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Technical Achievement and Outlook in FY2016

Fuji Electric

Innovating Energy Technology

FUJI ELECTRIC
REVIEW

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Through our pursuit of innovation in energy and environment technology, Fuji Electric creates environmentally friendly products and systems for using energy stably and most efficiently. We have been conducting research and development to pursue value for customers thoroughly by using the technologies of creating competitive components, building systems characterized by the use of these components, and connecting these systems with the Internet of Things (IoT). This issue is a compilation of the technical achievements of FY2016 and summarizes the outlook for the future. We hope that this issue will be helpful to create a new society.

Cover Photo:

(1) "7300WX-T3U/300" large-capacity UPS that facilitates data center energy savings, (2) Central Japan Rail Company's N700A Shinkansen equipped with Fuji Electric's propulsion system, (3) More convenient convenience store with open showcases and coffee machines, (4) "PVI1000BJ-3/1000" PCS supporting mega solar at various locations, (5) "ALPHA7" servo system that supports high-speed, high-precision, and safe operation in the factory automation field, (6) High-capacity direct liquid cooling power module for automotive applications to achieve high-efficiency and miniaturization, (7) Process automation characterized by the "MICREX-VieW XX" and various controllers, (8) Port container crane operated with Fuji Electric's electric equipment and control systems, (9) R&D Department distinguished by its innovative products and technologies

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Preface

Pursuing Innovation in Energy and Environment Businesses, We Contribute to the Creation of Responsible and Sustainable Societies Under the Slogan "To Be Enthusiastic, Ambitious and Sensitive"

Fuji Electric has been contributing to society in the fields of industrial and social infrastructure since it was established in 1923.

The earth currently faces energy and environmental problems as a result of rapid increases in population and industrialization. Fuji Electric's brand statement is "Innovating Energy Technology." By pursuing innovation in energy and environment technology, we will continue to provide the world with environmentally friendly and high added-value products and systems that utilize energy stably and most efficiently. This will contribute to the creation of responsible and sustainable societies.

In April 2016, we announced our FY2018 Medium-Term Management Plan, in which we are engaged in the Further Renovation of Fuji Electric. In April 2017, as operational reforms, we reorganized our Social Systems, Industrial Infrastructure, and Power Electronics businesses into the Power Electronics Systems Business Group that has newly started. Its aim is to create competitive components and enhance systems through competitive components to increase sales of systems outside Japan. In a wide range of industrial fields, we will deliver energy solutions that achieve energy optimization and stabilization and industry solutions that are aimed at productivity improvement and energy conservation through factory automation and visualization.

In order to accelerate research and development, Fuji Electric has transformed the development system into one in which each business group takes on functions related with product development, while the Corporate R&D Headquarters tackles advanced research and fundamental research. The Power Electronics Systems Business Group has also newly established and expanded its product development management function. At the same time, we have upgraded our research and development bases. In FY2015, we constructed the Development Center for power semiconductors in the Matsumoto Factory, and the Core R&D Center in the Tokyo Factory for company-wide R&D and instrumentation and control technology. In FY2016, we built the Power Electronics Technical Center in the Suzuka Factory to bring our power electronics researchers and engineers together.

Against this backdrop, our R&D focuses on producing power electronics products with top-level power semiconductors as core devices and then creating integrated and differentiated component and system products by adding our instrumentation and control technology. We are also thoroughly pursuing value for our customers by connecting these distinctive component and system products through the Internet of Things (IoT) and employing analysis, prediction and optimization engines (analytics software).

The result of our R&D is that we are establishing a product line of 7th-generation IGBTs to renovate our power semiconductors using Si. We are also committed to research and develop power semiconductors made of silicon carbide (SiC), which provides a lower switching loss and is expected to revolutionize power semiconductors, and pursuing synergy with power electronics products that utilize them. With a 1.2-kV SiC trench gate MOSFET, which we are developing as the next generation of planar gate devices already on the market, we have realized world-beating low-loss performance ($R_{on} \cdot A$ = 3.5 mΩ·cm^2) and high reliability. For power electronics products utilizing SiC power semiconductors, we have launched a large-capacity UPS (300 kVA) equipped with SiC hybrid modules that achieve an equipment conversion efficiency of 97.5%, the highest level in the industry. We are also developing power electronics equipment with All-SiC modules, in which both diodes and transistors are made of SiC. At the same time, we are researching and developing high-end inverters utilizing the characteristics of SiC semiconductor of low-loss and high-thermal-resistance and power distribution equip-

ment utilizing that of high withstand voltage.

In line with the trend toward electric vehicles, we are comprehensively developing power semiconductors for automotive applications, including discrete devices, modules, inverters and motors. Leveraging RC-IGBTs, thermal-cooling technology and packaging technology has reduced outer size and increased power density. Sample shipments have already begun for direct liquid-cooling power modules for automotive applications.

In the process automation field, to address our customers' challenges of high-quality product manufacturing and stable and efficient operation, we have enhanced the functionality of the plant monitoring and control system "MICREX-VieW XX." Greatly enhanced functions include faster data collection and display processing, long-term storage of plant data and improved security. We intend to provide the product to monitoring and control systems in plants of various industries, including chemistry, oil, gas and electricity.

In the factory automation field, we are developing components and systems that can meet different demands such as performance, cost, and openness. Through these development, we will offer systems, solutions, and services that allow customers to create values that differ depending on the region or industry. To give an example, our developed the new servo system "ALPHA7" achieves the highest level of fast and accurate control in the industry. In future, it will contribute to the fields of packaging machinery, robots and semiconductor manufacturing equipment.

Regarding the IoT, we have built an IoT platform with edge controllers for gathering data from field equipment at various sites and handling it and a mathematical engine for diagnosing and analyzing the data to perform prediction and optimization. Using this, we have operated a number of pilot projects including those at our own factories. While increasing its application examples, we confirmed its effects, such as improving productivity, manufacturing quality, operation and maintenance efficiency, and plant efficiency, as well as ensuring process quality traceability. We also aim to increase opportunities for use of vending machines utilizing the IoT. We are developing interactive communication technologies, such as digital signage, linkage with smartphones, voice and face recognition and gesture discrimination. Making use of these examples, we will provide valuable systems and services from our customers' perspective.

We will continue to work on common fundamental technologies for our wide range of products and advanced technologies that look to the future. Major themes include big data analysis, simulation, solid insulation using resin materials, semiconductor interface analysis, remaining life diagnosis for turbines applying metallic corrosion research, sensors, and current interruption technology for the design of GIS and other switchgears.

Fuji Electric has formulated the corporate mission of "We, Fuji Electric, pledge as responsible corporate citizens in a global society to strengthen our trust with communities, customers and partners" and adopted the slogan of "To be enthusiastic, ambitious and sensitive." "Enthusiastic" means the passion to contribute to society by creating new technologies and products for the world, "ambitious" means the vitality to set and strive for high goals whatever the difficulties may be, and "sensitive" means the richness of human spirit to be able to feel our customers' pleasure as our own. Under this slogan, Fuji Electric intends to continue accurately assessing the needs of society, to build a team from our diverse human resources and to contribute to the creation of responsible and sustainable societies through our innovation in energy and environment. We are truly grateful for the guidance and encouragement received from everyone.

KITAZAWA, Michihiro
President and Chairman of the Board of Directors

Technology Marketing: Role and Significance in Pursuing Customer-Value-Centered Product Planning and R&D

MIYANAGA, Hiroshi Professor, Department of Management of Technology, Graduate School of Innovation Studies, Tokyo University of Science

KONDO, Shiro Corporate General Manager, Corporate R&D Headquarters, Executive Officer, Fuji Electric Co., Ltd.

The time when high performance was the strongest selling point of products is in the past. Today, businesses cannot forgo having a customer-value-centered perspective in product planning and R&D. They can succeed only if they continue offering new concepts. What does Fuji Electric need, with its stronghold in core components and the system business built around them, to delve into this uncertain environment through structural reform? Professor Hiroshi Miyanaga, a leading specialist in management of technology from the Tokyo University of Science's Graduate School of Innovation Studies, talks with Shiro Kondo, Fuji Electric's Corporate General Manager from the Corporate R&D Headquarters, about the future of research and development.

Gathering information is the key to successful marketing

Kondo: I would like to take this opportunity to thank you for your ongoing support with training our young engineers through the management of technology (MOT) workshops at Fuji Electric. The company will celebrate its centennial anniversary in 2023. Keeping this in mind, we are currently pursuing a reform program "Renovation 2018," aiming to achieve sales of one trillion yen by this milestone. As part of the program, we reviewed our business and R&D structures completely, and the resultant reform of April 1 this year is designed to maximize Fuji Electric's strengths.

As you know, Japanese products are often criticized in the international market because they veer away from the value that customers really desire while being obsessed with offering excessively high quality.

The performance indices that have long been one of the competitive axes are no longer the key players. This fact has given us a big sense of crisis. We have come to understand that having a customer-centered approach is indispensable in product planning and R&D to overcome this difficult time of change. This understanding has led us to the structural reform of this time. Fuji Electric is literally at "square one" as it starts operating with a new structure. It is a privilege to have a specialist like yourself share your insightful opinions with us on this subject.

Miyanaga: This comes across to me as a very interesting endeavor, and I am keen to learn more about it.

Kondo: We can start with the business structure. Fuji Electric has two major lines of business. One is the component business, offering power converters, controllers, sensors and other components as individual products. The other is the plant business, in which we deliver plants consisting of component systems that we manufacture or purchase from external suppliers. These two have been operated by different divisions, but we integrated them into one business entity through the structural reform this time. What we aim to achieve through this is, while further strengthening the components business, to create systems that really represent the value our customers are looking for based on this strength. We can then consolidate the know-how as a package and leverage it to boost overseas sales.

Fuji Electric is also renovating the R&D structure

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1981: Joined NTT Electrical Communications Laboratories
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1996: Changed career course in the consulting business and joined SRI International
2000: Integral partner of Deloitte Tohmatsu Consulting LLC (present ABeam Consulting Ltd.)
2002: Executive Officer of the company
2004: Professor, Department of Management of Technology, Graduate School of Innovation Studies, Tokyo University of Science
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in tandem with the business reform. Through this, we aim to establish a system that allows us to pursue customer value validation at the earliest possible stage. Prototyping in product development has been focusing on technology-oriented validation, but this is also going to focus on ascertaining customer value. In addition, we have created a new team dedicated to technology marketing, to support the creation of value. This team is a pivot in driving our future growth by developing innovative projects.

Miyanaga: Technology marketing is vital to succeed in a business that is based on technology and engineering. Here is an example: a company that developed an integrated circuit (IC) for plasma TVs had only one client, Manufacturer X. The engineer responsible for developing the IC had no interest in purchasing X's plasma TVs (the products did not appeal to him). Ultimately, these TVs did not sell, and therefore the company's IC did not sell either. Eventually, plasma TVs lost their market share to LCD TVs, and became obsolete. Today, LCD TVs are also struggling.

Future is always uncertain and resources are limited. It is thus crucial that companies identify the best way to distribute their limited resources by using information and analysis.

Japanese manufacturers tend to focus on perfection, so they develop a customized product to meet requirements by company A, and then they develop another customized product for company B according to their preferences. They tend to start all over again for different customers.

What a company adept at technology marketing would do is to develop a product by generalizing the differences in opinions of companies A and B so that the product appeals to both of them. In order to achieve this, this company needs to stay in contact with all potential clients to obtain the necessary information. While many Japanese manufacturers have excellent technological capabilities, I think it is technology marketing that decides their destiny.

Kondo: I agree. For Fuji Electric, it is mostly the case that our clients have their own customers. It is therefore necessary for us to think what we can do through our products, to help our clients perform well in their competitive environment and sell more of their products to their customers. Japanese customers, for a long time, have been keen to propose their requirements. Today, however, we feel that customers are also in search of new styles of operating for the future, including the use of the IoT. In this sense, co-creation will be an important option to consider.

As you have just mentioned, the standardization of product development is one of the urgent challenges which Fuji Electric is faced with. We employ prototyping in order to validate customer value in advance, but this may lead to over-customization if we try to meet too many customer requests. What can we do to tackle this problem?

Miyanaga: That reminds me of an overseas automotive component manufacturer that well relates to this point. This company never turns down even far-fetched requests made by automotive manufacturers all over the world, so it has become somewhat a dependable organization for automobile manufacturers. This is why it can get information without making much effort. The company has built a system in which it reaches out to gather information, and also information comes to it.

One day, an automotive manufacturer in India commissioned this company to develop an electronic control unit (ECU) for an extremely low-priced vehicle. To meet this requirement, it was necessary to cut the manufacturing cost of this highly technological device. The Indian automotive manufacturer had approached many parts suppliers across the world, but no one thought it was possible to produce a high-performance ECU at lower cost. While they all refused the request, this component manufacturer that never said no to any request accepted the assignment by the Indian automotive manufacturer.

The component manufacturer managed to combine logic, analog, power supply control and other IC components into a single-chip unit, and succeeded in reducing the cost at the same time. More importantly, it did not pursue customization for this ECU, but applied standardized interfaces so that the product would be compatible with other car models. This was possible because the manufacturer had information from car makers across the world. Ultimately, this Indian automobile was not hugely successful, but the ECU was in great demand by Japanese, American and European automotive manufacturers. This is precisely how technology marketing can make a differ-

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2007: Director, Fuji Electric Advanced Technology Co., Ltd.
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2013: General Manager of Instrumentation and Control Systems, Industrial Infrastructure Business Group, Fuji Electric Co., Ltd.
2016: Deputy Corporate General Manager of Corporate R&D Headquarters, Fuji Electric Co., Ltd.
2017: Executive Officer of Fuji Electric Co., Ltd.
Corporate General Manager of Corporate R&D Headquarters.

ence.

Kondo: I agree that gathering information is a determinant factor for certain aspects of technology marketing. It is important to gather information from various sources, such as by communicating with a variety of people whether internal or external, reading newspapers, journals, reports and other public sources, and observing people's behavior. Real customer value must be discoverable by organizing information.

Miyanaga: For example, if you hear something from a customer, and mention it to another customer, you will get a new response. You can then present it to a third customer, and so on. By repeating exercises such as this, you will develop a reservoir of information and become adept at discerning valuable pieces of information.

Three hits in a row make a brand

Kondo: As mentioned earlier, we are considering an introduction of prototyping for evaluating customer value in advance. However, the prototyping at Fuji Electric has been focusing more on technology-oriented evaluation. Improvements must be made so that it can be leveraged in evaluating customer value.

Miyanaga: As you say, there are two types of prototyping. The technology-oriented one is called forward prototyping, and the other is known as backward prototyping. The latter aims to verify that certain concepts really offer value to customers.

For example, a component manufacturer always makes a full-scale model in styrene of the equipment under development, instead of drawings, and brings it over to the client's site. An actual operator of the equipment can try this model. When they try the model, they find that this part clashes, that part is difficult to operate, and so on, giving their raw feedback in real time. Based on this feedback, they modify the drawings. If backward prototyping is executed appropriately, it lowers the chance of needing to alter specifications in the later stages of the development, which would necessitate reworking.

Kondo: I can see that, if product planning is thoroughly discussed with the client already at this stage, the remaining process can be carried out with confidence, and we do not keep modifying the product plan in response to what our competitors may be doing.

Miyanaga: When developing key concepts for a product, it is always a good exercise to have three versions from the start, and develop them concurrently. That is, the first concept is for a product to be released initially, the second is for the product to be launched in a few years' time, and the third is for the product released another few years later. All three are prepared from the very beginning of the product development.

The product to be launched first must be realizable quickly by combining existing technology. Meanwhile, the concept for the third product can be complex and time-consuming to be realized, sometimes requiring basic research to start with. However, starting early, you will be ready to launch the second product by the time your competitors succeed in copying your first concept. When they catch up with your second concept, you are ready to launch the third one.

It is generally accepted that it takes three successful products made consecutively to establish a brand in its product category. Without producing three successes, the efforts in pioneering a new product cate-

gory may well be wasted if competitors overtake you.

Kondo: A "one-hit wonder," you might say.

Miyanaga: That's right. The effort in prototyping to achieve one success would be wasted if your competitors could easily build their successes on that.

Apple, for instance, launched the iPod first, closely followed by the mini, shuffle, nano and touch. By so doing, Apple has established itself as a brand in the digital-audio player field, and its competitors gradually gave up trying to keep up.

In this sense, creating three concepts at the beginning has a great advantage in terms of product development. If we have only one concept, we tend to try to pack everything in the first product. The more features there are to be created, the longer it takes to develop the product. Having three concepts means that those features may be distributed. It is possible to launch the first product as planned, and then observe customer reactions and the sales performance.

Kondo: I see. There is an option of throwing in the first product sooner as a pilot case while accepting certain imperfections.

Miyanaga: This is in fact a form of prototyping. Prototyping in the general sense is about making a product model, but in this case, it is prototyping of a business. By launching the first product, there are many insights to be gained, such as profitability and future prospects. They are valuable resources that can be leveraged in the next projects.

Kondo: While preparing the second and third concepts, the findings from the first launch can be added to improve them.

Miyanaga: Usually, Japanese companies are technically adept, so they only have to work on the development of product concepts. Once they master it, they have a good chance of performing well in the world market. During the era of high economic growth in Japan, products with a high performance were the winner, but the times have changed.

Technology marketing boosts sales

Kondo: What originally led you to study marketing?

Miyanaga: I originally worked at NTT's laboratory, specializing in semiconductors. As a researcher, the paramount objective was to achieve the highest performance. However, when I moved to a foreign-owned semiconductor firm, where I learned the importance of technology marketing through practice. I witnessed that technology marketing was the determinant factor in bringing the company's technical capabilities to light and allowing the business to grow.

Later on, I was made responsible for technology marketing. However, I had almost no resources to educate myself, as most marketing courses in an MBA program were based on a business-to-customer context. A business-to-business model was almost nonexistent. Technology marketing deals with engineers, which is fundamentally different from business to consumer marketing. This is the background of my coming to study business-to-business technology marketing at a graduate school for working people.

Kondo: We were faced with the same difficulty as we embarked on studying marketing, as most case studies were in the business-to-customer context. Your business-to-business model is incredibly valuable to Japanese manufacturers.

Miyanaga: In fact, I began teaching at the Tokyo University of Science's graduate school for working people as a result of trying prototyping for myself

based on my own past experiences. When I was working for a consulting firm, I hardly had enough time to train junior staff. My thoughts were that there might be many corporate executives who felt frustrated about not having enough time to educate their managerial personnel despite the fact that they knew it was important. If so, I thought there may be demand for services aimed at working people that I could offer based on my experience with some new case studies. Eventually, this brought me to the current position.

Kondo: Today, technology marketing has entered the mainstream of business-to-business marketing, but you found the subject a long time ago.

Miyanaga: I think that partly is due to the fact that I have experienced different companies and specialties, having seen the fields of R&D, a foreign-owned company, technology marketing and consulting.

Know customer value through communication

Kondo: In both cases of technology marketing and product planning using prototyping, it seems to me that success depends on communicating with many people and digesting what is learned from them as effectively as possible. The ability to do this is crucial. I think it is the determinant factor.

Miyanaga: Absolutely. Another advantage in the Tokyo University of Science is that, because students there have diverse backgrounds in terms of their business fields, the environment helps to improve communication skills. Others may not understand you if you rely on the terms used only in your company. You gradually learn to listen to and understand others while changing your ways of communicating with them so that you are better understood. This is perhaps an important point in pursuing technology marketing.

Kondo: It is in fact difficult to explain what we do. It is particularly difficult to communicate technical subjects without having a shared background.

Miyanaga: Even if your main business is component development, you need to be able to talk about automobiles if your end client is an automobile manufacturer. With clients in medicine and healthcare, you need to be able to communicate in their subjects. Without having field-specific knowledge and abilities in communication, it is impossible, in my opinion, to understand the clients' requirements. Needless to say, you must be familiar in the area of your specialty. It is important not to be complacent, and to continue striving to obtain further knowledge.

Kondo: I see. We sometimes encounter a situation where a product based on new concepts does not sell well despite the fact that customer advantages must have been carefully integrated in it. The reason for this misfortune is the lack of sufficient personnel who can communicate the new concepts to customers who use the product. This is a serious problem.

Earlier, we were talking about prototyping methodology to start developing three product concepts simultaneously. I think it is also important to start developing the human resources in tandem with the development of the concepts.

Miyanaga: Fuji Electric operates in a variety of business fields, such as power electronics systems, power generation, electronic devices, and food and beverage distribution. There are engineers with specialist knowledge in their respective fields, and this point is the company's strength. This strength can be further enhanced by integrating these individual talents.

Kondo: I could not agree more, but we have a weakness in horizontal communication, so we want to change it. For example, our vending machine development team came up with an interesting application for consumer service using smartphones. However, the idea could not be transplanted, for example, to the industrial business field as they could only understand technical matters. The creativeness in developing innovative services is not easy to be conceived of. I realize the importance of encouraging communication across business divisions so that they can convey and share value and ingenuity. As you have pointed out, Fuji Electric has potential for synergy, and our imperative task is to actualize the synergy.

It has been a great opportunity to hear your invaluable opinions on technology marketing and prototyping. I am reassured that Fuji Electric is on the right track toward the customer-value-centered endeavor in its new business organization that started on April 1. Thank you for your time today, and we look forward to continuing our collaboration.

Achievements and Future Outlook

IoT-Connected Powerful Components and Solutions Creating Customer Value

KONDO, Shiro
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Executive Officer, Fuji Electric Co., Ltd.

1. Introduction

Fuji Electric has been creating distinctive component and system products designed for the efficient use of energy through innovation in electric and thermal energy technology. For that purpose, we set power semiconductors and power electronics as our core technologies and make full use of instrumentation and control technology. By connecting such products through the Internet of Things (IoT) and utilizing analysis, prediction and optimization engines (analytics software), we have been continuing our thorough pursuit of customer value.

In FY2016, Fuji Electric has completed upgrading its research and development bases in an effort that was launched the previous year (see Fig. 1) and promoted the reorganization of its research and development system. In addition, the IoT Strategy Office was established that will play the role of formulating company-wide IoT strategies and promoting their implementation.

We have set a research and development policy of developing overwhelmingly powerful components and solutions in the areas we focus on and core technologies (see Fig. 2) by positioning the creation of customer value at the center of our activities. Specifically, we made efforts to reap the benefits from our work on silicon carbide (SiC) devices, enhancing and accelerating power electronics development, creating customer value by utilizing the IoT, accelerating the development for overseas business reinforcement, and continuously enhancing the development of common fundamental and advanced technologies. This paper introduces our latest development status.

