Internet. Not only that, cloud computing has enabled us to analyze big data on the Internet. These systems are today known as the Internet of Things (IoT). It is attracting much attention as potential technology for social revolution and business opportunities. According to the Gartner Hype Cycle 2018, IoT platforms have passed the period of Peak of Inflated Expectations and entered the Trough of Disillusionment stage.

The smart watch, the latest popular item, is a good example of the personal IoT. It gathers and analyzes various data with various sensors such as acceleration, gyro, pulse and GPS, and gives us advice for optimal feedback on exercise. More recently, we also hear more often about human microchip implants. Sweden, where the population is approximately 10 million, is keenly pursuing this new technology, with several thousand people already having a microchip implanted. In 2017, the Swedish State-owned Railway Company introduced a system that allows you to get on a train with an implanted microchip. This implanted device can gather biometric data more accurately than wearable devices such as a smart watch. The microchip can store all the smart cards inside your body, and it also serves as highly valuable sensors to monitor the state of your health. When information about humans is connected to the network, it will evolve into the Internet of Humans (IoH). While there are security and ethical issues still to be discussed, the technology is advancing steadily, backed by human curiosity. The era of the Internet of Everything (IoE) will be coming where not only objects, but humans, and everything else are connected to the network. New innovative services will be provided and change our lifestyles significantly. It seems a completely different age for me compared to when I installed yellow cables.

This conjures up a picture full of hopes and expectations, but I fear that some of us may struggle to catch these giant waves of change in the fields of manufacturing and medical care in Japan. For example, it is said that explosion-proof regulations are preventing the introduction of IoT devices at manufacturing sites. Even if the government encourages smartification, Japan-specific regulations are hindering such an initiative. Thus, these kinds of structural issues should be addressed promptly and wisely, along with technological issues.

The vast amount of data taken from humans and things would serve for nothing if it was merely stored at a massive data center. It is thus necessary to develop a system that extracts valuable information from the data and prompts appropriate actions. While I do not agree with the latest loose trend to consider multiple regression analysis as a part of artificial intelligence, it is true that machine learning technology, including deep learning, is making remarkable progress so that extremely complex data analysis can be done by computers. However, useful tools are not so useful if there is no one who can leverage them. It will not be easy to change the policy of organizations that had been rather indifferent to data analyses until recently. Fostering talented people is one of the major challenges to be addressed.

Facing the world that is oriented to the Analytics of Everything (AoE), there is something we cannot leave to computers yet; it is to determine the visions to be aimed at. In the world where things and humans are connected to the network, how do we want society to be, and what should we do to realize that society? At this time of transformation, we will be asked to have determination and act, to provide value to society, and to think about what value is to be created, with wide perspectives, rather than settling for a local optimization.

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New Value-Creating Solutions Starting From IoT: Current Status and Future Outlook

YASUKAWA, Yukio* YASUKAWA, Kazuyuki* FUKUZUMI, Mitsunori*

1. Introduction

The general meaning of the Internet of Things (IoT)*1 is that anything is connected to the Internet and data are shared and visualized. Its essence is to generate new customer values from the collected data and contribute to society with the values. Currently, various solutions have been disclosed as key technology not only for quality improvement and optimization but also for solutions to social issues such as work style reform, and greater usage of IoT is expected in the future.

Fuji Electric has been providing solutions for over 40 years that contribute to power stability and optimization, factory productivity improvement and energy savings, clean energy supply, food safety and security, etc. It has done this by continuing to innovate in the fields of energy and environmental technology and using competitive components and sophisticated control technology. Today we are more quickly implementing efforts to create higher customer value*2 by practically applying IoT.

This paper describes the current status and future outlook for efforts for new value-creating solutions with the use of such IoT by Fuji Electric.

2. World Trend in Customer Value-Creating Technology with Use of IoT

IoT and value creation utilizing IoT has been studied actively on a global scale.

This chapter describes the trends in Germany, the United States and Japan.

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2.1 Germany

Industrie 4.0, an issue tackled since 2013 in Germany, has changed its direction toward expansion from the viewpoint of value creation. It has gone from searching for a place to apply the concept to value creation and value improvement by cooperation and linkage with other fields. Hence, its concept has matured and proliferated steadily.

Linkage not only within Germany but also with the United States and China has been developed from the viewpoint of cooperation and linkage. A cooperation agreement with Japan was made in March 2015, and it has led to specific activities such issuing a joint statement.

In addition, a study on standardizing technology is also underway. It is remarkable that proposals for using the existing and specific standardizing technology, represented by the information model, OPC-UA and AutomationML, are progressing steadily.

2.2 United States

The Industrial Internet Consortium (IIC) established in 2014 under a civilian initiative has steadily increased its members. More than 260 companies including Fuji Electric and other Japanese companies have joined the consortium.

The 2 main activities in IIC and their statuses are as follows:

(1) Study on technology and security architecture

Discussions about Reference Architecture, disclosed also to non-members, are held continuously. Its own level of maturity has been developed and peripheral detailed technology arrangements are making progress. Security-related discussions have been active and other organizations are paying attention to the situation.

***1: IoT**

Abbreviation of the Internet of Things. In a narrow sense, it refers to a system where anything is connected to the Internet and information exchange is mutually executed. Currently it refers to the whole service realized with the system that generates new values. This concept comes from the fact that we now have Internet connection and data distribution and control at low cost along with information communication technology innovation.

***2: Customer values**

It refers to values recognized by customers to be appropriate for products, services, human resources and images.

(2) Field verification (test bed)

The ecosystem*3, centered on IIC members, is formed and architectures and concepts are demonstrated and verified. More than 80 companies participate and test beds are proposed actively, and 29 cases have been proposed and approved as of May 2018. Some cases indicated efforts beyond the frame of simple demonstration and verification. One example is "Intelligent Urban Water Supply" test bed, which aimed for water-supply operation optimization and improvement, where the demonstration target has been commercialized and many providers have actually verified the possibility of its introduction. In addition, a liaison conclusion has been completed with 38 organizations who participate in Industrie 4.0 as of May 2018, expanding the connection with other organizations.

2.3 Japan

In March 2017 in Japan, the Ministry of Economy, Trade and Industry proposed the Connected Industries concept as the direction for industries to head in. Each organization continues activities to realize this concept, and some organizations such as the Robot Revolution & Industrial IoT Initiative and the Industrial Value Chain Initiative disclose their activity results.

In addition, to use results and experiences in field systems that are a Japanese advantage, a study on "Edge Computing" that creates values in high-speed near equipment or machines without the Internet and LAN is underway. Ecosystems such as the "Field System" and the "Edgecross Consortium" have been formed since 2017.

3. Fuji Electric's IoT and Efforts for Customer Value Creation

3.1 Position of IoT in Fuji Electric

Fuji Electric positions power semiconductors and sensors as key devices and has a line-up of high-performance and high-functionality components that use the key devices. Furthermore, we contribute to the creation of responsible and sustainable societies through power generation, energy solutions, industry solutions, food distribution and other fields with these components, engineering technology, service technology, advanced optimal control technology and various solution technologies. We position the IoT system, which is a framework to digitalize any information of customer fields and create new customer values in cyberspace, at the core of the system solutions as shown in Fig. 1.

3.2 Customer value and creating technology

Fuji Electric classifies customer values in individual manufacturing industries into 4 categories: energy use optimization, facility operation optimization, operation optimization and human resource utilization optimization (see Fig. 2).

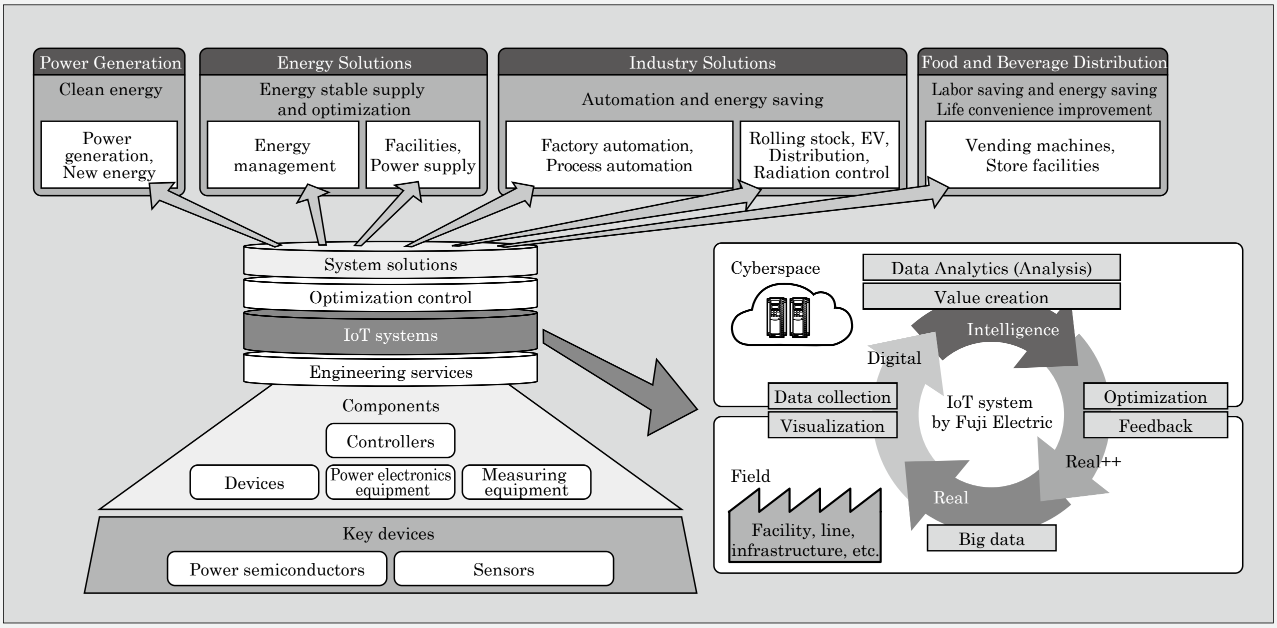

Fig.1 Fuji Electric system solution and IoT positioning

***3: Ecosystem**

Originally it meant an "ecological system" in biology. In management and IT fields, it is a system where multiple companies establish a partnership in product development and business activities for coexistence and co-prosperity beyond the industry frame and boundary utilizing each other's technologies and capital, involving developers, agencies, sales shops, advertising media, consumers and societies.

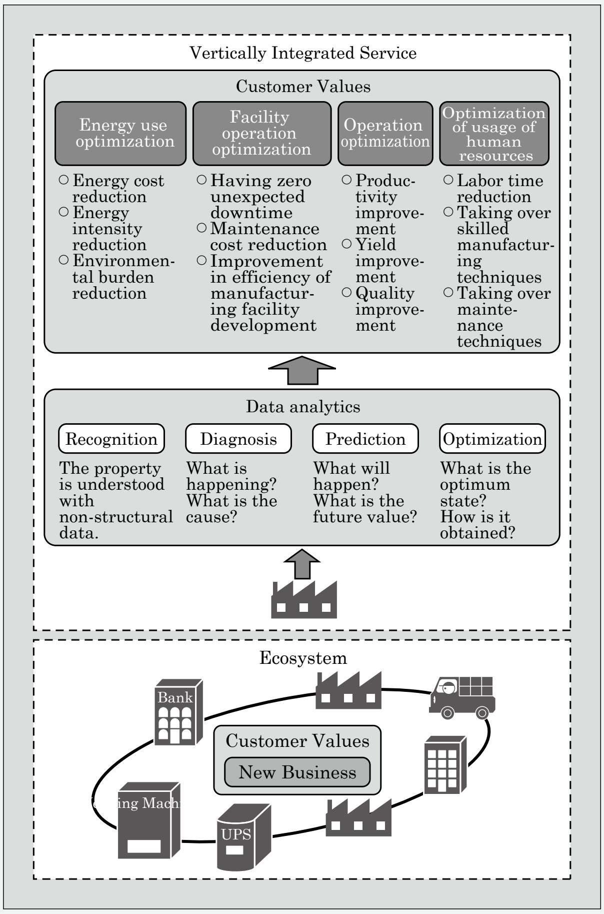

Fig.2 Customer value and creating technology

The technology to create these values is called data analytics and it consists of 4 technologies: Recognition technology, diagnosis technology, prediction technology and optimization technology. We provide a one-stop service from field data collection to customer value creation using data analytics and call the service a vertically integrated service.

Furthermore, the ecosystem, where companies of different industries cooperate with their strengths, generates new values.

3.3 Customer value creation solutions

This section describes the development cases for the customer value creation solutions described in Section 3.2.

(1) Energy optimization solutions

Reinforcement of energy regulations and standards has been progressing globally to reduce CO_2 emissions as global warming countermeasures. The target value for energy operation efficiency for companies has become severer as part of this effort. To achieve the high target, a company must make efforts integrally under a unified control method. ISO 50006, the energy management international standard, specifies that various energy optimizations (energy intensity reduction, energy conversion efficiency improvement, etc.) are managed by a unified method. This is accomplished by defining the energy management unit (EMU) for each building and device which are energy management targets, and then defining the energy intensity*4, operation efficiency and other energy performance indicators (EnPI*5) for each EMU. Fuji Electric has developed an energy management system which conforms to this standard. When the energy intensity worsens, the degree of deviation from the target, etc. can be monitored and energy loss factor analysis, which conventionally has been dependent on experienced engineers, is executed by automatic diagnosis with data-analytic system using result data (refer to "Improvement of Energy Efficiency According to International Standards-EMS Add-On Functions Using Data Analytics" on page 109).

Energy used at steelworks is classified into purchased energy and by product energy generated in production. The most important challenge for energy management in a steelworks is to balance the demand and supply of these energies according to the production situation and reduce wasted energies. For overseas steelworks, we have developed the "EMS-Package LITE" energy optimization package for power generation facilities that can be introduced and operated at low cost to settle this issue. This system automates the act of preparing a demand prediction model and plant model that conventionally required trial and error by an expert for several months. Energy management operators in a customer company enter power generation facility information (the number of boilers and turbines, facility characteristics information, etc.) and the past operation result data in the steelworks into an Excel sheet with the specified format. When this Excel sheet is uploaded to the system, data-analytic system automatically generates 6 models (purchased power cost, power receiving cost, dissipation

***4: Energy intensity**

Total consumption amount of power, gas, oil and other energies required to produce products of the unit amount. It is used as an index to see the energy saving progress status because it indicates the energy efficiency.

***5: Energy performance indicator (EnPI)**

Measureable results related to energy use amount, energy use purpose, and energy efficiency are together called energy performance. Specifically, they are energy use amount, peak power, energy consumption amount by purpose and various energy efficiency items. Their quantitative values (or scale) specified by an organization are called energy performance indicators (EnPI). They correspond to a ruler to measure energy performance and any indicators can be used for each purpose at the judgment of the organization.

amount, boiler fuel distribution, turbine steam distribution and turbine bleeding distribution) by improvement purpose and visualizes the scope for improvement to display it on a monitor. Furthermore, data-analytic system automatically generates an optimal operation plan for a power generation facility that is required for improvement. When the operator of the power generation facility executes the optimal operation according to this plan, the energy operation efficiency target value can be reached (refer to "'EMS-Package LITE' Energy Optimization Package for Power Generation Facilities" on page 114).

(2) Labor time reduction solutions

Labor shortages and an increase in personnel costs are growing in domestic convenience stores with an aging population and lower birthrate in Japan. It is difficult to immediately make convenience stores unmanned like ones overseas because they mainly have characteristics as a social infrastructure and provide various services; however, labor saving by improving the current work is required. Fuji Electric has been developing element technologies for smart showcases to achieve unmanned stores for labor saving in the future. In convenience stores, generally goods such as rice balls, sandwiches and lunch boxes are displayed while arranged in columns. There are many operations to be executed by a clerk, such as constantly monitoring the state of goods displayed, moving items to the front side when the head item is purchased, refilling and checking the freshness of goods. Smart showcases automatically detect the names, quantity and states of the displayed goods to reduce the work. This system consists of the product identification technology that uses image recognition technology with a camera and the product position recognition technology that uses the panel sensors using projected capacitive touch panels allocated in matrix state on a shelf surface. Especially the quantity and position of goods are recognized while the bottom surface shape of goods is detected with the panel sensor. For rice balls, sandwiches and others whose bottom surface shape differ individually, data analytics technology removes noise elements for higher recognition accuracy (refer to "Smart Showcase That Contributes to Labor-Saving of Store Work" on page 132).

(3) Ecosystem solutions

Fuji Electric has a line-up of digital signage vending machines which display product images on a large display. This digital signage vending machine has a system to download image information of products to be sold and backgrounds via the Internet. If the vending machine is assumed to be an image display terminal installed inside a building or on a street, it can be applied to various businesses. Accordingly, we have developed the advertisement distribution function and demonstrated the possibility of using it as the advertisement distribution business. This business is the ecosystem that consists of Fuji Electric which provides the digital signage vending machine and the advertisement distribution system, advertising agency, advertisement owner, vending machine operator, location owner (railway company, supermarket, hospital, etc.) and consumers. We have mounted a camera to the digital signage vending machine and implemented a function to collect market information such as the number, age, gender and visual line of consumers and time in addition to distributing and displaying advertisements. The demonstration test result indicated that this market information was valid for an advertising agency in recruiting advertising owners because response of advertising targets could be estimated. In addition, it was found that for a vending machine operator, the information was valid for predicting sales based on the data and making an appropriate product allocation plan. New values are created with the ecosystem whose core is the vending machine (refer to "New Information Service Solutions Utilizing Vending Machines" on page 127).

(4) Manufacturing solutions

Fuji Electric has been tackling quality improvement and cost reduction with digitalization and utilizing IoT systems for in-house manufacturing (refer to "Manufacturing Reform Utilizing IoT Technology" on page 122).

(a) Digitalization of production preparation

Digitalizing product design information allows 3D-CAD and other simulations. Therefore, simulations on a computer are available for manufacturability verification for process design, production line optimal layout design and automation facility software verification, for which actual machine verification was prerequisite. This drastically shortens the time needed to launch a manufacturing line.

(b) Quality improvement and labor saving with data analytics

For the semiconductor sensor manufacturing process, analyzing the past manufacturing result data with a diagnosis function using data analytics makes it possible to specify the factor of low production yield. For the press process, constantly monitoring various data of a press machine and detecting signs of defects (slug float) with the diagnosis function in the same way allows for higher quality and fewer monitoring personnel.

(c) Taking over skillful techniques

Welding work often depends on the high skill of experienced engineers. Therefore, welding work is digitalized with various sensing technologies and the data are used for skill education. In addition, a robot for difficult welding work has

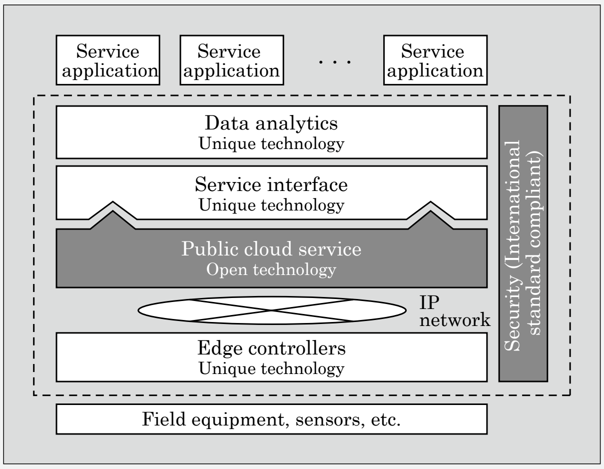

Fig.3 Structure of IoT platform

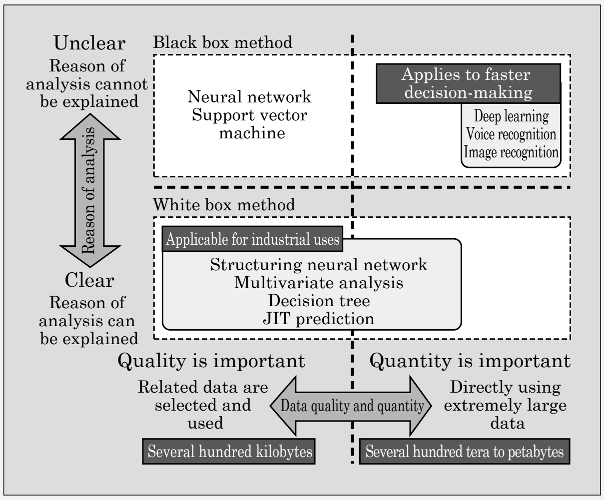

Fig.4 Classification of machine learning

been developed that uses sensing technology with image recognition to try to improve quality.

(5) IoT platform

To apply IoT systems to various solutions, it is essential to have a technology base that integrates field data collection technology, data analysis technology and advanced security technology to handle data safely. We have developed an IoT platform as such technology base. Figure 3 shows the IoT platform range, with its structure indicated by broken lines. A shortened development period, application portability and differentiation were realized with a combination of open technology such as an open source service and Fuji Electric-unique technologies (refer to "Overview of Fuji Electric IoT Platform" on page 136).

4. Future Outlook

4.1 Data analytics technology expansion

The machine learning-based analysis and reasoning technologies can be classified as shown in Fig. 4 with axes of data quality and quantity and analysis result basis. Especially for industrial use purposes, data quality and clearly indicating reasoning are regarded as important from the viewpoint of safety and reliability. Fuji Electric has focused on this area previously and continues to develop distinctive technologies and tools that can be mastered even by users who are not dedicated data scientists.

4.2 Field side value creation

The main purpose of edge controllers is to securely connect field equipment and other things to cyberspaces. Furthermore, it is necessary to enhance data values at the field side (called context data creation) such as by carrying out primary processing of collected data and synchronizing with image data so as to reduce IP network traffic. Fuji Electric has developed "OnePackEdge System" to respond to these requirements (refer to "Creating Value in Data with 'OnePackEdge System'" on page 118). In the industry and power generation fields, value creation such as diagnosis and analysis requires a response performance in milliseconds in many cases. It is impossible to satisfy these requirements via an IP network and cyberspace. Therefore, we satisfy the requirement to create values at the field side by mounting data analytic function to the OnePackEdge System.

4.3 Beyond IoT

IoT technologies, which connect things to cyberspaces, will develop to the form where things autonomously connect with each other in the future. The definition of things will include activities such as human resources and operations, and will be expanded to service*6. For services to be connected with each other, a network as a route, interface to the network (OPC-UA, etc.), information model as a common language between services and the description method (AutomationML, etc.) must be standardized. The IEC and ISO already have been jointly working on Smart Manufacturing-related standardization work. Standardizing interfaces between services allows a manufacturer to select the optimal manufacturing facility of another company

***6: Service**

A method where components are created with various operation applications or part of the functions of the applications and a new application system is designed by selecting and combining the components as needed is called service oriented architecture (SOA). The unit of the components is called Service. Although the object concept in the object orientation is included, the characteristic is that Service has a looser coupling than object so that Service can be coordinated on a network.

any time and entrust manufacturing according to the order received, for example. Simultaneously, various services can be shared by companies. This means that a company will be able to procure from the outside the innovation that is currently required and easily embed it into a system of its own.

There is an open innovation beyond IoT.

5. Postscript

This paper describes the current status and future outlook for solutions for new value creation and technical aspects of Fuji Electric while summarizing value creation with IoT which is being developed on a global level.

Fuji Electric will continue to make efforts for customer value creation paying attention to the world standardization trends and concentrating on our unique technology development.

Preferences

(1) Kondo, S; Fukuzumi, M. Instrumentation and Control Solutions in the New Age of the IoT: Current Status and Future Outlook. FUJI ELECTRIC REVIEW. 2016, vol.62, no.3, p.132-140.

(2) “Current Standards Landscape for Smart Manufacturing Systems”. National Institute of Standards and Technology U.S. Department of Commerce. https://dx.doi.org/10.6028/NIST.IR.8107, (accessed 2018-07-20).

(3) “PLATFORM INDUSTRIE 4.0 working paper Aspects of Research Roadmap in Application Scenarios”. Federal Ministry for Economic Affairs and Energy (BMWi), https://www.plattform-i40.de/I40/Redaktion/EN/Downloads/Publikation/aspects-of-the-research-roadmap.pdf?__blob=publicationFile&v=10, (accessed 2018-07-20).

Improvement of Energy Efficiency According to International Standards–EMS Add-On Functions Using Data Analytics

TATTA, Naoto* SUZUKI, Satoshi ‡ MATSUMOTO, Haruyuki*

ABSTRACT

As international regulations and standards become increasingly stringent, Japanese companies are being compelled to enhance energy efficiency by the environment situation surrounding them. Fuji Electric has reviewed current operating and developed new features for our energy management system, leveraging data analytics to improve energy efficiency in compliance with international standards. These features will facilitate the development of the framework of the SDCA cycle to maintain and manage energy-saving activities and will in turn speed up improvement, innovating activity and policy management through the PDCA cycle.

1. Introduction

Japan agreed to reduce the greenhouse gases emission by 26% compared to FY2013 by 2030 as the international public promise under "Paris Agreement" in December 2015. Ministry of Economy, Trade and Industry decided the energy innovation strategy in April 2016 to achieve the target. They set 35% energy efficiency improvement by FY2030, whose level is almost same as post-oil crisis, as the target, with "thorough energy savings" as one pillar of the strategy.

It is predicted that energy demand will increase and energy costs will continue increasing during medium and long term globally with the background of expansion in energy usage in developing countries. To support such world circumstances, the international standard ISO 50001 on energy management system (EMS) has been issued and actively introduced by overseas companies in Germany, the United States, China and other countries.

While regulations and standards are strengthened globally, in addition to the energy saving measures for each facility, finer and efficient operation of facilities according to energy demand is being required recently. Company measures of energy efficiency improvement locally or by departments has reached the limitation. Positioning the energy efficiency improvement as company management task and establishing the energy management base to proceed on improvement daily and continuously are required.

This paper presents the current operation tasks by focusing on the energy efficiency improvement with the current EMS and energy saving analysis approach. Moreover, it describes new functions of EMS that use data analytics, which contribute to the energy operation efficiency improvement according to international standards to settle these issues.

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2. Issues in Current Energy Analysis Management System

Fuji Electric has provided the energy analysis management system that uses "MainGATE/PPA" manufacturing result analysis support package (see Fig. 1) to efficiently analyze energy(1).

This package can be used to build a factory energy management system (FEMS) to analyze and manage factory energy by organically combining not only energy measurement data but also operating data of utility and production equipment, production output, and other production data. In addition, a building and energy management system (BEMS) can also be built to manage office and office building energy, namely, heat source, transport power, lighting, socket outlets, air conditioning, and other power sources. We have pro-

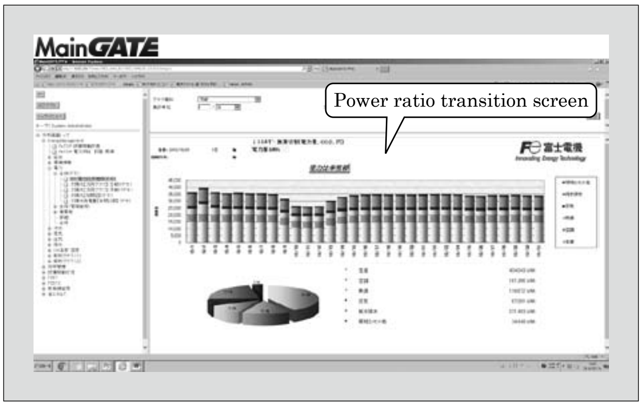

Fig.1 "MainGATE/PPA" analysis display example vided energy analysis templates based on the knowledge obtained from long time EMS construction experience to easily build BEMS systems.

Fuji Electric provides an EMS package solution for each of 3 areas below (see Fig. 2).

(a) STEP 1: Visualization
Energy data collection and visualization

(b) STEP 2: Comprehension
Multiangular analysis of collected result data

(c) STEP 3: Optimization
Whole plant optimization with usage of renewable energy, cogeneration and storage batteries

Fuji Electric has provided "comprehension" solutions to support improvement of the energy saving activities cycle (issue extraction from analysis and management and individual measures) by a customer with MainGATE/PPA. However, in many cases, the energy savings activities have not been established and cannot be executed continuously because there are 2 main issues in the operation aspect.

(1) Operation issue 1: Analysis operation process of energy saving activities

PDCA rules and judgment standards of issue extraction approach for energy efficiency improvement do not take root in the customer.

Furthermore, the human and time resources that can be allocated to analysis operation are limited and knowledge of individuals varies. Therefore, establishing and operating the series of energy saving activities analysis and operation process cannot be fixed, such as who sees what information and how the result is evaluated and operated for improvement, even if large amount of data can be collected with a lot of efforts.

(2) Operation issue 2: Crossing departments and integrated energy saving improvement activities

The energy saving activities are responsibilities of energy utility equipment departments related to the energy supply side and activities integrated with the manufacturing departments and operation departments at the energy demand side are not executed. The energy utility equipment departments would like the energy saving awareness and activities to take root in the manufacturing departments and administration departments; however, a valid measure cannot be found.

In addition, each layer-independent energy saving activities at the site are disturbed because energy management efforts have become one-way forced management requirement. However, user capability and operation system must be depended on when to use the current functions of MainGATE/PPA by Fuji Electric. Therefore, the energy saving issue settlement process (daily management, issue extraction and individual measures) cannot be established in many cases of improvement activities.

