

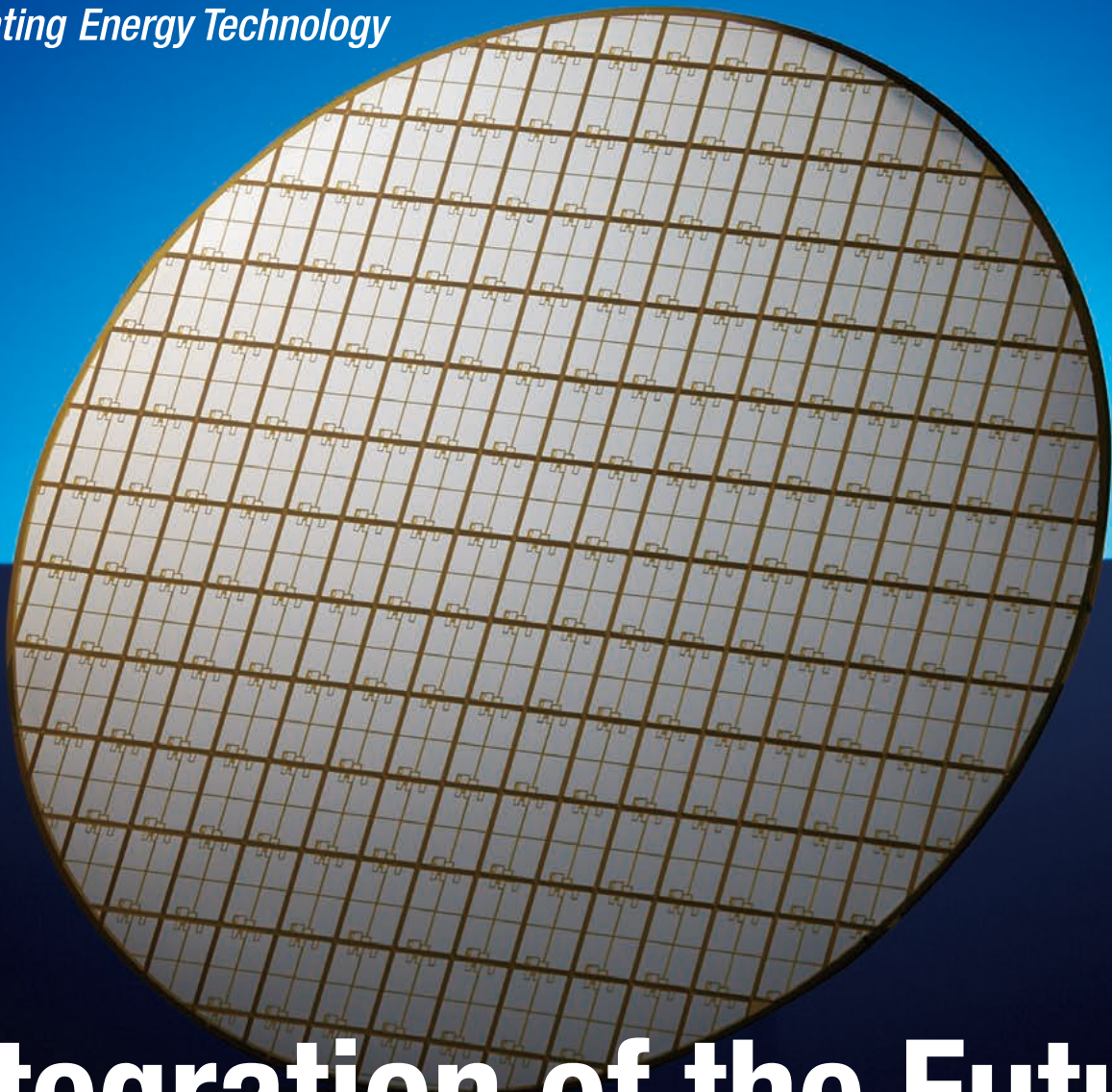
FUJI ELECTRIC REVIEW

2023
Vol.69 No.

2

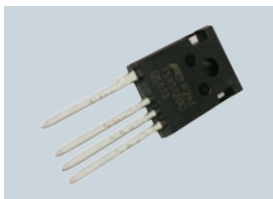
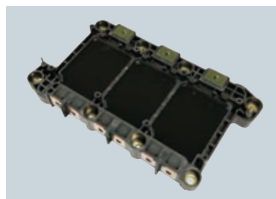
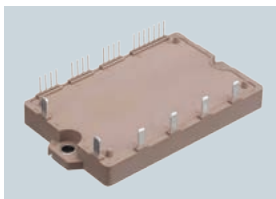
Technical Achievement and Outlook in FY2022





Integration of the Future

Fuji Electric's power semiconductors densely containing our unique power electronics technology and possibility of application. We have been improving these key devices to have a high withstanding voltage, high capacitance, low power loss, and compact & light-weight package. The key devices have vigorously playing active parts in the clean energy field including photovoltaic and wind power generation, the energy conservation field, demanded in the industry and the home, and the traffic field including hybrid and electric vehicles. Moreover, we have been developing the next generation power semiconductors of higher performance using new material SiC. Fuji Electric will continue to renovate energy technologies and contribute to realize a safe, secure and sustainable society.



Fuji Electric's power semiconductors

FUJI ELECTRIC REVIEW

2023
Vol.69 No.

2

Cover Photo:

- (1) Automotive power semiconductor module
- (2) "FRENIC-Ace (E3) Series" inverter
- (3) "FR3® Fluid-Applied Transformer"
- (4) Muara Laboh Geothermal Power Plant in Indonesia
(Photo courtesy: PT, SEML)
- (5) "Sustainable Vending Machine Series"



Technical Achievement and Outlook in FY2022

Geared toward achieving a decarbonized society, green transformation (GX) has been gathering pace as a countermeasure against global warming. In addition, the promotion of digital transformation (DX) has become an essential pillar to corporate growth.