Fig.1 Completed research and development bases

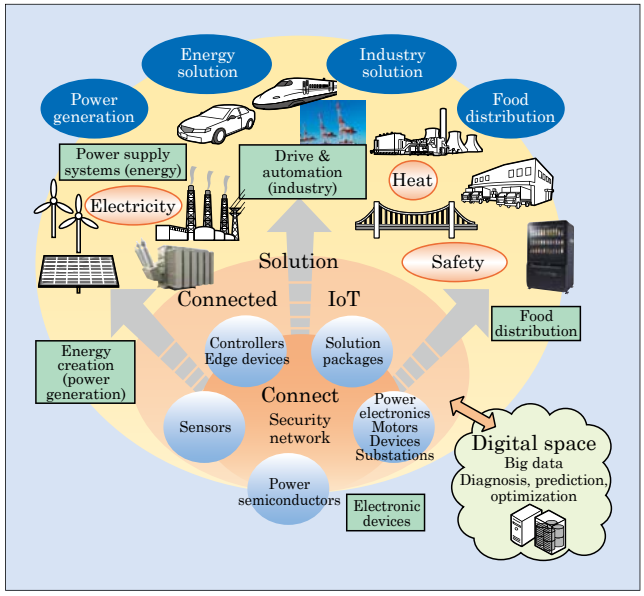


Fig.2 Fuji Electric's focused areas and core technologies

2. Solutions Creating Customer Value through IoT Utilization

The utilization of the IoT has been spreading on a global scale, signifying the beginning of the age of reform through digitalization. When seen from a higher perspective, these efforts have an essential point in common, although their scopes or other conditions are different. The point is to create customer value through the use of information and communication technology (ICT) which is now available at low cost.

Fuji Electric has defined the IoT as "a generic term for systems that digitalize every piece of information in a customer's field (machine, equipment, infrastructure, etc.) and create new customer value in cyberspace"

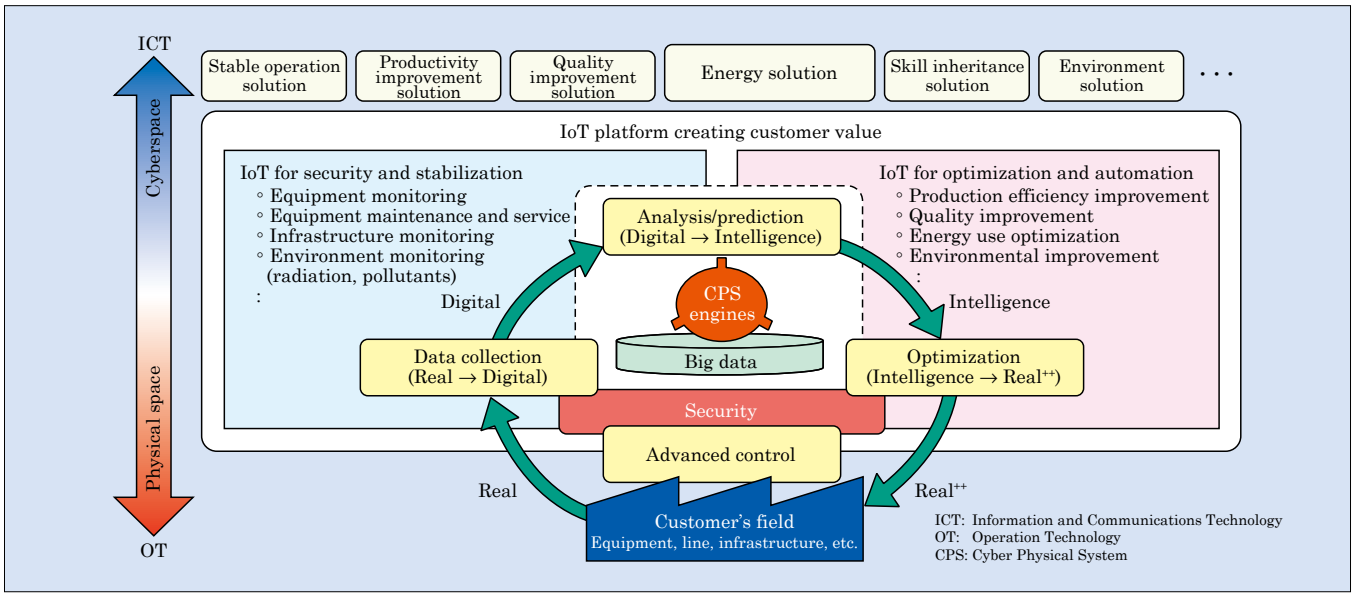


Fig.3 Fuji Electric's IoT concept

(see Fig. 3)[1]. We developed a platform of such value-creation mechanisms and provided solution menus such as energy optimization, stable operation, productivity improvement, quality improvement, skill inheritance and environmental improvement to continue commercialization and functionality enhancement.

With the further penetration of the IoT, an increasing number of things are expected to connect to networks autonomously. Fuji Electric has been developing original products that allow existing devices and equipment manufactured both internally and by other companies to connect to cyberspace (see Fig. 4)[1].

In order to create various customer value such as optimum energy use, stable equipment operation and improved productivity and quality, Fuji Electric possesses many kinds of technologies including analysis, diagnosis, prediction, optimization, advanced control and recognition. We call these technologies cyber-physical system (CPS) engines and position them as core technologies of the IoT platform (see Fig. 5).

Fuji Electric's IoT utilization concept is "Small & Quick Start." We think it important to identify a section that promises good effects and complete the process from implementation to effect evaluation within a short period, instead of trying to apply the IoT for over the entire range to address customer issues at a time. Among CPS engines, multivariate statistical process control (MSPC) is expected to produce good effects in particular on diagnosis and prediction on manufacturing sites. Fuji Electric has commercialized a software package of MSPC and is accumulating track records through its Small & Quick Start approach. We have been confirming operation effects, such as improving productivity, manufacturing quality, operation and maintenance efficiency and plant efficiency as well as ensuring process quality traceability in several projects, including those in our own factories, while increasing application examples. Our IoT utilization is not limited to the energy and industry fields. For

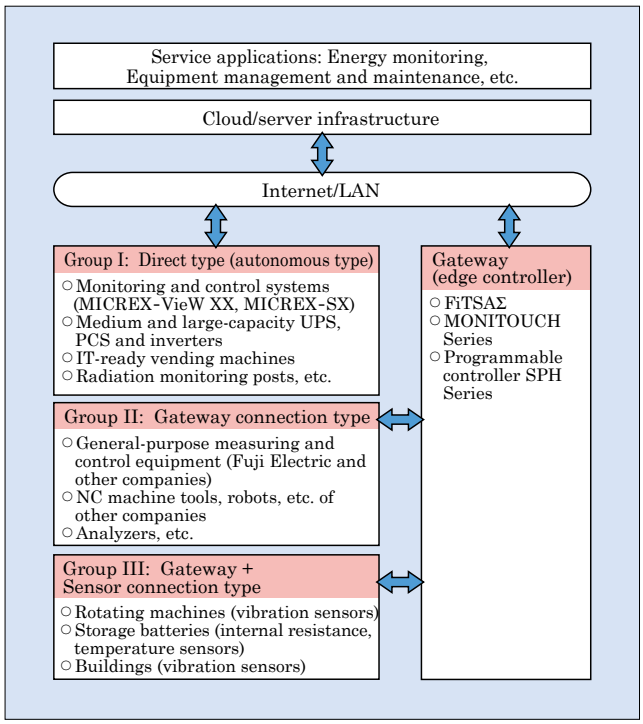


Fig.4 Product development based on type of connection to cyberspace

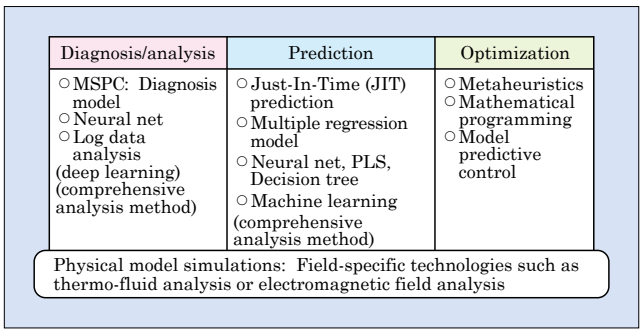


Fig.5 Examples of CPS engines

Fig.6 Digital signage vending machine

example, we are now developing interactive communication technologies for the next-generation vending machines, such as digital signage, linkage with smartphones, voice and face recognition and gestures (see Fig. 6).

We are determined to provide future systems and services that can offer value from the standpoint of customers.

3. Synergy of Power Semiconductors and Power Electronics Technology

Fuji Electric has been pursuing the development of new products and improving the performance of Si power semiconductors. We have already released the 7th-generation insulated gate bipolar transistors (IGBTs). In FY2016, we offered further line-ups of 7th-generation IGBTs. At the same time, we have directed our company-wide research and development efforts toward power semiconductors made of SiC from which a revolution in power semiconductors is expected due to its low switching loss. We have also moved forward with research and development of power electronics products incorporating these power semiconductors to pursue a synergy between power semiconductors and power electronics products.

In order to meet the expanding demand for high-voltage and high-capacity inverters and wind power generation systems, Fuji Electric has developed a high-power IGBT module with a rated voltage of 1,700 V for the line-up of the 7th-generation “X Series” IGBT modules. We reduced power loss by improving the characteristics of semiconductor chips and reduced thermal resistance considerably by using a high thermal conductive insulating substrate. Consequently, we have achieved products with the maximum rating of 1,700 V/1,800 A, which had been difficult with conventional technologies. Moreover, we raised the guaranteed continuous operating temperature to 175 °C from the conventional 150 °C to meet the requests for miniaturization, low loss and high reliability. We have also developed a reverse-conducting IGBT (RC-IGBT), which is an innovative technology, replacing IGBTs and free wheeling diodes (FWDs). RC-IGBTs adopt a technology for integrating an IGBT chip and an FWD chip and can improve the maximum rated current of module packages. We therefore are working on expanding the product line-up intended for the industrial field.

As for power semiconductors for automotive applications, Fuji Electric has been pursuing comprehensive development including discrete devices, modules, inverters and motors according to the increasing trend of electric vehicles. Automotive components are required to be compact. Combining RC-IGBTs with thermal-cooling and packaging technologies enables a considerable size reduction and high power density of modules. RC-IGBTs are thus increasingly adopted in IGBT modules for automotive applications. Sample shipment of direct liquid cooling power modules for automotive applications (see Fig. 7) started in FY2016.

As for SiC devices, Fuji Electric has developed trench gate SiC metal-oxide-semiconductor field-effect transistors (SiC-MOSFETs) using 6-inch substrates, which are the next generation devices of planar gate SiC-MOSFETs, which have already been placed on the market. Compared with Fuji Electric’s planar gate SiC-MOSFETs, this 1.2-kV trench gate SiC-MOSFET is based on the smaller design rules to reduce the cell pitch size to almost half, resulting in a reduction of the on-state resistance per unit area by about 50%. This has achieved high reliability and the greatest low-loss performance in the world ($R_{on}{\cdot}A$ = 3.5 mΩ·cm^2).

Fuji Electric has commercialized All-SiC modules with rated capacities up to 1,200 V/100 A by applying copper pin connection and resin molding technology to reduce the wiring inductance inside the modules and enable high-speed, highly-reliable operation of SiC devices at high temperatures. In FY2016, we designed a package with a new structure for capacity enlargement and achieved an All-SiC module with a rated capacity of 1,200 V/400 A that incorporated 1st-generation SiC trench gate MOSFETs (see Fig. 8). In North America, an increasing number of data centers have been built due to the introduction of cloud-based information systems and the IoT. Accordingly, the uninterruptible power system (UPS) market currently with a size of about 100 billion yen is expected to grow at an annual rate of 3% or more. Under such conditions, Fuji

Fig.7 Direct liquid cooling power module for automotive applications

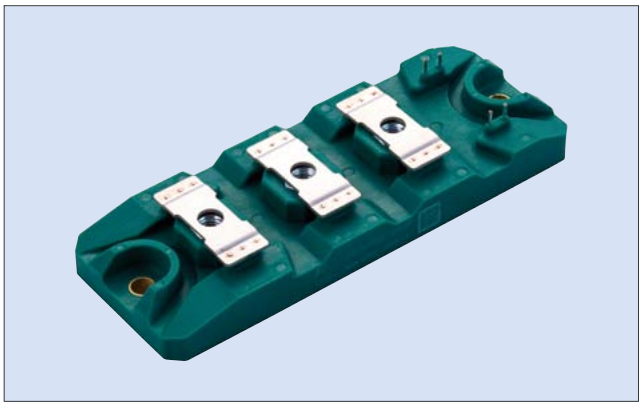


Fig.8 All-SiC module with rated capacity of 1,200 V/400 A

Fig.9 Large-capacity uninterruptible power system with SiC hybrid module incorporated

Electric launched the "7300WX-T3U" large-capacity UPS (300 kVA) (see Fig. 9). This product employs a "3-level power conversion circuit" that uses an internally developed SiC power semiconductor and a reverse-blocking IGBT (RB-IGBT) based on our original technology and have achieved the industry's highest equipment conversion efficiency of 97.5%. Even under a low load (load factor of 25%), this UPS has achieved an equipment conversion efficiency of 96.3%, which reduces power loss and contributes to energy saving.

Following this, we are currently promoting the research and development of power electronics equipment containing All-SiC modules in which both diodes and transistors use SiC. Examples of such products include a high-end inverter characterized by high thermal resistance and low loss, as well as distribution equipment providing high withstand voltage performance.

4. Energy Solutions

The introduction of a great amount of renewable energy sources and the review of the electric power trading market scheme have led to issues in the power system. These include frequency fluctuation in the power system and voltage increases due to the reverse power flow from distributed power sources and are required to be addressed. To meet the requirement, Fuji Electric plans to roll out storage battery control systems and variable inductance-based static var compensators (SVCs) as the core products intended for stabilization. As for the next-generation distribution and control devices, we have also been developing SVCs that take advantage of high withstand voltage, which is one of the features of SiC. Moreover, we initiated a new effort to participate in a demonstration project of a virtual power plant (VPP) that collectively operates utility customers' equipment, such as generators and power storage systems, to use them for electric power adjustment. We are currently studying technical findings and business models.

For the substation system field, Fuji Electric has developed electric distribution facilities and large-capacity power electronics equipment and provided various solution businesses including environmentally friendly systems. In the electric power field, the increase in global energy demand has led to further construction of power plants and substations, resulting in an increase in demand for switchgears. Fuji Electric has been aggressively pursuing global business expansion primarily in Asia, and has recently developed and released the 145-kV gas-insulated switchgear (GIS) "SDH714," which is compliant with the IEC standard (see Fig. 10). Reviewing the breaking mechanism and using aluminum alloy for the sealed container achieve the smallest and lightest class in the industry (30% reduction in footprint and 35% reduction in mass compared with conventional products). The new design has also produced a great improvement in maintainability.

In the power supply system field, the power consumption in data centers has been increasing sharply because servers are now designed for higher performance and density, and there are increasing needs for energy saving. Fuji Electric can halve the construction period (to about half a year) compared with conventional building-type data centers and undertakes engineering, procurement and construction (EPC) contracts that include an electric distribution facility with energy-saving equipment, UPSs and indirect outside air conditioners. One of the examples is the module-

Fig.10 "SDH714" 145-kV gas-insulated switchgear

Fig.11 External appearance of module-type data center delivered to IDC Frontier Inc.

Fig.12 Application example of “MICREX-VieW XX”

type data center delivered to IDC Frontier Inc. (see Fig. 11).

As for air conditioners intended for data centers, we have offered the “F-COOL NEO” indirect outside type air conditioner, which takes in only cold energy from outside air through a heat exchanger (cooling capacity: 40 kW). To address the exponential increase in heat generation that has resulted from servers being designed for higher performance and density in recent years, we have developed a new type for which the cooling capacity was improved to 56 kW. Some of its features include the combination of outside air-based cooling and a built-in refrigerator that can reduce the annual power consumption to almost one-third of that of typical air conditioning units. Additionally, the indirect use of outside air allows inside air to be less affected by moisture, dust particles such as PM2.5 and corrosive substances contained in outside air. Only a power supply is needed and no cooling water is required. We will continue rolling out EPC solutions for entire systems both within and outside Japan to provide systems and products intended for solving customer issues.

5. Industry Solutions

For the process automation field, Fuji Electric has greatly enhanced the functionality of the “MICREX-VieW XX” plant monitoring and control system for the purpose of addressing customers’ challenges of high-quality product manufacturing and stable and efficient operation. We have developed a remote monitoring station, high-speed data collection and display processing, long-term storage of plant data, and improved security. We will provide the product to monitoring and control systems in various plants, including chemical, oil, gas, and electric power plants. Figure 12 shows an example of application to the monitoring and control system for the Nishi Clean Center of the Environment Bureau of Kobe City.

Fuji Electric has many delivery records of electrical equipment for container cranes operating in ports and harbors around the world. We recently delivered electrical equipment and a control system for a container crane intended for a Japanese port (see Fig. 13). The drive system uses a stack-type PWM converter and a high-performance vector inverter to save space and achieve high performance and high reliability. The monitoring system incorporates the functions of state monitoring, cargo management, failure monitoring and failure trace back of the crane to enable immediate analysis and recovery in case of failure. The adoption of a high-accuracy anti-sway control system allows even inexperienced operators to perform stable operation equivalent to experienced operators.

For the factory automation field, Fuji Electric has been working on the development of components and systems that can satisfy different requests, such as performance-oriented and cost-oriented ones or openness. Through the development of such products, we will provide systems, solutions and services that will create different types of customer value depending on the region or industry. For example, we have developed and released the “ALPHA7” (see Fig. 14) and “SPH3000D.” The former is a new servo system that achieves the highest level of fast and accurate control in the industry and the latter is a motion controller for the “MICREX-SX Series.”

Motion control systems have been used in wide range of fields such as semiconductor manufacturing equipment, machine tools, printing machinery and

Fig.13 Container crane designed for ports and harbors

Fig.14 "ALPHA7" (Motor and servo amplifier)

packaging machinery for the purpose of positioning, speed control and torque control in industrial machines including production equipment and automation machinery in factories. Using the ALPHA7 and SPH3000D in such a system will enable motion control with a single CPU module. Since this eliminates the need for a costly dedicated module for motion control, a highly functional and high-performance motion system can be achieved in a cost-effective configuration.

We will promote its application to the fields of packaging machinery, robots and semiconductor manufacturing equipment.

6. Fundamental and Advanced Technologies

Fuji Electric has been continuing with research and development of fundamental technologies that support the technologies described above in a common way, while moving forward with advanced technologies with an eye to the future. Our efforts for common fundamental technologies include experiments, evaluation, analysis and simulations regarding electromagnetics, insulation, electromagnetic compatibility (EMC), thermal fluid dynamics, machinery and resin, metal materials. The efforts in the advanced technologies include research on gallium nitride (GaN) or other semiconductor materials that will take the lead over SiC, and computational science for predicting material physical properties and degradation phenomena.

In thermal power plants, ultra super critical (USC) turbines in which the steam temperature is raised to about 600 °C to improve efficiency are becoming the mainstream. The breakage risk of turbines increases due to the aging degradation of the material. Consequently, it is indispensable to have a remaining life diagnostic technology for predicting aging degradation. Unfortunately, there was no accurate remaining life diagnostic technology for USC turbines because they showed complex degradation phenomena. Fuji Electric has clarified the mechanisms of degradation phenomena including creep and embrittlement by way of long-duration tests and simulations. We established a life expectancy calculation formula that can predict degradation phenomena based on the changes in the grain diameter of the deposits in the material. We

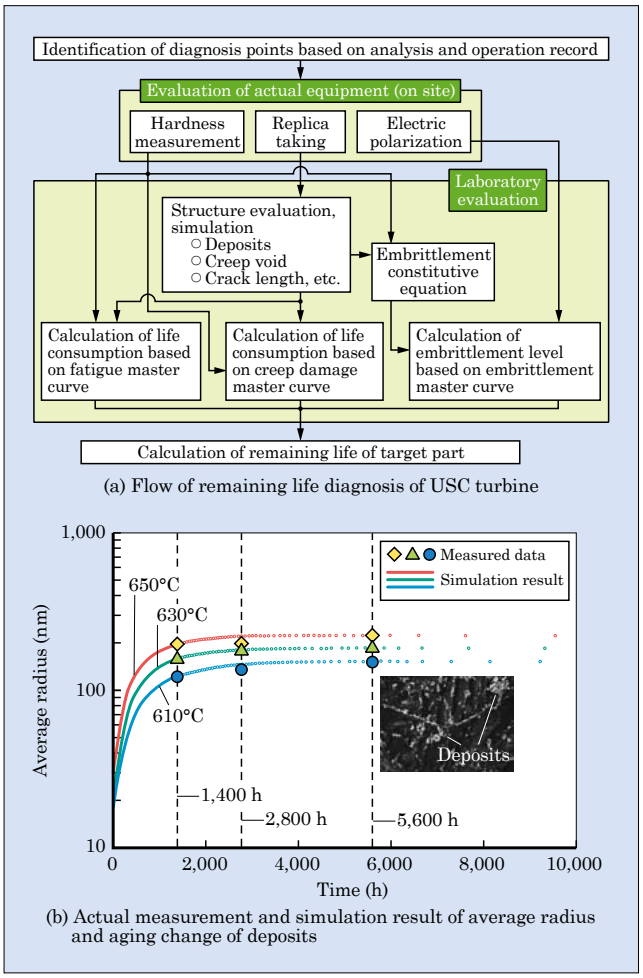


Fig.15 Remaining life diagnostic technology

have also developed a high-accuracy remaining life diagnostic technology by applying non-destructive inspection techniques such as electric polarization (see Fig. 15).

7. Postscript

This paper introduced an overview of the technologies on which Fuji Electric has been working: Technologies of using electric energy sources safely, securely and efficiently; technologies that contribute to energy saving through the effective use of thermal energy sources; and solution technologies that increase added value by optimally controlling these technologies and connecting them through the IoT. The importance of the creation of sustainable societies in harmony with the environment will further increase in the future.

Fuji Electric has embarked on reforming the new product development process from FY2016 to design products contributing to the creation of customer value and pursue research and development to serve that purpose.

We will continue to contribute to the creation of responsible and sustainable societies by providing high-value-added, environmentally friendly products and systems to our customers through our innovation in energy and environment technology.

References

(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.

Wide Area Network-Based Distribution Automation System for Tohoku Electric Power Co., Inc.