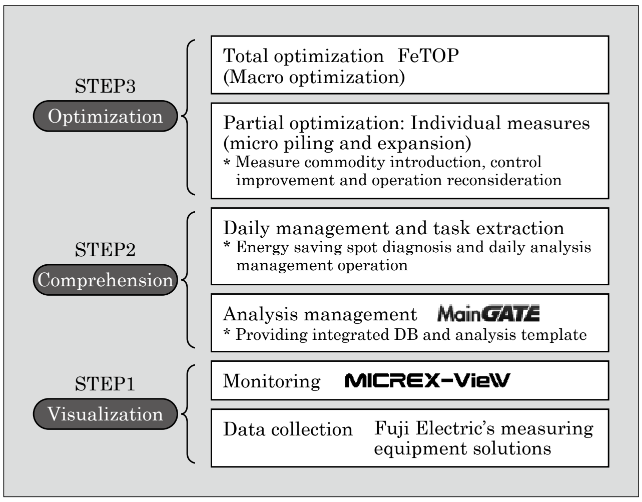

Fig.2 EMS structure by Fuji Electric

3. "MainGATE/PPA with DD" Energy Operation Efficiency Improvement Package

3.1 Development concept

Fuji Electric has developed the new functions for EMS according to ISO 50006 (energy performance measurement), standard cited from international standard ISO 50001 (EMS) to settle the issues in energy saving activities described in Chapter 2.

For the operation issue 1, we have developed the analysis function for energy loss factors of each energy management unit (organizations, lines, facilities, etc.) specified according to the management frame of ISO 50006 and the automatic diagnosis function. For the operation task 2, we have developed the general-purpose dashboard function where the energy efficiency achievement rate (results/targets), loss factors (control threshold values), etc. are displayed and operation is managed in real-time.

Using these functions allows constructing the operation environment for SDCA cycle to promote the maintenance and management activities for the energy saving activities. Furthermore, reducing loads of analysis operations by a customer allows higher speed improvement and innovation activities and policy management in PDCA cycle (see Fig. 3).

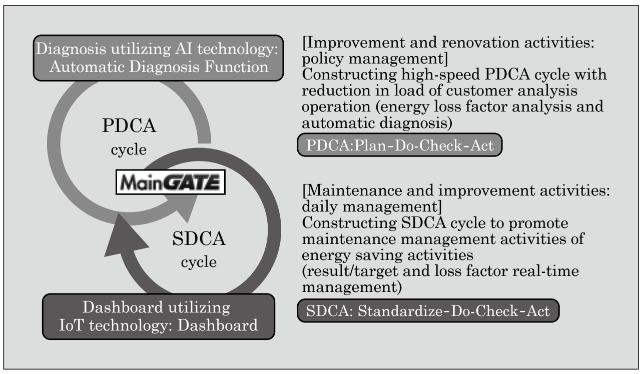

Fig.3 High-speed PDCA cycle and SDCA cycle

3.2 ISO 50006 management frame application

For the energy management, it is important to specify targets to evaluate the energy efficiency change (improvement/drop). In ISO 50006 management frame, the unit to manage some energy performance indicator*1 (EnPI) is called energy managed unit (EMU). We attach importance to daily management of energy efficiency and identifying the related variable (impact factors) that affects the energy efficiency. It is important to specify the management target standard from the past efficiency result data to manage the energy efficiency (energy consumption rate, equipment efficiency, etc.) and to manage the related variable that deeply affects the efficiency (see Fig. 4).

The energy operation efficiency improvement function is configured with EMU as the core. This system structure provides the function that organize the functions group (automatic diagnosis, real-time management function, etc.), which leads various energy operation efficiency improvement, as long as the user only defines data to be collected and their related factors on EMU (see Fig. 5).

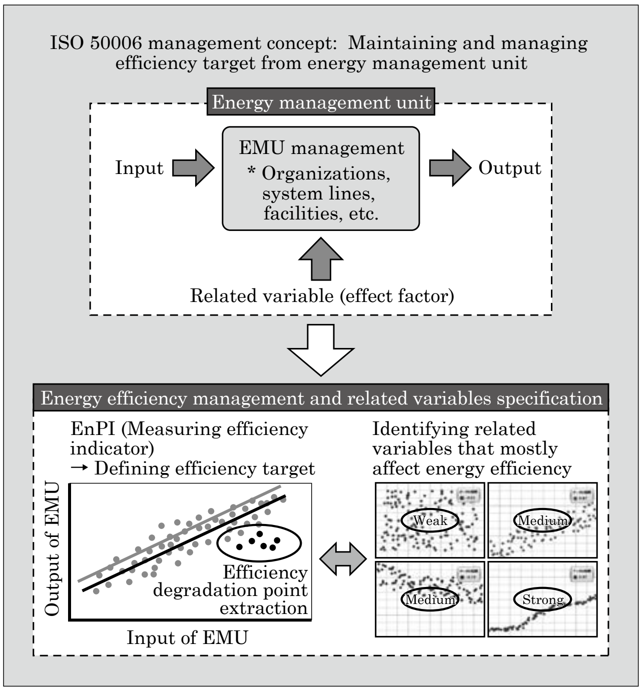

Fig.4 ISO 50006 management frame conceptual diagram

*1: Energy Performance Indicator (EnPI): Measurable result related to energy use amount, energy use purpose, energy efficiency is totally called energy performance. Specifically, they are energy use amount, peak power, energy consumption amount by purposes and various energy efficiency items. Their quantitative values (or scale) specified by an organization are called energy performance indicators (EnPI). They correspond to a ruler to measure energy performance and any indicators can be used for each purpose with judgment of the organization.

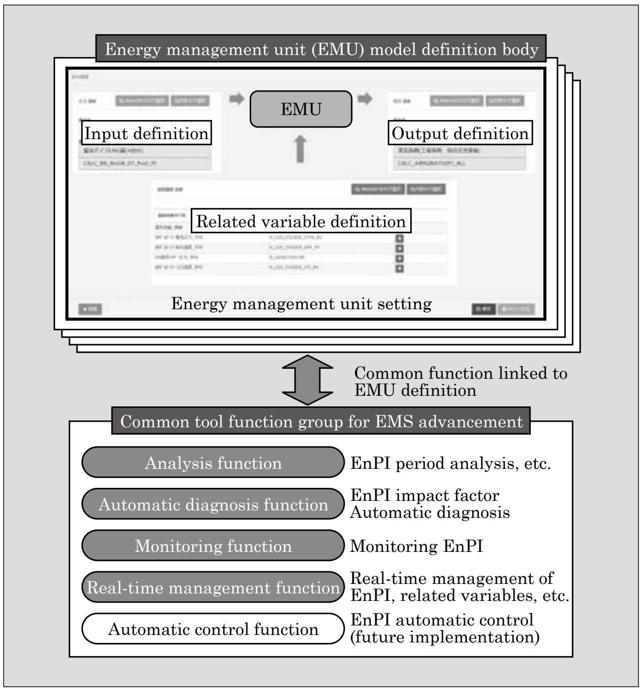

Fig.5 Modeling example based on EMU

For example, in the unit consumption management in some manufacturing process, the user assigns the consumption energy of a process for the EMU input, the production outputs of the process to the EMU output, and unit consumption-related impact factors (facility running information, operation information, etc.) to the EMU control function. After these settings, this product can analyze and automatically diagnose the unit consumption worsened period and impact factors (facility running state, etc. most contributing to unit consumption). Furthermore, deviation from the unit consumption target value can be monitored regularly with the monitoring function. The real-time management function can obtain an energy efficiency target, result separation and related factors that affect efficiency every day, providing an appropriate energy consumption-related operation suggestion on the manufacturing site. In addition, reproducing a model based on the defined EMU for the similar process and facility allows horizontal development and a new energy saving activity can be started quickly.

3.3 Energy operation efficiency improvement function (with DD)

The energy operation efficiency improvement function is an add-on function of MainGATE/PPA, developed on the basis of the development concept described in Section 3.1. It has the following major functions.

(1) Energy management unit (EMU) and energy baseline (EnB) definition function

(a) EMU definition function

EMU can be defined according to the tree layers of the units of facilities, lines, organizations and factories. Internal tags for input and output signals and factor related information of EMU are created and allocated from MainGATE/DB (database) that is the base of the data. It also has the computing function (4 arithmetic operation functions).

(b) EnB definition function

EnB is an evaluation standard (baseline) to quantify EnPI of each EMU definition in the specified period. Multiple efficiency target baselines can be defined from the past result value narrowed down to arbitrary period grouped by seasons and operation forms and operation condition for each defined EMU. In addition, the result values deviated from a normal range can be checked on Graphical User Interface (GUI) and the result value deviated on GUI can be removed to improve the baseline accuracy (see Fig. 6).

(2) Energy efficiency factor item extraction and monitoring function

(a) Analysis function in impact factor related strength calculation

When the related strength is calculated for the impact factor defined on EMU, analysis can be executed such as extracting the impact factor with high related strength based on the size of the correlation coefficient of the impact factor on EnPI for defined multiple EnB. In addition, there is a function where setting specific period data (manufacturing shift switching time, rest time, etc.) and related factor data boundary (specific temperature area, etc.) on EnB extracts the efficiency worsened point factor on GUI.

(b) Automatic efficiency monitoring function

The target baseline and alert baseline can be defined besides the baseline set with EnB definition function. The periodic monitoring function can monitor the point that is deviated from the alert baseline boundary (efficiency drop point) (see Fig. 7).

(3) Real-time management function

(a) General-purpose dashboard function

The dashboard function is included so that site operators can see information that they would like to see when they would like to see. Selecting a layer in the dashboard list (the same organization tree as

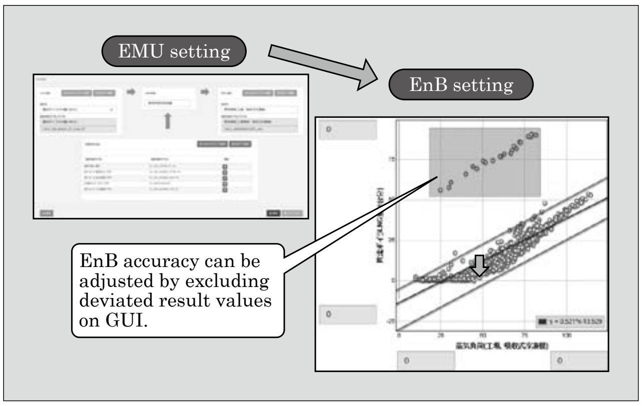

Fig.6 Baseline setting for energy management unit

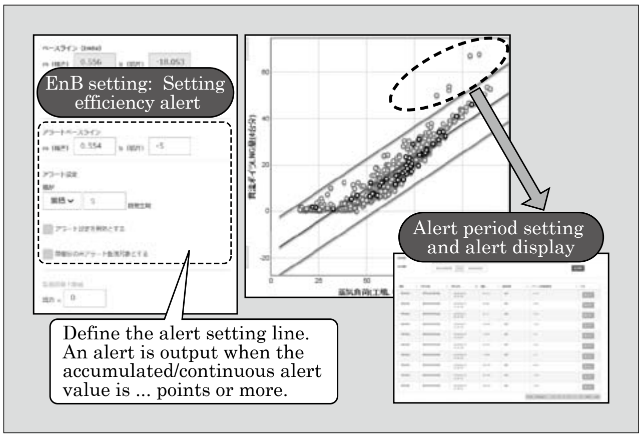

Fig.7 Energy efficiency factor item extraction and monitoring function

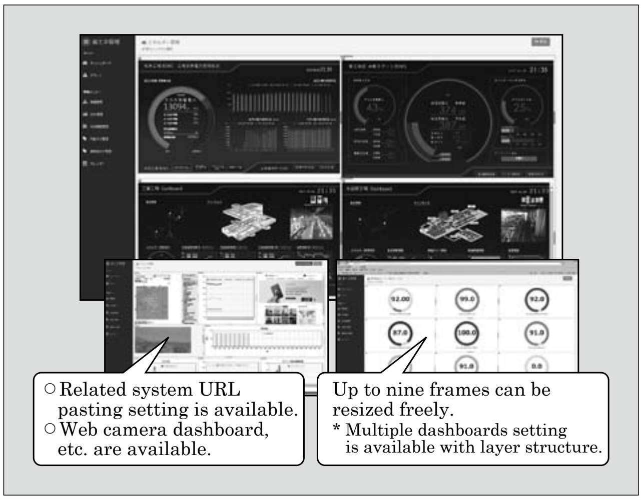

Fig.8 General-purpose dashboard function

EMU) displays the dashboard according to the setting. The dashboard can be changed to arbitrary frame size and consists of 9 frames (areas) (see Fig. 8). Each frame can display a line/bar graph, meter display, numeric value display, target/result management, simple screen creation, URL link, etc. In addition, the setting screen can be called any time to set and change the display format and display target data freely.

4. Automated Diagnosis Engine for Energy Efficiency Factors

We have developed the analytics engine to automatically diagnose the energy efficiency factors from the result data in addition to the function described in Chapter 3, to get higher speed and advancement of the analysis operation cycle in energy efficiency improvement activities.

4.1 Engine function

(1) Input to analytics engine

To diagnose the energy efficiency factors, the fac-

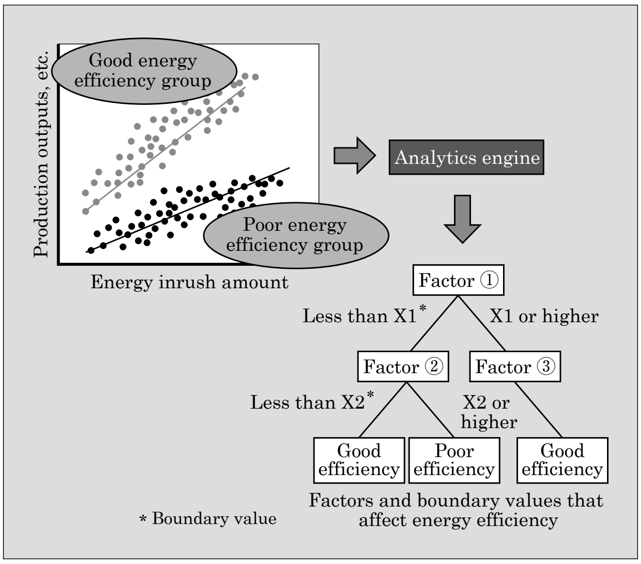

Fig.9 Analytics engine conceptual diagram

tors that generate differences between when the energy efficiency is good and when it is not good, must be extracted. Data groups with labels of good efficiency and no good efficiency each shall be input to the engine to extract the factors. These labels shall be attached based on EnB described in Section 3.2. The labels may be attached to the data groups specified by a user on GUI.

(2) Functions of analytics engine

The analytics engine learns the labeled data as teacher data and automatically creates a model to explain (predict) the label. Extracting explanation factors from the model, the user can determine the factors that significantly affect the label (good/not good of energy efficiency). In addition, values of what related variables and what period affects the energy efficiency can be analyzed because the label prediction boundary values (related variable boundary and time boundary) can be extracted (see Fig. 9).

4.2 Analysis case and evaluation

To evaluate the analytics engine functions, analysis was executed with result data of a plant (see Fig. 10).

(1) Target case

Plant utility steam supply boiler

(2) EMU definition

(a) Input to EMU: Boiler fuel
(b) Output from EMU: Steam supply amount
(c) Related variables: Boiler operation-related various measured values

(3) Analysis result

The result that steam differential pressure largely affects the energy efficiency was obtained as the factor that affects the energy efficiency of EMU defined above.

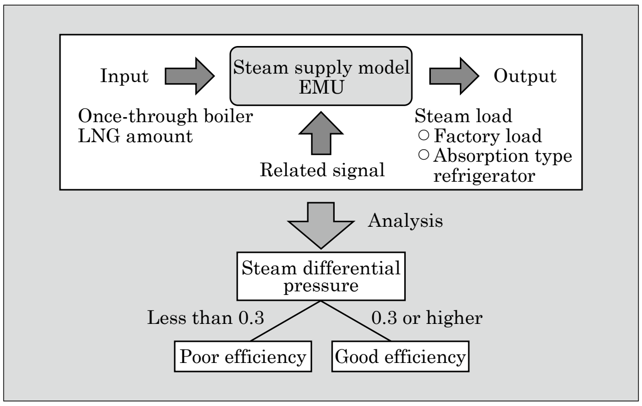

Fig.10 Analytics engine analysis case

(4) Result evaluation

The result that the steam differential pressure affects the energy efficiency of boiler operation was obtained through the analytics engine. This result was the same as the result of analysis executed by an experienced operator with a lot of manpower and time. In addition, for the boundary value of the impact of steam differential pressure on the energy efficiency, the result with the analytics engine was almost the same as the result with manpower.

5. Postscript

EMS add-on functions that use data analytics which contributes to the energy operation efficiency improvement according to international standards were described.

The necessity of energy customers to solve their own energy and environmental problems as management tasks has been increasing with the viewpoints of various laws and regulations, international standards and CSR, and impact of energy unit price jump.

Fuji Electric will take advantage of the current energy management solutions (visualization, comprehension and optimization) and the newly developed efficiency improvement function for energy operation. We will then organically combine the information on energy storage equipment, utility equipment and production equipment, and new energies including renewable energies whose future demand is expected to increase. In this way, we intend to aim establishing the automatic diagnosis technology and automating control that allows constant highly-efficient operation.

We will support customer activities to save energy and contribute to settle customer issues more than ever.

References

(1) Azumaya, N. et al. Energy Management Solutions to Support Energy Conservation Activities. FUJI ELECTRIC REVIEW. 2012, vol.58, no.1, p.9-13.

"EMS-Package LITE" Energy Optimization Package for Power Generation Facilities

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ABSTRACT

The energy consumption at steelworks fluctuates significantly depending on the state of production. It is important to monitor the demand for energy (both purchased and by-product) at all times and adequately control the supply and demand to stabilize power supply, lower power consumption, and reduce greenhouse gas emissions. For steelworks outside Japan, we have developed an energy optimization package for power generation facilities, "EMS-Package LITE," that can be installed and operated at low cost. It can inexpensively offer the system that calculate an optimal operation model from minimal input information and previous plant operation data, allowing on-site plant operators to operate a plant on the basis of the data calculated using the operation model.

1. Introduction

The energy required for production at steelworks is not fixed, but rather varies significantly according to the production situation. In addition to purchased energy, such as gas, oxygen and electric power, various kinds of energy are used, such as the by-product gas and by-product energy sources such as steam and electric power generated by production facilities.

A steelworks' energy management department constantly monitors and accurately controls these fluctuating energy demands to ensure a stable supply of energy. In addition, the department plays an important role in reducing energy consumption and greenhouse gas emissions by balancing and optimally controlling the supply and demand of complexly intertwined purchased and by-product energies.

In 2011, Fuji Electric launched its "Steel EMS

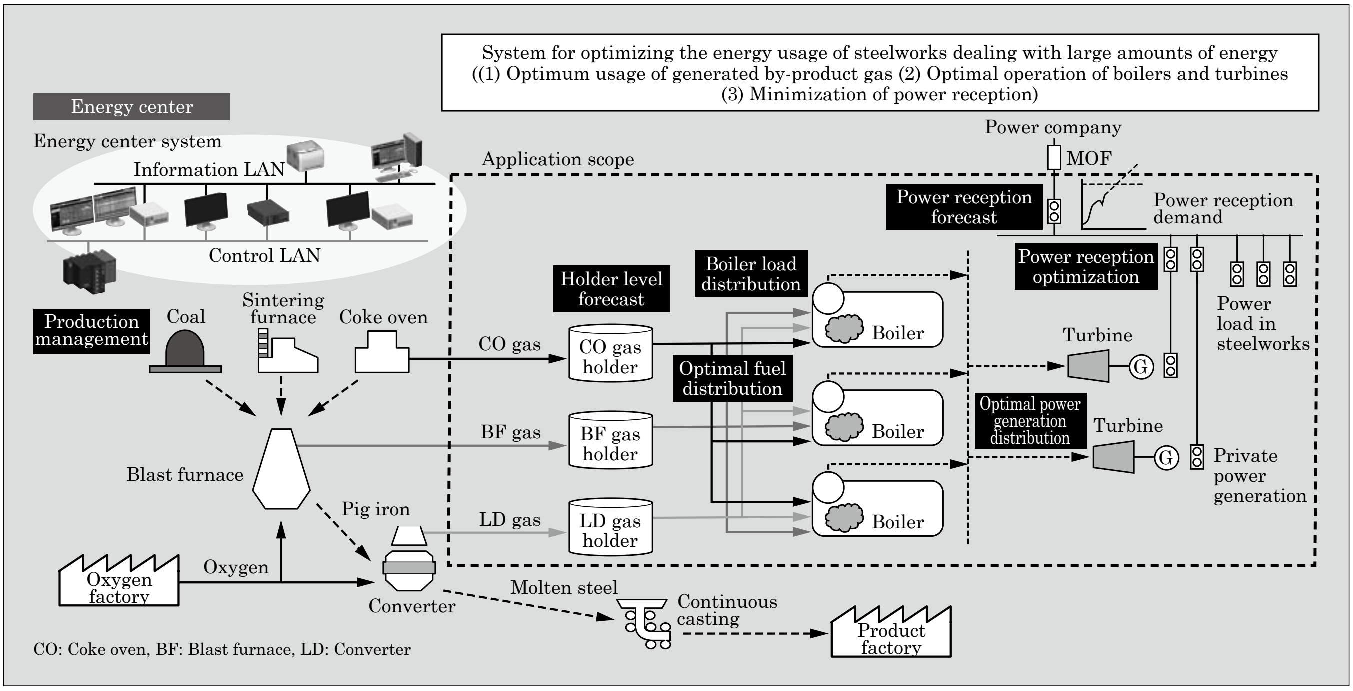

Fig.1 Scope of applicable facilities for "EMS-Package LITE" (power generation facilities)

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Package”(1). It has captured an overwhelming 90% or more of the market share at Japanese steelworks. It uses elaborate forecasting models and plant models to forecast the demand of multiple types of energy, create optimal operation plans and perform automatic control based on such plans.

Especially for overseas steelworks, we have recently developed “EMS-Package LITE” as an energy optimization package for power generation facilities that can be installed and operated at low cost.

2. Overview of “EMS-Package LITE”

Electric power is essential for operating the facilities of steelworks. In addition to purchasing electricity from a power company, there are cases where power is supplied by power generation facilities using by-product gas (blast furnace gas, converter gas, coke oven gas) in the steelworks.

This package outputs optimal operation plans in 30-minute intervals for a period of 24 hours based on the past operation data of the plant, as well as a minimum amount of other input data such as information of plant facilities, facility characteristics and production plans. Based on these optimal operation plans, cost reductions can be achieved by adopting procedures for on-site operators to follow. Figure 1 shows the scope of applicable facilities for EMS-Package LITE, and Figure 2, an overall view of the system. Table 1 shows the target specifications for the cost and energy savings effect of EMS-Package LITE.

Table 1 Target specifications for the cost and energy savings effect of “EMS-Package LITE”

Item	EMS-Package LITE*	Steel EMS Package
Cost (%)	14	100
Energy-saving effect (%)	20 to 50	100
Applicable energy	Power	Power, gas, steam

*Calculated at Steel EMS Package ratio of 100%

3. Main Features

3.1 Modeling (automatically generated information sheets and models)

This feature makes it easy for customers to perform modeling. Simply following the specified format, users first input into the information sheets in Excel*1 format concerning the number of boilers and turbines used for power generation at the steelworks, facility characteristic data, facility connection information, and cost information. Entering actual past operation data then, the models are automatically generated. Six kinds of optimal models are generated for each purpose, including those for energy savings and cost minimization. Figure 3 shows the workflow up to the generation of the optimal model.

3.2 Visualization (offline)

Visualization (offline) function converts actual past data into energy costs for each of the models and plots them on the models. This function allows users to visualize the room for energy savings. Figure 4 shows an example of visualizing purchased power costs. The

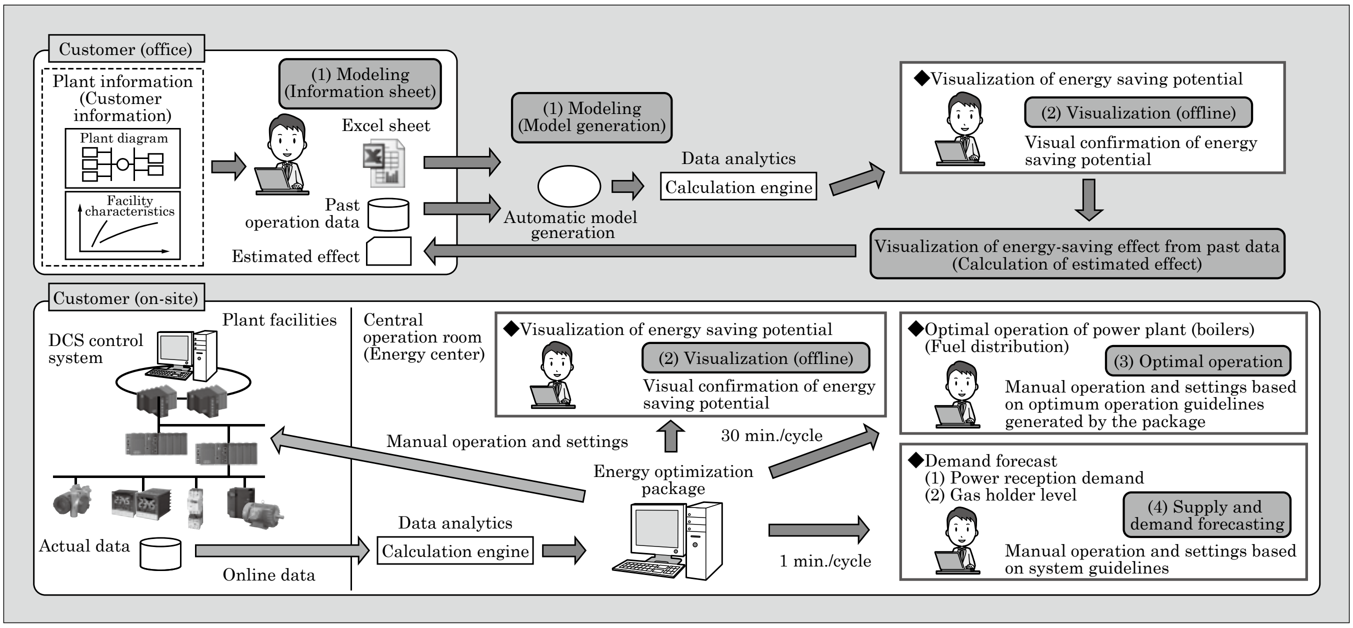

Fig.2 Overall image of “EMS-Package LITE”

*1: Excel is a trademark or registered trademark of Microsoft Corporation.

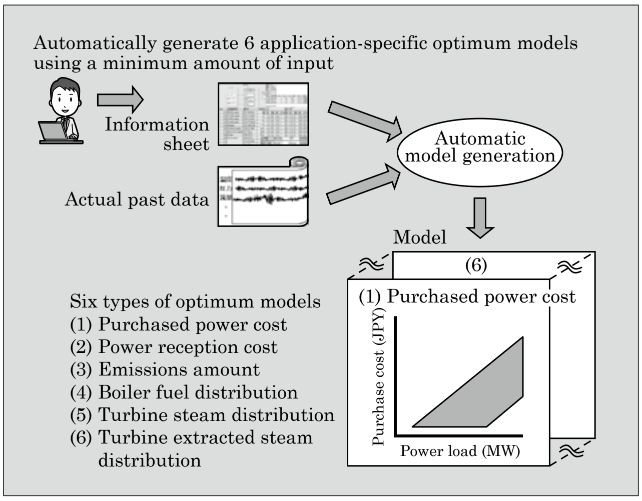

Fig.3 Workflow up to the generation of the optimal model

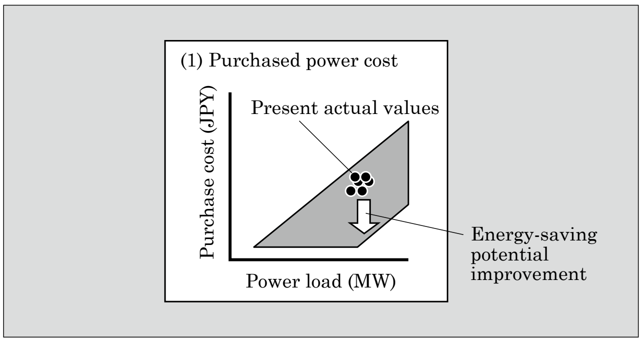

Fig.4 Example of visualizing purchased power costs

white arrow in the figure shows the room for energy savings.

3.3 Optimal operation and visualization (online)

In optimal operation, plant data (actual data) is collected online and used to create optimal operation plans (energy distribution) for the power plant in 30-minute intervals for a period of 24 hours via an optimal calculation engine. By following the optimal operation plans, on-site operators can achieve energy savings.

In addition, if there is a change in operation, the center operator can recalculate it on the spot to enable optimal operation based on the most recent operation. Furthermore, even though the optimal operation plan is calculated automatically based on the optimal model and actual data, the operation plan and energy balance of the facilities can also be changed as needed. Visualization (online) enables users to visually confirm the conditions of energy-saving operation since it simultaneously displays the actual state collected in real time via the OPC interface and the forecast energy-saving state after initiating optimal operation. Figure 5 shows the optimal operation work flow.

3.4 Supply and demand forecasting

The amount of generated energy and usage can be forecast for continuous production facilities (such as blast furnaces and coke ovens) based on changes in the out-of-operation plans, actual performance and the intensity of each of the facilities (boilers, turbines). Furthermore, the amount of generated energy and usage can be forecast for batch production facilities (converters) based on changes in the production plans, actual performance and the steelmaking intensity.