Under its management policy of contributing to the creation of a responsible and sustainable society through our innovation in energy and environment technology, Fuji Electric is advancing research and development efforts that contribute to solving social issues, including global warming countermeasures, and creating new value for customers, such as by promoting DX.

This issue provides an overview of our technical achievements in FY2022 and our future outlook. We hope you find this information to be useful.

The archives from the first issue, including articles in this issue, are available from the URLs below.

FUJI ELECTRIC REVIEW (English)

<https://www.fujielectric.com/company/tech/contents3.html>

FUJI ELECTRIC JOURNAL (Japanese)

https://www.fujielectric.co.jp/about/company/contents_02_03.html

FUJI ELECTRIC JOURNAL (Chinese)

<http://www.fujielectric.com.cn/jtkw.html>



FUJI ELECTRIC REVIEW vol.69 no.2 2023

date of issue: November 30, 2023

editor-in-chief and publisher NAKAYAMA, Kazuya

Corporate R&D Headquarters
Fuji Electric Co., Ltd.
Gate City Ohsaki, East Tower,
11-2, Osaki 1-chome, Shinagawa-ku,
Tokyo 141-0032, Japan

editorial office Fuji Electric Journal Editorial Office
c/o Fuji Office & Life Service Co., Ltd.
1, Fujimachi, Hino-shi, Tokyo 191-8502,
Japan

Fuji Electric Co., Ltd. reserves all rights concerning the republication and publication after translation into other languages of articles appearing herein.

All brand names and product names in this journal might be trademarks or registered trademarks of their respective companies.