For Tohoku Electric Power Co., Inc., Fuji Electric has delivered a wide area network-based distribution automation system allowing continuous operation even if large disasters occur.

The main features are as follows:

(1) By installing servers in 2 service offices distant from each other for mutual backup between the servers, one office can continue operating even if the other is struck by a disaster.

(2) The impact of a switchover on operations has been minimized by completing switchover to the backup server within 1 s.

(3) The operating terminals are connected to the server via a network and have no application software installed, improving maintenance efficiency and reducing system maintenance costs.

(a) Indoor unit (b) Outdoor unit

Line-up Expansion of "F-COOL NEO" Indirect Outside Air Conditioning Energy-Saving Hybrid Air Conditioning Unit

In recent years, the amount of heat generated by servers used in data centers has increased dramatically as a result of the higher performance and higher density of the servers.

To save energy in data centers, Fuji Electric has been offering the "F-COOL NEO" indirect outside air conditioning unit (cooling capacity: 40 kW), which introduces only outside cold energy through a heat exchanger, and has now developed a new type with a cooling capacity of 56 kW.

The main features are as follows:

(1) Concurrently operating an outside air cooling unit and built-in refrigeration cooling unit can reduce the annual power consumption to approximately one-third of that of usual air conditioning units.

(2) Indirect use of the outside air makes the product less susceptible to moisture, PM 2.5 and other types of dust and corrosive substances contained in the outside air.

(3) Power supply is the only necessary utility and no chilled water or cooling water is required. The downward air inlet (air blow) provides compatibility with access flooring.

"SVE135" Sealed High-Voltage Contactor

There is rapidly increasing demand for contactors for DC circuits as DC power distribution systems and electric vehicles are becoming increasingly popular. Hence, they are strongly demanded to achieve miniaturization, improved safety, and contact reliability. In order to meet these demands, Fuji Electric has developed the "SVE135" sealed high-voltage contactor with a rated voltage of 450 V DC and a rated current of 135 A.

The main features are as follows:

(1) The contact block is located in a sealed capsule in which insulating gas is enclosed. This has improved breaking performance and realized miniaturization and high contact reliability.

(2) The unique contact structure provides a high withstand capability, non-polarity of the main circuit and equal breaking performance both in the normal and reverse directions.

(3) The contactor can be mounted in any direction, and it has a minimum malfunction shock of 490 m/s^2.

(a) "ALPHA7"

(b) "SPH3000D"

Motion Control Systems

Motion control systems, which combine a servo system and motion controller, are expanding applications in industrial machines in general, including semiconductor, LCD manufacturing and electronic part processing equipment. In this situation, there are increasing needs to improve safety and maintainability in addition to further speeding up the systems, increasing their precision and reducing their set-up time. To meet these needs, Fuji Electric has developed and commercialized the "ALPHA7" servo system and "SPH3000D" motion controller. The ALPHA7 has achieved the industry's highest level of high-speed, high-precision drive control and is equipped with safety functions to support safer operation as a standard feature. The SPH3000D, which is capable of sequential control and motion control with one CPU unit, can maximize the performance of the ALPHA7. The motion control system combining the ALPHA7 and SPH3000D contributes to productivity improvement, cost reduction and enhanced safety.

"FST" (ϕ100 mm)

Production Line Extension of High-Accuracy Spool Piece Ultrasonic Flowmeter "FST"

High-accuracy spool piece ultrasonic flowmeters are capable of measuring the flow rate of various liquids including oils with a high accuracy of ±0.2% of rate by using 3 pairs of sensors in a pipe. This allows efficient flow rate control, which helps to save energy and improve the quality of the entire equipment.

Fuji Electric released the 50-mm diameter model of the high-accuracy spool piece ultrasonic flowmeter "FST" in 2016 and has now expanded the product line as described below to increase the range of applications.

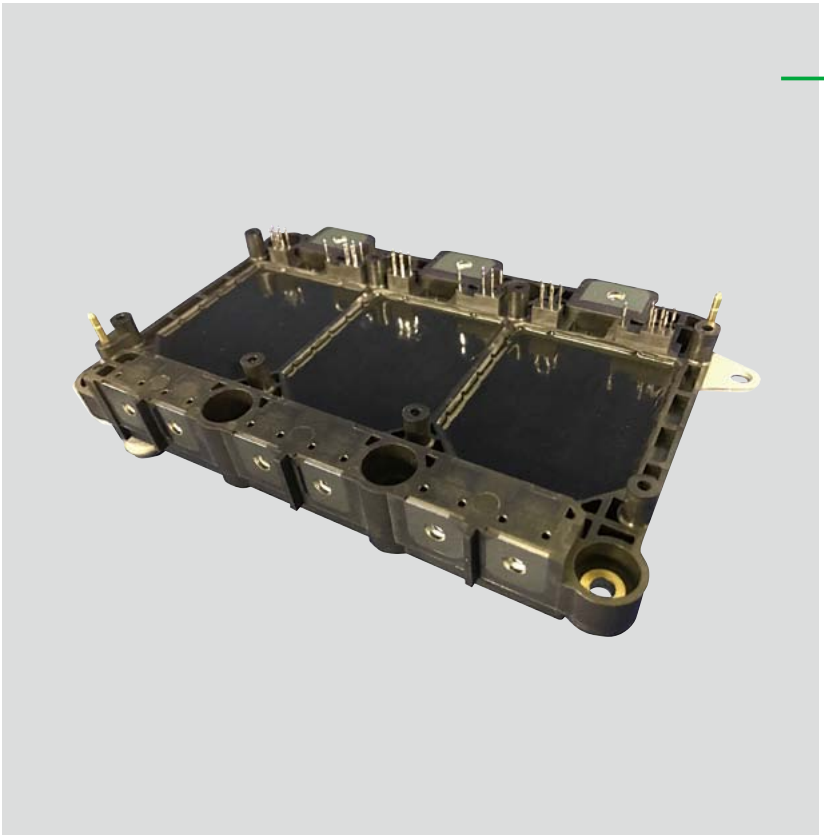
(1) For petroleum and chemical plants, explosion-proof models conform to the ATEX, TIIS and NEPSI standards (to be released gradually).
(2) The size selection has been expanded to include 3 typical diameters in the industry: ϕ50 mm, ϕ80 mm and ϕ100 mm.

Electrical Driven Door System for E235 Series of East Japan Railway Company

East Japan Railway Company started operating the mass-produced E235 Series commuter train on Yamanote Line services in May 2017. For this new model of cars, Fuji Electric delivered a rack-and-pinion mechanism type door system. The system for 539 cars (4,312 units in total) will be gradually delivered.

The main features are as follows:

(1) Improved safety realized by employing a door control sequence combining a high-resolution encoder and servo control to improve obstruction detection accuracy
(2) Improved maintainability achieved by reducing the size and weight (15% reduction from the conventional product) and integrating devices into a unit
(3) Improved environmental endurance by employing totally enclosed encoders
(4) Reduction of environmental burden by decreasing the amount of rare metal used
(5) Improvement of communication reliability and device condition monitoring function by providing compatibility with the Train Information Management System



High-Capacity Direct Liquid Cooling Power Modules for Automotive Applications (750 V/1,200 A)

Fuji Electric has developed power modules for electric vehicles and hybrid electric vehicles and launched them onto the markets, which are growing in Japan and overseas.

Automotive power modules are mounted in a limited space in automobiles and downsizing of products is required. Direct liquid cooling power modules for automotive applications have achieved increased power density by employing a lead frame for internal wiring to improve area efficiency. In addition, they employ a water jacket-integrated structure, which offers high heat dissipation performance. Furthermore, we have employed a reverse-conducting insulated gate bipolar transistor (RC-IGBT) integrating an IGBT and FWD into one chip for the power device, which has achieved the world's highest capacity rating for a general-purpose 6-in-1 module of 750 V/1,200 A.

All-SiC Module with SiC Trench Gate MOSFETs (1,200 V/400 A)

SiC devices are increasingly expected to be launched to meet such demands for power converters as high efficiency, downsizing and high capacity. Previously, Fuji Electric has produced all-SiC modules with a rated capacity of up to 1,200 V/100 A with a new structure package that applies copper pin connection and resin molding technology. This new structure package has low internal inductance and high temperature resistance, allowing SiC devices to operate in high-speed and with high reliability.

We have developed a high-capacity new structure package for the purpose of further increasing the rated capacity. By installing the 1 st-generation SiC trench gate MOSFETs, which combine low on-state resistance and high-speed switching characteristics, we have achieved an all-SiC module with a rated capacity of 1,200 V/400 A.

Commercial Operation Started at Takigami Binary Power Plant of Idemitsu Oita Geothermal Co., Ltd.

The Takigami Binary Power Plant, for which Fuji Electric received an order for a power generation facility from Idemitsu Oita Geothermal Co., Ltd. as an engineering, procurement and construction (EPC) project, started commercial operation in March 2017. Binary power generation is a system in which a heat source is used to evaporate a medium with a low boiling point and the resulting steam is used to rotate a turbine. It can make effective use of low-temperature steam or hot water, which could not be conventionally used, as a heat source, and is a promising power generation system.

This is the Fuji Electric's first commercial binary power plant, and the turbine was manufactured at Kawasaki Factory. The generating end output is 5,050 kW at the maximum, which is among Japan's highest.

While there were many factors that hindered outdoor work such as the Kumamoto earthquakes, a long spell of rainy weather and a cold wave, we completed the delivery as originally scheduled, thanks to the cooperation of the customer and related companies.

"PVI1000BJ-3/1000" Power Conditioning System for Large-Scale Photovoltaic Power Generation

Fuji Electric has developed the "PVI1000BJ-3/1000," a new power conditioning system (PCS) for large-scale photovoltaic power generation (mega solar) in Japan and overseas, as the mega solar market is continuously growing. With the features of the conventional product including high efficiency, outdoor compatibility and elimination of the need for air conditioning maintained, a significant size and weight reduction has been achieved. This makes the product applicable to mega solar power plants in mountainous areas.

The main features are as follows:

(1) Equipment capacity: 1,000 kVA
(2) DC input voltage: 1,000 V DC
(3) AC input voltage: 380 V AC
(4) Maximum efficiency: 98.5%
(5) External dimensions: W2,000 × D950 × H1,940 (mm)
(6) Mass: 2,000 kg (approximately 75% reduction from 7,500 kg of the conventional product)
(7) Various options: Cold weather model, salt-tolerant model, fuse branch and others

Latte Machine for Seven-Eleven Japan Co., Ltd.

Seven-Eleven Japan Co., Ltd. decided to add new drinks with fresh milk to the SEVEN CAFÉ menu. Fuji Electric worked on developing a system in which milk is being handled in a simple operation in hygienic conditions and environment.

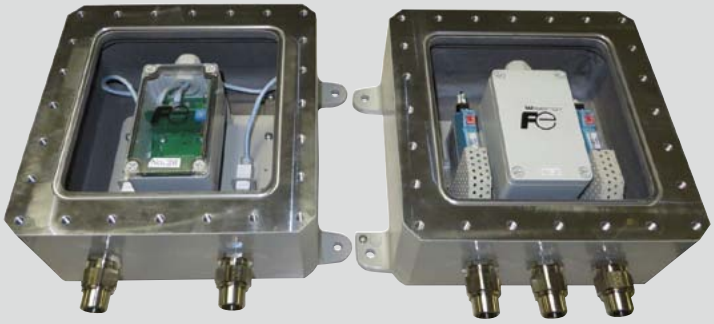
The main features are as follows:

(1) Aseptic packaged milk has been employed for the first time in the world, and an innovative piping system is used to prevent milk from remaining inside the piping at normal temperature.

(2) Maintenance of hygiene of the dispensing module has been simplified by using newly developed special detergent and self-cleaning functions.

(3) An in-line milk frothing mechanism that does not require disassembly for cleaning, which was conventionally needed, has allowed a fine froth to be produced.

(4) A structure has been adopted that prevents milk from being mixed in unintentionally, which is an allergen, by separating the latte dispensing stage from that for coffee.



(a) Transceiver (b) Wireless vibration sensor

Explosion Proof Certification of "Wiserot" Wireless Diagnostic System for Rotating Machine Vibration

The "Wiserot" wireless diagnostic system for rotating machine vibration is intended to promptly detect abnormalities by measuring the vibration of machinery and equipment, such as rotating machines, fans and pumps. Such equipment is employed in large numbers in automobile, steel, chemical (non-explosion-proof areas) and other manufacturing plants.

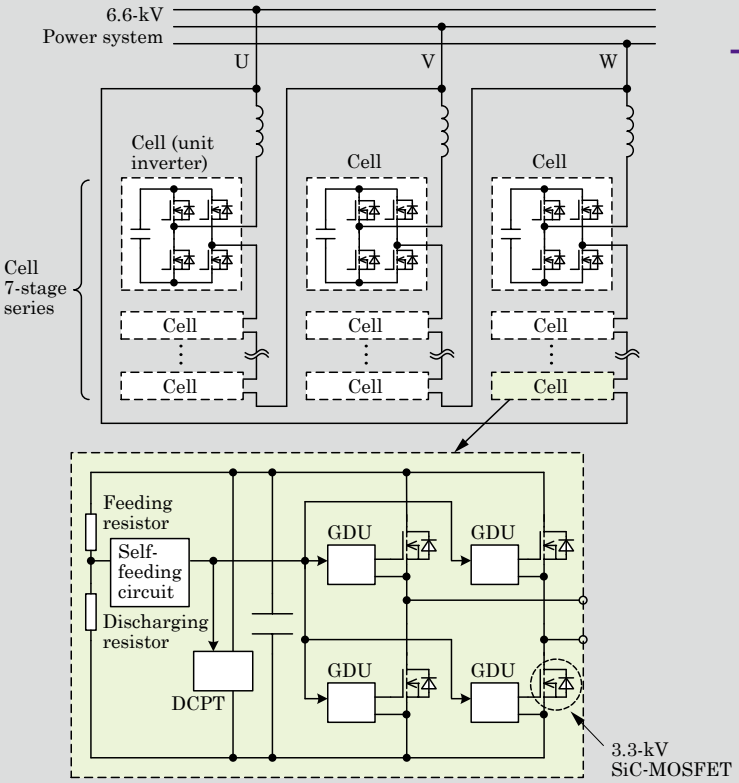
Fuji Electric has acquired explosion proof certification in Japan and overseas and offered an explosion-proof wireless vibration sensor as an addition to the line-up. The product can be used for explosion-proof areas in petrochemical and other plants in Japan and overseas. The explosion proof structure is Ex db IIB + H_2T4 Gb. While the main unit is made of aluminum casting, the top cover uses polycarbonate in consideration of wireless communication.

The explosion proof certifications acquired are as follows:

(1) IEC 60079-0/1/11

(2) EN 60079-0/1/11

(3) JNIOSH-TR-46-1, 2, 6: 2015



MMC-Based Static Synchronous Compensator (STATCOM) with Direct Interconnection with 6.6-kV Power System

Fuji Electric participates in the Strategic Innovation Promotion Program (SIP) of the Cabinet Office to work on the development of a modular multilevel converter (MMC)-based static synchronous compensator (STATCOM) capable of direct interconnection with 6.6-kV power systems without using an interconnection transformer.

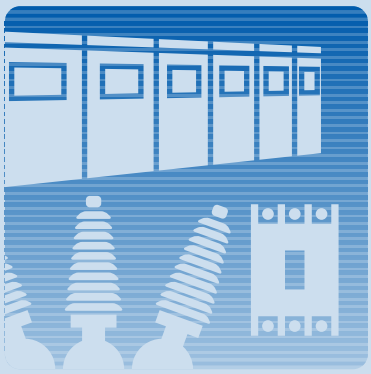
The main features are as follows:

(1) Efficiency can be improved by using 3.3-kV high withstand voltage SiC-MOSFETs as power devices.

(2) Peripheral circuits can be miniaturized with self-feeding technology, which provides a non-isolated power supply from the main circuit potential to the SiC device gate drive units (GDU) and DC potential transformer (DCPT).

(3) Fuji Electric's proprietary cell (unit inverter) DC voltage equalization control allows negative-sequence power compensation as well as reactive power compensation.

Energy Solutions in Power Electronics Systems



Energy Management
Substation Systems
Power Supply Systems
Electric Distribution, Switching and Control Devices

Outlook

Energy Management

Since the Great East Japan Earthquake, renewable energy sources have been introduced to a great extent, and the system of the electric power trading market has been reconsidered. Issues have been occurring in the power system, such as unsteady frequency and voltage increase due to reverse power flow from distributed power sources. Electric power companies are becoming increasingly demanded for creating business continuity plans (BCP) in the event of an earthquake disaster.

Fuji Electric has cultivated system stabilization technologies through various verification projects. It continues to provide, as the core of its stabilization measures, storage battery control systems and static var compensators (SVCs) with variable inductance that use those technologies. We are developing a SVC that uses silicon carbide (SiC) for the next generation. As disaster control measures, we will make full use of wide-area distributed system technology to support the stable operation of automated systems in electric power companies. As new efforts, we are participating in the verification project of virtual power plants (VPPs) and examining the technical aspect. This project is intended to adjust power by collectively managing the facilities of utility customers such as generators and power storage facilities. We will continue to contribute to society by developing and providing products that accurately satisfy market needs in a timely manner.

Substation Systems

For substation systems, we have been providing solution businesses such as reliability improvement, efficiency improvement and eco-friendliness by using electric distribution facilities and large-capacity power electronics devices. Outside Japan, in order to meet the expectation for infrastructure expansion in Asia, we set up a production base of transformers, switchgears and switchboards. We have been enhancing our organization toward completely localized businesses that include sales, engineering and service.

In the electric power field, Fuji Electric has developed and launched in the market an IEC standard-compliant 145-kV gas-insulated switchgear (GIS) that achieved significant miniaturization and weight reduction and is aimed to have improved maintainability. In the industrial and facility electric equipment field, the use of new energy sources is increasing as a result of liberalization of the electricity market. Hence, we have delivered electric distribution facilities that take into consideration miniaturization and maintenance saving for biomass power generation. In the industrial power supply field, we have received an order for the "S-Former," a rectifier of the largest scale in the world, for Bahrain in the Middle East. In the transportation field, we have been conducting a business for supporting stable transportation. We received orders for replacing substation equipment and multiple power monitoring systems that have reached the end of the lifetime and delivered them.

Power Supply Systems

For power supply systems, power consumption in data centers has been sharply increasing due to the enhanced performance and increased density of servers, heightening the need for energy saving. In addition, energy saving policies should increase the demand for upgrading equipment to energy-saving one.

For air-conditioners of data centers, a high cooling capacity 56-kW type has been added to the line-up of the "F-COOL NEO" indirect outside type air conditioner. For uninterruptible power systems (UPSs), we have launched into the market a high-efficiency and large-capacity UPS (333 kVA) that uses SiC devices and helps to reduce power consumption. The "F-DC POWER" DC backup power supply for servers has been made to support the Open Compute Project (OCP) specifications, which is expected to rapidly penetrate the IT market. We will continue to identify new management issues of customers through providing EPC solutions for entire system building in Japan and other countries, and offer systems and products aimed at resolving problems.

Electric Distribution, Switching and Control Devices

For electric distribution, switching and control devices, there is increasing demand for distribution equipment to use electricity efficiently and safely, as well as control devices to automate and optimize manufacturing system and production machinery. This has been occurring in relation to renewable energy-related facilities, electrical equipment in buildings and facilities, and control systems in factory production lines.

For low-voltage distribution equipment, we have developed 70-mm-pitch versions of the "BV Series" and "EV Series" bus plug-in-mounting circuit breakers. They can save labor and reduce wiring in installation work. Their operability has also been improved by using blank cover that does not require tools and the reduction of the insertion force. For medium-voltage distribution equipment, we have developed the "MULTI. VCB," a RoHS-compliant draw-out type medium-voltage vacuum circuit breaker. It reduces life cycle cost by improving the usability of the panel cutting profile, enhancing insulation performance and extending the greasing intervals.

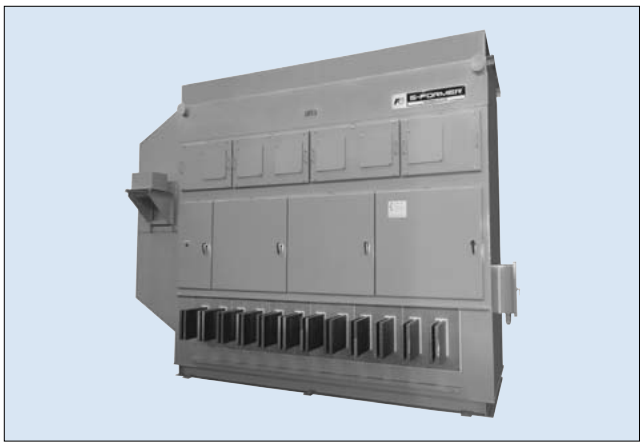
Substation Systems

1 "S-Former" Large-Capacity Transformer Rectifier for Indonesia: Replacement for Another Manufacturer's Rectifier

Fuji Electric has manufactured and delivered many units of the "S-Former" large-capacity transformer and rectifier in applications such as aluminum refinement and soda electrolysis. This S-Former for Indonesia was installed to replace an existing rectifier made by another manufacturer, and after the replacement, it will be coupled with an existing transformer made by the manufacturer. The main features are as follows:

(1) Considering future equipment expansion that may be requested by the customer, we have increased the rated direct current in the 6-pulse general connection system to 45 kA from 37 kA of the existing equipment.
(2) Despite the increase in current, we have miniaturized the internal structure and adjusted it to the existing installation dimensions and the position of the interface of AC and DC terminals.
(3) Fixing an aluminum terminal to the copper conductor inside the rectifier, we were able to connect the conductor to the existing aluminum DC busbar by welding.