(1) Power demand monitoring

The center operators constantly monitor the amount of power received, and if the forecast amount of power received is likely to exceed the contract value, they will ask the on-site operators of the power generation facilities to change the amount of power generation. Figure 6 shows an example of the demand monitoring screen.

(2) Gas holder monitoring

The center operator constantly monitors the forecast gas holder level, and if the gas holder level is

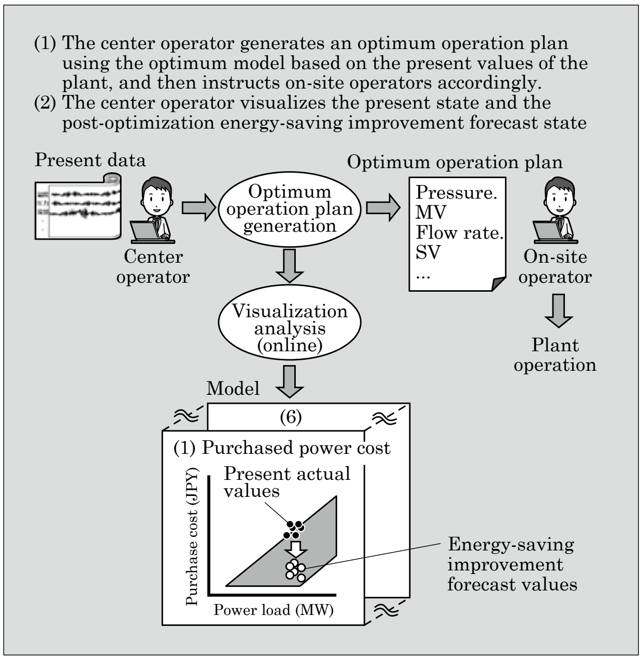

Fig.5 Optimal operation workflow

Fig.6 Supply and demand forecast (demand monitoring screen)

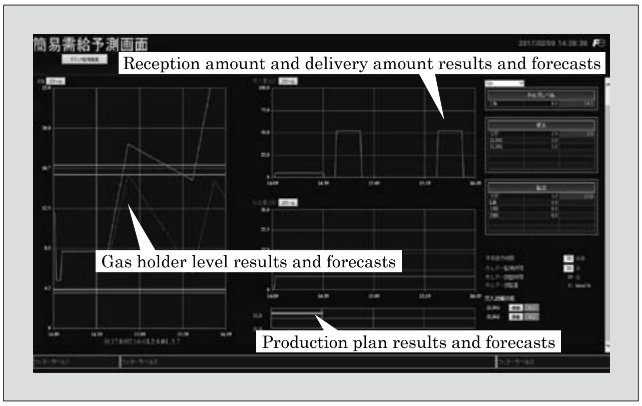

Fig.7 Supply and demand forecast (gas holder monitoring screen)

likely to exceed the upper or lower limit, the operator asks the on-site operators of the power generation facilities to change the fuel of the power plant. Figure 7 shows an example of the gas holder monitoring screen.

4. Evaluation

This package was designed to achieve an energy-saving effect equivalent to approximately 20% to 50% that resulted by Steel EMS Package. When field verification was carried out in an actual plant, the estimated result of the energy-saving effect was about 30%, thereby achieving our target. In addition, we were also able to achieve our cost target (see Table 2).

Table 2 “EMS-Package LITE” results

Item	EMS-Package LITE*	Steel EMS Package
Cost (%)	14	100
Energy-saving effect (%)	30	100
Applicable energy	Electric power	Power, gas, steam

*Calculated at Steel EMS Package ratio of 100%

5. Postscript

In this paper, we introduced “EMS-Package LITE” energy optimization package for power generation facilities.

Fuji Electric has utilized its many years of experience in the operation of energy centers at steelworks to achieve energy savings through optimization based on state-of-the-art control and software technologies. The adoption and proliferation of EMS-Package LITE is expected as a low cost solution to achieve energy-saving operation of steelworks in overseas countries, such as India and China, contributing to energy savings and reduction of greenhouse gas emissions worldwide.

References

(1) Narumi, K. et al. “Steel EMS Package” Optimizing Energy Management at Steelworks. FUJI ELECTRIC REVIEW. 2013, vol.59, no.3, p.165-169.

Creating Value in Data with "OnePackEdge System"

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ABSTRACT

Today, visualization is advanced for the process of each department, such as design, production technology, and a factory, and a large amount of data is collected. However, these data are not fully leveraged due to the lack of efficient coordination between departments and continuity of historical data over different processes. Thus, total optimization is required for cross-department coordination and data continuity through data gathering and analysis. Given this challenge, Fuji Electric has developed "OnePackEdge System" for creating a "value-generating database" to realize a smart factory. An additional data analysis assistant tool is also provided to make analysis more efficient and create value in data.

1. Introduction

As technologies such as the Internet of things (IoT), big data analysis and artificial intelligence (AI) evolve rapidly, we are faced with the challenge of how to specifically use the data for productivity improvement and predictive maintenance of equipment.

This paper describes the creation of value-added data using the "OnePackEdge System" as an example of how to overcome this challenge.

2. Assembly Process Data Collection System[(1)]

Customers increasingly need to accelerate the development of new technologies to meet the high demands of the market. For example, in the automotive industry autonomous driving, connected cars and electric motorization can be cited.

In many cases today, visualization and the collection of large amounts of data is already advancing in regard to design production technologies and at the departmental level of factories. Up until recently, it had been acceptable to initiate improvement of individual production departments and lines, but since these improvements are limited, a greater number of users are aiming for overall optimization. However, the data collected has not been sufficiently utilized due to inadequate sharing of data between departments and insufficient continuity of historical data across multiple processes. Therefore, it is necessary to carry out overall optimization through data collection and analysis that take into account the coordination and continuity between departments. Figure 1 shows the frameworks that reflect the current state and ideal future state.

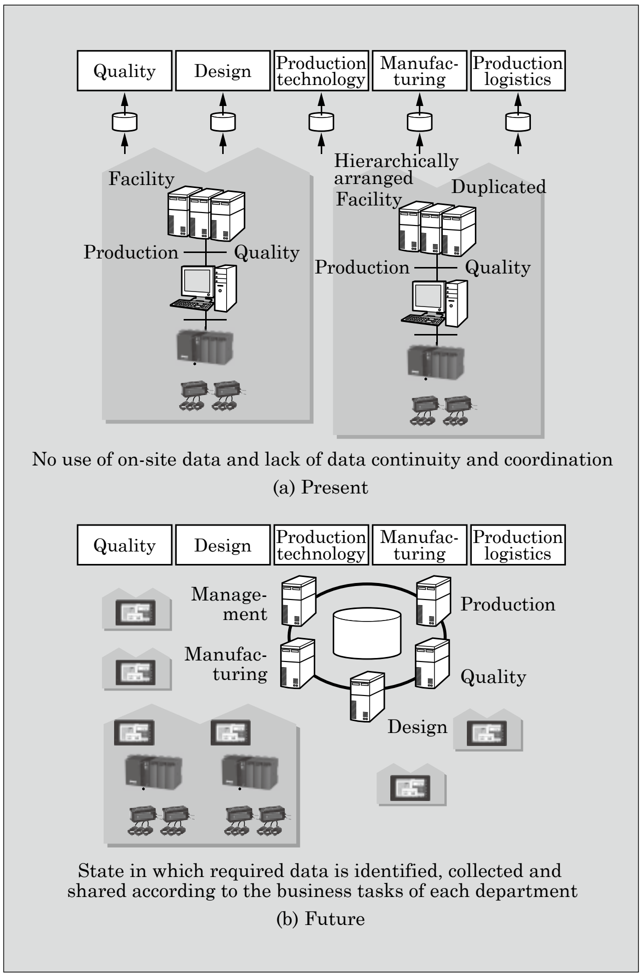

Fig.1 Framework of current state and ideal future state

In order to overcome these challenges and achieve smart factories, Fuji Electric has developed the "OnePackEdge System" as a system for building "profit-generating databases."

* Power Electronics Systems Business Group, Fuji Electric Co., Ltd.

2.1 Quality traceability for the assembly process field

Figure 2 shows an overview of the quality traceability solution provided by Fuji Electric The dashed line shows the scope of the OnePackEdge System. The quality traceability solution consists of a data collection section that collects raw data from sensors and manufacturing facilities connected via LAN and a server section for the databases that stores the data. The system collects the data needed by the user at the required time and makes it easy to carry out searches when it is necessary to trace stored data.

(1) Data collection section

(a) Data collection function

On assembly process lines, quality traceability requires data on the assembling and processing of each machine's work at all stages from start to completion (one cycle). For every process cycle, the OnePackEdge System collects the computer numerical control (CNC) and programmable logic controller (PLC) signals used to control each piece of machinery, as well as various sensor signals such as the pressure, temperature and vibration of each machine. Furthermore, as shown in Fig. 3, the system aggregates collected data within each process cycle (packaged data) to make it meaningful.

By doing this, it can reduce the amount of data collected compared with conventional systems that continuously collect data, because it only collects necessary data at the time it is required. As a result, this greatly reduces the effort required to identify data for analysis, greatly decreasing a user workload.

(b) Camera server connection function

In order to manage changes in 4M (men, machines, materials and methods), there is a need to centrally manage video taken with a camera along with analog inputs such as vibration and current.

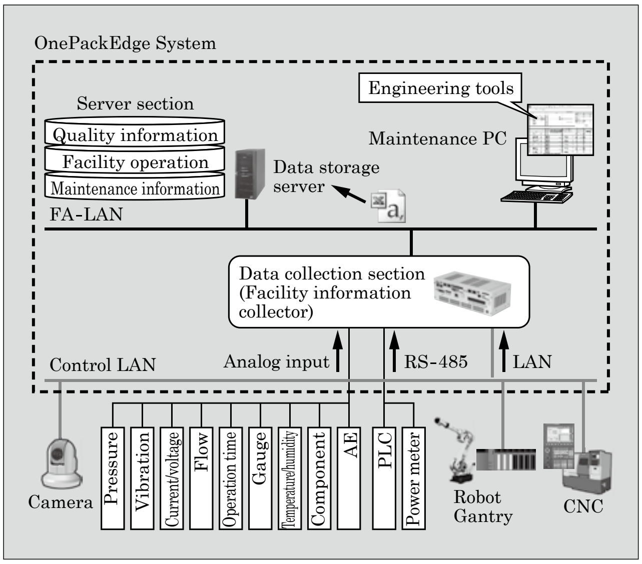

Fig.2 Overview of quality traceability solution

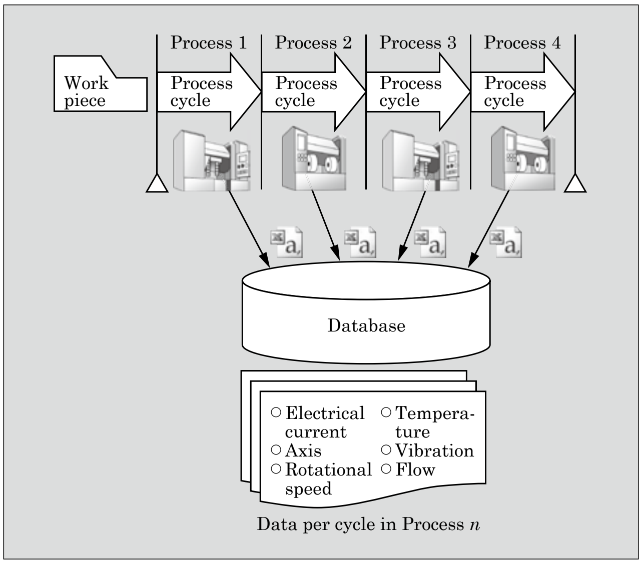

Fig.3 Image of data collection function

However, the camera is mainly managed by a camera system, and because analog data collected from sensors uses a different management system, it has been difficult to achieve centralized management.

As shown in Fig. 4, the system provides a function for monitoring events in the field by synchronizing the camera's recorded video with the analog data transition.

(c) Engineering tool

The engineering tool performs master maintenance of the system, while also adding and deleting data. This solution provides the engineering tool that use Excel*1. Figure 5 shows an overview of the solution. By using the engineering tools prepared on a maintenance dedicated PC, it is possible to specify start and completion signals for each cycle, define field names, data types and storage addresses for the collected data and register such information

Fig.4 Screen example of camera server connection function

*1: Excel is a trademark or registered trademark of Microsoft Corporation

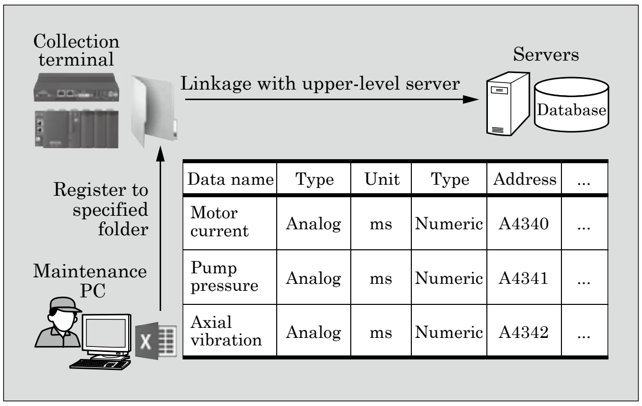

Fig.5 Overview of engineering tools

into the collection terminal's specified folder. As a result, users now can easily add and edit collected data.

(2) Server section

(a) Traceability search function

There is a close relationship between the operation information of manufacturing facilities and the quality information of products. Therefore, users often check operation information and quality information at the same time when problems occur on the production line. However, retrieving such information has been cumbersome because quality information is managed according to product, whereas operation information according to facility. This solution makes it possible to search via both facility axis and work axis, thereby reducing the labor required in user information retrieval.

(b) Data summary function

In order to track factors of abnormality, it is necessary to obtain abnormal values (those exceeding the threshold), maximum values, minimum values, and average values for each item of measurement. However, this takes a lot of effort because the amount of accumulated data is often huge. This solution automatically summarizes and displays these values on the traceability search screen to help reduce the task of checking data by users.

Table 1 Overview of facility information collector specifications

Function classification	Detailed classification	Specifications
Data collection	Collection target	○ PLC or CNC ○ Power meters ○ Various sensors (analog inputs) ○ Contact inputs (digital inputs)
	Collection cycle	○ High speed (1 ms): 16 points (analog inputs) ○ Medium speed (300 ms): 20 points* ○ Low speed (1 s): 128 points*, 24 points (analog inputs)*·**, 16 points (digital inputs)*·** ○ Cycle: 256 points
	Upper-level server transmission	FTP file transfer (supports FTP server and FTP client functions)
Data monitoring	Threshold value monitoring	Threshold monitoring for low-speed data 128-point upper upper limit, upper limit, lower limit and lower lower limit***
I/F	LAN	○ LAN0 (RJ45): 1 Gbits/s (for real-time monitoring) ○ LAN1 (RJ45): 1 Gbits/s (for future expansion) ○ LAN2 (RJ45): 1 Gbits/s (for upper-level PC connection and engineering tool connection) ○ LAN3 (RJ45): 100 Mbits/s (PLC or CNC connection)
	Serial	○ RS-422 (RJ45): For future expansion ○ RS-232C0 (D-SUB 9 pin): For future expansion ○ RS-485 (RJ45): Power meter connection ○ RS-232C1 (RJ45): For future expansion ○ USB0, 1, 2: For maintenance
	I/O	[Standard] ○ Analog inputs: 16 points, 4-20 mA/0-20 mA/±20 mA; Resolution: 14 -bit ○ Digital inputs: 1 point, 24 V DC, 4 mA ○ Digital inputs: 1 point, 24 V DC, Ry output [During I/O expansion] *Connection via expansion I/O (RJ45) ○ Analog inputs: 24 points, 4-20 mA/0-20 mA/±20 mA; Resolution: 14 bit ○ Digital inputs: 16 point, 24 V DC, 4 mA
	Compatible protocols	Mitsubishi MC protocol, FOCAS2 / Modbus RTU

* Only devices with a read response time of 10 ms or less per word

** Only at the time of I/O expansion

*** When monitoring threshold values, a value is judged to be abnormal when it is continuously above the threshold value for a consecutive number of configured times.

2.2 Facility information collector

In order to reduce the size and cost of the data collection section, Fuji Electric has developed a facility information collector that integrates the functions described in Section 2.1. It achieves a 95% reduction in

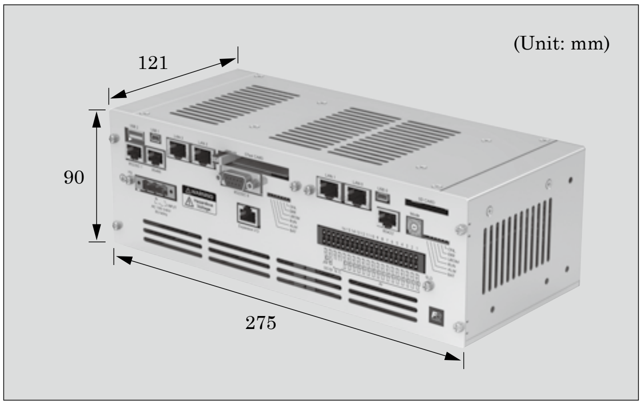

Fig.6 Facility information collector

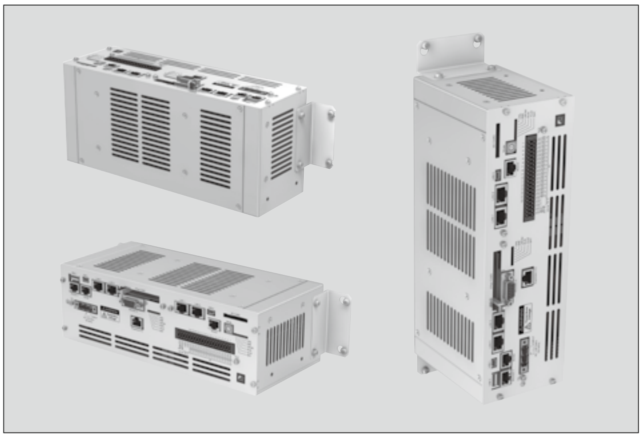

Fig.7 Example of installing facility information collector

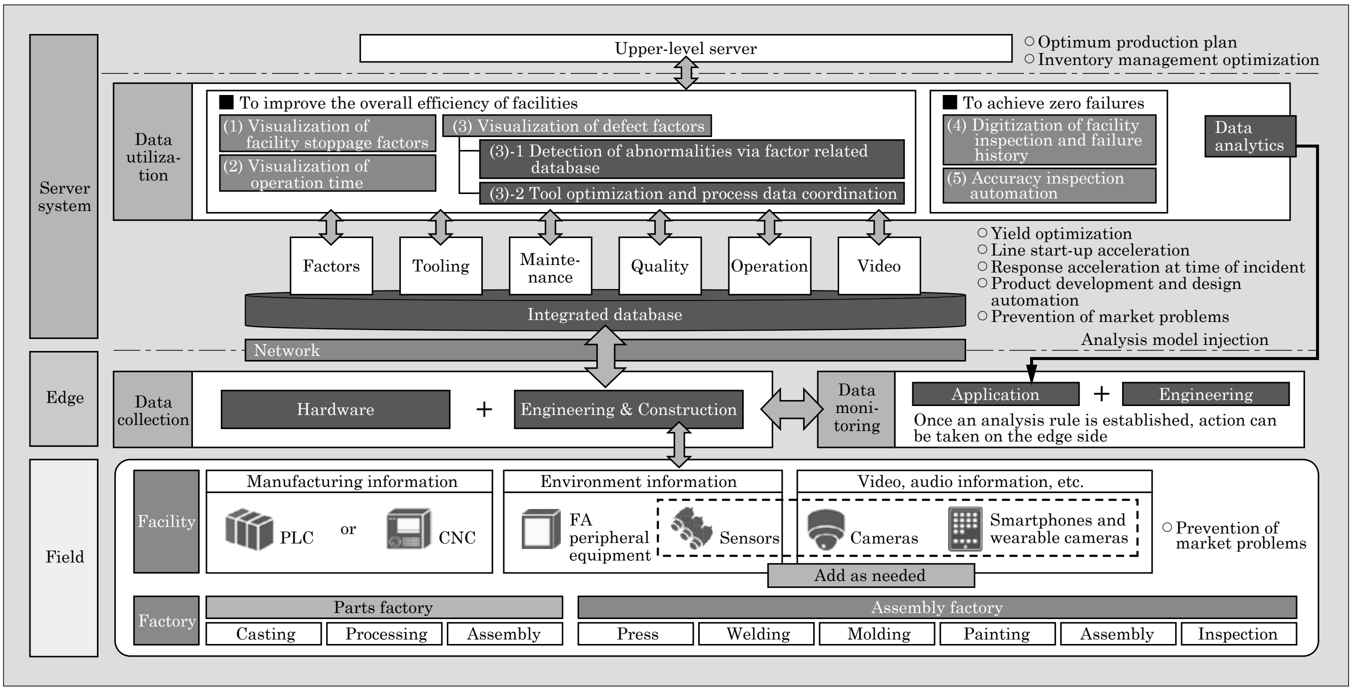

Fig.8 Future vision for the "OnePackEdge System"

volume compared with conventional Fuji Electric collection units. Table 1 shows an overview of the specifications, and Figure 6, the external appearance.

Furthermore, it can be mounted in 3 directions and vertically inverted as shown in Fig. 7 for easy integration into existing control panels.

3. Future Outlook

Figure 8 shows the future vision for the OnePackEdge System. By developing the data collection functions shown in the Figure, we are able to efficiently collect and accumulate meaningful packaged data via various facilities and sensors in the field. In the future, we plan to create new customer value from data by combining the meaningful data with data analytics to use it for applications such as predictive monitoring of production facility failures and product defects. Fuji Electric will continue to actively contribute to this type of data application and promote activities that create additional value from data.

In addition, we will provide a tool for analyzing meaningful packaged data. This tool will not only enable users to search and display the waveforms of accumulated data, but also include other functions such as filter and FFT analysis functions. This tool will also help improve the efficiency of analysis work through its waveform analysis based data distribution function and model waveform comparison function.

4. Postscript

In this paper, we described how the OnePackEdge System can be used to create value from data. Although the need for data collection is increasing due to the spread of IoT, it is way too easy to find oneself drowning in a sea of data that cannot be fully utilized. It is foreseen that valuable data ends up being undiscovered and productivity fails to be maximized. We intend to help customers utilize meaningful data to reduce production loss and management loss.

References

(1) Fujikawa, Y. et al. FA Solution That Applies IoT and Motion Control Technology. FUJI ELECTRIC REVIEW. 2018, vol.64, no.1, p.11-15.

Manufacturing Reform Utilizing IoT Technology

ONO, Masabumi* YAMADA, Takanori* NARUSE, Mitsuhiro*

ABSTRACT

In addition to the existing production innovation activities, Fuji Electric has developed its supply chain management (SCM) reform activity since FY2009 to build the system in which sales and manufacturing processes synchronize autonomously. We are committed to productivity and quality improvement, security and safety, labor saving, and energy saving. We also promote production innovation and the use of IoT according to each factory's manufactured items and business characteristics. Fuji Electric, an IoT solution vendor, proactively utilizes its own products and systems.

1. Introduction

In addition to conventional production innovation activities, Fuji Electric has been implementing supply chain management (SCM) reform activities throughout the entire supply chain from FY2009 and built a system in which sales and manufacturing processes synchronize autonomously.

We have been promoting manufacturing based Internet of things (IoT) through the use of large quantities of data utilizing dramatically improved information processing capabilities and artificial intelligence (AI). As a result, we are carrying out manufacturing reforms and aiming to achieve autonomously synchronized production, which we also refer to as the Fuji Electric Production System (FePS) (see Fig. 1).

2. Manufacturing Based IoT Concepts

Figure 2 shows Fuji Electric's manufacturing based IoT concepts. We are promoting IoT along 2 axes, namely SCM and product lifecycle management (PLM), to achieve productivity and quality improvement; safety, security and labor savings; and energy savings. By doing this, we aim to achieve a "connected smart factory" in expectation that it will optimize the entire factory including energy savings.

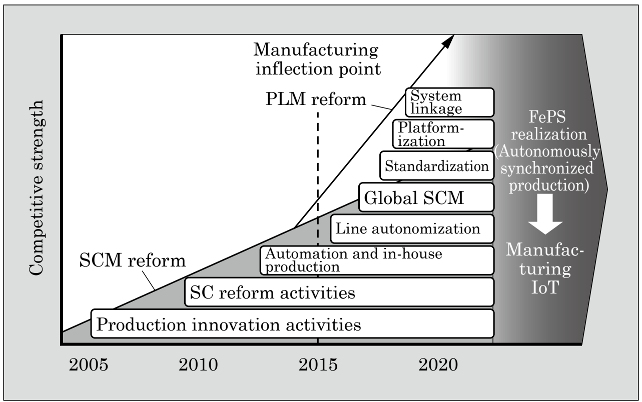

Fig.1 History of Fuji Electric's production innovation

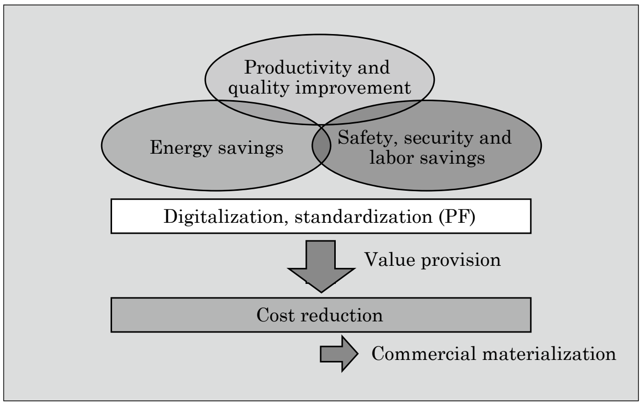

Fig.2 Manufacturing based IoT concepts

From the SCM axis, we are promoting the automation of production equipment and lines that utilize IoT. From the PLM axis, promoting standardization, digitization, and utilization of cyber physical systems (CPS).

IoT based manufacturing reforms aim to use data obtained from the field to simulate manufacturing via computers in order to achieve optimization by reflecting the results back into the field. To begin with, we established sensing technologies, information collection technologies and connection technologies, while developing a "Factory Visualization Dashboard" (see Section 3.2 below) that we have deployed at each factory.

Currently, in addition to standardizing manufacturing, we are promoting productivity and quality im-

* Production & Procurement Group, Fuji Electric Co., Ltd.

provements through the use of data.

3. Examples of Initiatives

Fuji Electric has been active in a wide range of manufacturing fields from electronic devices and components to plant equipment. Therefore, we are promoting production innovation and IoT advancement on the basis of the characteristics of the products and businesses of each factory.

Fuji Electric, also an IoT solutions vendor, actively utilizes its own products and systems in the development of IoT.

3.1 Production preparation utilizing CPS

Product functions are becoming increasingly sophisticated and diversified, and there has been increased demand to shorten the time required for market launch. It is against this backdrop that Fuji Electric is optimizing manufacturing processes through CPS, while shortening the time required to prepare production processes for mass production activities (see Fig. 3).

(1) Process design enhancement and increased efficiency through use of design information

In the process design, we decide manufacturing methods, personnel, amount of labor, equipment and tools while verifying manufacturability according to the product design. Therefore, process design is an extremely important work that has decisive influence on the QCD of products. To do this work, it has been necessary to spend a lot of time creating forms such as QC process charts and work instructions.

Therefore, we have built systems that can reduce the number of prototypes by extracting optimum manufacturing procedures while verifying manufacturability via computer with product design data, as well as create forms semi-automatically.

As a result, product design and process design can now be performed simultaneously while reflecting the results back into the product design, with the effect that preparation time for production is shortened and process design is simplified.

(2) Enhancement and efficiency increase in production line design

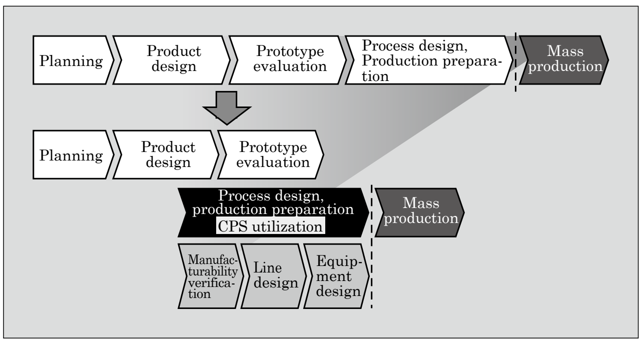

Fig.3 Improved production preparation efficiency via CPS

Fuji Electric has also developed a system that uses a computer to simulate the movement of people, things and equipment to build a more efficient production line. The system makes it possible to simulate takt time, line capacity and labor-hours using the line design tool that utilizes the manufacturability verification information mentioned above. Furthermore, by simulating the operations of workers, it is possible to pre-examine difficult-to-implement processes and processes that influence product quality while eliminating any issues that may occur. In this way, we are working to stabilize work quality and shorten line start-up time.

(3) Improving the design quality of automated equipment and shortening the verification period

After completing facility design, such as mechanical design, electrical design and software design, prototypes, are created and evaluated with the actual facility.

Therefore, prototyping and evaluation not only takes time, but also requires multiple prototypes to be created because this work is carried out by using real machines.

In order to reduce rework, improve design quality and reduce equipment development time by 20%, we have constructed an environment that uses 3D-CAD data to conduct prototyping and evaluation similar to that of real machines but using a computer instead.

Even when constructing a production line that uses several robots, interference between robots or a robot and human can be verified beforehand, thus making it possible to secure safety at time of actual machine verification.