The original Japanese version of this journal is "FUJI ELECTRIC JOURNAL" vol.96 no.2

Contents

Technical Achievement and Outlook in FY2022

Preface Contributing to the Creation of a Responsible and Sustainable Society Through Our Innovation in Energy and Environment Technology KONDO, Shiro	69
Through Our Innovation in Energy and Environment Technology, We Strive to Create New Customer Value and Resolve Social Issues While Addressing the Changes in the Market Environment NAKAYAMA, Kazuya	70
Highlights	72
Power Electronics Energy ☐ Energy Management ☐ Transmission and Distribution Systems ☐ Power Supply and Facility Systems ☐ Electric Distribution, Switching and Control Devices	81
Power Electronics Industry ☐ Factory Automation ☐ Process Automation ☐ Information Solutions ☐ Social Solutions ☐ Field Services	87
Semiconductors ☐ Industrial ☐ Automotive	93
Power Generation ☐ Renewable Energy and New Energy ☐ Solution Services	96
Food Distribution ☐ Vending Machines ☐ Store Distribution	100
Fundamental and Advanced Technologies ☐ Fundamental Technology ☐ Advanced Technology	102
FUJI ELECTRIC REVIEW vol.69 no.2 2023 Detailed Contents	108

Contributing to the Creation of a Responsible and Sustainable Society Through Our Innovation in Energy and Environment Technology



Fuji Electric was founded in 1923 and celebrates its 100-year anniversary this year. I would like to express my deepest gratitude to all concerned for their support and goodwill.

Fuji Electric's management policy is to contribute to society through its energy and environment businesses, in accordance with the pillars of our Corporate Philosophy, which are to “contribute to prosperity,” “encourage creativity,” and “seek harmony with the environment.” Fuji Electric's *raison d'être* is to create products and systems that can efficiently utilize electric and thermal energy and contribute to resolving social and environmental issues together with our customers and business partners. This is in line with the Sustainable Development Goals (SDGs) that the international community aims to achieve.

The green transformation (GX) is accelerating as the world works toward the realization of a decarbonized society. Energy suppliers are focusing on the expansion of renewable energy, the proliferation of decentralized power supplies, and fuel conversion, while users are promoting electrification and the effective use of thermal energy in various fields, in addition to energy saving. It has become more important than ever to optimize the balance between energy supply and demand, to provide a stable supply, and to use energy efficiently without waste.

Fuji Electric will respond to these social issues and customer needs through four businesses: energy, industry, semiconductors, and food and beverage distribution. We will further refine Fuji Electric's core competence in power electronics

technology and pursue synergy with power semiconductors, measurement and control technology, and freezing and heating technologies. We will also promote digital transformation (DX) through the integration of advanced digital and AI technologies, with the aim of creating new social value in the energy and environmental fields.

In its five-year Medium-Term Management Plan “Reiwa Prosperity 2023,” which marks its final year in 2023, Fuji Electric achieved its key management goal of a “net sales of 1 trillion yen and an operating profit ratio of 8% or more” a year ahead of schedule in fiscal 2022. In fiscal 2023, Fuji Electric will draw up a vision of what it wants to be in 2030 and formulate a three-year Medium-Term Management Plan beginning in fiscal 2024. In this plan, we will establish our growth strategies with consistency between backcasting, where we work backward with the future as the starting point, and forecasting, where we work toward the future with the current state as the starting point.

To continue to be a sustainable growth company, our employees will share the slogan outlined in our Corporate Philosophy: “to be enthusiastic, ambitious and sensitive.” In addition, employees with diverse individuality will work together to maximize our strengths as a team, innovate energy and environment technology, and contribute to the realization of a responsible and sustainable society.

As Fuji Electric takes on these challenges, I would like to thank all our stakeholders for their continued support and understanding.

KONDO, Shiro
President and COO

A handwritten signature in black ink that reads "Shiro Kondo". The signature is stylized, with a large, flowing 'S' and 'K'.

Through Our Innovation in Energy and Environment Technology, We Strive to Create New Customer Value and Resolve Social Issues While Addressing the Changes in the Market Environment

NAKAYAMA, Kazuya

Corporate General Manager, Corporate R&D Headquarters, Fuji Electric Co., Ltd.



One of the Fuji Electric's management policies is to contribute to the creation of a responsible and sustainable society through our innovation in energy and environment technology. To achieve this, we are fully committed to the research and development for creating new products. In fiscal 2022, to work toward the FY2023 Medium-Term Management Plan and the growth strategy thereafter, we focused our resources on electrification in the field of mobility, including automobiles, railcars, and marine vessels, as well as on developing commercial products for the global market. Our main initiatives for each business field are as follows.