Fig.1 "S-Former"



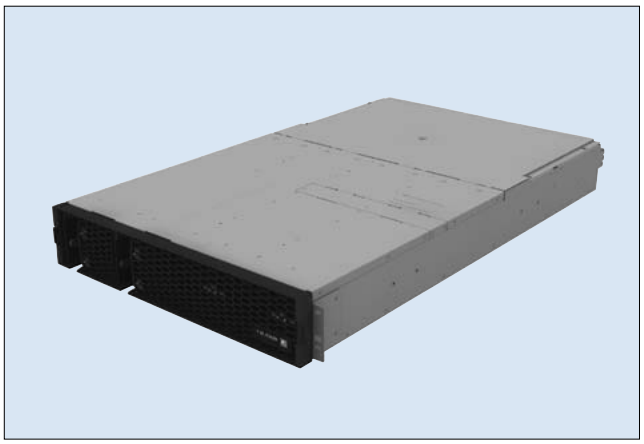
Power Supply Systems

1 "F-DC POWER" Power Supply Supporting OCP Specifications

In the data center market, which continues to expand attributing to the rapid proliferation of cloud computing, there is an urgent need to reduce the sharply increasing power consumption. Fuji Electric has already launched in the market the "F-DC POWER" DC backup power supply for servers which helps data centers save energy, and has developed a type that supports OCP (Open Compute Project) specifications. OCP provides specifications of IT equipment that is being promoted at the initiative of Facebook Inc. in the United States and is expected to rapidly penetrate the IT markets in North America and Japan. The main specifications are as follows:

(1) Output power: 7.5 kW (3 + 1 redundant configuration)
(2) Conversion efficiency: 94%
(3) Outline dimensions: W450 × D740 × H89 (mm)

Fig.2 "F-DC POWER" power supply supporting OCP specifications



Power Supply Systems

2 Modular-Type Data Center for IDC Frontier Inc.

Fuji Electric has carried out the construction work of Buildings 3 and 4 of the Shirakawa Data Center of IDC Frontier Inc. We have undertaken the work from basic designing to the construction management and of installation work, including construction and civil engineering works. This has been done as the main EPC contractor (engineering, procurement and construction). We have delivered electric distribution facilities, uninterruptible power systems and indirect outside air conditioners, including energy-saving-type equipment. The modular design concept enabled us to complete the work in half the period (about half a year) compared to the construction of a building-type data center.

The construction required a wide range of knowledge, in fields such as electricity, air conditioning, construction and civil engineering; Fuji Electric gathered wide-ranging technologies from our factories, test departments, CE departments, affiliated companies and subcontracting companies, and undertook the work as a turnkey project. Making use of this know-how and experience, we will continue to contribute to the construction of energy-saving data centers.

Fig.3 External appearance of Shirakawa Data Center (Building 4)

3 Data Center for Kingsland in Singapore

Fuji Electric Asia Pacific received an order for a set of facilities for a data center from Kingsland, a major data center provider in Singapore. It completed the delivery in December 2016.

For this data center, Fuji Electric Asia Pacific delivered high-voltage and low-voltage panels, transformers, generators, uninterruptible power systems (UPS), air-conditioners, fire-fighting equipment, security equipment, and monitoring systems. The system was built by combining our products with products of other companies. This was the first case of Fuji Electric Asia Pacific managing an EPC project like this as the prime contractor. Our track record was highly evaluated and led to a follow-up order for a data center expansion project for the same company. The work for the expansion project started in April 2017.

Fig.4 External appearance of a data center of Kingsland

4 “co-IZmo/I” Indirect Outside Air Cooled Container-Type Data Center

Data centers are required to reduce their massive power consumption and have scalability, that is, equipment can be added in stages in accordance with the scale of business.

Fuji Electric has jointly developed the “co-IZmo/I” indirect outside air cooled container-type data center with Internet Initiative Japan Inc. and has launched it inside and outside Japan. In 2016, we delivered an environment-friendly data center to a certain Asian country as a full turnkey project. The main features are as follows:

(1) Significant reduction in power consumption for air conditioning by cooling with outside air
(40% reduction in power consumption compared with conventional data centers)
(2) Flexible expansion in accordance with scale by using modular connection
(3) Reduction in the term of installation work by carrying out transportation and installation leaving servers mounted

Fig.5 “co-IZmo/I” (facility for verification in Japan)

Power Supply Systems

5 Cleanroom for Electronic Device Factories

Fuji Electric received an order for a cleanroom facility for manufacturing electronic devices for smartphones. This was an EPC project including the manufacture of equipment, procurement of interior materials, on-site installation and commissioning tests. We have delivered this facility.

The project involved renovating a building with general air-conditioners and with an area of approximately 6,500 m^2 into a cleanroom in a short work period of 3 months. In order to strike a balance between the short work period and high quality, we made common design specifications based on our delivery track records with similar facilities. By making equipment and materials common, we satisfied the demand for cost savings. The main specifications of the cleanroom are as follows:

(1) Cleanliness: Class 1,000 (Fed.Std.209D)
(2) Air flow type: Vertical laminar flow

Fig.6 Example of cleanroom

Electric Distribution, Switching and Control Devices

1 "EX Series" Electronic Earth Leakage Circuit Breaker

Power distribution facilities are required to have high power supply reliability in places such as hospitals and data centers. In recent years, they have come to need high-functionality electronic circuit breakers that have a leakage current pre-alarm, adjustable rated current and measuring functions. In order to meet these demands, Fuji Electric has developed the "EX Series" electronic earth leakage circuit breaker equipped with a compact earth leakage and measurement unit. The main features are as follows:

(1) 30% miniaturization in setting area compared with a conventional product (the same external size as our molded case circuit breaker)
(2) Leakage current pre-alarm function and setting of a wide range of sensitive currents
(3) Communication function that supports current and voltage monitoring and remote control
(4) Accessories that can be shared with existing series
(5) Compliance with global standards: IEC, JIS and GB

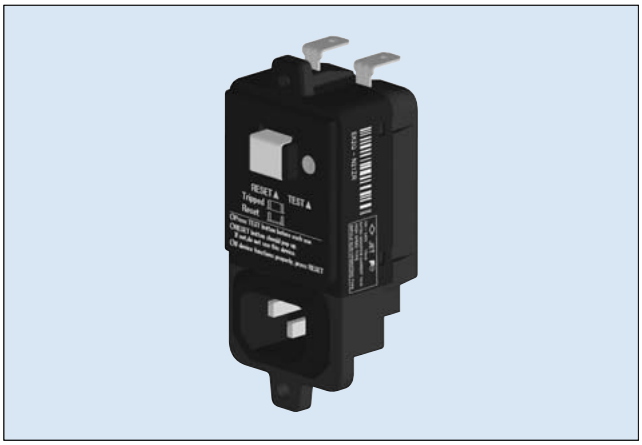
Fig.7 "EX250RAE"

2 "EK2Q" Energy-Saving-Type Earth Leakage Circuit Breaker

Earth leakage circuit breakers, which are used in electric equipment such as copiers and printers, have come to be required in recent years to have even lower power consumption. Fuji Electric has developed the "EK2Q" energy-saving-type earth leakage circuit breaker. It supplies power by setting the phase difference between input voltage and current to approximately 90°. Thus power consumption of the power circuit is greatly reduced. The main features are as follows:

(1) World's top-class energy-saving performance: Standby power consumption 15 mW/100 V AC (75% reduction)
(2) Compatibility with the current product: The same external profile as the current product provides compatibility in terms of mounting.
(3) Environmental measure: Free of cadmium in compliance with the RoHS directives
(4) Compliance with global standards: cULus, TÜV (IEC), CCC, and PSE

Fig.8 "EK2Q"



Industry Solutions in Power Electronics Systems

Factory Automation
Process Automation
Environmental Solutions
Instrumentation and Control
Transportation Systems

Outlook

Fuji Electric is committed to achieving further efficiency improvement, miniaturization and weight reduction based on power conversion technology in power electronics equipment and has been making contributions by applying them to various fields centering on society and industries.

Factory Automation

In factory automation, we have commercialized the "FRENIC-HVAC PD Series" inverter that incorporate a commercial power selector switch to meet the rising demand for energy saving in office buildings and factories. This series can significantly save space because it incorporates peripheral circuits, which had been necessary at the time of introducing an inverter, and requires no control panel. We have also commercialized the "FRENIC-eRHR" and "FRENIC-eRHC" compact converters. They significantly save energy and space by returning regenerative energy to the power supply in elevators and other applications.

For motion systems, we have commercialized the "ALPHA7" servo system, various series of servo motors and the "SPH3000D" motion controller to cope with the sophistication of production facilities. In addition, we have commercialized the "ALPHA5 Smart Plus Series" servo system and the "SPF Series" compact controller to launch them on the Asian markets, where production efficiency improvement and labor cost increases have been advancing. For HMIs, we have commercialized the "TECHNOSHOT Series," which places importance on visibility and external interfaces.

For rotating machines, we have commercialized motors that comply with overseas efficiency regulations including GB2 in China and EISA in the United States as efficiency regulations are increasingly being enforced globally.

Process Automation

For process automation, we have been providing equipment and systems that can help production facilities to operate stably and reduce specific consumption. We have done this with drive control technology, instrumentation and control technology, and industrial electric heating technology such as induction furnaces and melting furnaces as the core.

For the metal industry, we have delivered high-speed drive control systems to Indonesia and Turkey, which are expected to become central points of production for automobiles and household electrical appliances. In Japan, we have been expanding our business by providing monitoring control systems and industrial drive equipment with enhanced maintenance support and enhanced coordination with higher level systems while making effective use of existing software assets.

For the chemical and foods industry, as a result of diversification of consumer needs, there has been more construction of new manufacturing plants and greater modification of existing manufacturing plants for consumer market products. In these industries, the improvement of quality and manufacturing efficiency has been demanded more than ever, in addition to needs for high-mix low-volume production and stable operation. Fuji Electric has developed and started offering a system to predict abnormalities in a plant and notify the operators of them, in addition to the control technology it has cultivated until now. We are planning to add a function to notify operators of abnormality avoidance operations.

For the waste disposal industry, in addition to upgrading existing facility systems, there has been greater reconstruction as a result of deterioration of facilities and more construction of new facilities resulting from business integration. For upgrading, we make the maximum use of existing customer assets, such as application software. Meanwhile, for new facilities, we can optimize controllability in a way that applies our control know-how based on our abundant delivery track record. There is also a demand for reducing costs that are incurred for environmental measures such as for exhaust gas, and we provide solutions that combine gas analyzers with shorter response time.

For industrial electric heating industry, we have been expanding the application of induction heating by using the technologies of electromagnetic field analysis

and thermal analysis. From now on, we intend to expand power supply devices in higher frequency regions and apply them to new applications.

Environmental Solutions

For environmental solutions, we have developed a "sludge-less wastewater treatment system" as a new biological treatment system for wastewater. This combines a magnetic separation device that magnetically separates sludge and Bacillus suitable for wastewater treatment and generates little excess sludge. This system does not require a settlement tank or a sludge dehydrator, thus making it possible to both save space while reducing the initial cost of equipment and running costs related to electricity and chemicals.

In the greenhouse horticulture industry, we have developed a high-eave greenhouse construction method that reduces construction materials and improves daylighting performance and workability inside the facility. We have also developed a "CO_2 and heat supply system" that supplies CO_2 and heat for air conditioning by generating them from a single fuel. This system can reduce the running cost by about 30% compared with conventional equipment. The construction method and system are employed at the greenhouse horticulture of Salad Paprika Co.,Ltd.

Instrumentation and Control

For instrumentation and control industry, we will provide measuring equipment and sensors that support systems as competitive components by defining their applications and usage environment. We have launched a temperature controller for the plastic molding machine market in China, a safety standard-certified (SIL) pressure transmitter for petroleum and chemical plants, and a explosion-proof certified high-precision spool-type ultrasonic flowmeter. We have also expanded the functionality of the "FeMIEL2.0" wireless sensor network system for environmental information sensing that connects measuring equipment and sensor signals (temperature, humidity and analog output) to higher-level systems.

Transportation Systems

For transportation systems, we have jointly developed with Central Japan Railway Company a main power converter that uses silicon carbide (SiC) power semiconductor modules for Tokaido Shinkansen trains. A prototype has been mounted on the N700-Series Tokaido Shinkansen train, and test running is being carried out. This is the first case in the world in which a SiC power semiconductor module was used for the propulsion system of a high-speed railroad. We have also developed a compact and lightweight auxiliary power unit by applying high-frequency resonance circuit technology. For door drive systems for rolling stock, we have delivered rack-and-pinion-type electrical driven doors with improved reliability and maintainability compared with conventional pneumatic doors. They were delivered to Yamanote Line mass-production trains of East Japan Railway Company (JR-East), and commercial service started in May 2017.

Factory Automation

1 "FRENIC-eRHR" and "FRENIC-eRHC" Compact Converters

We have developed the following 2 series of regenerative converters that are more compact than conventional models: The "FRENIC-eRHR" and the "FRENIC-eRHC" PWM converter. The main features are as follows:

(1) Using a regenerative converter for an inverter significantly improve energy saving and braking capacity.
(2) Using a converter in place of a braking resistor or a braking unit make it possible to save space and reduce the generated losses.
(3) FRENIC-eRHC can significantly reduce the harmonics current by PWM control, thereby allowing conversion coefficient K_i in the harmonics suppression measure guidelines to be zero by being combined with an inverter. In addition, because it can operate with a power factor of almost one, it can miniaturize power supply transformer capacity and equipment.

Fig.1 "RHR22C-2EJ" and "RHR30C-4EJ"

2 "ALPHA5 Smart Plus Series," Servo System for Chinese and Asian Markets

In China and Asia, general-purpose interfaces using pulse train and analog signal are the mainstream in the control of processing machines, removal robots and packaging machines. Fuji Electric has developed the "ALPHA5 Smart Plus Series," which was made by making additions and improvements to the control functions of the "ALPHA5 Smart Series," which already has many track records. The main features are as follows:

(1) Implementation of the dynamic brake function
(2) Expansion of the single-phase input model (0.75→1.5 kW)

We have developed the compact controller "SPF Series," which becomes suitable for the control of a small-scale system with four axes or less by combining with the ALPHA5 Smart Plus Series and expanded the number of I/Os to 512 words from 360 words.

Fig.2 "ALPHA5 Smart Plus Series" and "SPF Series"

(a) "ALPHA5 Smart Plus Series" (Servo amplifier)
(b) "SPF Series"

3 "TECHNOSHOT Series" Programmable Operator Interface

Fuji Electric has launched the "TS2060" and "TS2060i" of the "TECHNOSHOT Series" programmable operator interface. The main features are as follows:

(1) Improvement of viewability (number of display colors, luminance, angle of visibility and contrast) by using the 5.7-inch TFT color LCD
(2) High-speed data communication with USB 2.0
(3) Improvement of expression and data retention capacity by increasing screen data memory capacity and backup memory capacity*
(4) Support for a wide range of communications by Ethernet installed as a standard specification*
(5) Improvement of convenience for data utilization with SD card*
(6) Reuse of graphics applications of "UG221H" and "V806" reusable with upward compatibility

*: TS2060i only

Fig.3 "TS2060i"

Factory Automation

4 Motors Certified for Overseas High-Efficiency Regulations

Efficiency regulations for motors (3-phase induction motors) have been increasingly enforced in each country for energy saving and other purposes, and legislation and regulations have been accelerating in each country. Fuji Electric has developed high-efficiency motors that conform to the efficiency regulations of China, the United States and Canada and have acquired the following certifications:

(1) For China [0.75 to 375 kW (2-, 4- and 6-pole machines)]:
Grade GB2 (efficiency class IE3) of GB18613-2012, certification for the new China RoHS and CCC (applicable models only)

(2) For the United States and Canada [0.75 to 30 kW (2-, 4- and 6-pole machines)]:
EISA, EEAct (efficiency class IE3), safety standards UL and cUL

(3) For the United States [0.75 to 55 kW (2- and 4-pole machines)], [0.75 to 45 kW (6-pole machines)]:
EISA (efficiency class IE3)

Fig.4 Motor for China certified for grade GB2

Process Automation

1 Electrical Equipment for Bar and Shape Rolling Mills

Fuji Electric has delivered electrical equipment for bar and shape rolling mills for a certain company in Indonesia. The latest control system achieved a high-performance and high-reliability system and improved added functions for maintainability and visualization of operation. The main features are as follows:

(1) We have developed a new 650-kVA product line of the "FRENIC4400 VM5R" 3-level inverter and used it for steel shearers. This reduced the overall capacity and realized cost savings and compactness.

(2) We have developed an operation monitoring function and a system with high maintainability, enabling stable operation.
- ○ Remote monitoring and maintenance by HMI and loaders
- ○ Utilization of operational data (current, voltage, speed and other data at any given time) of high-speed collection with "f(s)NISDAS 7"

Fig.5 Overall view of rolling mill line

2 "FRENIC4800" Drive for Reversing Mill at Nikko Works of Furukawa Electric Co., Ltd.

We have delivered a large-capacity water-cooling drive and synchronous motor for hot reversing mill at Nikko Works of Furukawa Electric Co., Ltd. The main features are as follows:

(1) Reduction of installation space by using a water cooling system (59% reduction compared with conventional products)

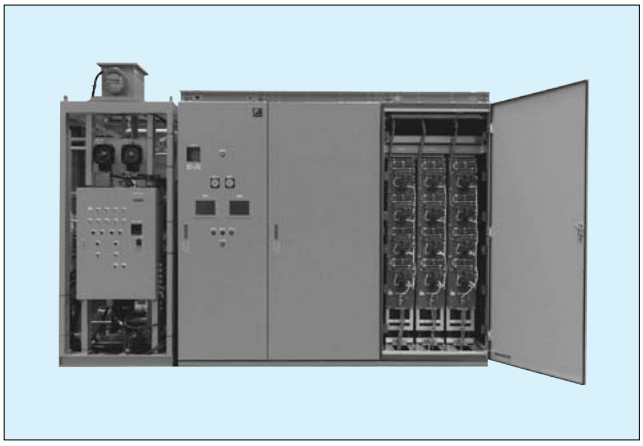
(2) Reduction of line harmonics by using a 3-level system (59% reduction compared with conventional products)

(3) Improvement of operability and visibility by using a new monitoring controller

(4) The "FRENIC4800 CM6/VM6" large-capacity water-cooling drive
- ○ Input: 3ϕ, 3,000 V, 5,200 kW
- ○ Output: 3ϕ, 3,100 V, 6,200 kVA
- ○ Overload capability: 150% for 1 min

(5) Synchronous motor
- ○ Output: 2,800 kW, 160/320 min^{-1}
- ○ Overload capability: 225% for 1 min

Fig.6 "FRENIC4800 CM6/VM6"



Process Automation

3 Electrical Equipment for Container Crane at Port

Fuji Electric has delivered a lot of electrical equipment to port container cranes all over the world. We completed installation of electrical equipment including the total control system of a container crane recently in Japan. The main sophisticated functions are as follows:

(1) A stack-type PWM converter and a high-performance vector inverter are used as drive equipment for a port container crane to achieve space saving, for high-performance, higher reliability and improvement of maintenance.
(2) This crane system is equipped with dedicated monitoring functions, such as observing crane status, managing cargo handling condition, detecting failure condition and trace back function, which achieve quick analysis and recovery of crane system.
(3) The sophisticated anti-sway control system allows even a non-skilled operator to operate the crane easily and stably like an expert.

Fig.7 Overall view of container crane

4 Replacement of Monitoring Control System for BT-CC Factory of Aichi Steel Corporation

When replacing aging equipment, manufacturers have recently been required to provide new added values while ensuring high quality and shortening the operational downtime, Fuji Electric has replaced the monitoring control system of the BT-CC factory of Aichi Steel Corporation. The main features of the new system are as follows:

(1) Safe and secure operations on a higher level are achieved. For examples, a multi-window display and the easy-to-understand operation similar to that of general-purpose OSs cause efficient and easy plant operation, and the integration of alarms and operation logs enables speedy failure cause analysis.
(2) High-quality and a quick start-up of the facility was achieved by conducting parallel run tests, that is, new operator stations and new controllers were connected to both the existing control LAN "DPCS-F" and the new control LAN (FL-net Ver. 3 compliant).

Fig.8 Monitoring control system

5 Replacement of Monitoring Control System for Waste Incineration Plants

Each municipality has been conducting large-scale renovations with the aim of having long-term operation of existing waste treatment facilities. Hence, monitoring control systems have been actively replaced as part of the renovation.

Fuji Electric has replaced the existing "MICREX-IX" system of the West Clean Center of the City of Kobe Environmental Bureau with the "MICREX-VieW XX," a latest monitoring control system. After the replacement, existing I/Os and PLCs are connected to the new system via network adapters. By reusing the existing assets, we ensured quality and shortened the upgrade period. Part of the equipment in the plant needed to perform monitoring control even during the replacement period. Therefore, we operated the new system and the existing system in parallel by leaving the existing "DPCS-F" control network operating until we switched them. Thus, we completed the replacement without affecting the operation of the plant.

Fig.9 Central control room of West Clean Center of City of Kobe Environmental Bureau

Process Automation

6 Remote Monitoring and Cut-Off System for City Gas Utilities

Fuji Electric has been delivering remote monitoring and cut-off systems for medium- and low-pressure governors for city gas utilities in order to reduce damage in the event of an earthquake. We made a proposal based on the past track record and received an order for a remote monitoring and cut-off system for low-pressure governors from a certain gas utility. We newly developed a slave station communication device that uses the LTE lines, as required by the system. Demand for 2,000 units or more can be expected in the future. The main features are as follows:

(1) Support for the LTE lines (Xi) of NTT Docomo Inc.
(2) Installation in a wall-mounted panel [W500 × H600 (mm)]
(3) Capability to back up the power supply for 24 hours or longer during a blackout
(4) Adoption of firmware that allows the communication protocol to be changed
(5) 8 analog inputs, 16 digital inputs and 4 digital outputs at the maximum

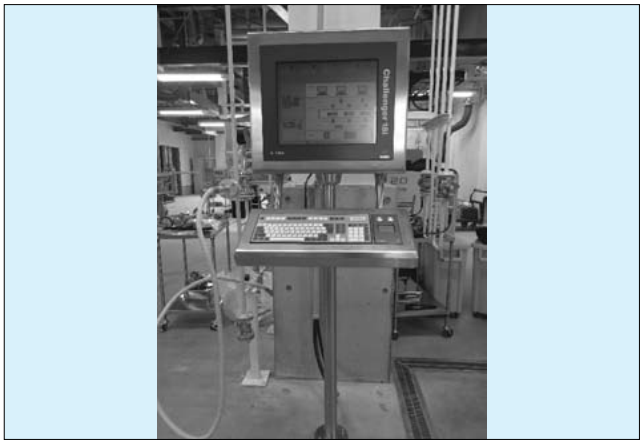
Fig.10 Example of installation of slave station communication device that supports LTE lines

7 Monitoring Control System for New Factory of Dow Corning Toray Co., Ltd.

Fuji Electric has delivered a monitoring control system that consists of the "MICREX-NX" distributed control system and field installed explosion-proof monitors for a new factory to be constructed in the Chiba area of Dow Corning Toray Co., Ltd.