Another benefit is that it becomes possible to evaluate operations at the time of mass production at facilities of remote sites, including those overseas, while also enabling operators to update software on the computers remotely.

3.2 Factory visualization dashboard

Manufacturing sites have conventionally made use of production progress management boards and Andon (a manufacturing status display system) to share on-site information and speed up countermeasures.

To achieve even better response, we developed and are installing "factory visualization dashboards" to achieve centralized monitoring of manufacturing key performance indicators (KPI) by collecting real-time 4M (man, machines, materials, methods) data at manufacturing sites and integrating various types of on-site information through the use of IoT (see Fig. 4).

By using factory visualization dashboards, various levels of management ranging from administrators and factory managers to line supervisors can ascertain quantitatively and in real-time KPI indicators necessary for daily management. This facilitates accurate and speedy response and overall optimization.

The dashboard is configured on a web screen so

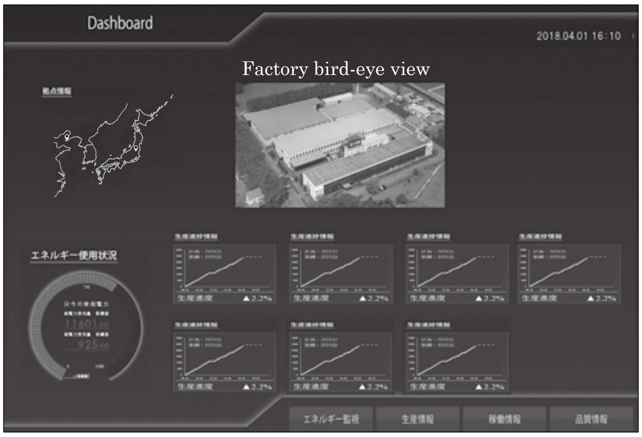

Fig.4 Factory visualization dashboard

that the display contents can be easily edited to correspond to changes in the process and line configuration. In addition, the network is configured taking into account security and access load distribution.

For older equipment that cannot output operation information, it is common to collect operation information based on operating status indicator signals. However, this only allows for limited types of information such as indicating normal operation, abnormal operation and stoppages. Therefore, we built a system for reading operation information from equipment control lines and displaying detailed operation states on a dashboard to visualize operation.

On integrated automation lines for mass produced products, the operation status and takt time of each piece of equipment are collectively displayed on the dashboard in real time as shown in Fig. 5. This makes it possible to quickly identify where takt disruptions occur. Furthermore, by using the video captured with web cameras, it becomes possible to investigate causes and take remedial measures.

In the future, we will continue to develop the dashboard and strengthen its analysis capabilities by combining analytics and AI.

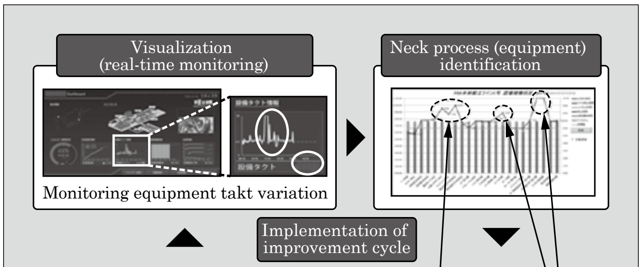

Fig.5 Examples of dashboard based improvements

3.3 Quality improvement and predictive maintenance through multivariate analysis

By using Fuji Electric's "MainGATE/MSPC" multivariate analysis tool, it is possible to detect abnormalities caused by multiple factors that cannot be monitored using individual data alone and extract optimum manufacturing conditions based on the relationship between quality and manufacturing factors. This tool is applied to manufacturing sites to improve quality and enhance equipment operation(1).

(1) Quality improvement in semiconductor manufacturing

Fuji Electric's pressure sensors are processed to extremely thin with a thickness of only several tens of micrometers by utilizing plasma etching for the back side of the Si wafer. Poor sensitivity will result if the thickness deviates from the specification range. Therefore, they must be processed with high precision (see Fig. 6).

To improve the quality, we investigated the cause of variation in thickness by applying MSPC for batch processes to manufacturing process data.

As a result, among the dozens of parameters, there were 2 specific parameters that highly contributed to the Q statistic (the degree of deviation from the normal model of the data being diagnosed) and were the main factors of variability.

By restricting these 2 parameters to within a certain range, it became possible to halve the variation in thickness.

(2) Predictive analysis of equipment abnormalities in press working

During press working, slug floats pose a big challenge. It is a situation in which scraps stick to the punch and come out of the die hole. Predictive detection has been difficult due to existence of various possible factors such as tool wear, clearance amount, processing oil viscosity, mold magnetization, and the attracting action between the punch and die (see Fig. 7).

Therefore, we implemented monitoring by mounting the press equipment with Fuji Electric's "Diagnostic Sensor Hub", a product that makes it possible to centrally manage measurement data by aligning the sampling cycles of various sensors such as temperature, current and voltage, 3-axis acceleration and

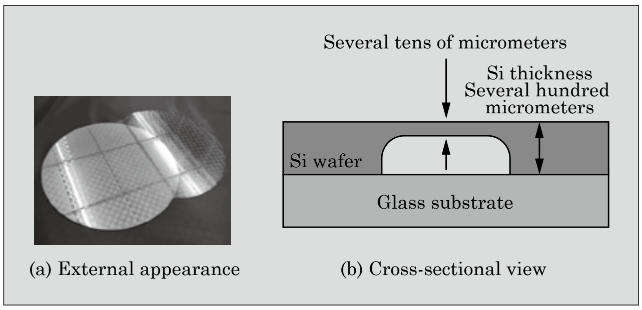

Fig.6 Wafer appearance and cross-sectional view

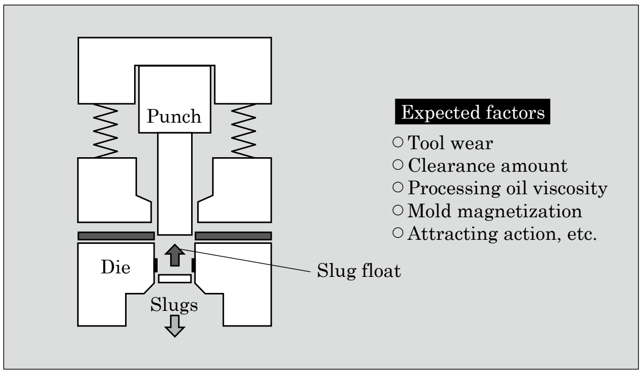

Fig.7 Occurrence of slug floats

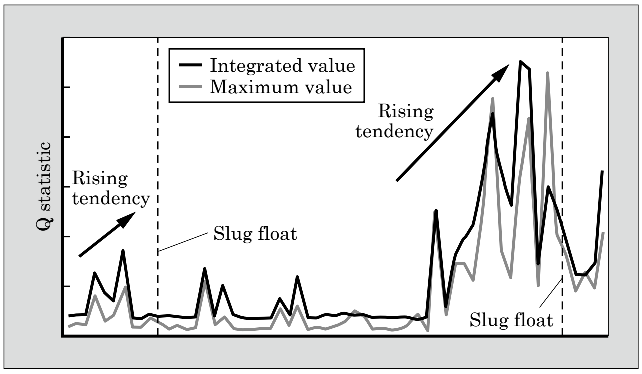

Fig.8 Signs of slug floats

strain sensors.

We created normal model based on data at normal operation and then analyzed the data before and after the occurrence of slug floats. As a result, we were able to achieve predictive detection by ascertaining rises in the Q statistic of sensing data before the occurrence of slug floats. We are currently accumulating data and carrying out detailed analysis in order to develop a method for preventing slug floats (see Fig. 8).

In the future, we plan to perform real-time analysis using MSPC to either stop equipment or set off an alarm upon signs of slug floats so that we can improve quality and increase the number of operating facilities.

3.4 Improving welding quality by digitizing skilled welding work

Welding work requires both the knack and know-how of highly skilled expert technicians and is susceptible to variations that greatly impact productivity and quality.

In recent years, the passing on of skills has become an issue as an increasing number of skilled technicians are retiring due to age. Furthermore, there is a shortage of skilled technicians who can guide others at overseas bases. It is often more difficult to train local technicians than technicians in Japan, while there also remains the challenge of developing an educational curriculum for the technicians.

Therefore, we are working to quantify welding processes through digitalization to facilitate the transfer of skills.

Moreover, in the future there is certain to be a labor shortage in Japan, and as such, the welding process also needs to be automated. In the next section, we will describe 3 steps for automating welding work and provide some examples along the way.

(1) Digitalization of the welding process

For welding quality, the strength of the welded part is important. To ensure the strength of the welded part, it is necessary to manage the penetration depth and penetration state.

Digitizing and quantifying the welding process and welding state is directly connected to maintaining and improving welding quality.

(2) Utilizing digitalization in technical education

Up until now, on the job training (OJT) has played a major role in training welding technicians because it endeavors to improve their skills through accumulated experience. However, a long period of time is required due to the sensory aspect of guidance and communication. Therefore, in order to facilitate early stage development, we have been developing and applying a skill diagnosis system that uses sensing technology to quantitatively evaluate skill levels (see Fig. 9).

When performing welding work, the worker judges the state of the work based on information received from the 5 senses, including seeing, hearing, touching. The worker controls the welding torch especially in response to changes in the melting state, such as relates to size and shape.

In addition to providing data such as welding current, voltage, feed rate and torch angle, the skill diagnosis system displays lists of the measurement results of the melting state obtained by the image sensor on the user's PC screen. After completing the welding, the worker himself can clarify the points of skill improvement by quantitatively examining the work.

In addition to the welding sites of each factory, we are promoting the use of the skill diagnosis system for training and educating new employees and are using it to maintain and improve quality through the use of a

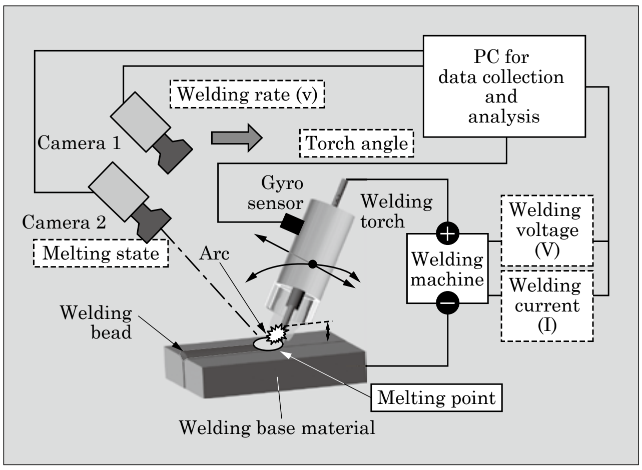

Fig.9 Welding work skill diagnosis system

certification program.

(3) Automation of difficult welding work through melting state sensing

For complex product structures, welding conditions must be established according to the structure. Therefore, welding is done manually because it is difficult to automate using robots. In particular, when dealing with structures that varying greatly in thickness, the technician must control the feeding operation of the welding torch while visually checking the melting state in order to ensure stable welding beads.

Fuji Electric is developing an automated welding technology for structures that are difficult to weld by using robot control that utilizes melting state sensing technology.

An image sensor mounted to the hand of the robot detects changes in the melting state and provides feedback for the operation of the robot. As a result, the feed rate of the welding torch is controlled to maintain a stable melting state at all times.

This technology will make it possible to automate the confirmation and judgment that are currently visually performed by skilled technicians, thereby enabling stable welding beads even for structures with a large variation of thickness.

In the future, Fuji Electric intends to apply automation to the welding work of all types of products in expectation that it will enhance maintainability and improve the quality of welding.

4. Postscript

In this paper, we described manufacturing reforms that apply IoT. To further advance this innovation, it will be important to integrate production technology with ICT technology, train IoT specialists such as data scientists and implement collaboration at the design stage that is the origin of this development. We plan to continue to actively utilize Fuji Electric's IoT products and systems, closely cooperate with related departments and promote further manufacturing reforms.

References

(1) Matsui, T. et al. Data Analysis Technology in Plant Control. FUJI ELECTRIC REVIEW. 2014, vol.60, no.1, p.21-26.

New Information Service Solutions Utilizing Vending Machines

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ABSTRACT

Fuji Electric has developed a digital signage vending machine with an advertisement distribution system that can provide product images and advertisements as well as relevant market information as part of value-added services leveraging IoT. The vending machine displays advertisements and product images on the front screen, and it is coordinated with a content server. The control module is equipped with functions to control the switch of advertising content, connect applications and services, ensure secure network connection, update the product images on display, and gather and compile market information. It can also use visual data gathered using a camera to analyze and aggregate market information.

1. Introduction

In recent years, vending machine sales have been decreasing due to competition from large retailers and convenience stores. As a result, beverage manufacturers need their vending machines to be differentiated from those of other companies. To meet this need, Fuji Electric has been promoting the proliferation of digital signage vending machines since 2010 as vending machines that display product images on large displays.

The Japanese market for digital signage equipment has been increasing year by year. Furthermore, by the time of the Olympic and Paralympic Games Tokyo 2020, we expect that the demand for digital signage vending machines will grow greatly and double in number compared with 2017 (see Fig. 1).

Fuji Electric has been developing an advertisement distribution system and digital signage vending machine that provide sales information while simultaneously displaying images and advertisements of products as a value-added service utilizing the Internet of things (IoT). This paper describes our new information service solution that utilizes this advertisement distribution system and digital signage vending machine.

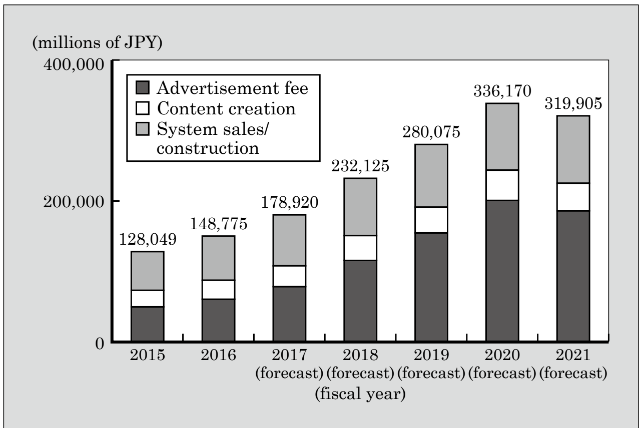

Fig.1 Market size for digital signage vending machines in Japan

2. Overview of the Advertisement Distribution System

Figure 2 shows an overview of our newly developed advertisement distribution system. Advertiser content is provided to the advertisement distribution system through an advertising agency. After this, it is delivered to each vending machine at a specified date and time by using the advertisement distribution function of the advertisement distribution system. Vending machines then combine the distributed advertisements and product images to display the content on the front screen.

The vending machine transmits the display his-

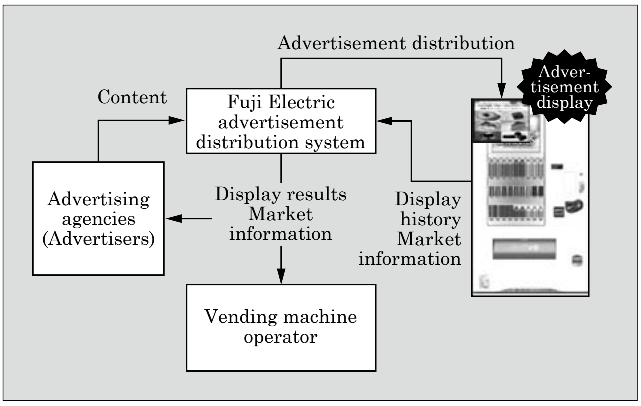

Fig.2 Overview of the advertisement distribution system

* Food & Beverage Distribution Business Group, Fuji Electric Co., Ltd.

tory of the advertisements to the advertisement distribution system, and the advertisement distribution system summarizes the display results in detail. In addition, market information collected and compiled by the vending machines such as sold products, sales date and time, and buyer gender and age group are transmitted to the advertisement distribution system and then provided to relevant persons such as advertisers, advertising agencies and vending machine operators.

3. Overview of the Digital Signage Vending Machine

3.1 Configuration and specifications

Figure 3 shows the configuration for the front of newly developed vending machine, and Table 1, an outline of the specifications. The vending machine has a basic configuration similar to that of vending machines for general hot and cold canned beverages and can hold up to 36 different types of products.

3.2 Advertisement display screen

The aspect ratio for the advertisement display screen is 1:1.78 as shown in Fig. 3, thereby enabling to display advertisements produced for mainstream full HD. Furthermore, the advertisement display section is arranged at the top of the screen so that advertisements remain visible even from a distance.

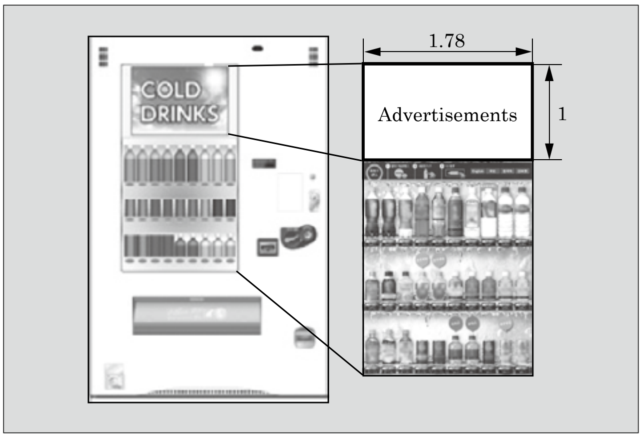

Fig.3 Configuration of the front of the vending machine

Table 1 Outline of the vending machine specifications

Item	Outline specifications	Function
Display unit	48-inch LCD display	For displaying products For displaying contents
Product selection unit	Touch panel	For selecting products
Camera	1.92 megapixels, color	For taking pictures for head-counts,attributes, etc.
Speaker	Power consumption: 3 W Quantity: 2 Size: ϕ50 mm	For playing advertisement BGM and messages to customers

4. Control Unit Functionality and Configuration

4.1 Overview of functionality

Figure 4 shows the functionality and configuration of the control unit. The advertisement distribution system consists of the following 5 functions:

(1) Device guided advertisement content switching

The device controls and makes decisions on whether to acquire content or not.

(2) Service connect engine (SCE))

The SCE is middleware capable of connecting applications and services on network.

(3) Virtual private network (VPN)

The VPN ensures communication safety.

(4) Content reassembly function

This feature updates the control functions for items such as images on vending machines.

(5) Market information collection and compilation

This function uses the vending machine's camera to collect information on users in order to create market information.

4.2 Device guided delivery request function

For existing vending machines, site operators make various changes for each machine, including changing the background display, hot and cold display and rearranging prices and products.

Moreover, for each vending machine, its product assortmemt and advertisements are changed according to the season throughout the year. Furthermore, these changes pertain not only to management information but also with regard to installation, transport, and removal.

As a result, there are some things that cannot be determined via the cloud, such as ascertaining installation environments and selecting product arrangements and advertisements based on the environment. Therefore, in this system, we have constructed a management system whereby content can be automatically added or updated, and advertisement content can be manually changed according to the device guided decision of operators who are familiar with the settings

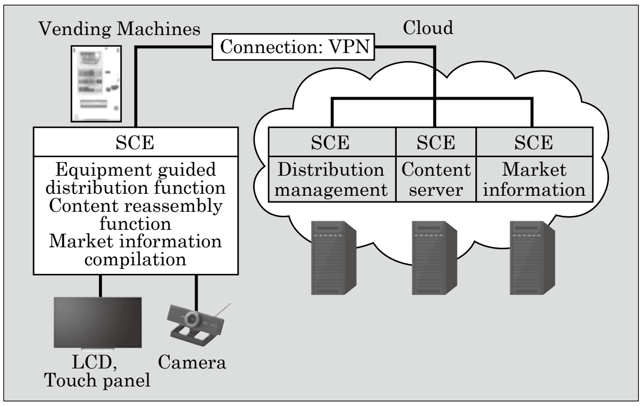

Fig.4 Control unit functionality and configuration

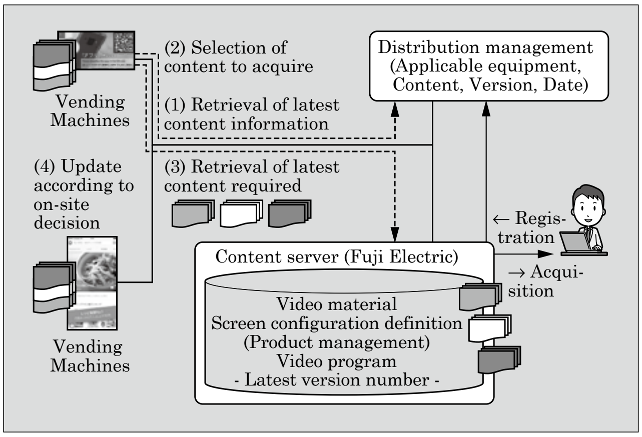

Fig.5 Overview of device guided advertisement switching function

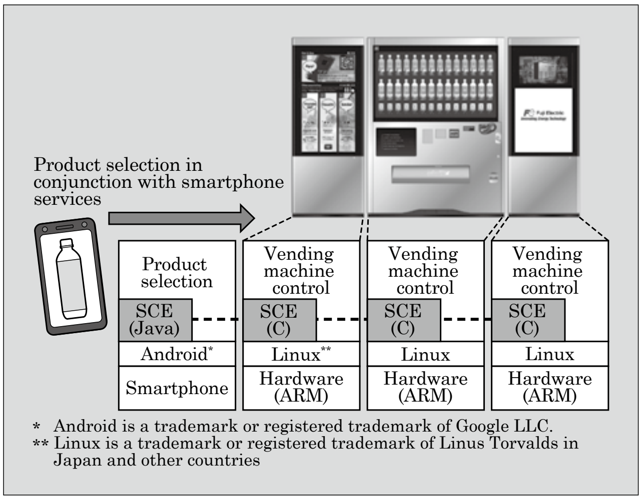

Fig.6 SCE concepts

and state of each particular vending machine. Figure 5 shows an overview of the device guided advertisement switching function.

(a) The vending machine retrieves the latest information from the list of distribution management content [see Fig. 5(1)].
(b) It determines the content to be acquired from information such as version number [see Fig. 5(2)].
(c) It contacts the content server to retrieve the content [see Fig. 5(3)].
(d) It enables site operators to manually or automatically update the content [see Fig. 5(4)].

4.3 Network application connected middleware (SCE)

As shown in Fig. 6, the SCE connects applications that were developed in different languages (Java*[1], C, etc.) on different hardware and on different operating systems.

Conventionally, the embedded software in our vending machines has run on middleware (software that acts as a bridge between the OS and the applications) that was independently developed by Fuji Electric using the programming languages such as C.

In addition to controlling sales and such in a manner similar to conventional vending machines through this middleware, the application developed this time controls the image display and touch panel features. Moreover, it also connects to other third party services provided in the cloud.

Therefore, we expanded the functionality of data-distributing middleware by enabling events to be shared between applications running on different hardware. By doing this, we have been able to achieve a lightweight middleware connection that focuses on the way services are called (service name, events, parameters) from applications running on the above-mentioned middleware developed by Fuji Electric.

The SCE manages communication related services and protocols such as HTTPS. As a result, the SCE makes it possible for developers to create applications without being aware of what hardware the application or service will run on or what communications protocol it will use.

4.4 Virtual private network (VPN)

As a countermeasure against crimes such as tampering with or spoofing advertising content and product display images, the vending machine and servers are securely connected to the cloud and terminals using a VPN as shown in Fig. 7.

The VPN that we utilize this time is a software virtualization technology for LAN cards, communication channels and switching hubs. The main features are as follows:

(a) It is a low cost solution.
(b) It has a high file transfer speed.
(c) It makes 1:N configurations easy.

4.5 Content reassembly

The advertisement and product arrangement screen of vending machines is subject to many customer requirements such as those related to its operation, display effect, position, color and size. When designing applications that meet the various requirements of customers, we have separated and organized application features to eliminate complexity by adopting the MVC (model-view-controller) architectural pattern, which is known for its use in GUI design with object-oriented language. Screen-related applications consist of these M-V-C components: (1) the model component for managing data structures related to content display position, size and rotation, (2) the View component for managing the logic and assembly drawings (XML files) of various images displayed on the screen and (3) the control component for controlling the model component through external events. The content re-

*1: Java is a trademark or registered trademark of Oracle Corporation and its subsidiary and affiliate companies in the United States and other countries

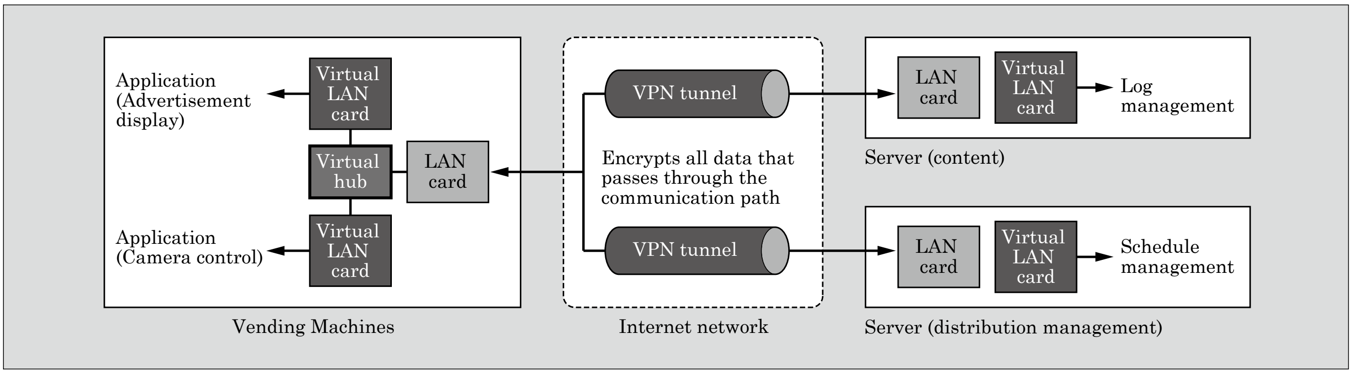

Fig.7 Example of software virtual VPN

assembly application enables the vending machine to update images with the content received from the advertisement distribution system based on assembly drawings when the operator updates or powers on the machine.

4.6 Collection and compilation of market information

Many digital signage systems unilaterally display images on the display. Therefore, an operator needs to stand near the machine to measure the effectiveness of the advertisements. In contrast to this, our recently developed vending machine automatically collects detailed market information that includes not only data on sold products and the time and date of the sale, but also the gender and age of the customer by using the built-in camera.

In addition, content providers such as advertisers are also interested in whether they can adequately appeal to potential customers using the displayed content. Therefore, the machine is also able to provide viewable information based on time, number of people, age, gender and eye gaze. This information is valuable to advertising agencies also when soliciting advertisers.

Furthermore, vending machine installation companies can predict sales by using the market information data and thus select appropriate product arrangements according to the location.

The built-in camera detects facial orientation and eye gaze for customers who want to ensure that their advertisements are being viewed. Moreover, from the viewpoint of personal information protection, only the following data is saved, which cannot be used to identify individual persons:

(a) Number of persons
(b) Age
(c) Gender
(d) Facial orientation
(e) Eye gaze

Furthermore, market information can be analyzed and aggregated using the data collected by the camera (see Fig. 8).

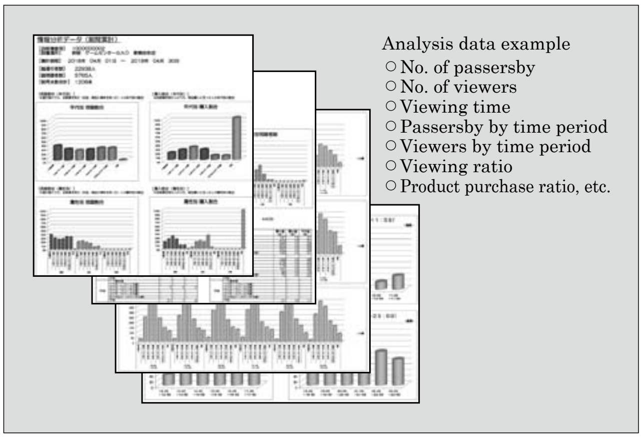

Fig.8 Experiment analysis charts

5. Implementation of Demonstration Experiment

In order to demonstrate the effectiveness of the advertisement distribution system, the vending machine was installed at an actual site to collect data as shown in Fig. 9.

In the demonstration experiment, we not only considered the effect of the presence or absence of advertisements, but also endeavored to establish a selection method for displaying advertisements based on market information.

Fig.9 Demonstration experiment unit

6. Postscript

In this paper, we described our new information service solution that utilizes vending machines. Using the advertisement distribution system that we developed can collect various types of market information. In the future, Fuji Electric will be committed to even more precise sales forecasts employing multivariate analysis and probability inference, allowing our customers to achieve optimization in sales promotion by using future forecast in addition to the analysis results of collected data.

Smart Showcase That Contributes to Labor-Saving of Store Work

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ABSTRACT

Convenience stores in Japan are struggling with high labor cost due to staff shortages, and they need to save labor on in-store work. To address this problem, Fuji Electric engages in the research and development of a labor-saving smart showcase that helps automate goods management, one of many in-store tasks at convenience stores. This smart showcase automatically recognizes the name and quantity of products in it. It combines a camera to identify product names and panel sensors to detect the quantity.

1. Introduction

The use of Internet of things (IoT) is accelerating, and this includes its use in the retail industry. In the United States, some grocery stores have already begun to use cameras and sensors to detect the movement of shoppers and goods. Shoppers complete payment by simply putting goods in their shopping bag and passing through a gate. This store frees customers from the inconvenience of waiting for a cashier.