In the Power Electronics Energy segment, we launched a transformer with a rated capacity of 2 to 100 MVA that uses natural ester oil as an insulating oil in December 2022. Since natural ester oil is non-toxic and highly biodegradable, it has a low environmental impact in the event of a spill, and since its flash point is higher than that of conventional mineral oil, it can streamline ancillary equipment such as firefighting equipment, as well reduce the installation cost of transformers. In the ED&C components business, we redesigned the "command switch" of operating and indicating devices. In addition to enhancing compatibility with recent mechanical devices that emphasize design, we have improved visibility by equalizing the brightness of the illuminated surface.

In the Power Electronics Industry segment, we have renovated the "FRENIC-Ace (E3) Series" of low-voltage inverters that support factory automation. In addition to the lineup of models with built-in Ethernet that support the adoption of IoT at production sites, we have incorporated a life expectancy diagnostic function for IGBT devices, which are key components. This enables the detection of inverter failures before they occur, thereby preventing sudden equipment shutdowns. We have also incorporated a traceback function to save the driving waveform immediately before the alarm stops so that it can be used to investigate the cause of the alarm stop. To ensure the quality of regional designs in applications outside of Japan, our door system for railcars has obtained Level 2 certification for Capability Maturity Model Integration (CMMI), an international standard for software development processes. The door system that we developed by applying

this process was adopted in New York City Transit's R211 cars, which went into commercial operation in March 2023.

In the semiconductor segment, we have developed power semiconductors that achieve highly efficient power conversion for industrial and automotive use. For industrial use, we have developed 2,300-V/1,200-A rated modules suitable for 1,500-V DC systems in response to the growing demand for higher efficiency, higher capacity, and reduced size in power conditioning system for renewable energy sources such as solar and wind power generation, the markets for which have been expanding in recent years. We have incorporated a 7th-generation IGBT chip to increase the current density compared with conventional products. In addition, we designed a terminal arrangement that facilitates multiple parallel connections. We are also developing a series of products equipped with SiC-MOSFET chips with a breakdown voltage of 2,300 V to meet the demand for further reductions in power dissipation. For automotive use, we have developed the "M675" direct water-cooled power module with a rating of 750 V/820 A, which is used in the drive inverter of electric vehicles. We have achieved reduced power dissipation in the equipped RC-IGBT and high heat dissipation in the cooler, leading to a 30% improvement in output current compared to conventional products. We are planning to expand into the rapidly growing Chinese market.

In the power generation business, Olkaria I Geothermal Power Station Unit 6 (86.9 MW), which was delivered to Kenya Electricity Generating Company PLC, began commercial operation in June 2022. We applied the technologies we have cultivated through the practical application of geothermal power generation equipment to achieve the maximum capacity for a single unit in Kenya. In the new energy market, we are developing hydrogen fuel cell systems for factories and facilities using polymer electrolyte fuel cell modules that are mass-produced for automobiles in preparation for the future advent of a hydrogen society. The configuration enables selection of the rated generation capacity from 50 to 480 kW according to the amount of hydrogen available at the installation site. We are currently conducting demonstration tests using

a prototype.