Equipment subject to monitoring control consists of 3 tanks and 2 mixers, process in which require batch control. In the same year, at the customer's another factory, the existing monitoring control system manufactured by another manufacturer was replaced by our system including MICREX-NX. The existing server in the system, however, is continued to use and shared with the new system. Two operator stations were installed for this system. Two explosion-proof monitors were installed to perform monitoring and control in the field of the explosion-proof areas. This has enabled operators facing field equipment and tanks to perform monitoring and control safely using the five senses of people, for examples, grasping changes in the sound and smell.

Fig.11 Explosion-proof monitor

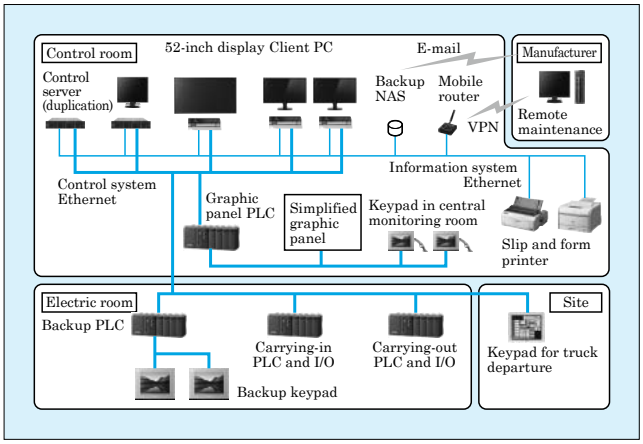


8 Monitoring Control System for Grain Silos

Since Japan is heavily dependent on import to meet the demand for grains for food and fertilizers, grain silos play an important role as an intermediate storage place for imported grains. Fuji Electric has developed a high-quality and high-functionality monitoring control system for grain silos with general-purpose SCADA and the "MICREX-SX" programmable controllers. The main features are as follows:

(1) It can set multiple conveyance routes in advance and automatically select an optimum conveyance routes according to a grain brand and the condition of a grain silo.
(2) By controlling the last transferred brand and air purge operation history, it prevents grains from being mixed up (contaminated).
(3) It records the conveyance route up to a silo and the condition of control and generates history data for tracing grains.

Fig.12 System configuration diagram



Process Automation

9 New Functions of "HEART" High-Efficiency Engineering Tool

The "HEART" is an engineering tool that can automatically generate control software from a control function specifications sheet prepared with Excel or Visio. It also allows users to monitor control state through that specifications sheet. Fuji Electric has recently developed the following new functions:

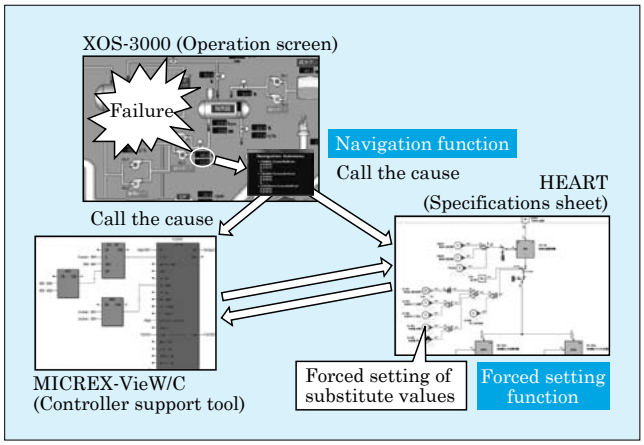
(1) Navigation

This makes it easy to trace the cause of a fault or an alarm from the operation screen in the event of trouble at the plant, allowing speedy action.

(2) Enforced setting

This is intended to avoid abnormalities temporarily or avoid secondary trouble in the event of a plant abnormality, a sensor failure or partial inspection of equipment. It allows operations to be continued using substitute values set by the user.

Fig.13 Navigation function and forced setting function



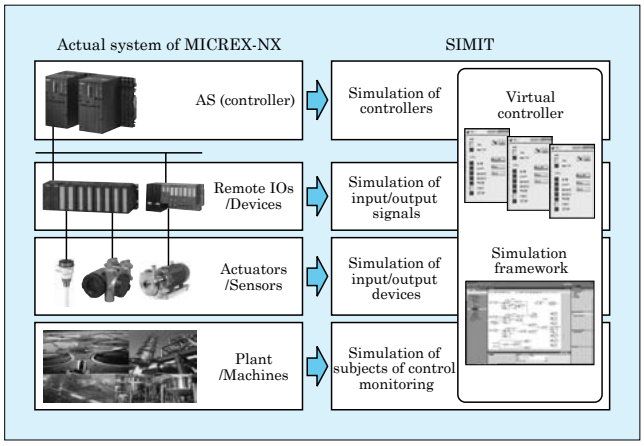
10 Integration of Plant Simulator SIMIT and "MICREX-NX"

Fuji Electric has started offering a digital engineering solution that enables integration between the "MICREX-NX" of DCS and SIMT of plant simulator.

SIMIT is an engineering tool using simulation. It can create models of input and output devices, such as sensors and valves, and whole controlled object that includes plants and machinery and simulate them. In addition, combined with a virtual controller, SIMIT serves as a training system for operators.

Seamless integration of SIMIT and the MICREX-NX can realize improved quality of control programs and optimized plant operations using simulation.

Fig.14 Image of SIMIT system



11 Functional Expansion of "MICREX-VieW XX"

Fuji Electric has expanded the functionality of the "MICREX-VieW XX" plant monitoring control system. We have added a new system configuration to resolve the challenges of high-quality product manufacturing and the stabilization and efficiency improvement of operation by customers.

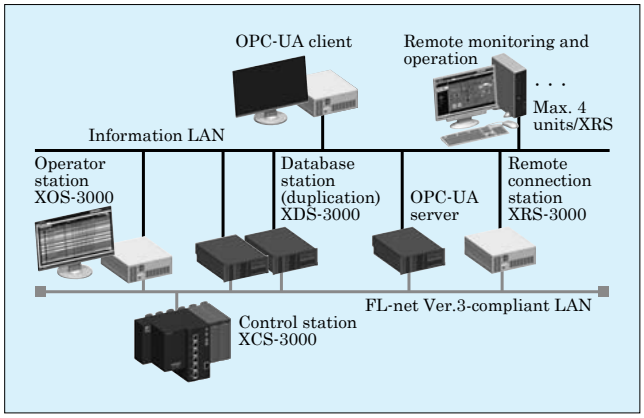
(1) We developed a remote connection station, which enables remote monitoring and operation from an office far from a manufacturing site, with the same screens and operability as those on the site.

(2) We developed an OPC-UA server, thereby ensuring high security that incorporates the latest communication technology and enabling flexible access to plant information.

MICREX-VieW XX has been continuously evolving with enhancing functions, such as with faster data collection and display processing, long-term storage of plant data, and security enhancement.

Reference: FUJI ELECTRIC REVIEW 2016, vol.62, no.3, p.186

Fig.15 Remote monitoring and operation and configuration of OPC-UA server

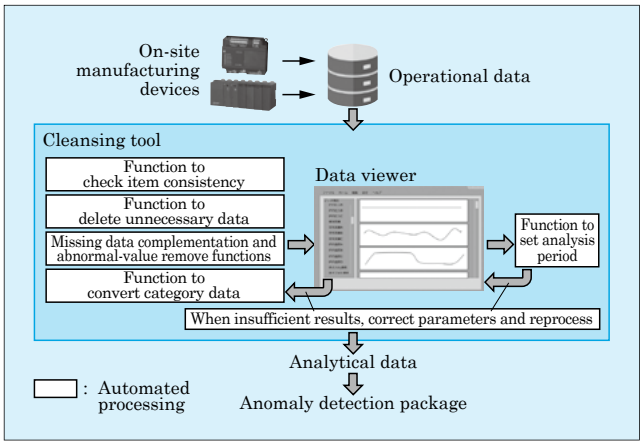


Process Automation

12 Data Cleansing Tool for Anomaly Detection

Fuji Electric has developed a data cleansing tool that creates data for performing anomaly detection using a large amount of operational data obtained from equipment or a plant. In anomaly detection using multivariate statistical process control, it is essential to correct missing data and abnormal value or to remove data of equipment down period (data cleansing) to obtain a correct diagnosis result because they are contained in the data obtained but are not related to the diagnosis. This tool automates data cleansing that had been manually performed by in-house professionals, allowing it to be performed even without expertise. In addition, the graph drawing function that can instantaneously operate a million sets of data has improved the efficiency of the cleansing result check, which in particular used to take many man-hours. We performed an evaluation using actual data and obtained the result that the check can be performed with about one-fifth the man-hours of the previous work.

Fig.16 Automation by data cleansing tool



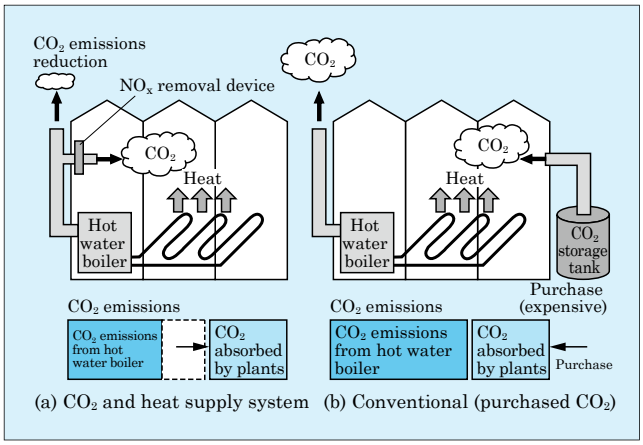
Environmental Solutions

1 High-Eave Greenhouse Construction Method and "CO_2 and Heat Supply System" for Greenhouse Horticulture

Fuji Electric has developed a high-eave greenhouse construction method for greenhouse horticulture that complies with Japanese standards. The method uses technology developed in the Netherlands, which is an advanced country in this field. High height eaves and construction material reduction improved the daylighting performance and workability inside the facility. We have also developed a "CO_2 and heat supply system" that generates and supplies CO_2 and heat, which are indispensable for increasing the yield, from a single fuel. This system supplies both heat and CO_2 that is generated when a heater operates. Its operating cost is lower by 30% than that of the existing system that separately generate them. This also contributes to a reduction in environmental burden.

The construction method and system are employed at the greenhouse horticulture of Salad paprika Co., Ltd. and will be applied more widely.

Fig.17 Conceptual diagram of "CO_2 and heat supply system"



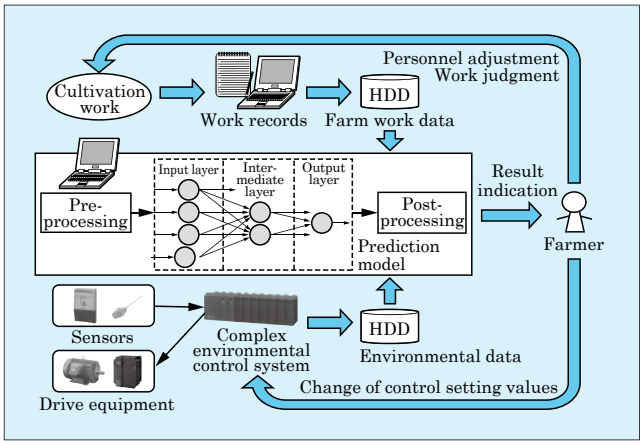
2 System for Predicting Production Process Data

Fuji Electric has developed a technology for predicting the yield of strawberries as one method to resolve issues in plant factories. It has achieved high prediction accuracy by performing machine learning based on the past environmental data and farm work data. In addition, this method eliminated the complex parameter setting that had been necessary for the conventional prediction method using mathematical formulas. As a result, man-hours are significantly reduced needed for adjusting the prediction model. By performing accurate daily yield prediction, this method makes it possible to predict both the amount to be shipped and the workload. Using the system allows a reduction in sales losses and improvement of profit by improving work efficiency.

The results of the demonstration experiment to predict short-term yield at "Tomatoh Farm," a plant factory in Hokkaido, showed that the system achieved a prediction accuracy of 15% on average. We will try to improve the mid- and long-term prediction accuracy and aim to apply the system to other crops.

Reference: FUJI ELECTRIC REVIEW 2016, vol.62, no.3, p.160

Fig.18 Configuration of system for predicting production process data

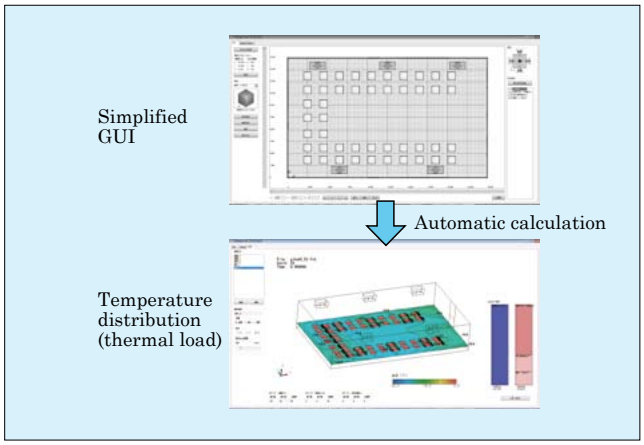


Environmental Solutions

3 Design Simulation for Refrigerated Warehouse

Fuji Electric has developed an engineering tool that allows the arrangement and selection of indoor air-conditioning equipment, such as unit coolers and air curtains, to be designed in a short time and with high precision. It is intended for large-scale frozen and refrigerated facilities, such as refrigerated warehouses. This tool features an intuitive arrangement operation function using a simplified GUI for indoor air-conditioning equipment and the 3D analysis function of thermal load and temperature distribution in refrigerated warehouses by thermo-fluid analysis. In thermo-fluid analysis in particular, we developed new "pseudo-non-stationary calculation" that combines stationary calculation and non-stationary calculation. It can predict non-stationary events specific to refrigerated warehouses, such as door opening and closing, and realizes quick and high-precision analysis. This reduced the time for arranging and selecting indoor air-conditioning equipment by 20% and enabled designing with 15% better thermal load prediction accuracy.

Fig.19 Design simulation with engineering tool



Instrumentation and Control

1 Temperature Controller "PXE5"

The temperature controllers of Fuji Electric, such as the high-quality and reasonably priced "PXF Series," have a track record of cumulative sales of 3 million units in the world. We launched the new "PXE5" for the plastic molding machine market in China in September 2016. The main features are as follows:

(1) Two-degree-of-freedom PID control in addition to PID auto tuning and fuzzy control
(2) Dual control with a single unit (for heating and cooling)
(3) Shallow design with a depth of 62 mm and a thickness of the front indicator section of 1.6 mm
(4) Front waterproof specification (NEMA4X)
(5) Loader interface

Fig.20 "PXE5"

2 Zoning Air Curtain for Refrigerated Warehouses

In refrigerated warehouses, the amount of load fluctuates significantly, and if it is small, the warehouse generates an energy loss by cooling wasted space. Fuji Electric has developed a zoning air curtain that can save energy by changing the cooling area in accordance with the amount of load. The main features are as follows:

(1) It allows temperature zoning that separates the temperature zone in a large space into two different zones by using only air flow.
(2) It achieves energy saving by raising the set temperature for areas with no products.
(3) The ceiling-mounted structure significantly reduces the risk of collision with forklifts.
(4) By introducing the moving mechanism (optional), the area of the temperature zoning can be changed.

Fig.21 Zoning air curtain with moving mechanism

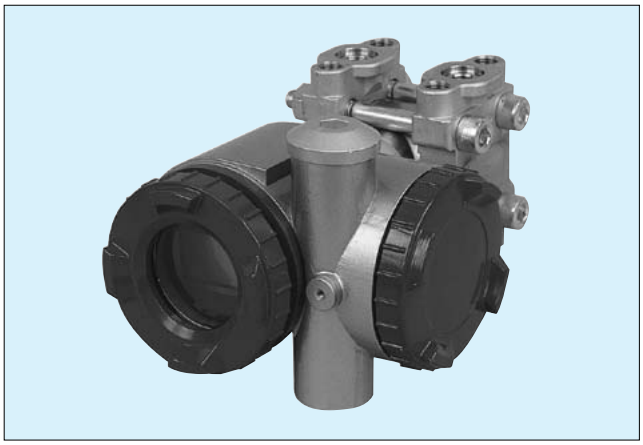
Instrumentation and Control

3 Functional Safety Certified Pressure Transmitter

At petroleum and chemical plants, there has recently been increased demand for reliable safety systems that are operated in emergency, such as emergency shutdown systems and firefighting equipment; also, for system components, conformity to the functional safety standard IEC 61508 has been increasingly required. To comply with this standard, Fuji Electric has developed a pressure transmitter with a significantly enhanced self-diagnosis function and has obtained the certification. In addition, we improved performance and functions such as the world's top-class response time. The specifications are as follows:

(1) Functional safety standard certification (IEC 61508)
Hardware: SIL2; Software: SIL3
(2) High-speed response
Dead time: 40 ms; Output update period: 40 ms
(3) HART communication
Latest version 7

Fig.22 Functional safety certified pressure transmitter

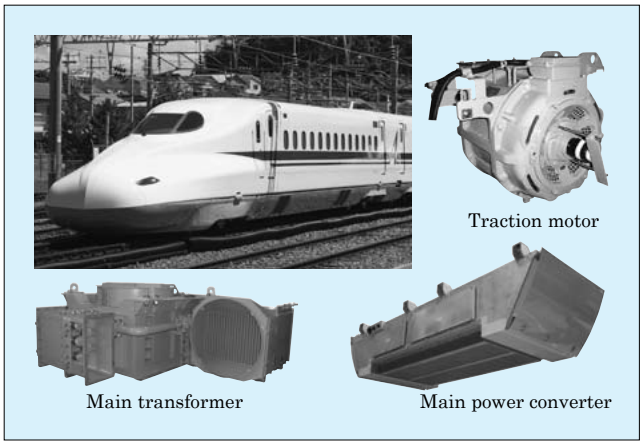


Transportation Systems

1 Electrical Equipment for N700A Shinkansen Trains of Central Japan Railway Company

Since March 2017, Central Japan Railway Company has been introducing N700A Shinkansen trains (third train) that reflect the latest results of technology development. Fuji Electric has manufactured propulsion systems (main transformers, main power converters and traction motors) as electrical equipment for N700-Series and N700A Shinkansen trains. The systems are based on power electronics technology and system control technology, and we have been delivering them since April 2007. For the main converter, we have achieved low noise and high efficiency by adopting a running wind cooling system that does not use blowers. For N700A (third train), we have adopted an electric gate signal system and used stainless steel as the box material to achieve further compactness and light weight. This has helps to improve environmental performance and save energy. The main parts are shared with the N700 Series and N700A (first and second trains) to maintain product quality.

Fig.23 Electrical machinery product for N700A Shinkansen trains



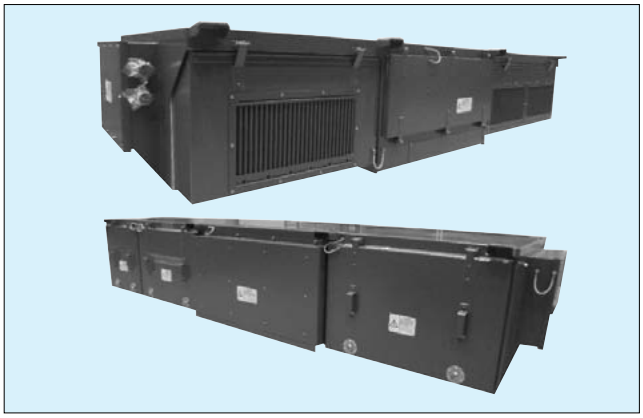
2 High-Temperature-Resistant and Dust-Proof Auxiliary Power Unit for Rolling Stock

Fuji Electric has been distributing auxiliary power units for rolling stock in Japanese and overseas markets. We have recently developed an auxiliary power unit for electrical rolling stock that has high-temperature resistance and improved dust-proof performance.

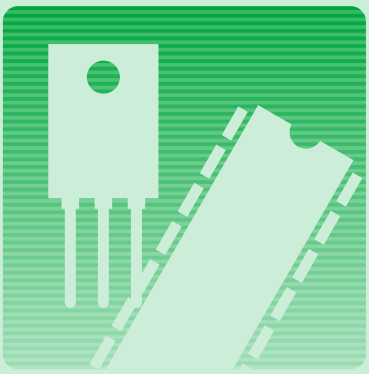
The input voltage of the auxiliary power unit is 750 V DC (3rd rail). The output voltage and capacity of that are 400 V AC and 146.4 kVA for three-phase units, and 240 V AC and 3.6 kVA for single-phase units. The main features are as follows:

(1) By applying high-frequency resonance circuit technology and miniaturizing the insulation transformer, we have miniaturized and reduced the weight of the unit.
(2) By installing a heat exchanger in the equipment room and adopting a heat sink in which heat pipes are inserted to cool the elements, we have improved the cooling efficiency, so that the auxiliary power unit can cope with an outside air temperature of 65°C.
(3) By increasing the tightening force of the inspection cover to improve the air-tightness of the packing around the cover, the unit complies with the dust-proof and waterproof standard IP65.

Fig.24 High-temperature-compatible dust-proof auxiliary power unit for electrical rolling stock



Electronic Devices



Semiconductors
Disk Media

Outlook

Semiconductors

Power semiconductors are being used in an increasingly wide range of applications in the fields of automobiles, photovoltaic power generation and wind power generation in addition to industrial equipment and home appliances. This is occurring along with the increase in global energy demand and greater awareness of the need for energy saving and energy creation in order to conserve the global environment, represented by a reduction in CO_2 emissions. Fuji Electric contributes to society by continuously developing power semiconductor products featuring high energy conversion efficiency, low noise and ease of use.

One representative example of power semiconductors is an insulated gate bipolar transistor (IGBT). The IGBT was developed in the 1980s, and underwent a change of generation of devices along with subsequent innovations such as loss reduction and high heat dissipation technologies. Fuji Electric's latest IGBT is now in the 7th generation. We have also worked on developing products that use silicon carbide (SiC) as a next-generation semiconductor material to replace silicon and developed an all-SiC module that applies the 1st-generation trench gate MOSFET.

For the industrial field and environment and energy field, we have developed a 1,700-V breakdown voltage high-power IGBT module that applies the latest 7th-generation IGBT technology. In addition to the product line-up with a package compatible with conventional products, we have developed a line of products with a new package, "High Power next Core (HPnC)," featuring high heat dissipation, low inductance and high reliability. HPnC is suited for modules to be used in the field of electric railways because of the features it offers, and we intend to deploy this product in the electric railway market in the future.