In China, unattended container-type convenience stores and unattended supermarkets operated by online mail order companies have been established with the aim of reducing operating costs. In these types of unattended stores, customers can enter locked stores after authenticating themselves at an entrance reader with their ID registered with a Chinese electronic payment service. When items to be purchased are placed in the checkout space, electronic payment of the total amount is made based on the electric tag attached to the product.

Convenience stores in Japan are also seeking ways to achieve labor savings to remedy labor shortages and high cost of labors However, it is difficult to move to unattended stores immediately due to the variety of services offered and the strong character of the infrastructure. Therefore, labor savings are being advanced through various labor-related improvements on the sales floor of the shop. This paper describes Fuji Electric's efforts on smart showcases that contribute to labor savings.

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2. Challenges Facing Convenience Stores in Japan and Use of Fuji Electric Smart Showcases

Japan is currently facing an aging population and labor shortage. This trend has affected many industries including the retail industry and it is expected that this will continue to cause labor expenses to rise. Furthermore, convenience stores have been adding new services to increase sales, but that has increased the type and amount of works which has become burdensome to store clerks. Therefore, emphasis is being placed on reducing labor costs while achieving labor savings that can create the capacity to offer new services.

In order to meet the labor-saving needs at convenience stores in Japan, Fuji Electric has been developing a smart showcase as one of the components for realizing the short term goal of achieving labor savings on the sales floor and the medium-to-long term goal of achieving store automation and transition to unattended stores.

In order to prepare the sales floor, it is not enough to simply put products on display. There are many burdensome works involved, such as moving products located at the back of showcases forward after products in front are sold, changing arrangements and layouts, replenishing stock and replacing soon-to-be expired products with new ones. The smart showcase contributes to labor savings by reducing shop work related to preparing the sales floor.

3. Features of the Smart Showcase

The smart showcase is characterized by its ability to automatically detect the type, quantity and status of products placed on the shelves of the showcase to manage the products actually displayed in the showcase.

This product management contributes to labor-saving. For example, when replenishing products, clerks can check what products and how many of them need to be replenished from anywhere in the store, and this helps eliminate carrying out unnecessary products to the sales floor and decreases the number of trips to and from the stockroom. Furthermore, this feature help improve the efficiency of the sales floor because clerks can check the state of showcases and find the location of products that need to be moved forward without walking around the sales floor.

In the smart showcase, it is assumed that identical products are arranged depthwise, and on the basis of this, the showcase identifies the name and position of frontmost products with the product name identification controller and detects how many products are placed in depthwise with the panel sensor controller.

As shown in Fig. 1, the smart showcase system mainly consists of the following devices:

(1) Product name identification controller

It identifies frontmost items using images taken with a camera.

(2) Panel sensor controller

It detects how many products are on the shelves of the showcase.

(3) Management controller

It centrally manages data received from the product name identification controller and the panel sensor controllers to notify the in-store tablets of the types, quantity and status of products.

(4) In-store tablet

It displays information to help the clerk check the showcase's product display condition.

The point of sales (POS) system has been introduced as a system for managing products in convenience stores and is characterized by its ability to manage the quantity of stock for the entire store. Therefore, the POS system alone cannot determine whether products are on a showcase or in the stockroom. In contrast to this, the smart showcase makes it possible to know what products are on the showcase, thus enabling clerks to manage the number of products actually placed on the sale floor.

In this regard, the Ministry of Economy, Trade and Industry has formulated the "Declaration of Plan to Introduce 100 Billion Electronic Tags for Products in Convenience Stores Formulated"[1] as an initiative to attach electric tags to all products handled by convenience stores by 2025 in order to facilitate individual product management. Electric tags provide several advantages such as the ability to read multiple electric tags at once from a distance, write IDs to individually identify products and manage information such as expiration dates. The challenge is to reduce the cost of electric tags and the cost of attaching them.

On the other hand, smart showcase cameras and panel sensors can identify products and detect quantity without having to attach an electric tag to products. Furthermore, unlike electric tags, it can detect the exact position of products, and in this regard, we expect that the smart showcases will be used in combination with electric tags in the future to enhance the identifying function for product location.

4. Product Identification and Detection Technology

4.1 Product name identification controller

The product name identification controller consists of a camera control component and product name identification component. The camera is connected via Gigabit Ethernet through a Power over Ethernet (PoE) hub. The PoE hub is used to supply power to the camera.

As shown in Fig. 2, the camera should be installed on the ceiling of a store with a height of approximately 2.5 m. A single camera is used to capture images of the entire product display for each individual showcase. For the product imaging system, we also considered mounting a camera to the ceiling of each shelf of the showcase to capture images directly above the products and mounting a camera at the foremost part

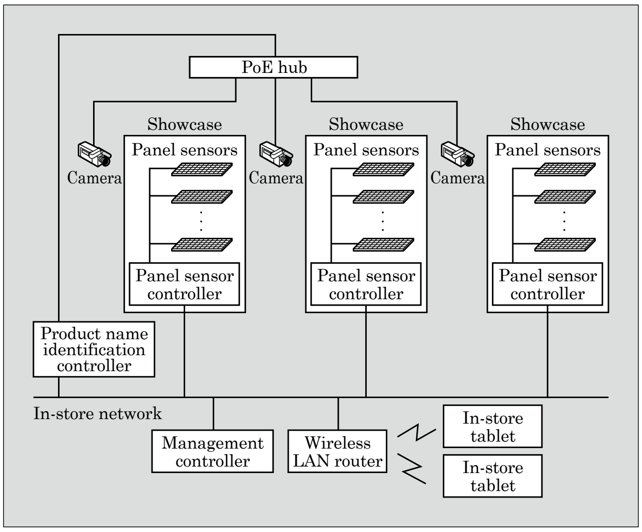


Fig.1 System configuration diagram

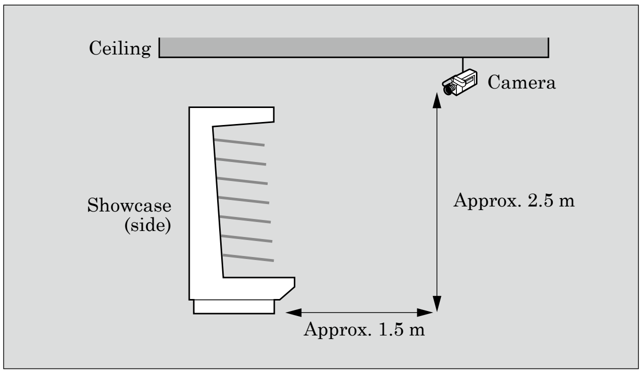


Fig.2 Relationship between the showcase and camera position

Fig.3 Showcase product image taken with the camera

of the shelves to capture images of the front of the products. However, we ended up adopting the method of capturing the images from the ceiling of the store for the following reasons:

(a) To prevent the camera from interfering with product display set-up and product purchasing
(b) To prevent reduction of the display space
(c) To reduce the number of cameras needed

A high-resolution (14 million megapixels) industrial-use camera is utilized to ensure that the images of each product are taken clearly. Figure 3 shows an actual image taken with the camera.

The product name identification controller identifies the product name ID and position of the frontmost products in the showcase using the images captured by the camera.

A “feature matching method” is used for identifying product names. This method uses the images of applicable products captured beforehand to register the product feature, which was extracted using machine learning, as matching data into the product name identification controller, and then matches against the feature of the images taken with the camera. In order to raise accuracy in identifying products, the matching data is prepared by capturing product images from various angles, because the camera will view products differently depending on how they are arranged and positioned in the showcase.

4.2 Panel sensor controller

The panel sensor controller detects the number of products by controlling the panel sensors. A panel sensor is integrated into each shelf of the showcase and the products are placed on the panel sensors.

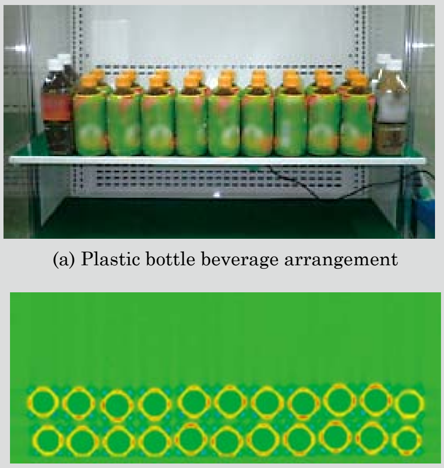
The panel sensors utilize projected capacitive touch panel technology that arranges the transmitting electrodes and receiving electrodes as a matrix. When a product is placed on a panel sensor, the capacitance between the transmitting and receiving electrodes changes, and this enables the shape of the contact surface to be recognized by sensing changes in capacitance at each intersection of the matrix and then plotting it two-dimensionally.

Products handled by convenience stores use various container shapes and materials, and the way each product sensed by the panel sensors differs, thereby switching the quantity detection algorithm for each individual product.

For example, in the case of products such as plastic bottle and canned beverages, which are characterized by a stable contact surface shape and large dielectric constant, the contact surface shape can be detected clearly because the signal strength is strong and there are few differences between individual items. As an example, Figure 4(a) shows 22 actual plastic bottle beverages placed, and Fig. 4(b) shows the two-dimensional plotted image of the detection state of the 22 beverages on the panel sensors. For these types of products, the quantity of products is detected via template matching using pre-registered plotted patterns.

On the other hand, in the case of unstable shaped products such as rice balls, which are characterized by individually different bottom surface shapes and an easily deformable contact surface, the signal strength of the contact surface varies and discrepancies occur according to individual differences and how products are positioned on the shelf. This makes it difficult to detect the quantity of products using template matching. Figure 5(a) shows an extract of the individual-detection state of rice balls. These types of products are divided into valid and invalid detection regions by setting a threshold value for the signal strength [see Fig. 5(b)]. Small regions are removed as noise, and the quantity of products is detected based on areas of the effective region.

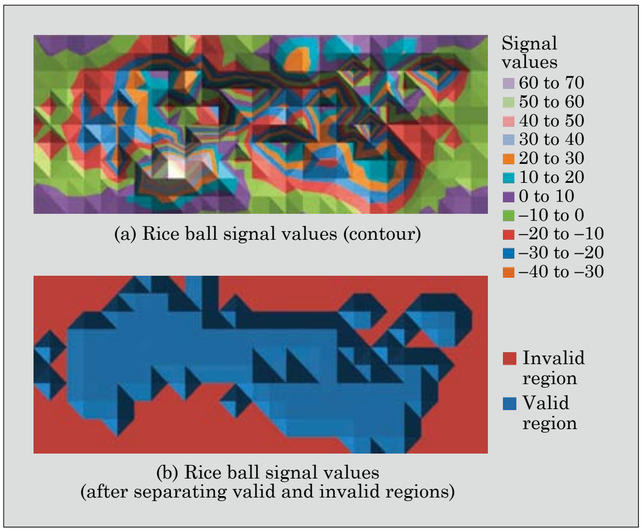
With these contrivances, by combining camera based product name identification and panel sensor based product quantity detection, we were able to achieve an identification accuracy of 94%, exceeding our original target of 80%, when identifying the prod-



(a) Plastic bottle beverage arrangement

(b) Detected image

Fig.4 Example of detecting 22 plastic bottle beverages



(a) Rice ball signal values (contour)

(b) Rice ball signal values (after separating valid and invalid regions)

Fig.5 Detecting individual rice ball (excerpt)

uct names, quantity and status of 70 typical convenience store products, such as beverages and rice balls, that were placed on the showcase shelves.

5. Application Example

A prototype of the smart showcase was exhibited at the Supermarket Trade Show in February 2018. Figure 6 shows the prototype. Panel sensors were installed for the prototype on the third shelf from the top. A camera was not used due to circumstances at the exhibition hall, and thus the position and type of frontmost products were fixed. The prototype displayed a list of names, quantity and items requiring replenishment on the screen for 10 different types of products. A demonstration was provided in which the quantity and items requiring replenishment changed in real time as products were removed from the shelf. The smart showcase was very popular, especially for the fact that it did not require the use of electric tags.

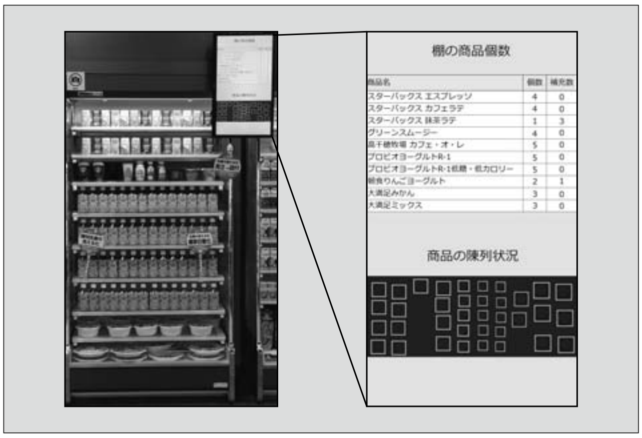


Fig.6 Smart showcase prototype

6. Postscript

This paper described a smart showcase that contributes to store labor savings. In the future, we plan to continue to expand the number of applicable products and improve the identification accuracy of product names, quantity and status.

The use of IoT has great potential in convenience store and supermarket applications because it achieves labor savings for the store and improves the convenience of customers. High-quality sensing technology is essential for utilizing IoT, and as such, we plan to continue developing sensing technology as we develop and release products and systems that provide high customer value.

References

(1) Ministry of Economy, Trade and Industry, “Declaration of Plan to Introduce 100 Billion Electronic Tags for Products in Convenience Stores Formulated: To solve social challenges lying in supply chains”. 2017-04-18. http://www.meti.go.jp/english/press/2017/0418_003.html, (accessed 2018-06-18).

Overview of Fuji Electric IoT Platform

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ABSTRACT

There is a worldwide trend in many industries today to use the Internet of Things (IoT) for their businesses. Fuji Electric has developed the Fuji Electric IoT platform based on our various elemental technologies and system technology that combines them. This platform is the common foundation that can integrate field engineering, in which Fuji Electric excels, field-based data analytics, and multi-vendor connection technology for field devices to easily deliver customer-value creation solutions in a secure and safe manner.

1. Introduction

There is now a worldwide trend in many industries including manufacturing, distribution and social infrastructure to use the Internet of Things (IoT) for their businesses. The IoT provides means to extract data from all things in the real world to create new values and build new business models from the gathered data.

In order to provide different services using the IoT, technology for gathering data from various types of field devices and sensors, data analysis technology for utilizing the data gathered, and advanced security technology for handling data safely are essential. We have developed the Fuji Electric IoT platform based on our various elemental technologies and system technology that combines them.

2. Overall Picture of Fuji Electric IoT System

Figure 1 shows an overall picture of Fuji Electric's IoT system. Fuji Electric provides solutions to facilitate resolution of customer issues while demonstrating the effect of application of the IoT technology in in-house factories and incorporating the knowledge gained in the process. Fuji Electric provides customers with good services and values never known before by using the IoT technology for many applications, such as energy saving of factory equipment, lines and an

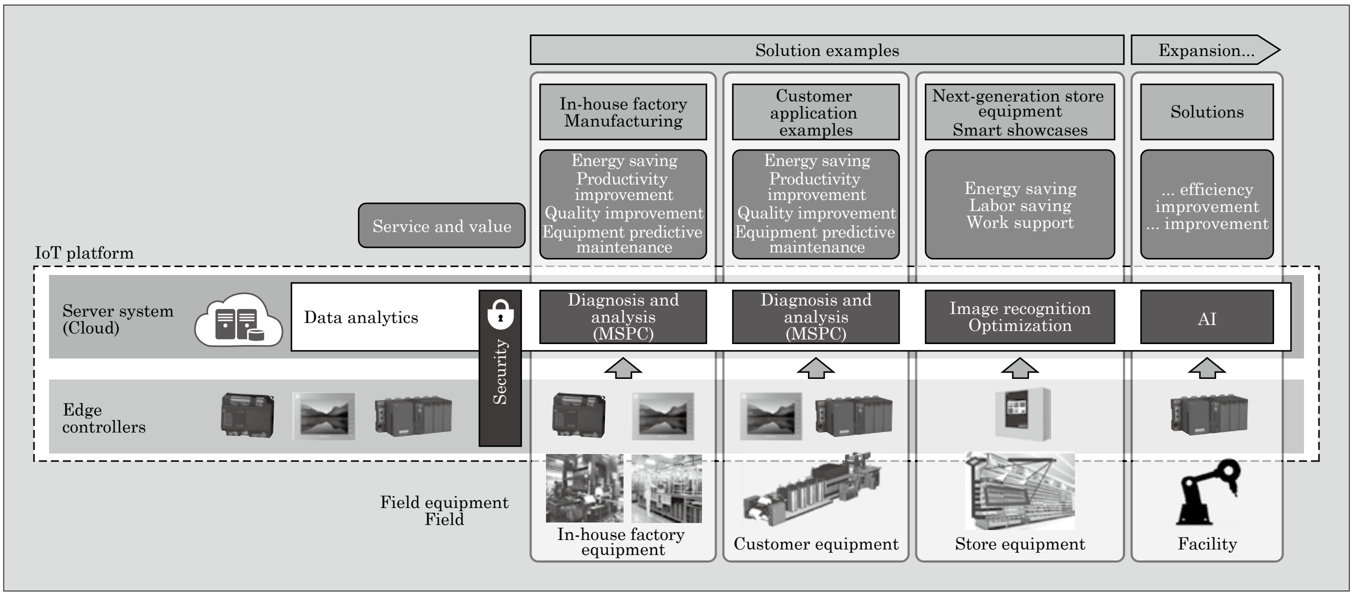

Fig.1 Overall picture of Fuji Electric IoT system

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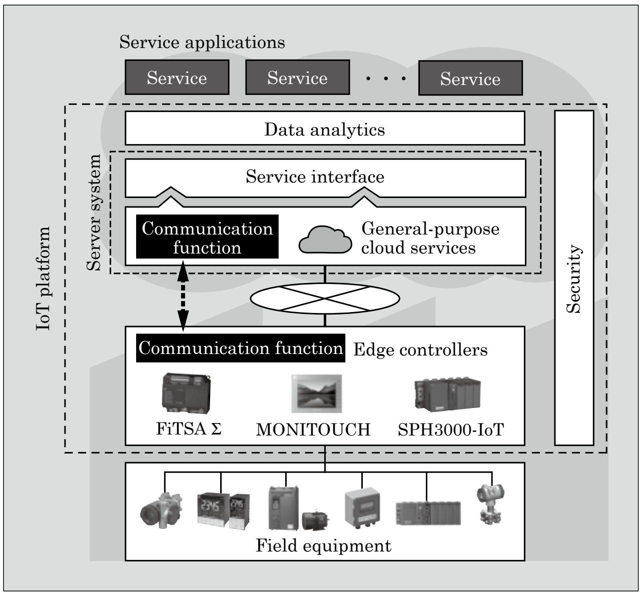

Fig.2 IoT platform

entire factory, improvement of productivity and quality and provision of predictive maintenance, and labor saving and support for workers in stores.

This platform is the common foundation that can integrate field engineering, field-based data analytics, and connection technology for multi-vendor field devices, in which Fuji Electric excels, to easily deliver customer-value creation solutions in a secure and safe manner. Figure 2 shows the configuration of the IoT platform.

The IoT platform consists of edge controllers that gather field data, a server system providing an execution environment for service applications, communication function to connect between them, security function for protecting system operation and data analytics that analyzes the data gathered.

For this platform, Fuji Electric uses open-source software for cloud services, standard technologies (de facto standards) for the communication protocol and security, and our proprietary technologies for edge controllers and data analytics to achieve the portability and differentiation of the service applications.

3. IoT Platform

3.1 Server system

The server system provides an execution environment for service applications that achieve services required by customers. The server system is required to ensure high reliability and high stability in operation of service applications, to allow operation at low cost, and to readily accommodate addition of new services, customers and devices.

To meet these requirements, we built the server system on the basis of general-purpose cloud services. Cloud services are provided by various vendors (cloud vendors) and some customers may specify certain vendors. As shown in Fig. 2, service applications are implemented via service interfaces in general-purpose cloud services in this configuration. These service interfaces realize multi-vendor support, in which functional difference between cloud services provided by various cloud vendors is absorbed, to allow service applications provided by Fuji Electric to be readily implemented in the cloud environment specified by the user.

For the communication function to exchange data with edge controllers, Message Queue Telemetry Transport (MQTT), a standard protocol, has been adopted to allow easy connection with cloud services of other companies. An authentication function is also provided to identify the edge controller to communicate with and ensure safety of communications.

In addition, server system operation management is provided for monitoring to see if service applications are running normally. The functions of this operation management include registration, addition and change management of users and service applications, performance monitoring, resource monitoring, network monitoring and log monitoring for detecting abnormal conditions and the system operator is notified of any abnormality detected (refer to “Server Systems Utilizing General-Purpose Cloud Service” on page 140).

3.2 Edge controllers

Edge controllers serve as gateway functions such as gathering field data and sending them to the server system in the upper level. Accordingly, they have the functions of security and communications with the server system in addition to interfaces for gathering data from field devices.

Fuji Electric has built many systems for plant monitoring and factory line control and provided solutions for these applications by gathering and using their field data. By taking advantage of the know-how in data gathering in the field, which we have accumulated while establishing a track record, we have developed edge controllers suited for applications and cost requirements to meet the demands from the field for use of the IoT.

Edge controllers provided by Fuji Electric shown in Table 1 can be connected to a few hundred types of field devices, including PLCs, inverters, NC machine tools and robots, allowing users to select devices suited for the respective applications and to facilitate introducing the IoT on site.

These edge controllers do not only function as data

Table 1 Fuji Electric’s edge controllers and their characteristics

Model	Characteristics
FiTSA Σ	Compactness, high versatility and device connectivity
MONITOUCH V9-IoT	On-site real-time screen display and device connectivity
SPH3000-IoT	High-speed real-time processing making use of features of PLC

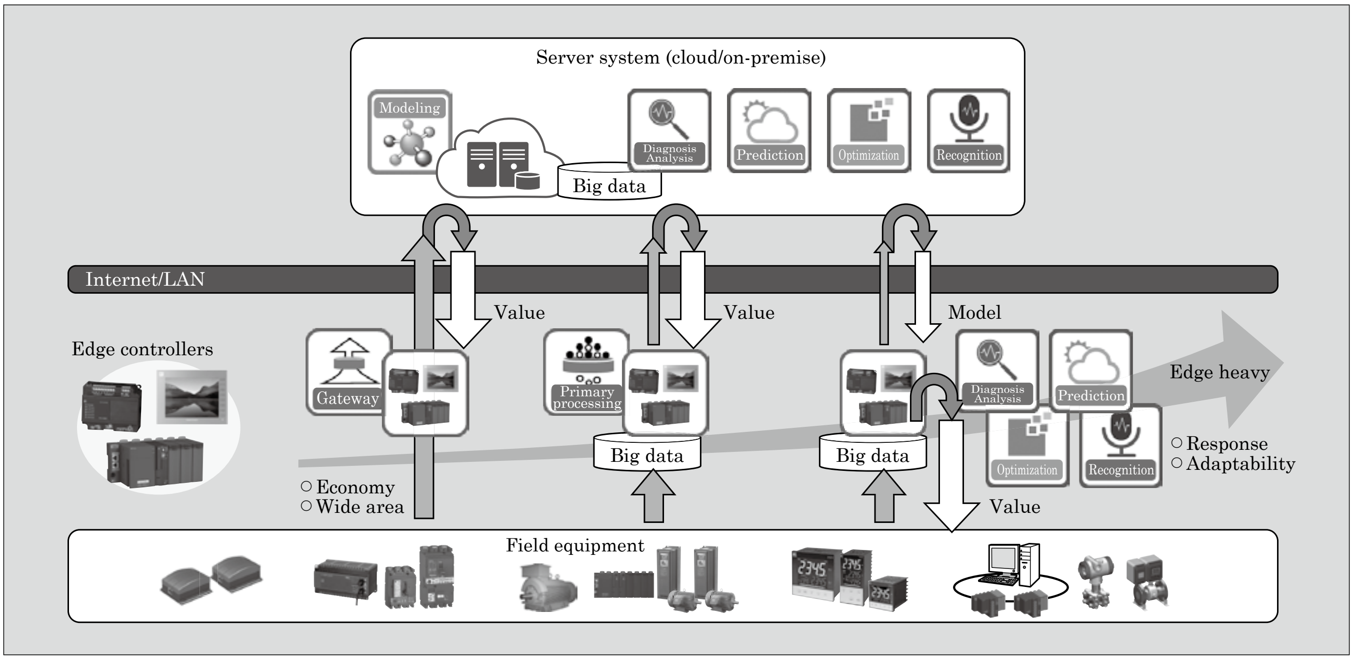

Fig.3 Schematic diagram of edge heavy processing

gathering devices as they conventionally have but also have the functionality of primary processing of data in themselves without transferring raw data from the field to the server to ensure security and reduce the load on the upper-level network. In addition, edge controllers can share real time processes for the advanced processes, such as data analysis, prediction and optimization, which have conventionally been performed only in a server system (called "edge heavy" processing). This feature provides solutions to fields where real-time response is required. Figure 3 shows the schematic diagram of edge heavy processing (refer to "Edge Controllers Connecting Field Devices and Cyberspace" on page 144).

3.3 Security

Connecting all things to the network by IoT has created new risks to things and their users.

The risks include interference in services due to unauthorized access to systems and falsification and leakage of important information such as personal data and factory production information stored in IoT devices and systems. If the extent of the impact of attack reaches control of field devices, life may be exposed to risks.

An environment must be built in which users can use field devices, systems and services with a sense of security. Accordingly, Fuji Electric has formulated new security policies for the IoT system based on ISO/IEC27017:2015[1], an international standard, and IoT Security Guidelines[2]. With the security policies at the core, we strive to reduce risks and protect important information by the management operation system for the organization and personnel and the technical and physical mechanisms, as shown in Fig. 4.

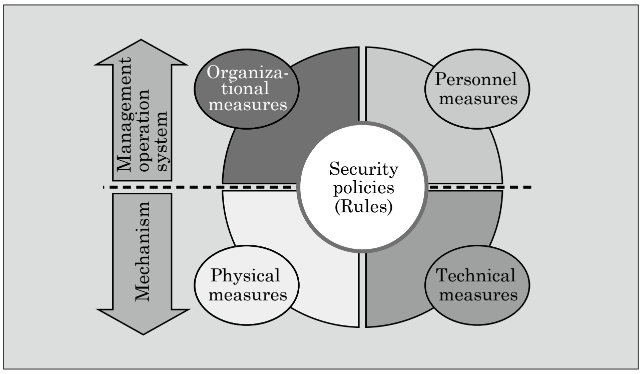

Fig.4 Concept of security

(1) Security measures by management operation system

As organizational measures Fuji Electric has built a system of systematically classifying information security-related risks and implementing management. We also have established frameworks of monitoring IoT systems and responding to incidents in the Fuji Electric Computer Security Incident Response Team (Fe-CSIRT), which responds to and prevents information security incidents generated in the Fuji Electric Group,

As personnel measures, we provide Fuji Electric employees with security education and training to raise awareness to strengthen security.

(2) Security measures in mechanisms

As physical measures, we implement physical protection of IoT devices and prevention of theft of information assets by entry management and locking up.

As technical measures, we employ advanced security technologies for each server system, edge controller and communication system to prevent information leakage due to unauthorized access from the outside or unauthorized use (refer to "IoT System Security" on page 154).

3.4 Data analytics

Data analytics, which is a generic term for technologies for diagnosis, prediction, optimization and recognition that use statistics, machine learning, mathematical application and artificial intelligence technology. It is positioned as the core technology for this platform. Specifically, it learns operation data from plants, equipment and production lines and then generates models according to the purpose. Using these models, it often creates customer values, such as optimum use of energy, stable operation of equipment, improvement of productivity and quality and labor productivity increase. In the industry and distribution fields, there are peculiar issues: different configuration, target value, input parameters, control response characteristics and use environment for each target device, equipment, system, and their application; limited volume of collection data for learning; and typical black-box inference of AI, which tends to be avoided to ensure reliability.

For resolving these issues, Fuji Electric has continued development of data analytics for over 20 years and has many technologies. The following describes 4 representative data analytics technologies owned by Fuji Electric shown in Fig. 5.

(1) Diagnosis

In addition to multivariate statistical process control (MSPC), which has been applied in many cases, there is a technology using machine learning called kernel principal component analysis (kernel-PCA). We have solutions that use this technology such as abnormal diagnosis and remaining life estimation by nonlinear model, which have been applied to diagnosis and factor analysis for various types of equipment, photovoltaic power generation, transformers and buildings in factories.

(2) Prediction

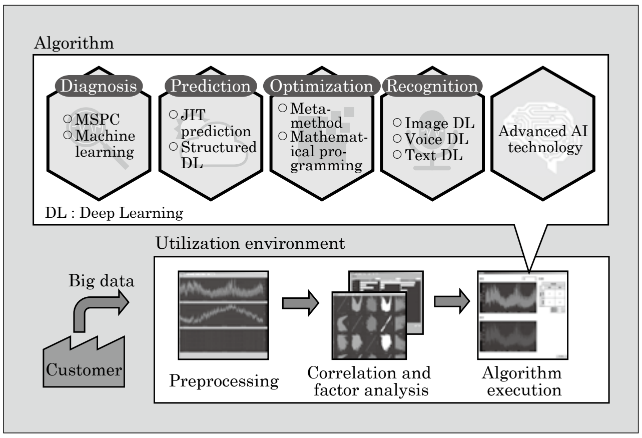

Fig.5 Data analytics

We have demand prediction and predictive detection solutions using just-in-time (JIT) prediction and multi-layered neural network technology (deep learning), which are suitable for demand prediction for industrial plants, factories, electric power, and crop yields.