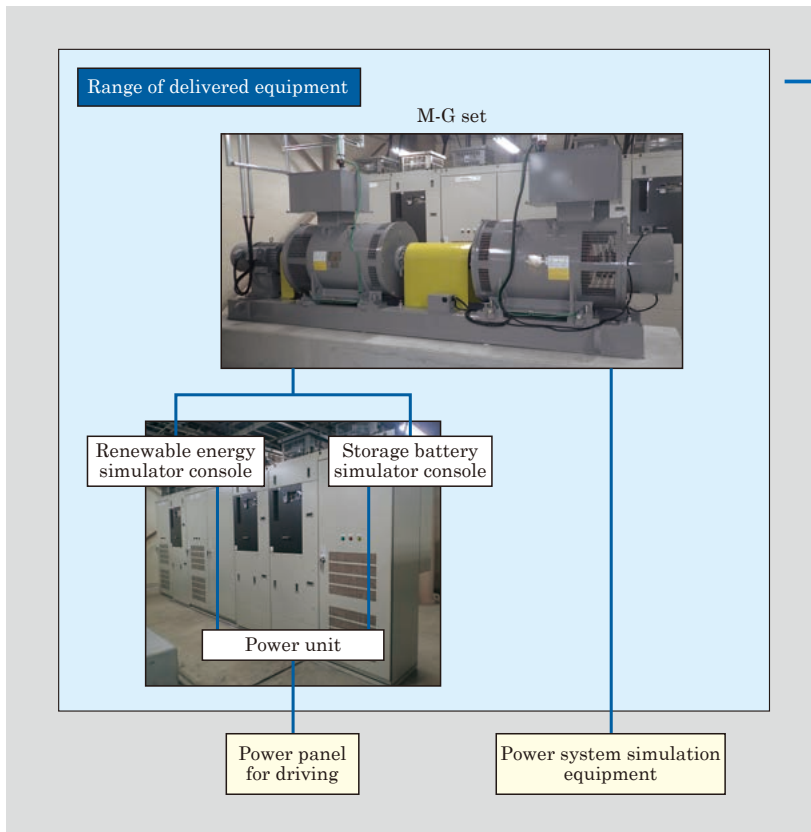
In the food distribution segment, we have developed the “Sustainable Vending Machine Series,” which features higher energy saving performance than the previous series. In addition to using an inverter to drive the compressor of the cooling units, we optimized the structure of the refrigerator and the arrangement of vacuum heat insulation materials to reduce annual power consumption by up to 20% compared with our vending machine from the previous year. In addition, sales and inventory can be checked remotely via the newly equipped bi-directional communication devices, thereby contributing to labor saving in operations.

In the fields of fundamental and advanced technolo-

gies, we worked to advance electrical insulation technology, which is essential to further reduce the size of electrical equipment. To achieve both thermal conductivity and insulation, we have developed a technology to increase thermal conductivity by mixing insulating resin with a high thermal conductivity filler, as well as to modify the filler surface to prevent aggregation of the filler, which is the starting point for dielectric breakdown.

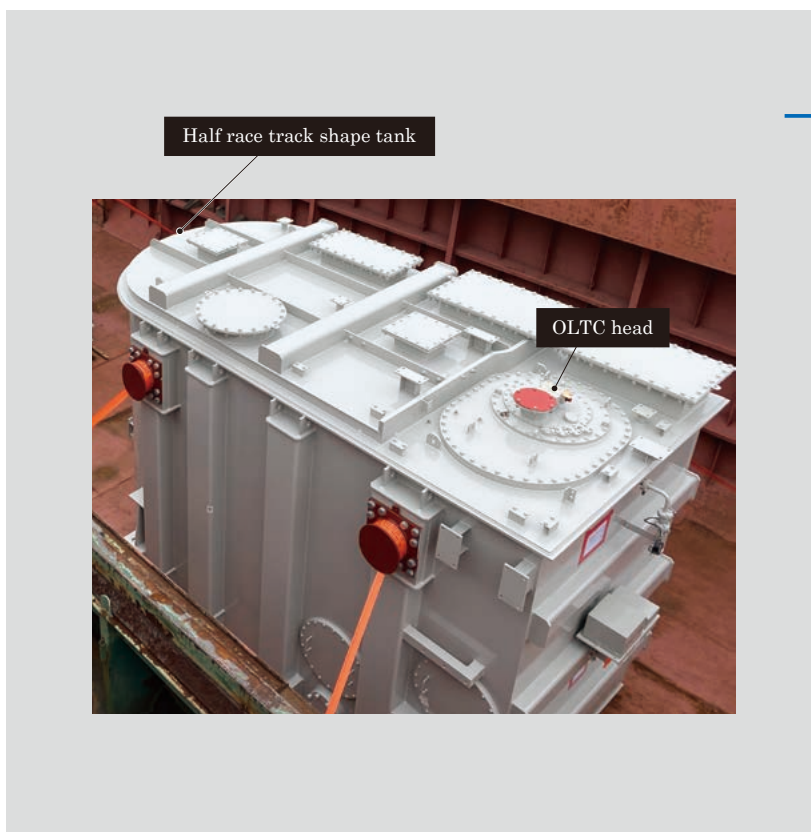
Fuji Electric will continue to pursue innovation in energy and environment technology to create new value for customers and resolve social and environmental issues, thereby contributing to the creation of a responsible and sustainable society.