We have also promoted innovations in IGBT and free wheeling diode (FWD) technologies and developed an RC-IGBT. An RC-IGBT chip integrates an IGBT chip with a FWD chip, allowing for an improvement in the maximum rated current of the module package, and we are working to expand the line-up of products for the industrial field.

In the automotive field, Fuji Electric has developed the "F5114H" high-side 2-in-1 intelligent power switch (IPS). It applies the 4th-generation IPS technology and contribute to miniaturize electronic control units (ECUs) that are becoming intricate as electronic control are increasingly used. The SSOP-12 package, which has the same external dimensions as SOP-8 package, has been equipped with 2 chips that have the same functionality as that of previous products. This makes it possible to have 2 channels with the same footprint as one-channel products. For automotive DC-DC converters and chargers, we have developed the 2nd-generation SJ-MOSFET "Super J MOS S2A Series", which achieves high-efficiency power conversion. This product conforms to AEC-Q101, a reliability standard for automotive electronics. It has further reduced the on-state resistance standardized by the unit area and improved the trade-off between switching loss and voltage surge during turn-off switching, thereby achieving both lower loss and better ease of use. In the field of automotive IGBTs used for motor drives of hybrid electric vehicles and electric vehicles, we are developing a line-up of products using the above-mentioned RC-IGBTs and our original direct liquid cooling structure.

Regarding discrete products, we have commercialized the "High-Speed W Series" high-speed discrete IGBTs with TO-247-4L package, which achieves high-efficiency power conversion, for UPSs and photovoltaic power generation PCSs. Having 4 terminals in this package can lower the emitter common inductance of the gate drive circuit and the wiring inductance of the gate-emitter loop, significantly reducing the switching loss. In addition, we have worked to meet market demands for improved efficiency of the power circuit during light loads, reduced standby power and system cost reduction. To this end, we have offered the "FA1A60N" critical mode PFC control IC capable of power factor improvement and the "FA6B20N" LLC current resonant control IC, which operates soft switching control, for high-efficiency power supplies. These can be interconnected to have automatic switching between operation

modes, and this has led to a significant improvement in efficiency during light loads and a reduction in standby power while accommodating a wide range of input voltages of 85 to 264 V AC. It has also successfully reduced the number of components. Fuji Electric intends to continue developing environmentally friendly power semiconductor products and contribute to the creation of responsible and sustainable societies.

Disk Media

Along with the advent of the IoT age, the global volume of information is expected to dramatically increase and hard disk drives (HDDs) are expected to continue to undertake an important role of offering high-capacity and low-cost storage. As a magnetic recording media supplier for HDDs, Fuji Electric started the mass production of 2.5-inch media with a recording capacity of 1 TB/disk, which is the industry's largest, and 3.5-inch media with a recording capacity of 1.33 TB/disk for nearline servers in FY2016. We intend to continue developing and offering media meeting market demands and contribute to the development of an IT-based society.

Semiconductors

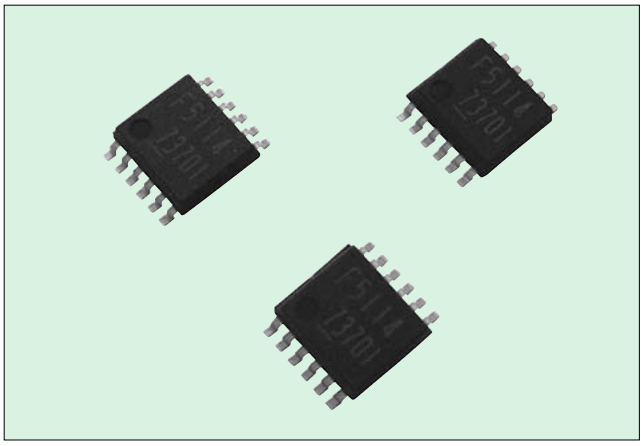
1 "F5114H" High-Side 2-in-1 IPS for Automobiles

There are demands for miniaturization and higher reliability of semiconductors in the field of automotive electrical equipment. In response to them, Fuji Electric has developed the "F5114H" high-side 2-in-1 intelligent power switch (IPS) for automobiles using the process and device technology of the 4th-generation IPSs for the purpose of further miniaturization.

The SSOP-12 package has the same external dimensions as those of the SOP-8 package. Further, it is equipped with 2 chips that have equivalent functionality to that of conventional products, including over-current protection, over-temperature protection, open load detection and low-voltage detection. Each chip is separated with lead frames and operates independently, allowing a channel to avoid affecting operation of the other channel even when it fails. The product is designed to ensure reliability against higher temperatures of the device and environment by employing reliable wire that can be used in a high-temperature environment.

Reference: FUJI ELECTRIC REVIEW 2016, vol.62, no.4, p.261

Fig.1 "F5114H"

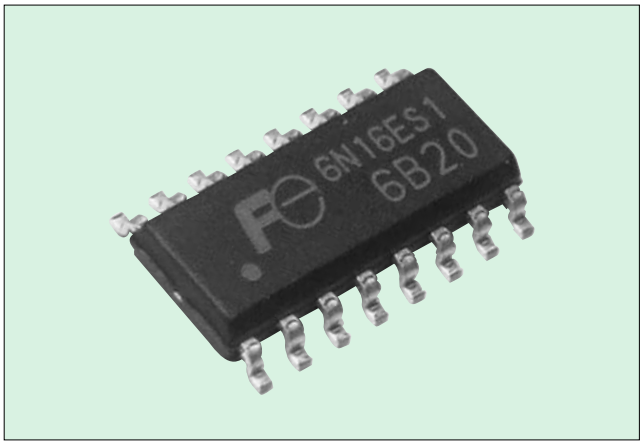


2 "FA6B20N" LLC Current Resonant Control IC for High-Efficiency Power Supplies

Power supplies with an output power of over 100 W widely use LLC current resonant circuits capable of soft switching control, which is effective for noise reduction, and are required to improve efficiency and reduce system cost. Fuji Electric has developed the "FA6B20N" LLC current resonant control IC, which achieves further efficiency improvement during light loads and the reduction of the number of components while accommodating a wide range of input voltages of 85 to 264 V AC. The main features of power supplies that use this IC are as follows:

(1) By interconnection with the "FA1A60N" power factor correction (PFC) control IC, a power supply can improves its entire efficiency, including that of PFC circuit, during light loads (efficiency with output power of 5 W: 75%).
(2) Power consumption in the standby state can be reduced.
(3) Heavy load start-up is possible during low input voltage.
(4) Automatic switching between normal state and standby state is provided.

Fig.2 "FA6B20N"



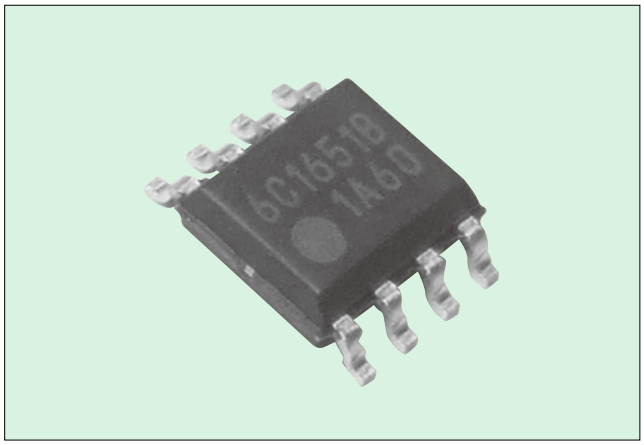
Semiconductors

3 "FA1A60N" Critical Mode PFC Control IC for High-Efficiency Power Supplies

Switching power supplies with a relatively large capacity used for electronic devices are required to have a power factor correction (PFC) circuit for suppressing a harmonic current. Fuji Electric has developed the "FA1A60N" critical mode PFC control IC. It achieves both improved efficiency and lower standby power during light loads of power supplies. In addition to the existing bottom skip function (maximum frequency limiting), which improves efficiency during light loads, a burst function, which intentionally provides a switching stop period in the standby state, further reduces standby power consumption while maintaining a PFC output voltage. Furthermore, burst operation can be provided according to the input voltage information by interconnecting with the "FA6B20N" LLC current resonant control IC. This makes the standby power consumption less dependent on the AC input voltage, allowing for a further improvement in the power supply characteristics. The main features are as follows:

○ PFC efficiency 90.4% (with 5 W load at 100 V AC: 77.4% with conventional product)

Fig.3 "FA1A60N"

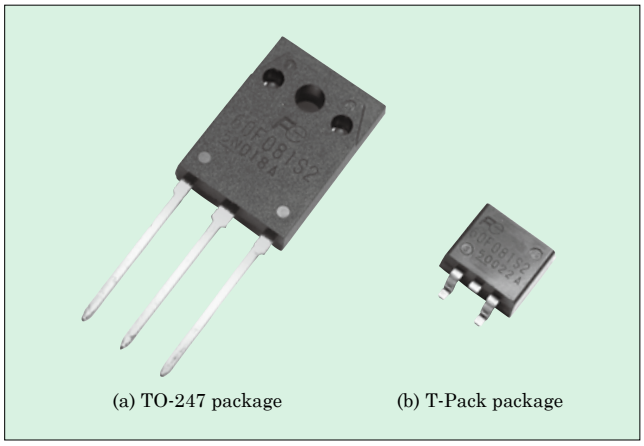


4 "Super J MOS S2A Series" 2nd-Generation SJ-MOSFET for Automotive Applications

Fuji Electric has developed the "Super J MOS S2A Series" 2nd-generation SJ-MOSFET for automotive applications that is a power MOSFET suited for automotive DC-DC converters and chargers. This product has achieved a 25% reduction in the on-state resistance per unit area from conventional products. It also offers a 5% reduction in the surge voltage during turn-off (when used for the chopper circuit, driving with 2-Ω gate resistance). In this way, the product features a lower loss than that of conventional products, making it easier to use. It conforms to AEC-Q101, a reliability standard for automotive electronics, and meets diverse demands with the following product line-up:

(1) Breakdown voltage: 400 V, 500 V and 600 V
(2) On-state resistance: 25.4 to 160 mΩ (600-V breakdown voltage model)
(3) Package: TO-247, T-Pack

Fig.4 "Super J MOS S2A Series"



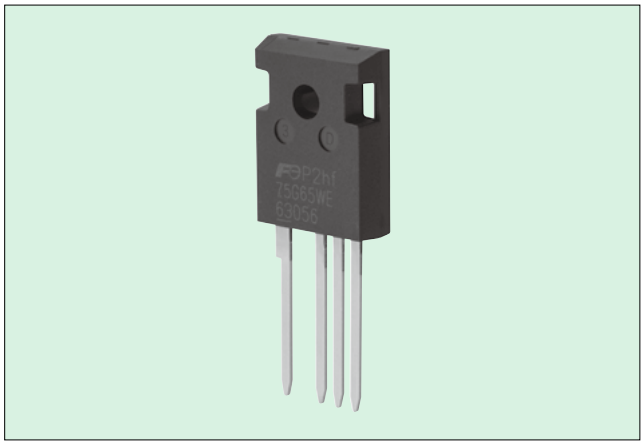
(a) TO-247 package (b) T-Pack package

5 "High-Speed W Series" High-Speed Discrete IGBT in TO-247-4L Package

Uninterruptible power systems (UPSs) and power conditioning systems (PCSs) are increasingly being required to improve efficiency. For that equipment, Fuji Electric has developed the "High-Speed W Series" high-speed discrete insulated gate bipolar transistor (IGBT) contained in the TO-247-4L package, which has an additional sub-emitter terminal. As compared with the conventional product in the TO-247 package, a significant reduction in switching loss has been achieved. The main features are as follows:

(1) Reduced common inductance of the emitter
(2) Reduced switching loss by lowering the wiring inductance of a gate-emitter loop
(3) Turn-off loss: Reduced by approximately 15% (from TO-247)
(4) Turn-on loss: Reduced by approximately 55% (from TO-247)
(5) Rated voltage/current: 650 V/50 A, 75 A, 1,200 V/40 A

Fig.5 "High-Speed W Series" (TO-247-4L package)



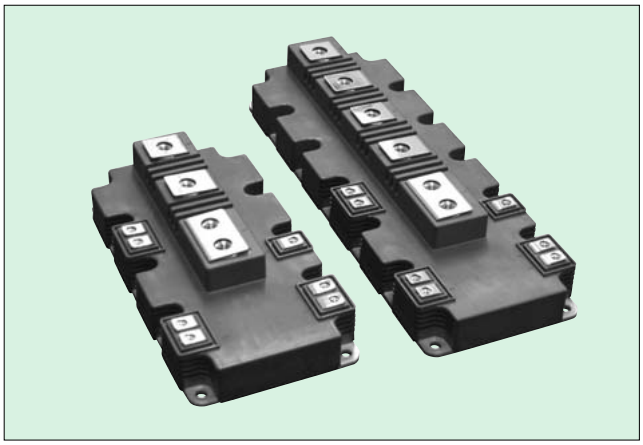
Semiconductors

6 7th-Generation "X Series" 1,700-V High-Power IGBT Module

Demand is increasing for high-power IGBT modules for high-voltage, high-capacity inverter systems and power conversion equipment of wind power generation systems used in the field of industrial infrastructure. Fuji Electric has developed high-power IGBT modules with a rated voltage of 1,700 V of the 7th-generation "X Series" IGBT module.

Fuji electric has successfully reduced power dissipation by improving the characteristics of semiconductor chips and significantly reduced the thermal resistance by using newly developed high thermal conductivity insulating substrate. These new technologies realized a maximum rating of 1,700 V/1,800 A that could not achieved by conventional technology. In addition, the continuous operation guaranty temperature has been increased to 175°C from the conventional 150°C by improving ΔT_j power cycle capability and higher heat withstand capability of the insulating silicone gel. The new product can satisfy market demands such as miniaturization, lower power dissipation, higher reliability and so on.

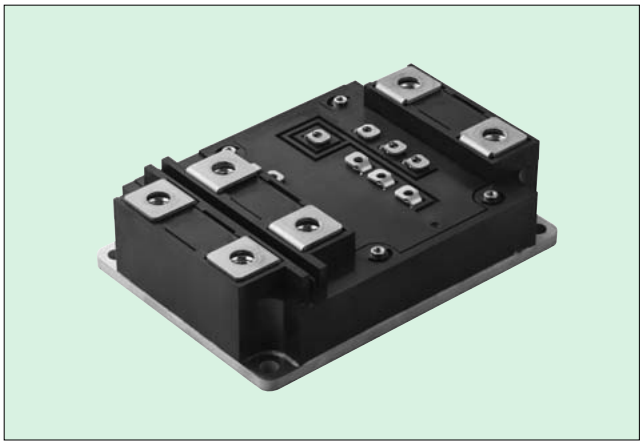
Fig.6 7th-generation "X Series" 1,700-V high-power IGBT modules



7 "HPnC" Package for High-Power IGBT Modules

Power conversion equipment are being demanded to further increase current density and improve efficiency. To meet them, Fuji Electric has developed the "HPnC" (High Power next Core), a new package for high current and voltage for the electric railways and renewable energy (photovoltaic power generation and wind power generation) sectors. The features of HPnC include lower loss and T_{jop} of 175°C achieved by applying the 7th-generation chip technology. In addition, heat dissipation has been improved by applying an AlN isolation substrate as a packaging technology. Furthermore, the main terminal structure applying a laminated structure has made it possible to reduce the internal inductance to 10 nH, realizing high-speed switching. RoHS compliance has also been achieved by ultrasonic terminal bonding. By applying these technologies, a 12% current density increase and efficiency improvement have been realized as compared with the conventional "HPM."

Fig.7 "HPnC"



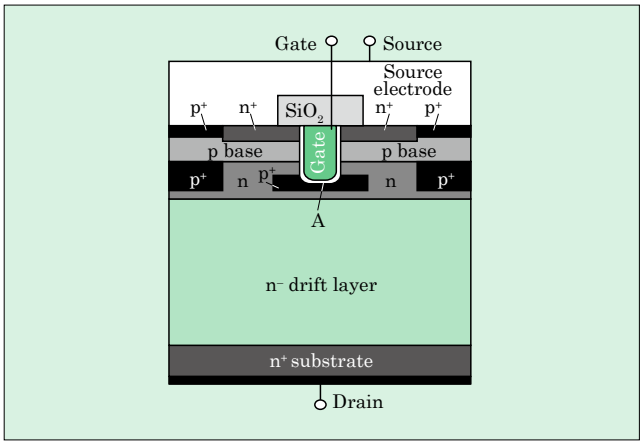
8 6-Inch SiC Trench Gate MOSFETs

Fuji Electric has used a 6-inch silicon carbide (SiC) substrate to develop SiC-MOSFETs with a trench gate structure featuring a further reduced on-state resistance during operation. A trench gate SiC-MOSFET with a 1,200-V rating uses smaller design rules with the cell pitch size approximately halved from that of the conventional products having planar gate structure, reducing the on-state resistance per unit area by about 50%. The trench gate SiC-MOSFETs developed have a structure with the gate oxide film at the bottom of the trench covered with a p-type diffusion layer (see A in the figure). This structure mitigates the electric field in the gate oxide film when a reverse voltage is applied, improving the reliability of the gate oxide film.

In FY2017, we plan to develop trench gate SiC-MOSFETs offering even higher breakdown voltage with the 1,700-V and 3,300-V ratings.

Reference: FUJI ELECTRIC REVIEW 2016, vol.62, no.4, p.218

Fig.8 Cross-sectional structure of SiC trench gate MOSFET



Semiconductors

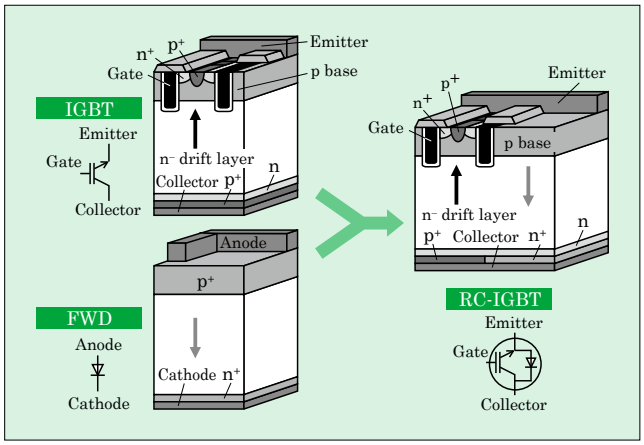
9 RC-IGBT Chips for Industrial Applications

To increase the rated current of insulated gate bipolar transistor (IGBT) modules, Fuji Electric is developing an RC-IGBT chip integrating an IGBT chip with a free wheeling diode (FWD) chip. By using this chip, products with a rated current that cannot be achieved with the 7th-generation IGBT modules can be developed and mounted in a package that is smaller than conventional products.

To reduce the die size of a 1,200-V breakdown voltage device by 25% from the existing 7th-generation IGBT and FWD chips, Fuji Electric has conducted measures as follows: establishing photolithography technology for the wafer backside, optimally designing the pattern and pitch of the IGBT and FWD portions, and establishing an optimum lifetime control method for RC-IGBT chips. This has made it possible to improve the maximum rated current with the same package by 20%.

Reference: FUJI ELECTRIC REVIEW 2016, vol.62, no.4, p.241

Fig.9 Cross-sectional diagram of RC-IGBT chip

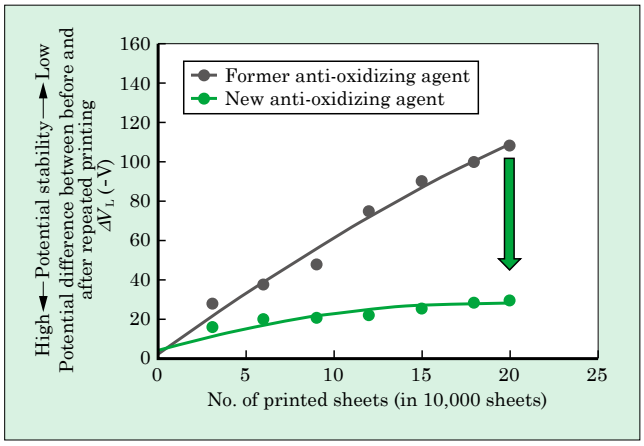


10 Negatively Charged High-Functionality Organic Photoconductors

The lifetime of electrophotographic printers and copiers are becoming longer in terms of maintenance free operation while increasing the operating speed. Photoconductors, which are the main component, are required to offer high-speed response and high durability. Charge transport materials with high-speed response have the drawback of being susceptible to unstable potential behavior due to the influence of discharge products.

Fuji Electric is developing a negatively charged high-functionality organic photoconductor with stable potential behavior that can endure long-term use. The surface of a photoconductor is oxidized by the influence of discharge substances generated from the charged components. Hence, in view of the structure of the charge transport material to be applied to the surface layer, as well as compatibility, we have selected the structure of the anti-oxidizing agent and optimized the amount of agent added. These have led to a significant improvement in the potential behavior.

Fig.10 Improvement of potential stability by anti-oxidizing agent



Disk Media

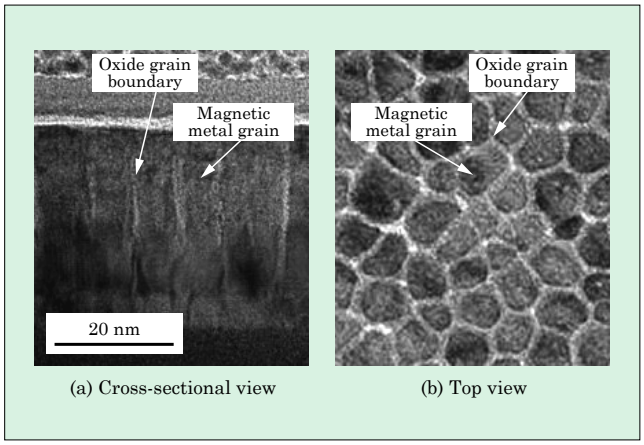
1 Recording Density Improvement of Shingled Magnetic Recording (SMR)-Based Magnetic Recording Media

In the hard disk drive (HDD) market, there is ever-increasing demand for recording density as the driver of the market is shifting from PC to data center applications. Accordingly, commercialization of HDDs that employ shingled magnetic recording (SMR), which is a new recording system, is in progress.

To develop recording media best suited for SMR, Fuji Electric is working on the design optimization of a multilayer thin film including a multilayer granular magnetic layer. With reduction and uniform of intergranular coupling strength and with proper control of inter-layer coupling strength, we have realized a high level of both linear density and track density to achieve a high areal density of 1,330 Gbits/in^2.