(3) Optimization

We have solutions such as energy plant optimum operation and optimum power generation planning, which have been applied to various EMSs including factory energy management system (FEMS), building and energy management system (BEMS) and cluster energy management system (CEMS), energy cost optimization for plants and data centers, and power generation planning for utility companies.

(4) Recognition

We have deep learning based solutions such as voice and image recognition, which have applications including product recognition in smart showcases and maintenance work in indoor hydroponic facilities and manufacturing shop floors.

Generally, 80% of the application process of data analytics is said to be used for preprocessing. Most of this preprocessing is accounted for by tasks represented by cleansing and modeling of learning data, for which analysis engineers take time and use trial and error. For improving efficiency of this preprocessing, we have developed a tool to automate cleansing and modeling.

This tool has been used to improve the efficiency of cleansing such as elimination, replacement and supplementation of missing or abnormal values in input data, facilitate decision-making on whether or not diagnosis is possible by the visualization function, and improve the accuracy of diagnosis and prediction with overfitting prevention function. We will continue with the development to reduce working time and improve efficiency for data analysis to encourage the use of data analytics (refer to "Data Analytics as Core of Value Creation" on page 148).

4. Postscript

This paper has presented an overall picture of Fuji Electric IoT platform. In view of expansion of the IoT, while cooperating with other companies, which are providing solution services and data analytics that we do not have, Fuji Electric intend to enhance further functionality of our IoT platform to provide new customer services.

References

(1) ISO/IEC27017: 2015.

(2) IoT Security Guidelines Ver. 1.0. IoT Acceleration Consortium; Ministry of Internal Affairs and Communications; Ministry of Economy, Trade and Industry. 2016.

Server Systems Utilizing General-Purpose Cloud Service

MIYAZAKI, Tsuyoshi* **KITAMURA, Takashi ‡** **TAKEUCHI, Osamu ‡**

ABSTRACT

Fuji Electric has developed a server system that offers an execution environment for IoT services using service applications on a general-purpose cloud service. It absorbs the difference between the cloud services provided by various cloud vendors, allowing service applications to have portability between cloud vendors. Other features include communicating with edge controllers, saving gathered data on the database and monitoring the states of running service applications and resource load. Utilizing server systems allows Fuji Electric to quickly deliver high-quality IoT services that increase customer value.

1. Introduction

Fuji Electric has developed the Fuji Electric IoT platform for the purpose of prevalence of the Internet of Things (IoT) service business. Figure 1 shows the configuration of the platform. On the Fuji Electric IoT platform, the part that offers an execution environment for service applications to provide services required by customers is called server system, which has been built by using general-purpose cloud services. Use of general-purpose cloud services allows infrastructure and hardware resources to be flexibly added or deleted according to the scale of the customer. This facilitates reduction of the lead-time for providing a new IoT service, allowing users to reduce the initial and running costs. It also reduces the troublesome task of operation and maintenance because troubleshooting during operation is left to cloud vendors. In addition, backing up in multiple locations provided by cloud vendors allows the platform to be highly resistant to disasters, such as earthquakes and floods.

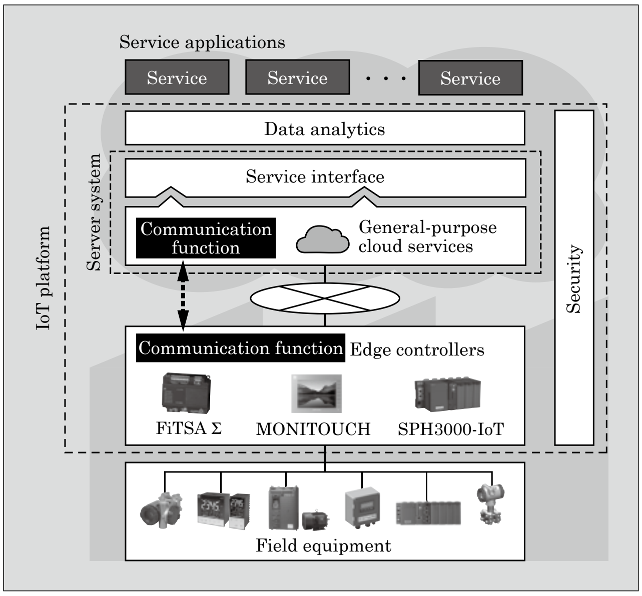

Fig.1 Configuration of Fuji Electric IoT platform

This paper presents an overall picture of the server system on the Fuji Electric IoT platform together with the individual functions that constitute the server system.

2. Server System

The server system on the Fuji Electric IoT platform is required to have the following features:

(a) Ease of system construction with a small-scale configuration
(b) Ease of resource expansion by addition of IoT services and edge controllers
(c) Capability of providing services linked with edge controllers and services of other companies
(d) Capability to ensure security
(e) Capability of stable operation and ease of operation and maintenance
(f) Capability of offering services to overseas customers
(g) Continued provision of existing services provided on premise*1

Figure 2 shows the structure of the server system. To meet these requirements, we have adopted general-

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‡ Power Electronics Systems Business Group, Fuji Electric Co., Ltd.

*1: On-premises: Installing and operating information systems, including servers and software, on the premises managed by the user (generally a company)

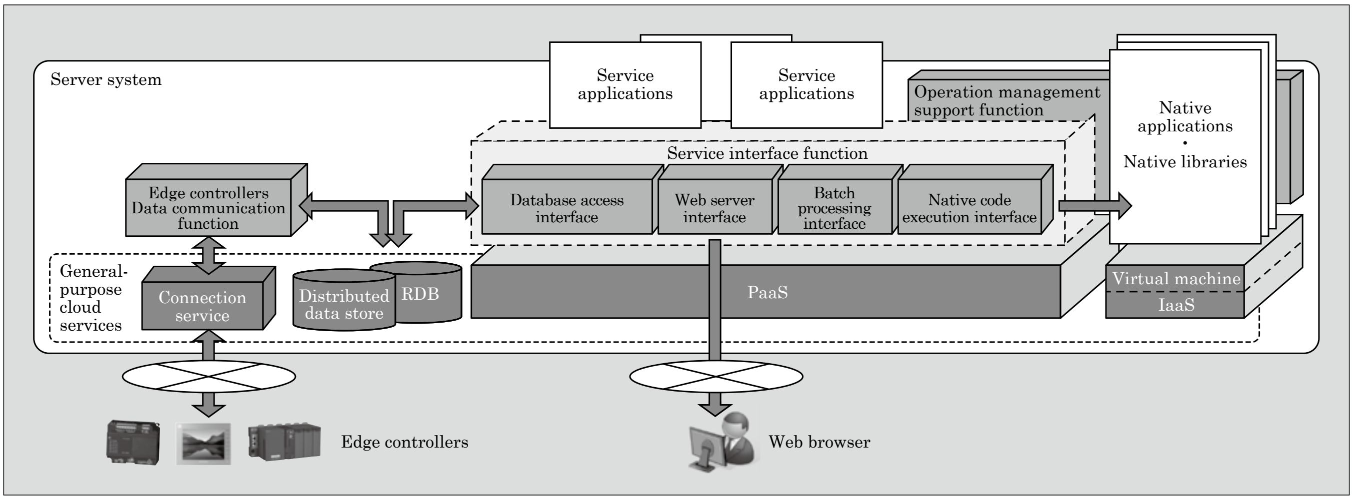

Fig.2 Structure of server system.

purpose cloud services provided by cloud vendors (see Table 1) for the server system and developed the functions described as follows:

(1) Service interface function

This function provides common interface that is used to achieve portability between different cloud vendors for service applications and efficiently develop service applications for users.

(2) Edge controller data communication function

This function provides communication with edge controllers responsible for gathering data in the field and stores this data in a distributed data store.

(3) Operation management support function

This function monitors the service application running state and resource load state and notify any error generated to improve service operation quality.

Table 1 General-purpose cloud services

Service name	Service description
Relational database (RDB)	○ Managed database with high availability ○ Allows disk capacity expansion and other scale-up
Distributed data store	○ Managed database for storing text data, binary data, etc. ○ Allows scale-up such as disk capacity expansion and cluster addition
Platform as a Service (PaaS)	○ Platform for running service applications including hardware and OS ○ Open-source Cloud Foundry used ○ Allows resource expansion of hardware used
Infrastructure as a Service (IaaS)	○ Infrastructure environment required for operating information systems such as hardware and network ○ Allows resource expansion of hardware used and secure communication divided between multiple network levels
Virtual machine	○ Computer environment that a user can occupy on an IaaS ○ Allows resource expansion of hardware used
Connection service	○ Environment for simple and secure gathering of data from edge controllers ○ Allows resource expansion following addition of edge controllers and access control for gathered data

3. Service Interface Function

This function is required to provide the following features:

(a) Multi-vendor support in view of the case that the customer specify a specific cloud vendor
(b) Capable of quickly adding service applications and increasing the number of users
(c) Ensured sense of security for users in the use of service applications
(d) Support for various Web browsers
(e) Capability of high-speed handling of data of various formats (numeric value, text, image, voice)
(f) Support for existing services

To meet these requirements, we have developed the following 4 types of interfaces.

3.1 Database access interface

The database access interface is used to access the relational database (RDB) and distributed data store provided by general-purpose cloud services.

Cloud vendors employ their own particular RDB and distributed data store for their general-purpose cloud services, and the difference between different vendor's databases must be absorbed within the database access interface. To deal with this issue, we have developed the common interface through which service applications access databases. This interface absorbs the database difference by individually implementing processes for accessing different types of databases. This has made various general-purpose cloud services available for use without depending on specific cloud vendors. As a database, using distributed data store capable of accumulating text and binary data allows users to handle various data formats.

3.2 Web server interface

The Web server interface help develop Web applications efficiently to release to customers.

For efficient development of Web applications, we employed the model-view-controller framework provided for open-source software (OSS) to develop the security function for user authentication and user-specific access control and session management function that accommodates increase of the number of users. This allows users to use their desired Web browser for using Web applications with a sense of security. Increase of the number of users is also quickly accommodated.

3.3 Batch processing interface

The batch processing interface is used to efficiently develop and execute batch processing applications for purposes such as aggregation and form creation.

We developed parallel processing execution and distributed processing execution functions in a multi-thread and multi-instance environment for high-speed execution of individual batch processes and simultaneous execution of multiple batch processes. These functions minimize the impact of adding new service applications on existing service applications.

3.4 Native code execution interface

The native code execution interface is to execute applications and libraries written in the C Language.

Generally, service applications are run on a Platform as a Service (PaaS), which makes unusable existing services and data analytics services written in the C language that are provided on-premise. To use these services, we have developed the function for this server system that service applications on a PaaS execute existing services and data analytics services implemented on a virtual machine on an Infrastructure as a Service (IaaS).

4. Edge Controller Data Communication Function

This function is required to provide the following features:

(a) Capability of communicating with edge controllers and IoT devices provided by other companies
(b) Ease of communication even with increased number of devices connected
(c) Safe communication between edge controllers and the server system
(d) Capability of communication of data of various formats (numeric value, text, image, voice) in view of future expansion of applications

4.1 Employment of de facto standard protocol

Communications between edge controllers and the server system employ the Message Queue Telemetry Transport (MQTT) protocol, which is widely in use as a de facto standard. This allows communications with edge controllers and IoT devices provided by other companies and facilitates communications even when the number of devices connected increases.

4.2 Connection authentication

Data sent by edge controllers are provided with an access token for device authentication. The access token can be verified by the server system to allow communication only with edge controllers permitted to communicate. This ensures safe communications between edge controllers and the server system.

4.3 Employment of distributed data store

Data sent from edge controllers are stored in a distributed data store. As a file data format for storing in a distributed data store, we have employed the Java Script Object Notation (JSON) format, which supports various data formats. This allows various types of data such as measured values and images to be communicated between edge controllers and the server system.

Service applications can use data stored in a distributed data store via the service interface function described earlier.

5. Operation Management Support Function

This function is required to provide the following features:

(a) Ensured stable operation of service applications
(b) Capability of efficient operation management
(c) Capability of prompt recovery from any error generated
(d) Capability of preventing impact of any error

Table 2 Operation management support function

Function name	Function description
Application monitoring	○ Monitors the viability and log of various service applications and detects any error generated in real time. ○ Allows stable operation of service applications and prompt recovery.
Resource monitoring	○ Monitors the resource state of virtual machines on a PaaS and IaaS and detects any error such as resource insufficiency in real time. ○ Allows stable operation of service applications, prompt recovery and prevention of any error from spreading.
E-mail notification of any error detected	○ Notifies the administrator of any error detected by application monitoring and resource monitoring by e-mail. ○ Allows improvement of efficiency of operation management and prompt recovery.
Operation monitoring portal site	○ Provides a portal site to show the operating state of service applications. ○ Allows stable operation of service applications and improvement of efficiency of operation management.

generated on other service applications

To meet these requirements, we have developed the functions listed in Table 2.

6. Postscript

This paper has described a server system that makes use of general-purpose cloud services. By using general-purpose cloud services, IoT services with high customer value can be provided promptly at a high quality level. The server system absorbs the difference between various general-purpose cloud services to allow use of the cloud vendors specified by customers.

In the future, Fuji Electric intends to develop functions of linking with service applications provided by other companies and providing our service applications to other companies. We will thereby work to enhance the functionality of the server system to offer IoT service with even higher customer value.

Edge Controllers Connecting Field Devices and Cyberspace

UEDA, Motoyuki*　SATO, Yoshikuni*　KADOSAKI, Toyofumi*

ABSTRACT

An edge controller, used in an IoT system, collects data from field devices. Its data processing is currently becoming more advanced, called edge heavy, by sharing computing with upper layers. Fuji Electric offers advanced real-time IoT solutions by assigning edge controllers part of the analysis and prediction tasks in addition to data collection. Our IoT product line includes the display-based "MONITOUCH V9-IoT," PLC-based "SPH3000-IoT" and gateway-based "FiTSA Σ," each with device-specific attributes.

1. Introduction

An edge controller is a component of the Internet of things (IoT) system used in the industrial field, including industrial processes. It collects data from various field devices installed on-site at customer facilities. Recent edge controllers have come to perform data processing that requires more advanced functions and high-speed response by dividing the processing performed in the upper layer, in addition to collecting field device data. This is called edge-heavy computing. This paper explains the challenges of edge controllers, the function and features of Fuji Electric's edge controllers, and application examples and the future outlook.

2. Challenges and Market Trend of Edge Controllers

Edge controllers collect data from various field devices and serve as a bridge to an information system network, such as computers and clouds, in the upper layer. Thus, their main function was converting communication protocol as the gateway device that connects field networks, where field devices are connected, and information networks.

On the other hand, because of the challenges described below, computing is becoming edge-heavy, that is, edge controllers installed closer to the field divide and process data that have previously been processed by computers and clouds in the upper layer.

(1) Challenges in data processing

(a) Increase in traffic cost due to a greater load on networks or cloud devices

(b) Decline in real-time response accompanied by the bottleneck of processing

(c) Concern by users about lowered security related to transmission of raw field data to the outside

The emergence of edge controllers that can realize edge-heavy computing is increasing the needs in manufacturing sites and demands for edge controllers as shown in Table 1.

On the other hand, the demand for edge controllers is expected to increase by 10% to 15% a year[1]. To meet this, however, the challenges below need to be solved.

(2) Upper system connection

(a) Processing balance between edge controllers and the upper system, and accumulation of know-how

Table 1 Needs of manufacturing sites and demand for edge controllers

Needs of manufacturing sites	Demand for edge controllers
Improvement in manufacturing value (improvement in productivity by shortening the time required for production preparation)	Provision of higher real-time data by selecting production information at sites
Diversified and small-quantity production (realization of mass customization)	Higher processing capability to process control system and higher-level information system at sites
Reduction in programming load	Provision of easy programming tools and applications
Connection between vendors	Application in open architecture such as industrial open network
Expansion of service business of FA equipment and device manufacturers	Revitalization of services such as remote monitoring, support, and preventive maintenance, and implementation at sites on the basis of the data collected by edge controllers

* Power Electronics Systems Business Group, Fuji Electric Co., Ltd.

(b) Security assurance when edge controllers are connected to the upper systems and clouds

3. Fuji Electric's IoT System and the Role of Edge Controllers

3.1 Fuji Electric's IoT solution

For Fuji Electric IoT system, we provide control devices serving as execution base and a series of technologies, including field data sensing, gateway, network connection, data analysis and prediction, optimization control, and advanced control. We have various IoT solutions that utilize products and technologies to create customer values.

3.2 Position of Fuji Electric edge controllers

The edge controller of Fuji Electric is a platform that collects and accumulates various field data and serves as a gateway that utilizes network connection technology to pass the data to cyberspace.

In the future, field devices, machines, and equipment will become IoT components and directly connect to the network. Regarding the connection to cyberspace, a field device can be classified into the 3 types below (see Fig. 1). Edge controllers serve as the gateway device that connects cyberspace and the field devices in group II and group III.

(1) Group I: Direct type

Field devices that are directly connected to cyberspace. This includes monitoring and control systems, medium and large capacity uninterruptible power systems (UPSs), high function inverters, vending machines linked with IT and radiation monitoring posts.

(2) Group II: Edge controller type

Existing devices that have no function of directly connecting to cyberspace (controllers, inverters, general-purpose equipment such as measuring equipment, and analyzers). They are connected to cyberspace using the local communication function of individual products, regardless of whether they were made in-house or by other manufacturers. To connect this type of equipment to cyberspace, Fuji Electric provides edge controllers, including the "MONITOUCH V9-IoT," based on a field type display, the "FiTSA Σ," based on a general-purpose gateway device, and the "SPH3000-IoT," based on a programmable controller (PLC). These edge controllers can connect PLCs, inverters, NC machines, robots and measuring equipment of other manufacturers and greatly contributing to the building of IoT systems for field devices.

(3) Group III: Edge controller + sensor type

This type connects rotating machines, breakers and buildings, which have no local connection function or intelligent function at all. Sensors, such as those for vibration, temperature, current, are connected to edge controllers, and the state of the object is digitalized via sensors.

To achieve edge-heavy computing, edge controllers need to solve challenges, such as an increase in the communication traffic cost due to an increase in the amount of field data, decline in real-time responsiveness, and concern about lowered security, as shown in Chapter 2. In addition, to respond to the request of manufacturing sites, edge controllers need to have various performances and functions, such as a high processing capability to divide and execute the process that are performed by a control system and higher-level information system, real-time data supply, open architecture application, and service application, such as predictive maintenance in the field.

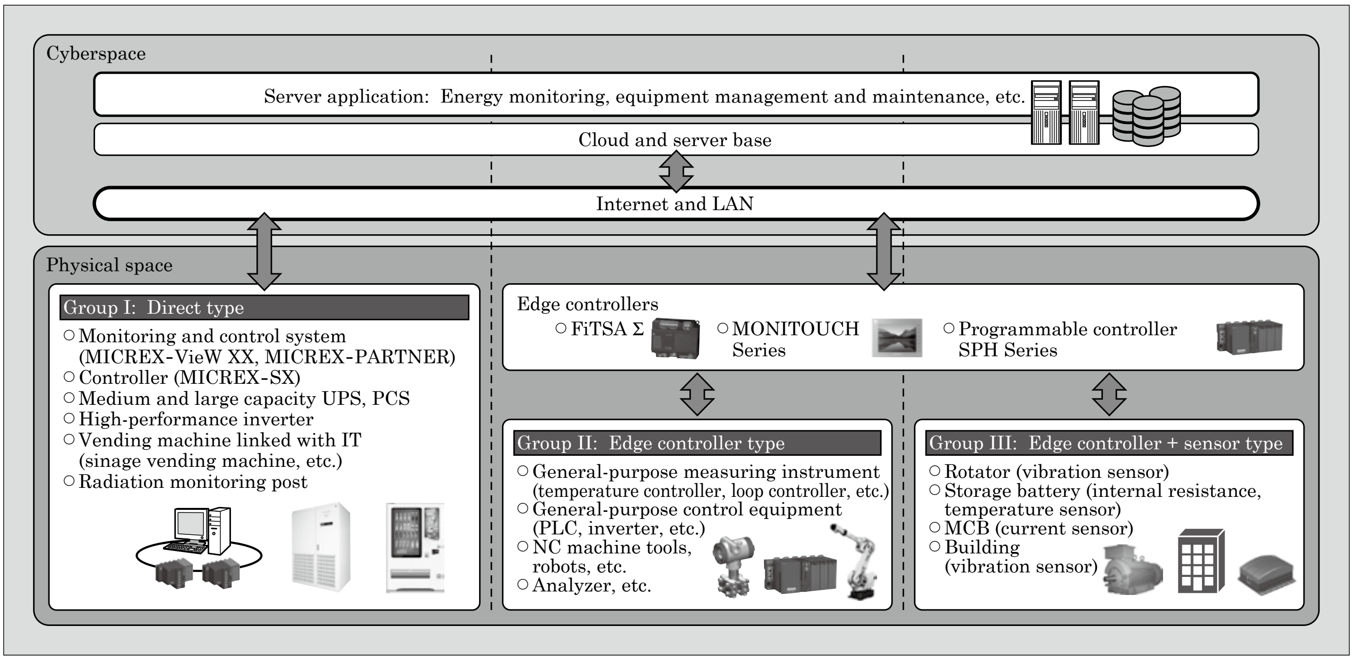

Fig. 1 Types of connection to cyberspace

We offer edge controllers based on the technologies for data collection, data analysis and prediction, optimization, and advanced control to provide IoT solutions. To cope with edge-heavy computing, edge controllers divide and implement part of the data analysis and prediction technology and optimization technology performed in cyberspace to solve challenges such as traffic cost, real-time responsiveness and security concerns. Thus, the edge controllers can respond to the request of manufacturing sites and provide solutions more in real time.

4 Characteristics of Fuji Electric Edge Controllers

Table 2 shows the characteristics of MONITOUCH V9-IoT, FiTSA Σ, and SPH3000-IoT, which are the edge controllers of Fuji Electric.

To respond to various demands shown in Chapter 2, it is necessary to enhance data handling (collection, accumulation, processing), which is the gateway function of edge controllers, connection networks, and security functions, and to provide engineering that supports the functions of the edge controllers (see Table 3). As shown in Fig. 2, it is necessary to divide and implement the functions of cyberspace and the edge controller.

Table 2 Characteristics and performance of edge controllers

Model	Characteristic	Diagnosis performance*
MONITOUCH V9-IoT	Real-time screen display on site, equipment connectivity	1,000 ms
FiTSA Σ	Small, high versatility, equipment connectivity	500 ms
SPH3000-IoT	High-speed real-time processing utilizing features of PLCs	50 ms

*The performance when provided with the real-time diagnosis function of multivariate statistical process control (MSPC), which is one of data analysis and prediction technologies, is mounted. The performance is approximately 10 seconds when the diagnosis is performed at a server in cyberspace.

Table 3 Functions required of edge controllers

Function category	Outline
Data handling	A. Data collection Collecting various data for system state analysis and equipment diagnosis B. Data accumulation Accumulating and transferring collected data C. Data processing Adding values to collected data (mounted with part of data analysis and prediction technology)
Network	○ Support for standard protocols for realizing connection among cyberspaces ○ Support for open protocols for realizing connection among field devices of various manufacturers
Security	Reducing security risk of cyberspace connection
Engineering	○ Engineering tools for realizing various functions ○ Horizontal link support among edge controllers ○ Vertical link support between cyberspace and edge

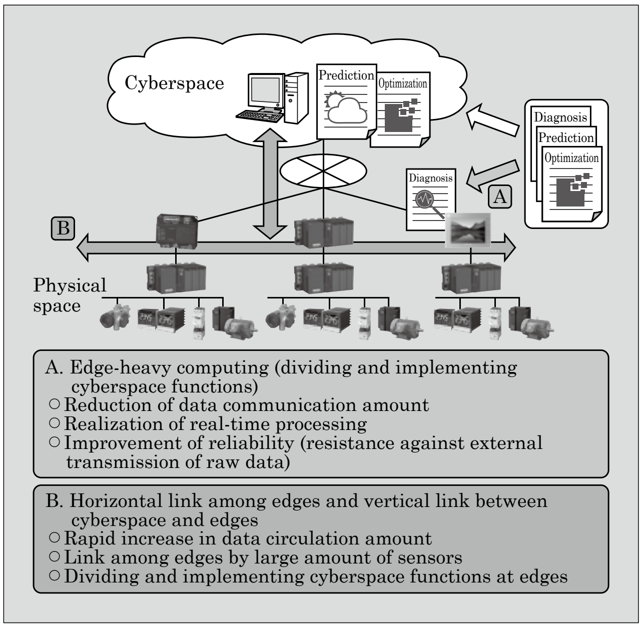

Fig. 2 Division of functions of cyberspace and edge controller

5. Application Examples of Edge Controllers

The following presents application examples of edge controllers for each issue of customers.

(1) Field data collection

Some customers are not able to connect computers to collect data because an equipment network cannot be connected, there is no installation space for computers, or high-speed sampling cannot be performed. SPH3000-IoT has rich equipment connection interfaces and data handling functions, which are the characteristics of PLCs, and can quickly collect data in a period of milliseconds. It is also small and can be installed in a limited space in a production facility, and the installation work can also be easily performed (see Fig. 3).

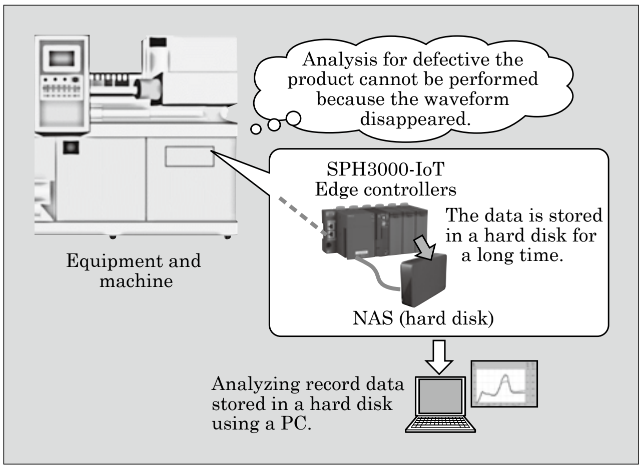

Fig. 3 Example of equipment data collection

In addition, the collected data can be stored in the external hard disk (NAS) connected to the edge controller as an archive.

(2) Introduction of field type diagnosis

Analyzing the collected data can clarify a solution to problems of customer equipment. For example, when the defective product rate increases in a large production facility, analyzing the waveform of sensors provided on the stored facility can clarify that a deterioration in a consumable component of the facility and increase in defective products are related to each other and that the consumable needs to be replaced. The MONITOUCH V9-IoT is an edge controller a single unit of which can perform a series of processing including data collection, analysis, diagnosis, and judgment display for equipment (see Fig. 4).

Thus, customers can collect data with edge controllers as an initial step of IoT introduction, and create further value from data analysis.

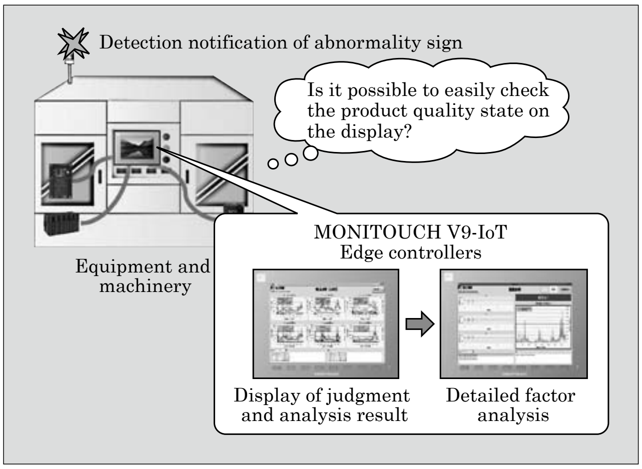

Fig. 4 Example of introduction of field type diagnosis

6. Postscript

This paper has explained edge controllers that connect field devices to cyberspace.

The need for edge-heavy computing is increasing with diversification of systems and services that use the IoT. It is becoming increasingly necessary to divide functions between the field and cyberspace.

Fuji Electric will work to develop edge controllers on the basis of utilization technology for open technologies, such as multi-core microcomputer, embedded security, real-time OS, and a general-purpose OS including Linux*1; real-time control technology that has acquired from PLC development; and engineering support technology. Through this development we will solve issues: low cost, high environmental endurance, high reliability, and high speed, which are necessary for field devices.

We will continue providing IoT solutions that lead to the creation of higher customer values.

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*1: Linux: Trademark or registered trade mark of Linus Torvalds in Japan and other countries

Referemces

(1) "Industrial Network Gateways Market Research (FIVE-YEAR MARKET ANALYSIS AND TECHNOLOGY FORECAST THROUGH 2020)". ARC Advisory Group. https://www.arcweb.com/sites/default/files/Documents/study-brochures/study-industrial-network-gateways.pdf, (accessed 2018-08-17).

Data Analytics as Core of Value Creation

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ABSTRACT

The advance of the Internet of Things (IoT) facilitates the collection of a large amount of data. Data analytics is the core technology for creating customer value. There are 3 major challenges to apply this technology in the industrial context: (i) impractical accuracy when an insufficient number of cases are available for learning, (ii) limited application to areas that require clear explainability of results, and (iii) complex modeling for ordinary system designers. To solve these issues, Fuji Electric has leveraged its original innovations and developed data analytics tools. The implemented analytical methods ensure wide applicability, with a particular focus on diagnosis and forecasting, which are widely demanded.