M-G Set Demonstration System Combined with Renewable Energy and Storage Battery

As the adoption of renewable energy expands, maintaining the inertia power, which depends on synchronous generators, has become a challenge in the operation of power systems. The M-G set consists of a motor (M) and a synchronous generator (G) that are arranged on the same axis and generates electricity through the rotational force of the motor. It runs on renewable energy and storage batteries to accommodate increased renewable energy while maintaining inertia power, thus creating expectations of contributing the power system stability. Fuji Electric has delivered an M-G set demonstration system to the Central Research Institute of Electric Power Industry that combines renewable energy and storage batteries. This system consists of an M-G set, a renewable energy simulator console, and a storage battery simulator console. It enables the frequency and voltage maintenance capability and the behavior of the M-G set itself to be verified under the assumption that a storage battery and an M-G set equivalent to 100MVA are installed in the power system to which a large amount of renewable energy is introduced.

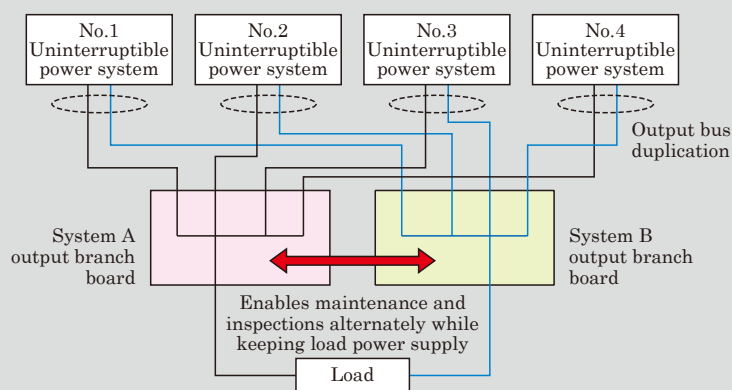


Special Three-Phase Transformer for Minamiota Substation, TEPCO Power Grid, Incorporated

Fuji Electric delivered a special three-phase transformer of 154kV and 200MVA to the Minamiota substation of TEPCO Power Grid, Incorporated. The special three-phase transformer has a structure of iron cores and the windings, both of each phase housed in separate tanks and their leads of the windings are connected in the common duct. Therefore, the three-phase transformer is divided into three single-phase transformers that can be transported and reassembled on site. As bridges on transportation routes deteriorate over time, there are an increasing number of projects where ordinary three-phase transformers cannot be transported due to size and weight restrictions, and inquiries for special three-phase transformers have increased in recent years. In this project, we designed the tanks of each phase to have a half race track shape and stored the on-load tap changer (OLTC) in the U-phase tank to reduce the weight, and as a result, the installation area has been reduced by 20% compared to typical special three-phase transformers of the same specifications.