This technology has been applied to the media for mobile HDD (1 TB/disk) that started mass production in September 2016 and is planned to be gradually applied to media for data center HDD in the future.

Fig.11 TEM images of magnetic recording media



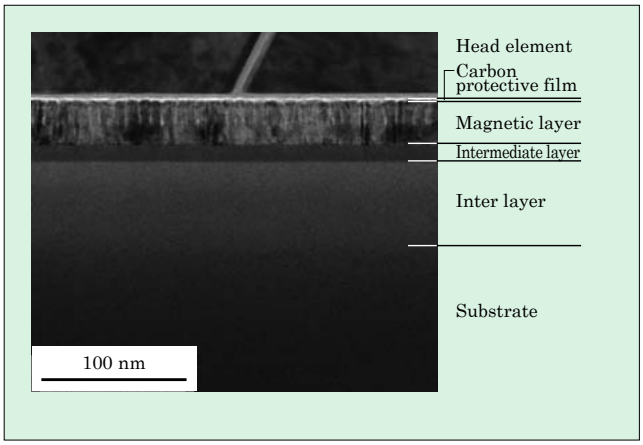
(a) Cross-sectional view (b) Top view

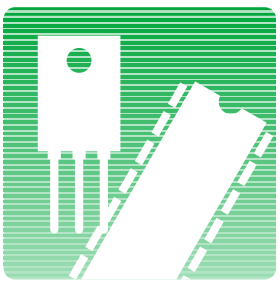
Disk Media

2 High-Reliability Magnetic Recording Media for Nearline Servers

For nearline servers, which require particularly high capacity and reliability among HDD applications, Fuji Electric has developed a 3.5-inch aluminum magnetic recording medium with a recording capacity of 1.33 TB/disk. It is required to provide high reliability appropriate for the operating environment, as well as a shorter distance between the head and the magnetic layer to increase the recording density. Accordingly, we optimized the sputter deposition and cleaning conditions to reduce the number of small defects of a few nanometers in height. In addition, we improved corrosion resistance by reducing the film thickness distribution of the carbon protective film by 10% from that of the conventional product and restraining the increase in surface roughness during sputter deposition. Furthermore, we doubled the sputtered film hardness from that of the conventional product, thereby achieving mechanical durability. By taking these approaches, we acquired qualification of the customer and started mass producing the product in March 2017.

Fig.12 Image of head disk interface (HDI)





Power Generation

Power Plants
New Energy

Outlook

Major topics in the Japanese electricity market in FY2016 include entry into the retail electricity business was fully liberated in April 2016 and all consumers can now freely choose utility companies and their service menu. Due to the liberalization of retail sales, electricity trading methods are changing. Moreover, in FY2016, in response to the change of the "Feed-in Tariff (FIT) scheme for renewable energy," the number of applications for entering into a grid connection agreement increased. Another major topic is that the government started inviting applications for the "subsidy project for the surveys for the development of geothermal resources" in March 2016 to promote geothermal energy development.

In the electricity markets outside Japan, regulations on greenhouse gas emissions have been tightened. The Working Party on Export Credits and Credit Guarantees of the Organisation for Economic Co-operation and Development (OECD) agreed the policy of limiting exports of coal-fired power generation equipment (started being applied in January 2017) in the wake of the Paris Agreement.

In the fields of thermal and geothermal power generation, as market conditions changed in this way, Fuji Electric worked on research and development with the focus on improving the efficiency of equipment and plants and expanding services, and this resulted in good results.

In the field of thermal power generation, we received orders for steam turbines and generators for biomass co-firing power generation in Japan, as well as 3 sets of steam turbines and generators from Asian countries outside Japan.

In the field of geothermal power generation, Fuji Electric received an order for binary power generation system, which is Fuji's second binary unit in Japan, and is moving ahead with work to complete it at the end of FY2017. Outside Japan, the only order received was that from Indonesia due to postponement of plans and other reasons, but we are working on many prospective projects to conclude contracts in FY2017. In the field of thermal and geothermal power generation services, we are continuously striving to broaden product range to address customer needs. In order to expand the range of services provided outside Japan, we have been offering engineering works by cooperating with affiliated companies. In addition, we have received orders for modifying turbines and generators in accordance with customers' operation, and these are in progress.

In the field of nuclear power generation, solutions are called for both in terms of resumption of operation and decommissioning of nuclear power plants since the Fukushima Daiichi Nuclear Power Station accident. Under the circumstances, Fuji Electric is offering technologies and products, including remote handling equipment and earthquake-proof panels, conforming to new regulatory requirements. There is also a need to promptly acquire an ability to safely dispose of and store the radioactive waste generated in the process of operation and decommissioning of nuclear facilities. Fuji Electric is working jointly with Amec Foster Wheeler plc of the United Kingdom to develop and apply in Japan a waste solidification technology using geopolymer materials with various characteristics.

In the field of photovoltaic power generation, while construction of mega-solar power plants in Japan is on the decrease after peaking in FY2014, there is still demand for plants of the 20-GW scale, and such demand is expected to continue in the future. In FY2016, the Kamikita Rokkasho Solar Power Plant (DC output 71 MW and AC output 51 MW) and Yamaguchi Hikari Solar Power Plant (DC output 19.6 MW and AC output 14 MW), for which we received orders as engineering, procurement and construction (EPC) projects, were both completed in February 2017. The most recent issues in this field include cost savings for ensuring profitability despite the reduction in the FIT purchase prices and power system stabilization that becomes necessary with the increased introduction of renewable energy. To solve these issues, we are developing and providing high-performance, low-cost power conditioning systems (PCSs) and power system stabilization systems.

In the field of wind power generation, construction of large-scale wind farms started in FY2016 and the market is expected to continue to grow in the future. We have been building up a good track record in delivery of power system stabilization systems combining storage cells and PCSs. In the future, we will work on EPC, in addition to sale of systems, in earnest by utilizing the know-how we acquired with photovoltaic power generation engineering.

In the field of fuel cells, we delivered 1 unit of phosphoric acid fuel cell (PAFC) for city gas and 3 units for sewage digestion gas, to which FIT applies. Outside Japan, fire protection systems that prevent fires by reducing the oxygen concentration in a room are becoming widespread in Germany and other countries. Fuji Electric focuses on applying fuel cells to this system and has delivered the first unit for cold storage warehouses, where application of the system is considered to be particularly effective. Furthermore, to realize solid oxide fuel cells (SOFCs) with high power generation efficiency, we have been participating in a project of the New Energy and Industrial Technology Development Organization (NEDO) and working on the development of field demonstration equipment of the 50 kW class.

Power Plants

1 Start of Operation of Units 5 and 6 at Lahendong Geothermal Power Plant in Indonesia

Fuji Electric has completed a handover of Lahendong geothermal power plant with net output of 40 MW (20MW × 2 units) in Indonesia, where geothermal development has been promoted increasingly. This project was ordered as an EPC contract to Sumitomo Corporation as a prime contractor. Fuji Electric took up the power plant entire engineering and delivered the major equipment of the power plant, such as geothermal steam turbines, generators, condensers, cooling towers, hotwell pumps and gas extraction system (GES). Commercial operation of Unit 5 started in September 2016 and Unit 6 in January 2017, which is about 3 months ahead of schedule. Employed axial flow exhaust steam turbines contributed to a lower height installation level comparing to an upward exhaust type installed in the existing units in Lahendong area and reduced the construction costs. In addition, the steam turbines and generators were delivered in skid-mount packages, and this contributed to shortening the construction periods.

Fig.1 Panoramic view of Units 5 and 6 of Lahendong Geothermal Power Plant

2 Reheat Steam Turbine Equipment for Suzukawa Energy Center

Fuji Electric received an order from IHI Corporation for one-casing reheat steam turbine equipment for a thermal power plant of Suzukawa Energy Center Ltd. (rated output: 112 MW, 3,000 r/min; main steam: 16.7 MPa [absolute pressure]/566°C; reheat steam: 566°C). We have completed its manufacturing, delivery and installation works. This power plant intended for the retail electricity business applies co-firing of coal and biomass, which is renewable energy, and it started commercial operation in September 2016.

Fuji Electric's medium-capacity one-casing reheat turbine was employed for the main turbine equipment, which requires high reliability and efficiency. It realizes a compact arrangement for a reheat turbine with the one-casing structure and direct mounting of the main steam valve on the turbine. Furthermore, we delivered condensing equipment and feed water heating equipment so that the steam turbine cycle could be optimized overall.

Fig.2 Reheat steam turbine

Power Plants

3 Reception of Orders for Steam Turbines and Generators for Thermal Power Plants in Japan

Fuji Electric received orders for steam turbines and generators for thermal power plants in Japan in FY2016. They include those for the Houhu Biomass & Coal Power Plant (112 MW) of Air Water & Energia Power Yamaguchi Inc. received from Sumitomo Heavy Industries, Ltd. and for the Buzen Biomass Power Plant (75 MW) of Buzen New Energy LLC. received from JFE Engineering Corporation. These are high-efficiency power generation facilities that employ a reheat system using biomass fuel as the main fuel and they are intended for the power selling business that makes use of the "Feed-in Tariff (FIT) Scheme for renewable energy." Fuji Electric intends to continue in the future to provide steam turbines and generators for high-efficiency power generation facilities that utilize biomass fuel and low-grade coal and allow for the effective use of resources and reduction of environmental burdens. In this way, we will contribute to the stable supply of power and help to prevent global warming.

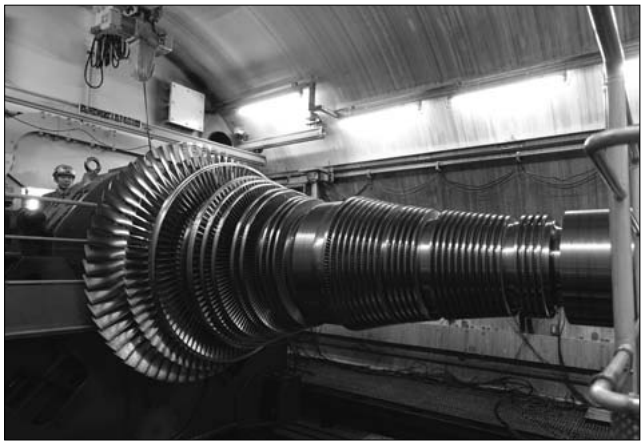
Fig.3 Architectural rendering of Buzen Biomass Power Plant

4 Replacement of Steam Turbine in Unit 2 of Hsinkang Powerplant of Taiwan's FCFC

This project involves replacement due to aging of the 56-MW steam turbine in Unit 2 of the Hsinkang Power plant of Formosa Chemicals & Fibre Corporation (FCFC) of Taiwan. The old turbine was delivered by another company in 1988. This is the first project for replacing another company's steam turbine with Fuji Electric's while making use of most of the foundation. Fuji electric received the order for the replacement of the steam turbine and auxiliary equipment and completed shipping of the products at the end of March 2017. In this power plant, Unit 3 (101 MW) and Unit 4 (147 MW), Fuji Electric delivered, are operating smoothly.

We were awarded the order because our good relationship of trust with the customer and maintenance were appreciated, and our proposal for replacement with the latest facilities came to fruition. This renewal project will be the new basis in the overseas thermal power generation services market, which is expected to expand in the future. We intend to continue building up know-how in new service fields to expand the services business.

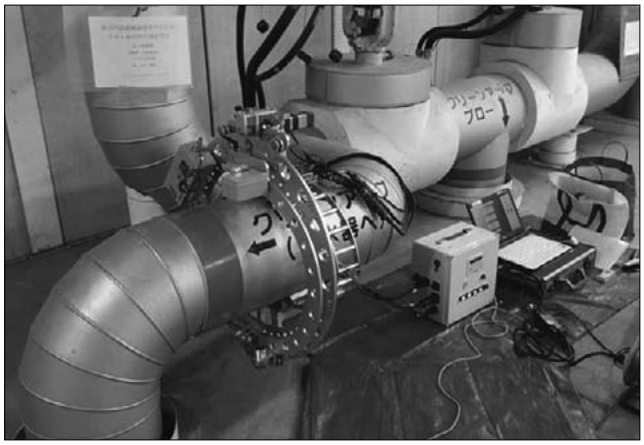
Fig.4 Steam turbine replacement (high-speed balance test)



5 Pipe Wall Thickness Measurement Technology Using Radiation – Three-Beam Method

Recently, it has become increasingly important to manage pipe wall thickness (thinning) from the perspective of ensuring stable operation of power plants. Conventionally, measurement of pipe wall thickness required thermal insulation materials to be removed from piping. Fuji Electric has used the attenuation characteristic of radiation observed as it passes through materials to develop a system capable of measuring pipe wall thickness without the need to remove thermal insulation materials. This system employs the three-beam method (Patent No. 5375541) that use radiation irradiated from three directions to find a numerical value of each wall thickness. We conducted research and development for the system jointly with Tohoku Electric Power Co., Inc. and it has been certified as a new test method in the Rules on Pipe Wall Thinning Management for Thermal Power Generation Facilities (JSME S TB1-2016). The system does not require qualifications for handling, designation of controlled areas or permission for use. This is because it is an approved device with certification label that uses low level radiation sources. It is an easy-to-handle small and lightweight device.

Fig.5 Example of installation of pipe wall thickness measuring device

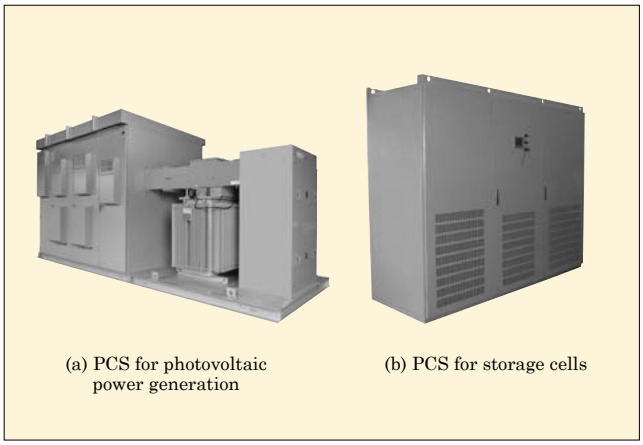


New Energy

1 Electrical Equipment for Hidaka Kuratomi Solar Power Plant

Photovoltaic power generation and wind power generation are power sources whose output fluctuates and required to suppress the fluctuation to reduce the impact on systems. Within the service area of Hokkaido Electric Power Co., Inc., those newly applying for interconnection with the power system have to install storage cells to control the power at the interconnection point to within a certain range of variation. The contract power at the interconnection point is 9 MW and the required regulation is within ±1% in one minute. Fuji Electric received an order from Kita Koudensha Corp. for electrical equipment including a control system for the Hidaka Kuratomi Solar Power Plant. This power plant, which is the first large photovoltaic power plant with fluctuation suppression in Hokkaido, started operating in April 2017. We delivered the PCSs for photovoltaic power generation, PCSs for storage cells, extra-high voltage power receiving and transforming system and system controller for fluctuation control and the customer installed lithium ion batteries with a total rated capacity of 3.6 MWh to construct the system.

Fig.6 PCS for photovoltaic power generation and PCS for storage cells



(a) PCS for photovoltaic power generation

(b) PCS for storage cells

2 Phosphoric Acid Fuel Cells for Wolf ButterBack KG of Germany

Fire prevention systems that prevent fires by reducing the oxygen concentration in a room are becoming widespread in Germany and other countries. Fuji Electric is focusing on the application of phosphoric acid fuel cells (PAFCs) to these fire prevention systems. In December 2016, we delivered the first unit for deep freezing warehouses, which is expected to be a major application, to Wolf ButterBack KG of Germany. Using the exhaust air with a low oxygen concentration discharged from fuel cells, this system is capable of suppressing compressor energy consumption (running costs), noise and vibration. It thus provides a higher degree of environmental friendliness and efficiency than conventional systems that use membrane separation and adsorptive separation to reduce oxygen concentrations. We intend to make the most of this achievement in further expanding applications of fuel cells to fire prevention systems of deep freezing warehouses.

Fig.7 Phosphoric acid fuel cell

3 Solid Oxide Fuel Cells for Industrial Use

In addition to the phosphoric acid fuel cells (PAFCs) with a power output of 100 kW currently on sale, Fuji Electric is developing solid oxide fuel cells (SOFCs). We have been participating in the "Technology Development for SOFC Commercialization Promotion" of the New Energy and Industrial Technology Development Organization (NEDO) since FY2014 and aimed at putting a cogeneration system of a few tens of kilowatt in practice. In FY2016, we evaluated the performance of verification equipment of the 45-kW class in the actual size. The results proved we had achieved a DC power generation efficiency of over 55% (equivalent to AC power generation efficiency of 50%) and exhaust heat recovery efficiency of over 30%, which were performance targets. In addition, we completed designing and building one-package demonstration equipment. Starting in FY2017, we have been conducting demonstrations using field demonstration equipment of the 50-kW class with the aim of bringing the product to the market in FY2018.

Reference: FUJI ELECTRIC REVIEW 2017, vol.63, no.1, p.30

Fig.8 Solid oxide fuel cell

Food Distribution

Vending Machines
Store Distribution

Outlook

Vending Machines

In this past 5 years or so since Fuji Electric started considering how vending machines could be made more interactive, we have examined a variety of mechanisms. We have promoted the realization of digital signage vending machines utilizing large screens, linkage with smartphones, and bi-directional communication through voice recognition, facial recognition and gestures. On the other hand, beverage manufacturers started rapidly providing point services by linking vending machines with smartphones in FY2016.

The aim is to lock in customers. When an application that can link with vending machines is installed in a smartphone, beverage coupons or giveaways can be offered according to the points that are given for every purchase from a vending machine. The obtained coupons can also be given to others as a gift, thereby serving as a tool for connecting people. Beverage manufacturers have been implementing various ideas. For example, when a person passes near a vending machine that provides this service, the location of the vending machine automatically pops up on their smartphone as information and guides the person to purchase a beverage through the smartphone.

Making devices smart has also been advancing in vending machines in China. Displays are mounted on vending machines and are used for advertisements and the payment of electronic money. Support for the management of vending machine operation has been serving as one of the important technologies for expanding vending machines, for example, controlling sold-out products and grasping sales data.

From now on, vending machines will be required to sell not only beverages but also foods, commodities and various other products. We will continue adding to our product line-up new models that are aimed at shifting to automated stores.

Store Distribution

In February 2017, we started full-scale supply of a latte machine, which is a new model of coffee machines for convenience stores. It can make fine foam from milk in a short time. In the past, Fuji Electric has manufactured and sold beer dispensers, for which it has developed its original mechanism for making fine foam. This technology has been applied in the latte machine. It is actually little known that vending machines make coffee by actually grinding coffee beans and dripping hot water on the spot. Fuji Electric has worked on developing vending machines and functional parts for them and, meanwhile, found that researching evaluation methods that quantify tastiness itself is also a key to success. We will continue our pursuit of cooking techniques that can compete with specialized restaurants, which stick to authenticity and can provide products in a short time.

Since most shops on the premises of train stations have become similar to convenience stores, developing fine locations one after another is important for the convenience store industry. In order to simplify and speed up store construction, Fuji Electric has developed a showcase with a built-in cooling unit. This product requires neither coolant piping that has conventionally been used to connect the outdoor unit with the showcase nor piping that is to process drain water generated by cooling. It can be operated immediately after being installed and connected to the power supply.

We have previously provide showcases with a built-in cooling unit, and many of the previous showcases have the cooling unit at the bottom of the main unit. The intent was to install a large cooling unit in a stable way. However, it creates a dead space above the floor, which reduces the capacity for showcasing products. Our newly developed non-leak open showcase “USFTL22D1” has revised the structure of the main unit. The cooling unit is housed in the upper section to restrain the reduction in the showcasing space.

Labor shortage and overwork have become social issues. The vending machine, supermarket and convenience store industries are no exception. As a result of providing finely tuned services, the contents of operations have become complex, and the amount of operations that need to be managed has increased as well. Equipment provided by Fuji Electric not only needs

to pursue better quality but also is required to allow maintenance and operations to be performed simply and quickly.

We will continue to work toward providing human-friendly and earth-friendly equipment by combining the IoT, mechatronics and cooling and heating technology we excel at.

Vending Machines

1 "JI35" Digital Signage Vending Machine

Fuji Electric has jointly developed the "JI35" large-sized digital signage vending machine with JR East Water Business Co., Ltd. The product concept is to propose experiencing new value. We are conducting the market testing to be ripe for expansion. The main features are as follows:

(1) Smartphone users can buy a product by scanning the QR code of a product into the vending machine using smartphone application.
(2) It has a new design that is different from conventional ones, with the height changed to 2.1 m from 1.8 m and totally new icons (external appearance) that have not been seen in the previous vending machines.
(3) It has a design that gives a sense of unity with large displays, with two 46-inch LCD displays and a large touchscreen at the front.

Fig.1 "JI35"

Store Distribution

1 "USFTL22D1" Non-Leak Open Showcase

Fuji Electric has developed the "USFTL22D1" non-leak open showcase, which can be used for in-building stores. Arranging a built-in cooling unit in the upper section of the showcase achieves a low-floor design to streamline installation work and reduce the risk of coolant leakage. The main features are as follows:

(1) The drain water self-evaporation function eliminates the need for underground piping and has streamlined installation work.
(2) The lower floor has made it possible to increase the number of shelves and extend the product-showcasing area.
(3) It employs R1234yf, which is a coolant with a low environmental burden, for the first time in the showcase industry.
(4) Modularization of the cooling unit has improved the serviceability and maintainability.

Fig.2 "USFTL22D1"

Services

Services

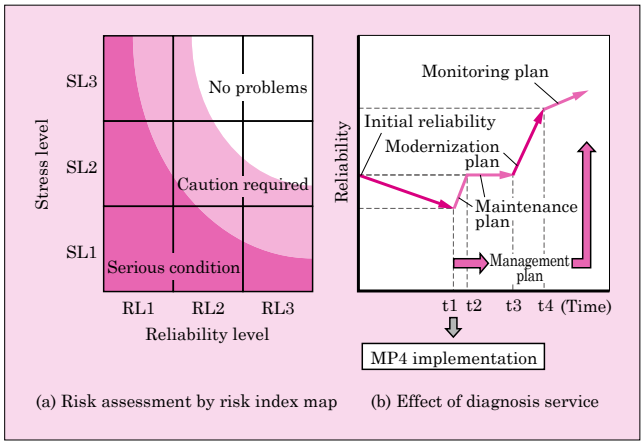
Services

1 Overall Diagnosis Service for Electric Distribution Facilities

The overall diagnosis service for electric distribution facilities is a proposal service that helps to improve the reliability and stability of electric distribution facilities. It does this by combining the facility diagnosis technology of Fuji Electric and the consulting technique "MP4" of Schneider Electric. It analyzes risks that can impede the stable operation of an electric distribution facility and minimizes the effect of the risks on the production facility. The steps of MP4 are as follows:

(1) The distribution system and the production facility are identified.
(2) The stress level and reliability level of the electric distribution facility and electric equipment are evaluated.
(3) Using a risk index map, the overall importance of the electric distribution system including operation and management is analyzed.
(4) As four recommended items, a maintenance plan, a modernization plan, a monitoring plan and a management plan are proposed.