1. Introduction

Recently, it has become possible to easily collect a large amount of data thanks to the development of the Internet of things (IoT). This creates solutions that produce various values one after another. This paper explains data analytics, which is the core technology for creating solutions and serves as the core of value creation.

2. Challenges to Be Solved by Data Analytics

The data analytics of Fuji Electric is a general term for statistics, machine learning and artificial intelligence technologies to perform recognition, diagnosis, prediction and optimization (see Fig. 1). These technologies progress quickly worldwide. In some fields such as image recognition and games like go and shogi (Japanese chess), they outperform humans. However, in the industrial field particularly many clients need solutions. There are the 3 following major challenges of recognition, diagnosis and prediction, and various efforts are being made for them.

(1) Challenge a: Practical accuracy cannot obtained from an insufficient number of learning cases.

In the industrial field, terms and data tendencies are different depending on the application. Therefore, there is small number of learning cases, and a practical level of accuracy cannot be obtained.

(2) Challenge b: Inference base cannot be explained

Since the basis for the inference result is unknown, and the application is limited in a field that requires reliability.

(3) Challenge c: Complex modeling for ordinary sys-

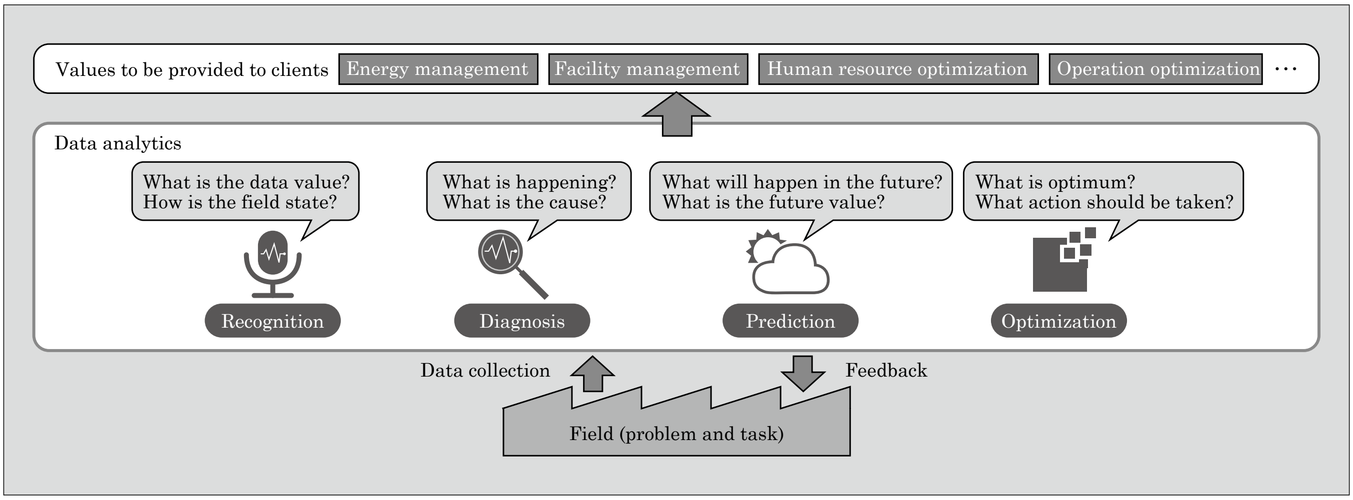

Fig.1 Data analytics

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tem designers

To construct high-performance diagnosis and prediction models, trial and error learning by data scientists is necessary, and it is difficult for general designers.

3. Whole Image of Data Analytics

Solutions using our data analytics are classified into recognition, diagnosis, prediction and optimization (see Fig. 1). For recognition, solutions such as voice input, image recognition, and semantic analysis improve efficiency of maintenance work at a manufacturing site to create customer values. For diagnosis, solutions such as abnormality diagnosis and remaining lifespan estimation, improve the yield rate and quality to create customer values. For prediction, solutions such as demand prediction and sign detection reduce cost and supporting driving to create customer values. For optimization, solutions such as optimal operation and power generation planning for energy plants reduce fuel cost to create customer values.

4. Introduction of Data Analytics

Data analytics is a core technology that can realize various solutions by learning a large amount of data, constructing high-precision models and utilizing them. This chapter explains our unique technology that can solve the challenges in Chapter 2.

4.1 Text recognition technology

Text recognition technology generally consists of 3 types of processing.

- ○ Dividing sentences into words and parts of speech
- ○ Converting synonyms into the same words
- ○ Processing, extracting and aggregating sentences in accordance with the purpose of analysis

The important processing part of text recognition technology is converting synonyms into the same word. Technology for automatically creating synonyms from a large number of documents was developed, and the accuracy is high for general terms where it is easy to collect learning cases. However, in the industrial field where learning cases are limited, there is problem of impractical accuracy, as described in Challenge *a* of Chapter 2.

To convert synonyms into the same word, we create 2 types of dictionaries, one for general terms learned with a large amount of cases and one for technical terms learned with limited cases. The result of each dictionary's sentence processing is integrated (see Fig. 2). Following these approaches[1], we have realized a high recognition accuracy by using general terms to complement the industrial fields where there is a difficulty in collecting learning cases.

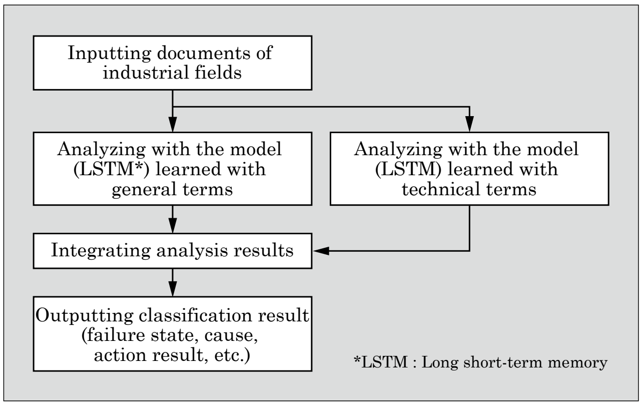

Fig.2 Text analysis method using several dictionaries

We are currently developing a plant maintenance system using this text recognition technology. The system can shorten the failure time by extracting records (failure state, cause and action result) that are close to the current state of the plant from the past maintenance records.

4.2 Diagnosis technology

We have applied multivariate statistical process control (MSPC), which has been used in the chemical process field, to diagnosis technologies such as abnormality diagnosis. We are developing abnormality diagnosis technology using machine learning to expand the application to objects having more complicated characteristics.

There are various diagnosis methods for complicated characteristics. In this section, the kernel-principal component analysis (PCA) method will be used as an example.

In normal machine learning, it is necessary to have learning cases of both normal data and abnormal data. However, there are few learning cases of abnormal data in the actual manufacturing process, and no practical accuracy could be obtained (Challenge *a*). The kernel-PCA solves this problem by performing learning only with abundant normal data and detecting states that are different from normal data (abnormality).

The kernel-PCA enables diagnosis even with non-linear characteristics by mapping data to a higher dimensional space using kernel functions and performing PCA in the higher dimensional space. Normal kernel-PCA can diagnose normal and abnormal states but does not have methods for determining the cause (vibration, voltage, etc.) when it diagnoses the state as an abnormality (Challenge *b*). Thus, we expanded advanced technology called the reconstruction based contribution (RBC) method[2] and applied that to kernel-PCA so a diagnosis basis similar to a normal MSPC can be presented (see Fig. 3). As a result, it is possible to quickly cope with an abnormality in the client equipment.

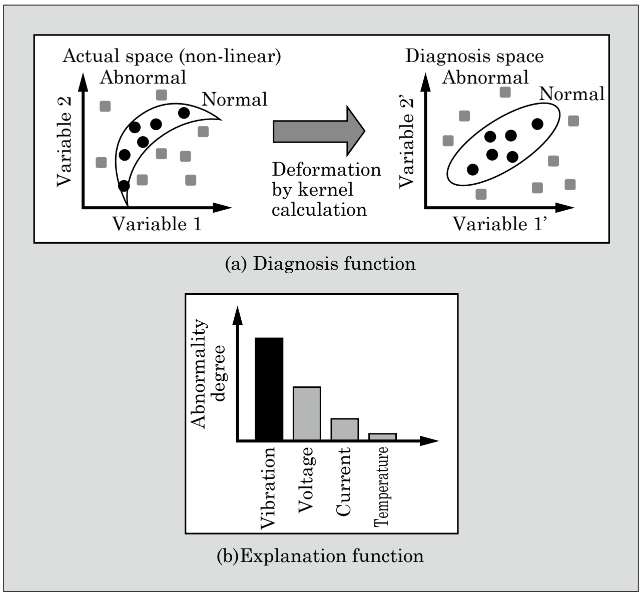

Fig.3 Diagnosis method using kernel-PCA

4.3 Prediction technology

Fuji Electric is developing various prediction technologies for objects. Just in time (JIT) modeling prediction is mainly used for objects having a limited amount of learning data, and a hierarchical neutral network such as deep learning is used for objects that can obtain a large amount of learning data*1.

JIT prediction is a technology that extracts data similar to the prediction object from the past data to make a prediction (see Fig. 4). With respect to Challenge *a* and Challenge *b*, the power demand and the merchandise sale amount are predicted as target objects for example based on similar cases. Therefore, a practical level of prediction is possible with objects with limited learning data, and the basis for the prediction is easy to understand (it is possible to present the basis for a prediction such as "the temperature is similar to that of the prediction target day" and "the day of the week is the same"). On the other hand, regarding Challenge *c*, developers needed to create models that define the definition of "similar" through trial and error. Regarding objects with changing consumption trends such as power demand and merchandise sales amounts, the definition of "similar" needs to be updated on a daily basis. To deal with this problem, we have used a decision tree, one type of machine learning, and developed a method that automatically defines the degree of "similarity." This method analyzes the recent trend of the prediction object with a decision tree, and automatically defines the similarity according to the variable importance obtained from the decision tree.

This method has been adopted in "ECONO-CREA," a power company cloud system and a solution for new power where there is a limited learning data amount because of the recent electricity deregulation. The system has been jointly developed by Fuji Electric, NTT DATA Corporation, and Kyowa Exeo Corporation. It won the Minister of Internal Affairs and Communications Award and general grand prize of ASP and SaaS section at ASPIC IOT Cloud Award 2017.

To cope with both Challenge *b* and Challenge *c*, we have added our unique approach to the hierarchical neural network. Regarding Challenge *b*, we designed the network structure, and extracted and visualized the correlation between input and output to indicate the basis for prediction. Regarding Challenge *c*, neurons counts and the combined state were conventionally determined by trial and error. The method we developed determines whether the neurons in the hidden layer is working effectively or unnecessary, and can automatically delete unnecessary neurons in the hidden layer. Figure 5 shows the analysis flow when a 4-layer network learns the data obtained by mixing 8 kinds of function data having different characteristics. It can be explained by extracting the characteristics of the input and output learned in the network in a function shape. The 3-layer structure is being applied to demand prediction of large electric power companies, prediction of streamflow into dam, and remaining life assessment of transformers. Regarding a network structure with 4 or more layers, the principle develop-

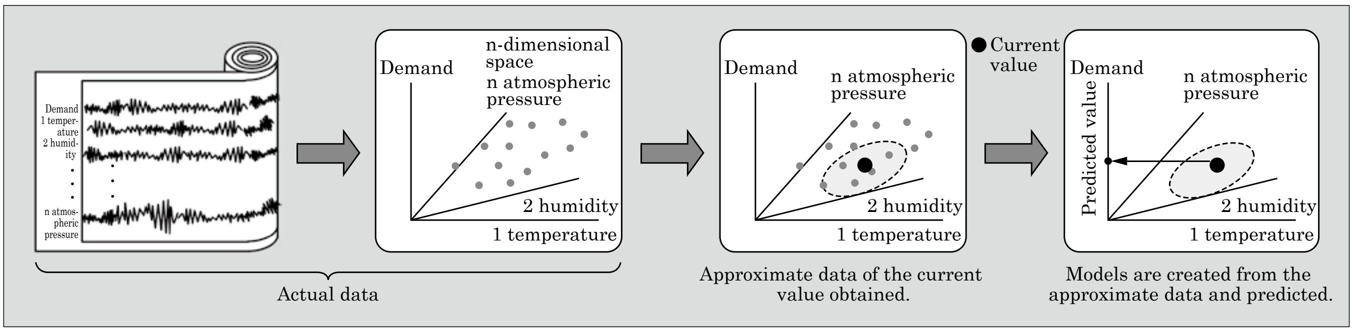

Fig.4 Conceptual diagram of JIT prediction

*1: Neutral network, Deep learning: Refer to "Supplemental explanation 1" on page 158.

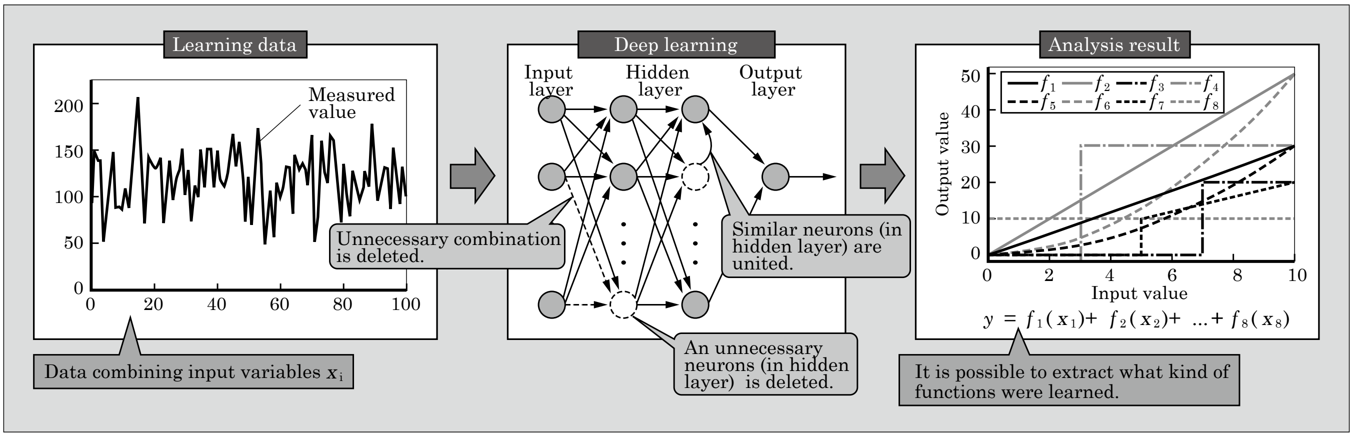

Fig.5 Analysis flow of deep learning

ment has been done, and the operation support system of the plant is being intensively developed.

5. Data Analytics Tool

Various types of data can now be easily collected by IoT; however, in contrast, there are not enough data scientists to analyze the large amount of data. Therefore, we are developing data analytics tools so other people besides data scientists can easily analyze data. This tool is particularly directed toward diagnosis and prediction, which are in high demand. Several methods are mounted so it can be applied to various targets (see Table 1 and Fig. 6).

The common function would be a cleansing function. The cleansing function can easily remove, replace, and complement the missing values and abnormal values as data pre-processing that generally takes up 80% of data analysis. Thus, the time needed for data analysis can be shortened.

Table 1 Function outline of data analytics

Category	Function	Method
Common	Cleansing	Removal, replacement and complement of missing values and abnormal values
Diagnosis	Visualization	Principal component analysis (PCA)
		Generative topographic mapping (GTM)
		t-distributed Stochastic Neighbor Embedding (t-SNE)
	Modeling	PCA
		Partial least squares (PLS)
		Kernel-PCA
		Support vector machine (SVM)
		eXtreme Gradient Boosting (XGBoost)
Prediction	Modeling	PLS
		Just in time modeling (JIT)
		Hierarchical neural network (deep learning)
	Quality simulation	PLS
		JIT

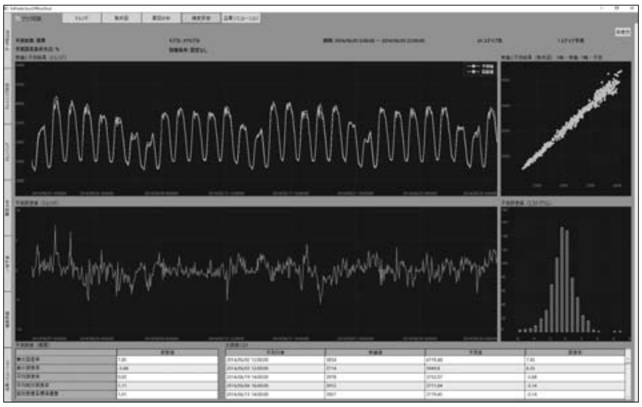

Fig.6 Example of prediction screen using data analytics tool

The visualization function in diagnosis determines the possibility of diagnosis. It compresses the multi-dimensional data into 2-dimensional data, and determines the data to be diagnosable if the abnormal data and the normal data are separately shown, and not diagnosable if the data cannot be separated. This function can determine whether the target data is diagnosable.

Figure 6 shows an example prediction screen of a data analytics tool. The reason for implementing several methods is because suitable technologies are different depending on the characteristic complexity of the diagnosis and prediction target. It is not easy for data scientists to determine which method is the best, and it has conventionally been determined by trial and error. Therefore, the tool has a function of automatically presenting the best method. A method that can handle complex characteristics also learns noise, and the accuracy may be reduced in the case of actual use. To prevent this, the method clearly separates the learning data and the test data so verification can be done under the same conditions as in actual use. This mechanism allows those who are not data analysts to easily analyze data and verify the results.

The quality simulation function determines the best manufacturing conditions with the manufacturing factories and plants as objects. This function learns combinations of various normal conditions and quality data in the past as quality simulation models. By simulating a quality change when the manufacturing condition is changed, the manufacturing condition that improves the yield rate and the quality can easily be obtained.

6. Application Example

The following refers to an example of applying the system to the temperature prediction of a manufacturing plant using deep learning. It predicts the temperature of intermediate products of several hours later from several tens of types of measurement data such as fuel and raw material quality. The temperature of intermediate products affects the quality of final products, and it is necessary to accurately control the temperature. Since the time constant of plants is long, it was necessary to predict the future temperature and control it in a feed-forward manner. The characteristic of the plant is not only complicated, but there is also a change in quality because of the difference in the lot or the origin of the raw material. Thus, it was difficult to automate with computers and controlling was done by human judgment. On the other hand, applying deep learning has made it possible to model complicated phenomena. To update the sequential model with close data, it became possible to deal with chronological change without human judgment.

As shown in Fig. 7, the change in the actual value can be properly predicted, contributing to the creation of customer values by improving the quality of products. Figure 8 shows an example of the analysis result of deep learning. When the ratio of a certain raw material component is increased, the temperature of the intermediate product drops. When the pressure rises, the temperature of the intermediate product rises. On the other hand, it is possible to quantitatively grasp that the flow rate hardly affects the temperature of intermediate products. That is, clients can use deep learning without anxiety by checking what kind of learning has been performed.

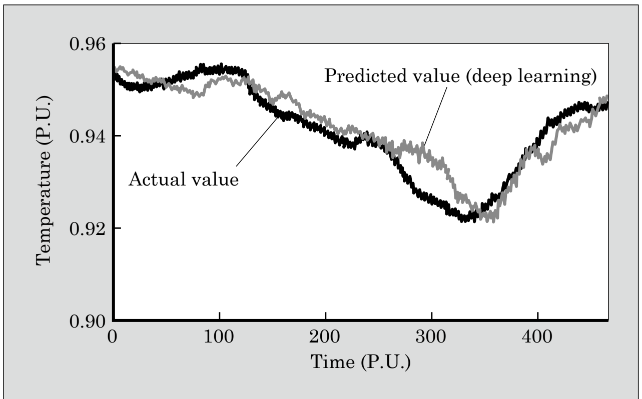

Fig.7 Temperature prediction result of manufacturing plant

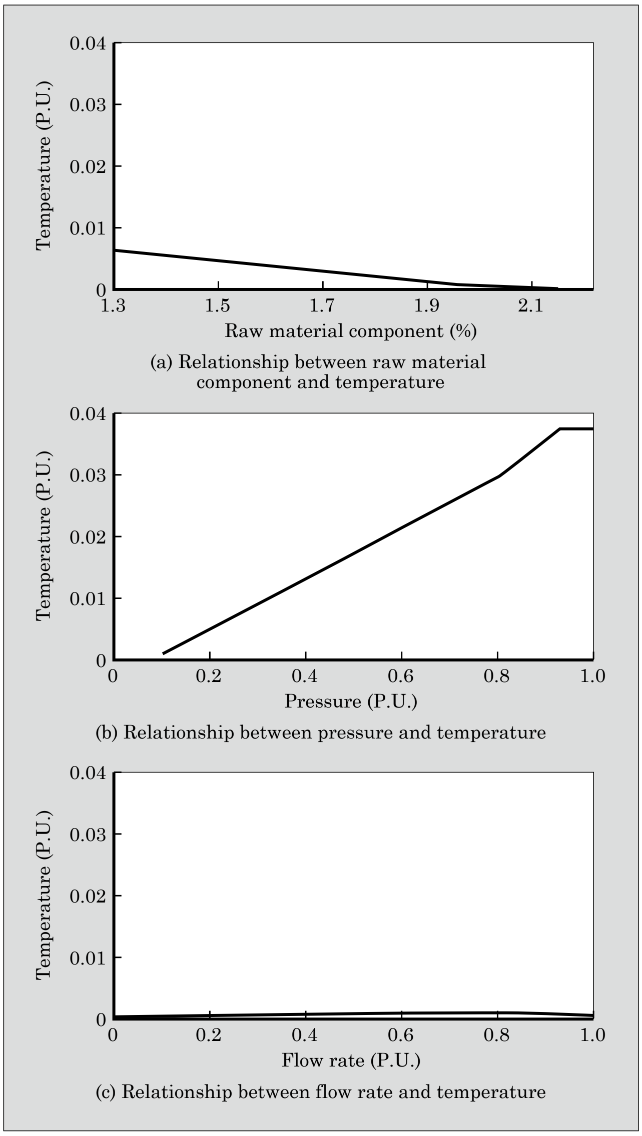

Fig.8 Example of analysis result using deep learning

7. Postscript

This paper describes data analytics, which serves as the core of value creation, has been described.

A large amount of data can be collected with IoT technology. However, conventional technologies could not handle an enormous amount of data sufficiently, and their performance result was not always satisfactory. To provide solutions that accelerate development using these huge data, we think that our unique data analytics is useful. Fuji Electric will expand the application to actual plants in the future to further create customer values.

References

(1) Yi Yang, Jacob Eisenstein. Unsupervised Multi-Domain Adaptation with Feature Embeddings. NAACL2015.

(2) Carlos F. Alcala, S. Joe Qin. "Reconstruction-based

Contribution for Process Monitoring with Kernel Principal Component Analysis". American Control Conference, 2010.

IoT System Security

UMEZAKI, Kazuya*

ABSTRACT

The current rapid growth of the Internet of Things (IoT) leads to a significant increase in cyberattacks and security incidents on the IoT devices. To address the IoT security risks, efforts to produce standards and guidelines has been progressing in Japan and other countries. Fuji Electric has established the information security policy based on the IoT security standards and guidelines and takes technical, physical, organizational, and personnel measures to build IoT systems that are secure and safe from their threat.

1. Introduction

Internet of Things (IoT) devices have been rapidly increasing in number recently. In 2020, about 30 billion IoT devices are predicted to be connected to the Internet(1). As a result, cyberattacks and security incidents targeting IoT devices are also increasing rapidly. Thus, standards and guidelines for IoT security are being developed in Japan and overseas.

On the basis of this situation, Fuji Electric is proceeding with IoT security efforts.

This paper explains examples of IoT system security problems and threats, the concept of IoT security measures based on guidelines in Japan and overseas, and Fuji Electric's efforts.

2 IoT Security Trend

2.1 Security problems of IoT system

The IoT is "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies(2),(3)." The following effects are expected(3).

(a) Connecting things to a network makes it possible to collect information quickly and accurately, and control devices and systems in real time.

(b) Mutually linking devices and systems in different fields enables new functions to be provided.

The following would be IoT security problems(3).

○ The extent of threat impact resulting from various devices and systems being connected
○ Difference in security concepts and requirements among various devices and systems
○ Limitation on security measures that can be taken associated with restrictions on the functions and performance of IoT devices
○ Insufficient monitoring of IoT devices
○ Long life cycle of IoT devices

Thus, connecting IoT produces values. On the other hand, there is a concern that the devices and equipment that have not been conventionally connected to the Internet may undergo cyberattacks, increasing security threats.

2.2 Example of security threat against IoT devices

The examples below are known as security incidents of IoT devices(3).

(a) Web cameras and home energy management systems (HEMS) connected to the Internet were accessible from the outside because of improper setting.

(b) A vulnerability in the multimedia system of an automobile was attacked, enabling unauthorized remote operation that affected driving.

In both cases, there was unauthorized access from the connection path to the outside such as the Internet or Wi-Fi*1. Unauthorized access succeeded because the device users did not perform appropriate setting and management (access via the development and maintenance interface remained possible, or the default password was not changed) and IoT devices were vulnerable.

Hijacked IoT devices may be used as a stepping stone and cause further invasion and attacks on other parts of a system. In September 2016, several distributed denial-of-service (DDoS) attacks were caused by "Mirai," the botnet of malware targeting vulnerable

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*1: Wi-Fi: Trademark or registered trademark of Wi-Fi Alliance

IoT devices. This brought great confusion to the Internet in the entire area of the East Coast of the United States.

3 IoT Security Measure

Regarding IoT security, standards and guidelines related to security are being developed in Japan and overseas. Table 1 shows the main standards and guidelines.

There are various IoT security approaches to these security standards and guidelines, but the basic concept is as follows.

(1) Risk analysis

Identify the assets to be protected, and analyze threats and its influence.

(2) Security measure

Determine and implement the measures against threats on the basis of risk analysis.

3.1 Risk analysis

Risk analysis comprises following three steps: clarifying system configuration, identifying information assets, and analyzing threats.

(1) Clarifying system configuration

There is a slight difference depending on the standards and guidelines, but the IoT system is generally classified into 4 layers as shown in Fig. 1.

The components (devices and systems) in each layer of the IoT system and the dataflow between them are identified and documented.

Table 1 Standards and guidelines related to IoT security

Classification	Publisher*	Name of standards and guidelines	Date of issue
Overseas	oneM2M	oneM2M Technical Specification Application of Security Technology	2016-03 (V1.0.0) 2018-02 (V2.0.1)
	GSMA	GSMA IoT Security Guidelines	2016-02 (V1.0) 2017-10 (V2.0)
	IIC	IIC Security Framework	2016-09 (V1.0)
	CSA	Security Guidance for Those Adopting IoT at Early Stage	2016-02 (V1.0)
	OTA	OTA IoT Trust Framework	2016-03 (V1.0) 2017-06 (V2.5)
Japan	IPA	Guidance on Security Designing in IoT Development	2016-05 (first edition) 2018-04
	IoT Promotion Consortium	IoT Security Guideline	2016-07 (V1.0)

* oneM2M: International standards organization of M2M and IoT technologies in the electronic information communication field
GSMA: GSM Association. Business organization of the GSM scheme, which is one kind of mobile phone systems.
IIC: Industrial Internet Consortium. Business organization that promotes implementation of industrial IoT.
CSA: Cloud Security Alliance. Non-profit organization specialized in cloud security.
OTA: A lower branch of Internet Society, an international non-profit organization related to the Internet
IPA: Information-technology Promotion Agency

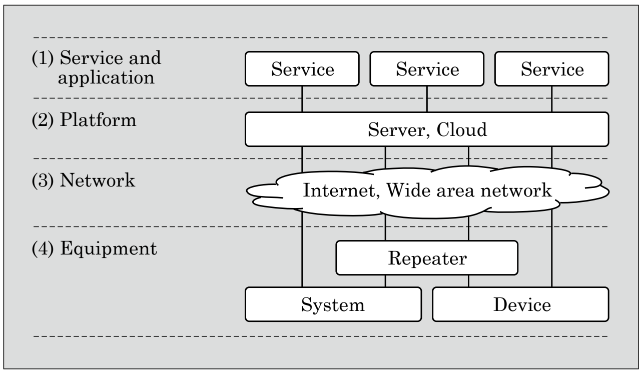

Fig.1 Hierarchical structure of IoT system

(2) Identifying information assets

The information, functions, and assets contained in the IoT system components are clarified, and then objects to be protected are identified by importance.

(3) Analyzing threats

Existing analysis methods are applied in threat analysis for IoT systems. STRIDE, which is one of the analysis methods, performs analysis for the types of threats shown in Table 2, and extracts vulnerable parts that may be affected by the threats[(3) to (5)]. The degree of influence is analyzed on the extracted threat. In DREAD, which is one of the analysis methods, the in-

Table 2 Threat types and examples of STRIDE

Types of threats	Examples of threats
Spoofing	Unauthorized acquisition of IDs and credentials (passwords, for example) causes spoofing of IoT devices and users.
Tampering	Data is rewritten in one of the stages of data collection, processing, migration or storage in the IoT system.
Repudiation	Bad data is supplied to the system by unauthorized device connection, not allowing the system to operate properly.
Information Disclosure	Data is accessed in an unauthorized manner in one of the stages of data collection, processing, migration or storage in the IoT system.
Denial of Service	A large amount of data is transmitted to the IoT system components, and the system functions become unavailable.
Elevation of Privilege	Devices and users without authority can access functions and data of the IoT system.

Table 3 Risk evaluation method DREAD

Evaluation axis of influence	Description
Damage potential	Degree of damage when vulnerability is attacked
Reproducibility	How easy attacks can be reproduced (success)
Exploitability	How easy attacks can be misused
Affected users	Scale of users influenced by attacks
Discoverability	Possibility that attackers find vulnerability

Table 4 Classification of security measures

Types of measures	Examples of measures
Technical measures	User identification and authentication, device identification and authentication, access control, firewall, intrusion detection system, communication path encryption, data encryption, log collection, etc.
Physical measures	Information processing area management, prevention of information asset theft, management of electronic media, deletion and disposal management of information assets
Organizational measures	Building organizational system, operation in accordance with rules and procedures, system monitoring, vulnerability handling system, incident response system, etc.
Personal measures	Improvement of employee awareness, education, training, etc.

fluence of the attack on the vulnerability is evaluated by the evaluation axes shown in Table 3[(4)].

3.2 Security measure

Based on the risk analysis result, security measures are selected and implemented for those risks with a large influence.

Security measures can be divided into 4 types—technical measure, physical measure, systematic measure and personal measure—as shown in Table 4.

4. IoT Security Efforts of Fuji Electric

4.1 Fuji Electric IoT platform

As shown in Fig. 2, our IoT platform has a configuration in which field devices link with services on the cloud with IoT devices called edge controllers as gateways.

For security on this IoT platform, we have developed a security policy considering the risk analysis result and various guidelines, and we are promoting measures shown in Fig. 3 based on the policy.

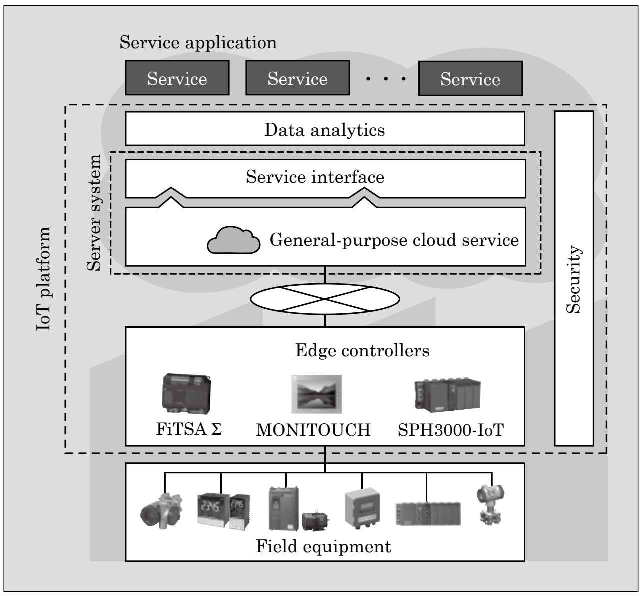

Fig.2 Configuration of Fuji Electric IoT platform

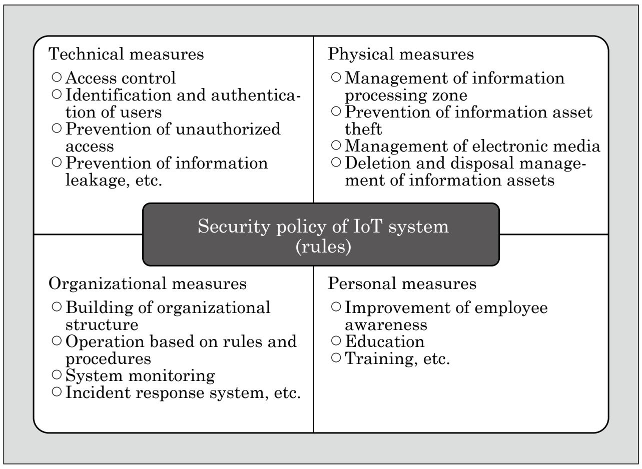

Fig.3 IoT security policy of Fuji Electric

4.2 Security policy of IoT system

We have developed an in-house standard for IoT system security. The standard is applicable to our IoT systems and related business activities, such as development, construction, operation, and maintenance, computers and electronic storage media used for these tasks, and the employees who work for the tasks. The in-house standard is based on the concept of security standards and guidelines such as ISO/IEC 27017: 2015[(6)] and IoT security guidelines[(3)].

4.3 Technical and physical security measure

(1) Measure in general-purpose cloud service

The server system of the IoT platform is built on an external general-purpose cloud service. The general-purpose cloud service is selected and used after checking the security measure status. Specifically, the cloud service provider has acquired ISO 27001 and ISO 27017 certifications and takes the following measures to secure confidentiality, integrity and availability (CIA).

(a) Measure as data center

Intrusion prevention, entry/exit management, operation evidence management, etc.

(b) Measure against network

Firewall, intrusion detection, communication encryption, redundancy etc.

(c) Measure against physical storage and physical server

Access restriction, data encryption, virus infection prevention, operation evidence management, redundancy, etc.

(d) Measure against the virtualization infrastructure

Separation by network virtualization, vulnerability information support, auto failover, etc.

(2) Measure against server system and service on cloud

For the service IoT platforms such as data analytics and service interfaces developed by Fuji Electric, the following security measures of the conventional server cloud application are applied.

(a) Avoidance of vulnerability

Conformity with guidelines for secure software development

(b) Prevention of unauthorized access

Identification and authentication of users of service, access control, protection of important data, etc.

(3) Measures on edge controllers and communication

Regarding edge controllers, which access the IoT platform on a cloud, identification, authentication and communication encryption are performed as follows to prevent unauthorized access.

(a) Authentication and encryption on the communication path.
(b) Intrusion prevention at connection points (firewall, VPN, etc.) to a network.
(c) Mutually authentication between the server system and edge controllers.
(d) Access control to the server system.
(e) Device authentication for the edge controller as a data source by the service interface.

4.4 Organization and human security measure

(1) On the basis of the Fuji Electric Risk Management Rules, which were formulated in May 2006, the Company manages risk in a coordinated, systematic manner. Information security is managed as a part of the risk management (see Fig. 4). To protect confidential and personal information properly, Fuji Electric has formulated and implemented a policy and rules related to information security. We seek to strengthen information security by instituting annual training programs for employees and endeavor to prevent information leaks. Companies that handle customer's confidential and personal information and require a high-level information security management have acquired external certification, such as an information security management system (ISMS) certification and Privacy Mark certification.

(2) Fe-CSIRT

We have established the Computer Security Incident Response Team (Fe-CSIRT) in April 2017 to enhance flexibility and defense capability against security threats that are becoming diversified and complicated such as targeted cyberattacks and attacks on the control system and IoT vulnerability.

As one of the IT strategy groups of Fuji Electric, the team deals with and prevents information security incidents that occur within the Fuji Electric groups under the existing information security management system in cooperation with the office that leads monitoring, audit and education.

Regarding IoT, we also constructed an organization and operational structure for incident response as with the Fe-CSIRT system.

5. Postscript

Security of an IoT system has been explained in this paper. Cyberattacks and security incidents are increasing with the increase in the number of IoT devices. We are constructing an IoT system that can be used safely and securely by developing security policies considering the threats against an IoT system and implementing measures in terms of the system and the mechanism.

Cyberattacks are progressing every day, and it is indispensable to have an ongoing approach to security measures. Fuji Electric will continue developing technology to ensure the security of IoT systems.

References

(1) 2018 White Paper on Information and Communications in Japan. Ministry of Internal Affairs and Communications.
(2) ITU-T Y. 2060 (4000), Overview Of Internet Of Things. 2012.
(3) IoT Security Guidelines Ver. 1.0. IoT Acceleration Consortium; Ministry of Internal Affairs and Communications; Ministry of Economy, Trade and Industry. 2016.
(4) Security Guidance for Early Adopters of the Internet of Things (IoT). Cloud Security Alliance. 2015.
(5) IIC Security Framework. 2016.
(6) ISO/IEC 27017: 2015.

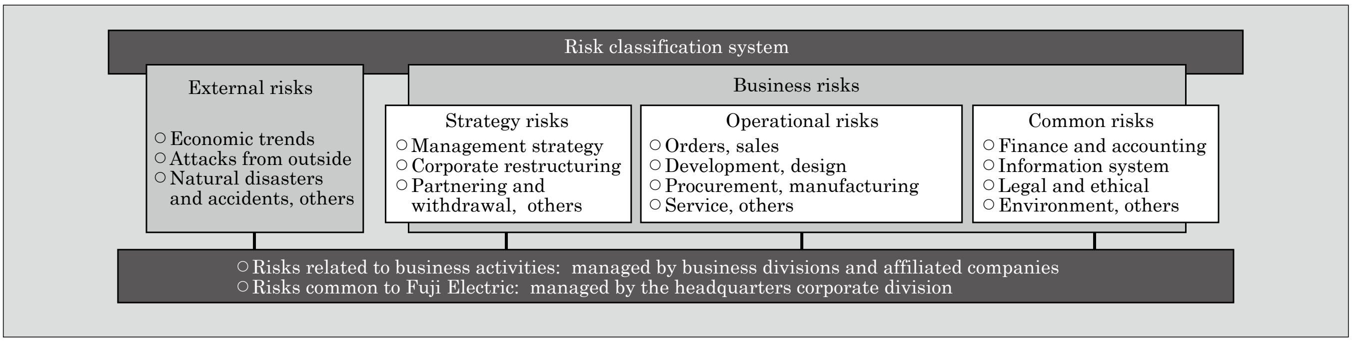

Fig.4 Risk classification system and management system of Fuji Electric

Supplemental Explanation

Supplemental explanation 1 Neural Network, Deep Learning

p.150

A neural network is a general term for models expressing neural cells inside a human brain and the connection thereof by using mathematical expressions in an information processing system. There are various types, such as a hierarchical neural network and a recurrent network. Fuji Electric has been continuously studying ways to practically realize neural networks since the 1990s, and we have applied them to various systems.

Deep learning is a kind of neural network and is a network structure itself having a large number of layers. For example, there is a deep neural network simply with an increased number of layers, a convolutional neural network designed for image processing, and a long sort-term memory (LSTM) designed for text recognition. Since the 2000s, the learning performance has been greatly improved by the development of learning algorithms and the improvement of calculation capability, and it is now a central technique of the recent third-generation AI boom.

“F-COOL NEO” Energy-Saving Hybrid Air-Conditioning Unit Indirectly Using Outside Air (Cooling Capacity 56 kW)

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In recent years, the amount of heat generated by servers used in data centers has increased dramatically due to their high performance and density. The heat generated by servers is generally cooled through the use of air conditioners. In order to save energy of the air conditioners and take advantage of natural energy, efforts are being made to adopt outside air cooling that utilize outside air as a cold heat source. Outside air cooling is classified as either direct system that directly use outside air or indirect system that use a heat exchanger to discharge heat to the outside air.

Fuji Electric has offered its “F-COOL NEO” hybrid air-conditioning unit (cooling capacity of 40 kW). It combines refrigeration cooling with indirect outside air cooling that is insusceptible to moisture, dust and corrosive substances. We newly developed a new model with a cooling capacity of 56 kW (see Fig. 1).

1. Features

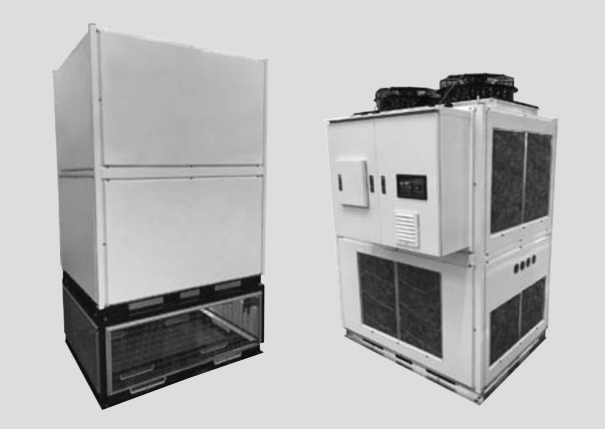
The main features of the F-COOL NEO are as follows:

(a) Yearly power consumption can be reduced to approximately one-third of that of general air conditioning systems due to the combined usage of indirect outside air cooling with refrigeration cooling.

(b) It is less susceptible to moisture, dust (such as PM2.5) and corrosive substances contained in outside air because it indirectly uses the air.

(c) Only the power supply is required. There is no need for cold water or cooling water.

(d) The supply air (blowing air) opening faces downward to accommodate installation on raised floors.



(a) Indoor unit　　(b) Outdoor unit

Fig.1 “F-COOL NEO” (cooling capacity 56 kW)

2. Specifications

Table 1 shows the specifications for the F-COOL NEO. The supply air opening of the 56-kW type faces downward. The energy consumption efficiency (Tokyo annual average) is COP*1 = 10, which is equivalent to that of the 40-kW type.

Table 1 “F-COOL NEO” specifications

Item		Specifications	
		FCA-56 A	FCA-40 A (conventional product)
Cooling method		Indirect outside air cooling (antifreeze) + compression refrigeration cooling (R410A)	
Specification voltage (V) (option indicated in parentheses)		400 (200)	200 (400)
Rated cooling capacity (kW)*		56	40
Maximum power consumption (kW)		26	16
Rated supply airflow (m^3/h)		12,000 Setting range: 2,500 to 16,800	8,500 Setting range: 2,500 to 12,000
Outside air intake temperature range (°C)		−15 to +43	
Supply air temperature setting (°C)		18 to 35	
Supply air direction		Downward	Lateral direction
Dimensions (excluding electric panel)	Indoor unit (mm)	W1,180 × D1,591 × H2,650	W1,180 × D1,158 × H2,300
	Outdoor unit (mm)	W1,180 × D1,591 × H2,288	W1,180 × D1,000 × H2,700
COP 26 °C supply air at rated supply airflow (Tokyo annual average)		10	

*At above 35 °C, the cooling capacity drops below the rating

*1: COP (coefficient of performance): Cooling capacity (kW) / Cooling power consumption (kW)

* Power Electronics Systems Group, Fuji Electric Co., Ltd.

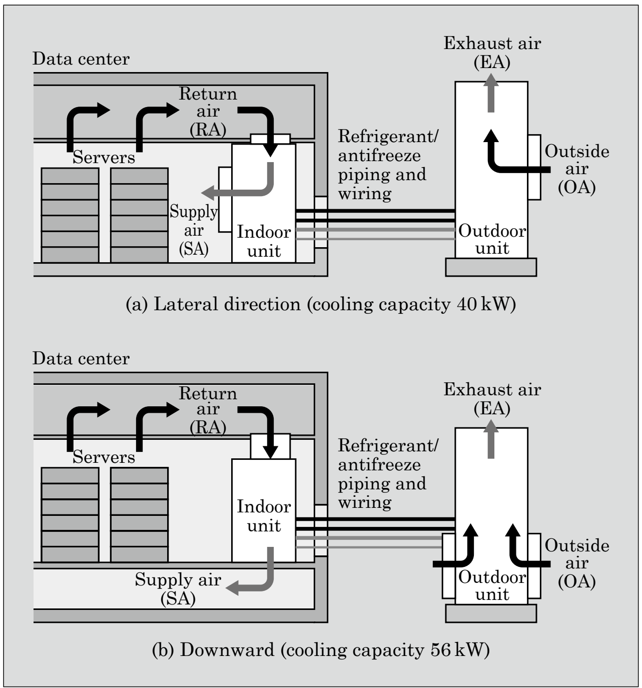


Fig.2 "F-COOL NEO" application examples

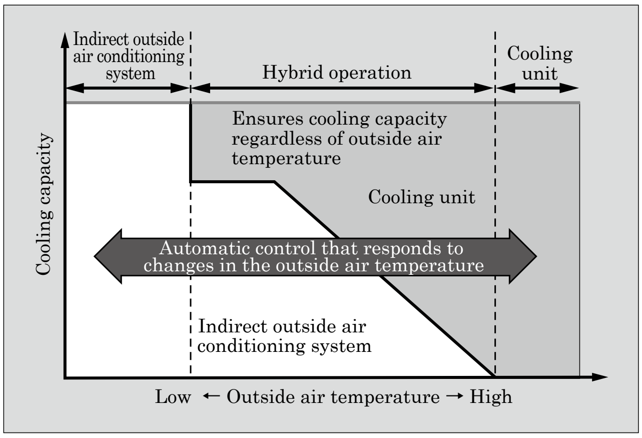


Fig.3 Schematic representation of the capacity sharing between the indirect outside air cooling and refrigeration cooling

3. Application Examples

Figure 2 shows examples of applying the F-COOL NEO to a data center.

In order to cool the data center, cool air is supplied in the lateral direction from the indoor unit with server racks installed on the floor [see Fig. 2(a)], or supplied from underneath the floor with server racks installed on a raised floor [see Fig. 2(b)]. The former has the benefit of suppressing construction costs, while the latter has the advantage of providing uniform cooling over a wide floor space. The choice of systems often depends on the size of the data center and the performance of the installed servers.

Our recently developed type, delivering a large cooling capacity of 56 kW, has the supply air opening facing downward so that it will be used on raised floors of relatively large data centers.

4. Supporting Technologies

This section describes the operation control method for achieving energy savings in the F-COOL NEO. The control method is basically the same for both the 40-kW type and 56-kW type.

Indirect outside air cooling is highly efficient because it does not use a compressor. However, cooling capacity decreases as outside air temperature increases. A refrigerator is used to compensate for any insufficiencies in the cooling capacity of the indirect outside air cooling system. In order to achieve energy savings by reducing the operation of the compressor as much as possible, the system maximizes the use of outside air cooling by automatically selecting the appropriate mode from among several operating modes.

Figure 3 shows the schematic representation of the capacity sharing between the indirect outside air cooling and refrigeration cooling. It shows the ratio of capacity sharing between indirect outside air cooling and refrigeration cooling by plotting the outside air temperature on the abscissa and the cooling capacity on the ordinate. In order to maintain cooling capacity regardless of the outside temperature, operation is primarily carried out by the following 3 modes:

(1) Indirect outside air cooling independent operation (indirect outside air cooling mode)

The indirect outside air cooling system runs independently when the capacity of the indirect outside air cooling is sufficient for the cooling load.

(2) Combined use of indirect outside air cooling and refrigeration cooling (hybrid operation mode)

The refrigerator is used to compensate for any insufficiencies when the cooling capacity of the indirect outside air cooling system falls below the cooling load. However, its usage must be minimized because running the compressor will lower overall efficiency.

(3) Refrigerator independent operation (refrigeration cooling mode)

The refrigerator is used independently when the outside air cooling capacity is ineffective due to the outside air temperature exceeding the return air temperature.

Figure 4 shows the schematic representation of the operation of major equipment at each F-COOL NEO cooling mode. As mentioned above, the F-COOL NEO consists of 2 cooling systems, namely, an indirect outside air cooling system and a refrigeration cooling system. The indirect outside air cooling mode only uses a pump and fan to cool the air [see Fig. 4(a)]. The hybrid operation mode simultaneously operates refrigeration cooling, which uses the compressor and expansion valve, along with indirect outside air cooling [see Fig. 4(b)]. The refrigeration cooling mode operate refrigera-

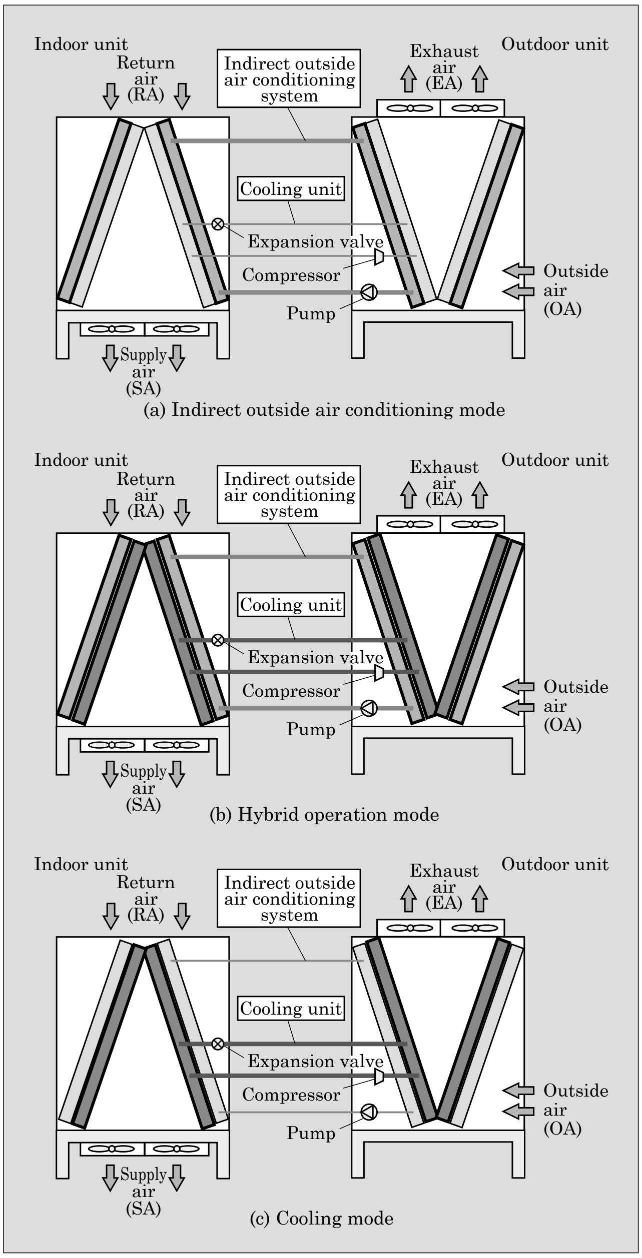


Fig.4 Operation of major equipment at each cooling mode

tion cooling, which uses the compressor and expansion valve instead of the pump [see Fig. 4(c)].

The 56-kW type needs a larger heat exchanger to achieve a cooling capacity beyond that of conventional units, while also maintaining energy saving performance. Although the heat exchanger for the 40-kW type was installed upright, the same configuration in the 56-kW type would have led to an increase in equipment dimensions. Therefore, the heat exchanger in the 56-kW type is segmented and installed at an angle to resolve the issue.

Launch time

November 2017

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“MONITOUCH TS1000 Smart Series” Programmable Operator Interface, Enhancing Usability and Visibility

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The expansion of globalization through the rapid development of the Chinese and Asian markets has led to increased demand for product supply stability and reduced product prices.

In the industrial sector, the demand for human machine interface (HMI) has been increasing, being used in various types of machinery.

In order to meet the growing demand in the Chinese and Asian markets, Fuji Electric developed the “MONITOUCH TS1000 Smart Series” as a programmable operator interface designed to enhance usability and visibility while consolidating functionality and launched it in August 2018.

1. Overview

Figure 1 shows the external appearance of the “TS1100Si” of the MONITOUCH TS1000 Smart Series and Table 1 shows its main specifications. The MONITOUCH TS1000 Smart Series provides a line-up of 7-inch and 10.2-inch screen sizes, demand for which is at its highest in the Chinese and Asian markets. All models are compliant with major global and regional standards, such as CE, KC, UL and cUL, enabling them to be used throughout the world.

The Series utilizes a TFT color LCD with 65,536 colors through the use of LED backlights, thereby enhancing visibility and expressiveness and guaranteeing reliable status display and usability at production sites. A sleek, simple design is adopted for the external appearance so that it can be mounted to any machine without any sense of incompatibility.

Fig. 1 “TS1100Si”

* Power Electronics Systems Group, Fuji Electric Co., Ltd

Table 1 Main specifications of the “MONITOUCH TS1000 Smart Series”

Item		TS1070S	TS1070Si	TS1100Si
Main unit specifications	Screen size	7 inches		10.2 inches
	Display device	TFT color		
	Resolution	800 × 480 dots		
	Display colors	65,536 colors		
	Backlight	LED		
	Touch screen	Analog resistive film system		
	Conformity standards	CE, KC, UL, cUL		
User memory	FROM	26 MB		
	SRAM	128 KB		
External interface	COM1 D-sub9 pin (female)	RS-422/485 Data length: 7, 8 bits Parity: Even, odd, none Stop bit: 1, 2 bits Baud rate: 4,800, 9,600, 19,200, 38,400, 57,600, 76,800, 115,200,187,500[*1] bits/s		
	COM2/COM3 D-sub 9 pin (male)	COM2:RS-232C COM3: RS-422/485 (two-wire type) Data length: 7, 8 bits Parity: Even, odd, none Stop bit: 1, 2 bits Baud rate: 4,800, 9,600, 19,200, 38,400, 57,600, 76,800, 115,200 bits/s		
	LAN	N/A	1 ch	
	USB-A	1 ch		
	USB mini-B	1 ch		
Power supply	Rated voltage	24 V DC ±10%		
	Power consumption (max. rating)	11 W or less		12 W or less
Physical environment	Ambient temperature	0 °C to 50 °C[*2]		
	Ambient humidity	85% RH or less (without dew condensation)		
	Contamination level (IEC 60664-1)	2		
	Operating altitude	2,000 m or less		
	Operating atmosphere	No corrosive gas and no excessive dust (no conductive dust)		
	Ambient storage temperature	−10 °C to +60 °C		
	Ambient storage humidity	85% RH or less (without dew condensation)		
Installation conditions	Protective structure: Panel front	IP65 equivalent (when using a waterproof gasket[*3]) IP40 equivalent (when not using a waterproof gasket[*3])		
	Protective structure: Rear case	IP20 equivalent		
	Dimensions (mm)	W198.8 × H141.8 × D38.0		W266.8 × H206.8 × D38.0
	Panel cut dimensions (mm)	189.0 × 134.0 (+0.5/−0)		257.0 × 199.0 (+0.5/−0)

*1: 187,500 bits/s only applies to Siemens MPI/PPI communication
*2: To prevent accidents, use at a wet-bulb temperature of 39 °C or less
*3: Optional item

2. Functions

2.1 Server function

In recent years, the demand for remote monitoring and control of machines has been increasing. The MONITOUCH TS1000 Smart Series comes equipped with VNC server functionality ("i" type only), and it can be remotely monitored and controlled from a PC, tablet and smartphone via a wireless LAN Ethernet*. Furthermore, in situations where a user need to manage data from a higher level system, it also provides FTP server functionality, enabling the user to read and write files located on the USB drive inserted into the MONITOUCH TS1000 Smart Series from your PC connected through Ethernet.

2.2 Remote control

By connecting a PC and the MONITOUCH TS1000 Smart Series via Ethernet, a user can use the remote desktop function to implement the control of the PC screen on the MONITOUCH TS1000 Smart Series. Moreover, it can also be operated by connecting a mouse to the USB port of the MONITOUCH TS1000 Smart Series. Furthermore, by using "TELLUS & V-Server" remote monitoring software, information on the production site can be collected in real time via Ethernet for remote monitoring and management. Please note that the license of remote desktop and TELLUS & V-Server must be purchased separately.

2.3 8-way communications

Eight-way communications combine Ethernet based connections (8 protocols) and serial based connections (3 protocols) to enable a single MONITOUCH TS1000 Smart Series to connect up to 8 different types of devices or programmable logic controllers (PLC) and peripheral devices of other companies. In addition, it also supports simultaneous communication with the 8 types of devices and data transfer between devices.

2.4 Operation log and security functions

In recent years, safety of machinery has become an important issue. The MONITOUCH TS1000 Smart Series contributes to the design of highly safe machines by using operation logs and security functions.

The operation log enables the user to record operations in chronological order, such as switch operations and numerical input on a screen. This makes it possible to refer to history logs and learn who, when, and what operation was executed to analyze factors of abnormalities.

Security functions are managed by user name and password, and security levels can be set from 0 to 15. Security can be set for screens and switches at varying levels, and logged-in users can perform operations at their authorized level.

*1: Ethernet is a trademark or registered trademark of Fuji Xerox Co., Ltd.

3. Features

3.1 Inheritance of screen assets

The MONITOUCH TS1000 Smart Series can use the screen data of the previous model MONITOUCH TS1000 Series as is.

3.2 Reduction in size and weight

The panel cut size and screen size have remained unchanged, while achieving external miniaturization of 10% to 15% over previous models and mounting footprint reduction. Furthermore, it achieves weight savings of 30% to 40% over previous models by replacing the fixations of the housing with a structure that does not require metal plates.

3.3 External interface

(1) USB drive mounting direction

Previously, USB drive was inserted into a port on the back of the case, and that required extra space behind the case in the enclosure. The MONITOUCH TS1000 Smart Series no longer requires this space to be secured because USB drive can now be inserted from underneath the case.

(2) Adoption of NAND flash memory

Previously, a NOR type was utilized as nonvolatile memory (FROM), but the current model has adopted a NAND FROM in order to facilitate increase in screen data capacity and cost savings. As a result, the screen data size capacity has been increased 2.6 times.

(3) NAND flash memory error correction code

An 8-bit BCH error correction code (ECC) scheme has been adopted for the NAND flash memory, and it contributes to enhanced bit error correction.

3.4 Battery voltage detection function

A button cell battery used to back up history logs, etc. was previously prompted replacement every 3 years regardless of whether or not the battery was consumed. Now, the MONITOUCH TS1000 Smart Series is environmentally friendly designed to monitor the battery voltage and prompt the user to replace it by displaying a warning on the screen when the battery is in undervoltage.

3.5 Power consumption

Power consumption is reduced by 25% by adopting a high-efficiency switching power supply IC and achieving circuit power saving.

Launch time

August 2018

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