Fig.1 Risk assessment and effect of diagnosis service



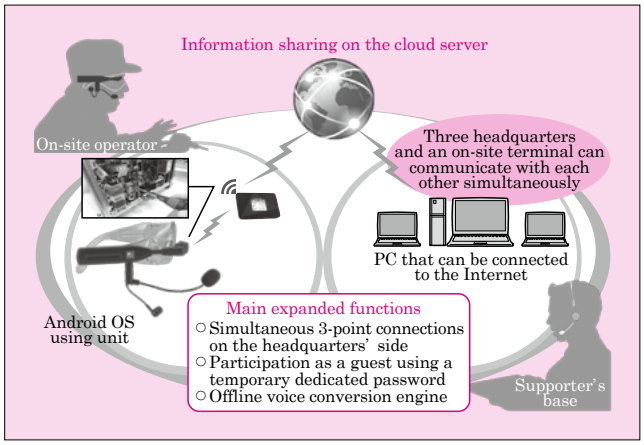
2 Functional Expansion of "FWOSP" Wearable Remote Operation Support Package

The "FWOSP" wearable remote operation support package is a cloud service that supports an improvement to on-site work quality and efficiency and the handing-down and accumulation of technical know-how.

We have expanded the instruction and support function to bi-directionally connect a glass-type wearable unit held by an operator and a PC at the headquarters with sounds and images, as well as the operation support function to record work procedure for instructions in advance and work results with voice. [(2) and (3) are options].

(1) By simultaneously connecting a work site and three headquarters, it enables more accurate operation support for on-site operators.
(2) Issuing a temporary dedicated password has enabled instructions and support to be given by third persons while tightening security.
(3) Work results can be recorded with voice even when offline, for example, in a poor communication environment.

Fig.2 "FWOSP"



3 Diagnosis Service for Photovoltaic Panels

The revised "Feed-in Tariff (FIT) Scheme for renewable energy" was enforced on April 1, 2017, and maintenance, inspection and management of facilities were incorporated in the assessment criteria to secure long-term stable power generation. To meet these criteria, Fuji Electric has provided remote monitoring and maintenance work as optional services.

There are various challenges of monitoring abnormalities in the amount of power generated by photovoltaic power generation facilities and degradation of photovoltaic panels. Fuji Electric has developed a diagnosis algorithm that detects an abnormality in the amount of power generated and degradation of photovoltaic panels by identifying changes in performance of the photovoltaic panels systematically. We have constructed a wireless string measurement system using this algorithm on a cloud environment and have started providing it as a diagnosis service for photovoltaic panels.

Fig.3 Example of screen of measurement system and abnormal condition of photovoltaic panels

Fundamental and Advanced Technologies

Fundamental Technology
Advanced Technology

Outlook

Fuji Electric has been focusing on the development of overwhelmingly competitive components and solutions that create customer value. At the same time, we have also been vigorously working on the research and development of fundamental technology and advanced technology that support such development.

In the fundamental materials technology, we have been developing material design technology that use simulation in order to securely develop intended physical properties, such as high-heat-resistance resins, insulations or catalysts, in a short period of time. We are also developing simulation technologies for changes and degradation, such as corrosion, of metal structures.

Furthermore, we have aimed at considerable reduction of development and design periods of component products and developed model-based design techniques for power electronics equipment and circuit breakers to reduce the number of prototyping. The techniques have been applied in practice as occasion arises.

The IoT technology has been attracting attention as a solution that creates customer value, and Fuji Electric is also attempting to expand the solution, under the key word "Small, Quick Start & Spiral-Up," leveraging our abundant field devices and distinctive advanced analytical technologies. As a fundamental technology for that purpose, we have developed a technology to operate different OSs, such as a real-time OS and a general-purpose OS, on a single multi-core CPU to support the multi-functionality of embedded devices used for field devices. As an analysis technology, in order to speedily execute an analysis that matches a purpose, we have developed a data cleansing technology that pre-processes data into a form suitable for the analysis and have implemented it as a tool for Quick Start. We are also developing big data analysis technology for solutions in specific sectors. For example, we have developed a demand and supply control system for power producer and suppliers who are increasing as new players in Electricity System Reform. It can make market transaction and power generation plans that apply financial engineering and estimate demands for electric power; thus significantly reducing operation hours and maximization of profits.

We are actively working on development of SiC-MOSFETs that use silicon carbide (SiC), which has higher dielectric breakdown voltage and thermal conductivity than Si does. To achieve the low on-state resistance and high reliability, we make maximal use of the cutting-edge analytical technologies, such as synchrotron radiation topography and various spectroscopic analyses, and are also developing new analytical techniques. We have developed a technique that allows us to evaluate the structure of MOS interfaces with atomic-scale resolution and have been applying it to the development of a model of ideal interface design. We are also focusing on the development of gallium nitride (GaN) devices, which may provide lower on-state resistance.

As an advanced device that applies SiC devices, we are developing an MMC-based static synchronous compensator (STATCOM) that allows direct connection to the 6.6-kV power system without a transformer through participation in the Strategic Innovation Promotion Program (SIP) of Cabinet Office.

To differentiate our thermal power plants from other manufacturer's, we have clarified the degradation mechanism of the materials of USC turbines, which are gradually becoming the mainstream and in which the steam temperature is increased to approximately 600 °C. We have developed a life expectancy calculation formula that estimates degradation and developed a high-precision life expectancy diagnosis technology that combines non-destructive testing.

To develop compact and lightweight switchgear, which is strongly requested by customers, we have enhanced our current-breaking technology. We have developed an arc-extinguishing pressure analysis technology, high-precision electromagnetic field-thermo-fluid coupled analysis and an IEC standard-compliant gas-insulated switchgear (GIS) that has achieved significant miniaturization and weight reduction.

As a sensing technology that creates new customer value, we have developed a high-sensitivity spectroscopic technology that applies birefringent Fourier

spectroscopy. This technology achieves about 100-fold detection sensitivity of conventional spectroscopes and enables previously impossible measurements, such as on-line foreign object inspection of foods and chemicals and degradation measurement of concrete. In addition, we are also developing distinctive sensors that utilize MEMS technology, along with solutions that make use of the sensors.

We have developed a multi-cell direct high-voltage input circuit technology for data centers, which are expected to increase from now. It can directly supply direct current from kilovolt-level high-voltage alternating current. This technology allows omitting power receiving and distribution facilities and improving the efficiency of the entire system by about 12 points from conventional power supply system configurations. It thus helps develop an innovative low-cost and high-efficiency power supply system.

As described above, Fuji Electric tackles cutting-edge technologies that lead to innovation in electric, thermal, and environment technology and provides components and solutions that can be overwhelmingly differentiated and create customer value, while brushing up our fundamental technology that supports our product development.

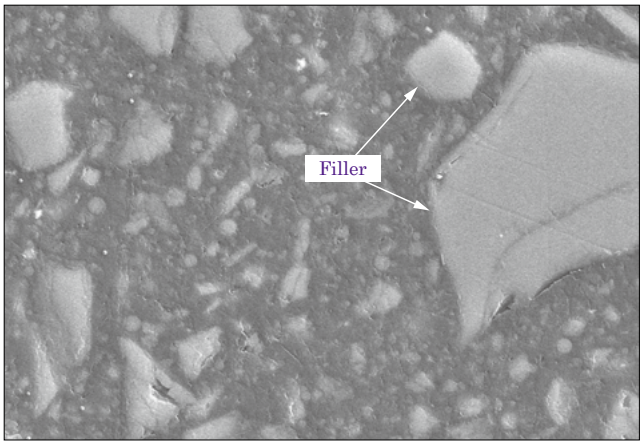
Fundamental Technology

1 Insulating Resin Molding Technology for Cubicle-Type Gas-Insulated Switchgear (C-GIS)

To miniaturize cubicle-type gas-insulated switchgear (C-GIS), Fuji Electric is promoting the solid-state insulation of vacuum circuit breaker (VCB) components by using an epoxy resin, which has high electrical insulation.

Conventional epoxy resins for high-voltage equipment had high coefficients of linear expansion and often had defects such as cracks, thus making it difficult to employ them to products. To resolve this, we have mixed epoxy resin with a filler that have high strength and a smaller coefficient than conventional one and used a curing agent to improves the adhesion to the filler. With this measure, we have developed an epoxy resin with reduced cracking that achieves both low linear expansion and high strength. We will examine its application to other products.

Fig.1 Micro-structure of epoxy resin

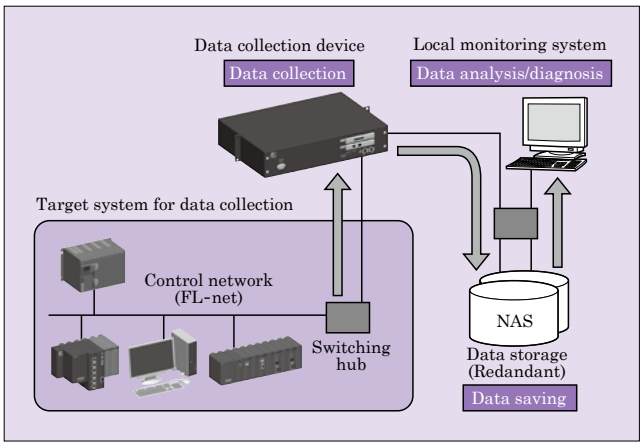


2 Data Collection Device That Supports Legacy Equipment for Industrial Plants

Equipment is often added or partially replaced on monitoring control systems for industrial plants that have been operating for a long period of time. Because of this, controllers of different generations and various networks are mixed together, and this has become a bottleneck in terms of stably operating facilities and reducing operational costs.

With the purpose of facilitating the maintenance of equipment in monitoring control systems, we have developed a data collection device that supports legacy equipment such as various networks and controllers. This device eliminates the need for modifying controllers or the installing additional networks and can be installed and removed without affecting the existing system. The filter function selects necessary maintenance information from a large amount of collected data and the summary function summarizes multiple pieces of related data. They reduce the amount of data and realize long-term data accumulation and trend monitoring.

Fig.2 Configuration of data collection device

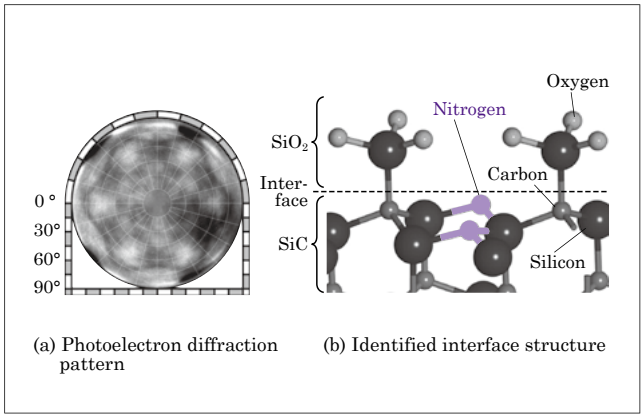


Advanced Technology

1 SiC Analysis Technology by Photoelectron Diffraction

To dissipate less power of SiC-MOSFET, it is essential to have an optimum design of the MOS interface (SiO_2/SiC). To perform optimum interface design, it is necessary to know the arrangement of elements that constitute the interface on an atomic scale. Fuji Electric evaluated the interfaces of actual elements having different characteristics by photoelectron diffraction that uses synchrotron radiation X-rays. By analyzing the position of atoms from photoelectron diffraction patterns with atomic-scale spatial resolution, we have clarified the atomic arrangement of nitrogen that contributes to dissipation of less power. Based on the results, we have developed a model of ideal interface design and applied a process technology to approach the model. In this way, we have realized a high-performance SiC-MOSFET with lower power dissipation than conventional ones. Part of this research was conducted as a joint effort with the Nara Institute of Science and Technology.

Fig.3 Interface structure that was identified as a photoelectron diffraction pattern of nitrogen



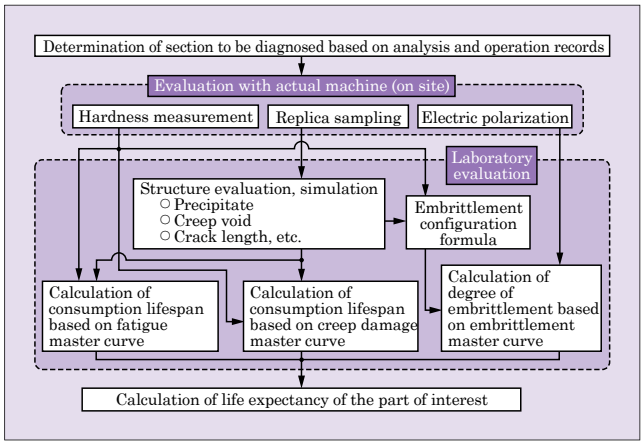
(a) Photoelectron diffraction pattern (b) Identified interface structure

2 Life Expectancy Diagnosis Technology for USC Turbines

In thermal power plants, ultra super critical (USC) turbines, in which the steam temperature is increased to approximately 600°C for higher efficiency, are becoming the mainstream. When a turbine is used for a long period of time, aging degradation of the materials increases the risk of damage. To prevent damage, diagnosis technology for life expectancy that estimates aging degradation is essential; however, for USC turbines, the degradation phenomenon is complex, and there has been no high-precision life expectancy diagnosis technology available.

Fuji Electric has clarified the mechanism of degradation phenomena such as creep and embrittlement through long-hour testing and simulation. By developing a life expectancy calculation formula that estimates degradation phenomena from changes in the size of precipitates in materials and applying non-destructive testing methods such as the electric polarization method, we have developed a high-precision life expectancy diagnosis technology. We will contribute to plant maintenance and stable power generation with this technology.

Fig.4 Flow of life expectancy diagnosis

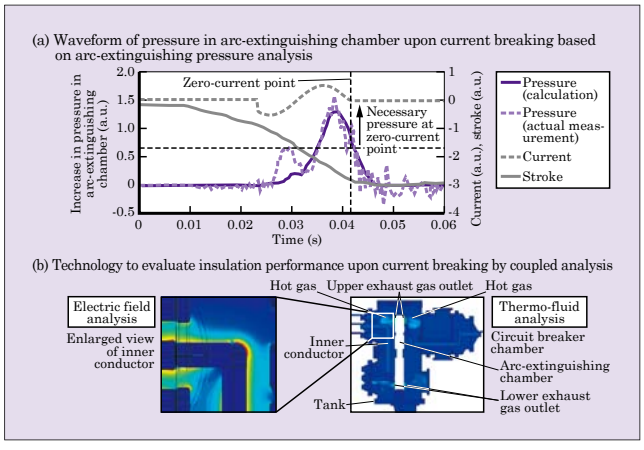


3 Current Breaking Technology in Gas-Insulated Switchgear (GIS)

Fuji Electric has developed IEC standard-compliant gas-insulated switchgear (GIS). We have developed a new current breaking technology for the new GIS, in which the arc-extinguishing chamber adopts a tandem thermal puffer system capable of reducing the operating force of the mechanism section and achieving size and weight reduction.

In the development of this current breaking technology, we have developed technologies, such as an arc-extinguishing pressure analysis that takes nozzle abrasion into consideration [see Fig.(a)], a high-precision electromagnetic field-thermo-fluid coupled analysis that takes into account the movement of moving contacts and the generation of hot gas, a breaking performance estimation by means of estimating the conductance attenuation process at a zero-current point, and evaluation of insulation performance upon current breaking that takes into consideration insulating gas density reduction due to hot gas through combination of thermo-fluid analysis and electric field analysis [see Fig.(b)]. We passed a third-party certification test by applying these current breaking evaluation technologies to design.

Fig.5 Developed technology for current breaking evaluation



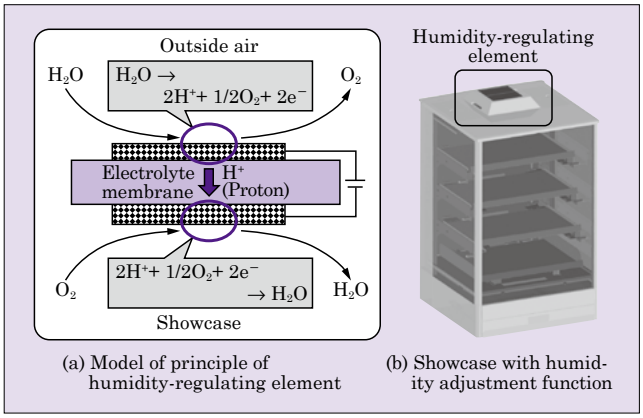
Advanced Technology

4 Food Showcase with Humidity Adjustment Function

There is increasing demand for technology that enables foods to be sold with maintaining freshness and tastiness. Fuji Electric has been developing a humidity-regulating element that can control humidity in food showcases to maintain the freshness and tastiness of foods by applying the fuel cell technology developed by Fuji Electric. As shown in Fig. (a), by applying voltage to the humidity-regulating element, the moisture contained in the outside air is decomposed into O_2 and H^+ (proton). The generated H^+ can move to the showcase through the electrolyte film and form water (vapor). The formed water is theoretically clean, making it possible to hygienically control the humidity in the food showcase.

We will work on improving the durability and maintainability and strive to commercialize food showcases that can maintain the tastiness of food.

Fig.6 Principle of humidity-regulating element and food showcase with humidity adjustment function



(a) Model of principle of humidity-regulating element

(b) Showcase with humidity adjustment function

5 Multi-Cell Power Supply Equipment Technology Supporting Direct Input of High-Voltage Alternating Current

Fuji Electric has developed a multi-cell power supply equipment for data centers. It can directly receive kilovolt-level high-voltage alternating current and it eliminates the need for an intermediate transforming facility. The main features are as follows:

(1) High-voltage and high-frequency conversion circuit

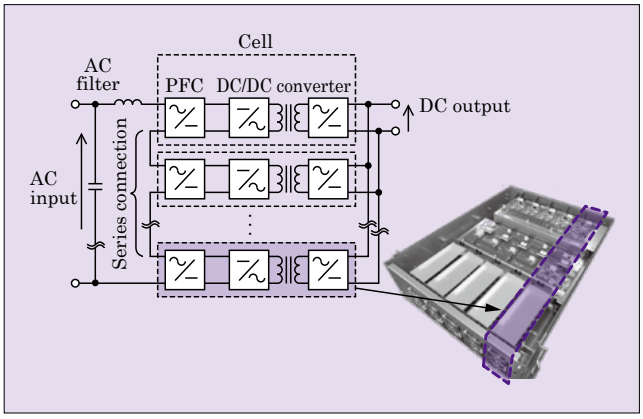
Conversion circuits (cells) composed of low withstand voltage switching devices are connected in serial (multi cell system), allowing the equipment to achieve high frequency operation.

(2) Miniaturization

Multi-level operation with a multi-cell system and a miniaturized AC filter and transformer due to a high-frequency switching of 70 kHz achieve a rack-mountable size despite a high withstand voltage.

The efficiency of the prototype was 96.0% at the rated output, which is approximately 12 points higher in the entire system than conventional system configurations.

Fig.7 Circuit configuration and appearance of multi-cell-type power supply device

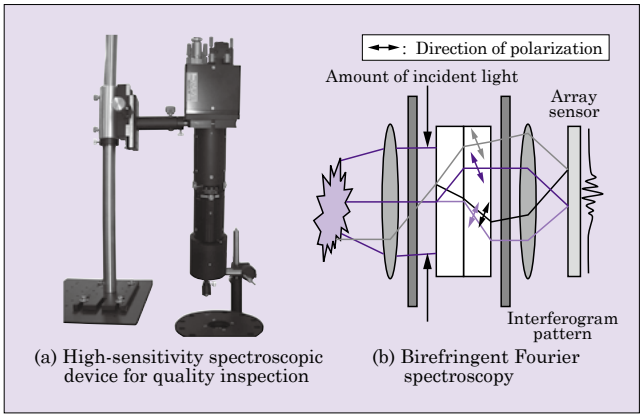


6 High-Sensitivity Spectroscopic Achieving Non-Contact and Non-Invasive Inspection

Fuji Electric has developed a high-sensitivity spectroscopic technology that achieves non-contact and non-invasive real-time inspection of medicine and foods in manufacturing lines. This technology uses birefringent Fourier spectroscopy. This method can collect light without waste using its slit-less structure, making it possible to perform spectroscopic measurement efficiently even with weak light. Its detection sensitivity is about 100 times higher than conventional dispersive spectroscopes that use slits. This technology enables foreign object inspection, which has been performed offline by sampling, to be performed online in real time.

By taking advantage of these features, we are also working on applying it to the measurement of degradation of concrete enclosures and non-invasive measurement on health care, as well as on quality inspection for medicine and food.

Fig.8 Prototyped high-sensitivity spectroscopic instrument and birefringent Fourier spectroscopy



(a) High-sensitivity spectroscopic device for quality inspection

(b) Birefringent Fourier spectroscopy

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4 "Super J MOS S2A Series" 2nd-Generation SJ-MOSFET for Automotive Applications
5 "High-Speed W Series" High-Speed Discrete IGBT in TO-247-4L Package
6 7th-Generation "X Series" 1,700-V High-Power IGBT Module
7 "HPnC" Package for High-Power IGBT Modules
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* Non-consolidated subsidiaries

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Reliable Turbine Services LLC
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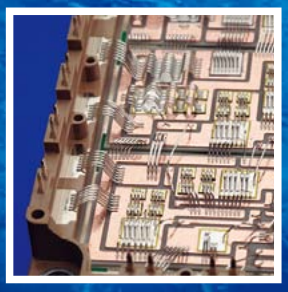
Corrosion Resistant, Material, and Hot Water Utilization Technology

Geothermal Power Plants



Device Technology

Power Devices (IGBT)

Power Electronics Technology

Power Conditioning Systems (PCS) for Megasolar Plants

Power Electronics Technology

Inverters

Power Electronics Technology

Uninterruptible Power Supply Systems (UPS)

Heat Excange and Refrigerant Control Technology

Hybrid Heat Pump Vending Machines

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