(a) "UPS7500WX-T4"



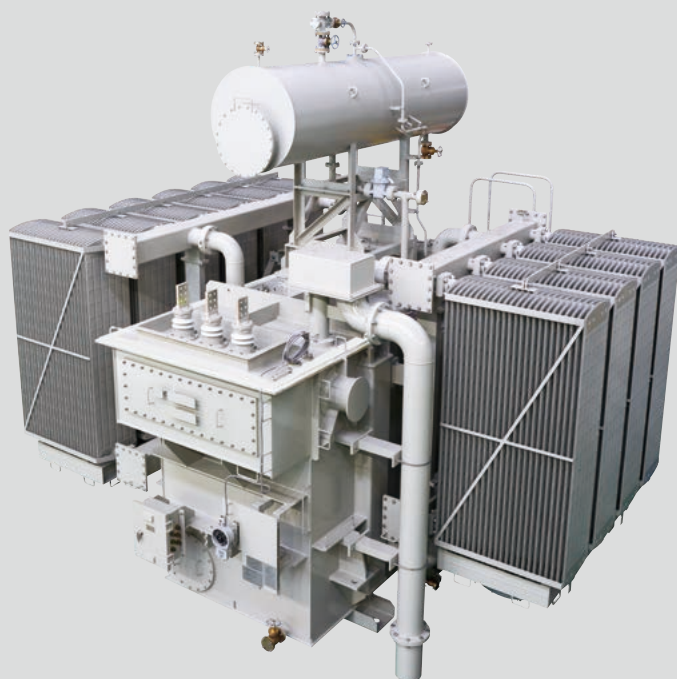
(b) System configuration

Delivery of a High-Capacity UPS System to a Data Center

In recent years, the hyper-scaling of cloud operators and the improvement of business continuity of enterprises have attracted attention. In data centers, demand is thus increasing for larger capacity power supply systems and uninterruptible power systems that can supply power even during maintenance and inspection. Fuji Electric has delivered a high-capacity UPS system with a parallel redundant configuration to a data center.

The main features are as follows:

- (1) The system has a 3+1 configuration, each unit having a capacity of 1,200 kVA, to supply up to 3,600 kVA even when one unit is under maintenance or inspection.
- (2) Each UPS unit has two outputs and dual output bus, allowing the system to continue load feeding even during maintenance or inspection of an output branch panel by feeding power through the other output branch panel.



Deployment of FR3[®] Transformers in the Data Center Market in Japan

In recent years, demand has been growing, especially among foreign customers, for transformers that use natural ester insulating oil for data centers in Japan, where capital investment is substantial. Natural ester oil is highly biodegradable and non-toxic, and its impact on the environment can be reduced in the unlikely event of an oil spill. In addition, it has a flash point of 326°C, which is higher than that of mineral oil (188°C) and does not burn easily, allowing ancillary equipment such as fire equipment to be simplified to save installation costs. Fuji Electric has launched In December 2022 the "FR3[®] Fluid-Applied Transformer," a transformer with a rated capacity of 2 to 100 MVA that uses natural ester oil, and received an order for a 25 to 30 MVA transformer for a data center in Japan. Natural ester oil has a high viscosity, but we redesigned the structure inside the transformer to achieve the required cooling performance with dimensions equivalent to that of transformers that use mineral oil.

We will continue to offer proposals for data centers, where demand is expected to increase, thereby contributing to the conservation of the global environment.



(a) Standard model for $\phi 16$ holes



(b) Thin model for $\phi 22$ holes
(Silver bezel specifications)



(c) Thin model for $\phi 30$ holes

Redesigned “Command Switch”

In recent years, the panel designs of mechanical devices have been subject to continuous refinement. In response, Fuji Electric has stylishly redesigned its “command switches” to be attached to panels.

The main features are as follows:

- (1) A design applicable to a wide range of machinery and equipment, from machine tools to medical applications
- (2) An additional thin model that protrudes less than the panel surface to make the entire device look slimmer and prevent unintended contact or erroneous operation by operators
- (3) Illuminated pushbutton switches with the illuminated surface enlarged by 20% from the previous design, improving visibility with bright, uniform surface illumination in all corners
- (4) Button press surface with a finger-fitting design to reduce operator fatigue during prolonged operations



(a) Standard model



(b) Model with Ethernet communications

“FRENIC-Ace (E3) Series” High-Performance, Standard Inverters

In line with the advancement of factory automation, efforts to improve productivity by collecting and analyzing large amounts of equipment data are gaining momentum in production facilities. To meet these needs, Fuji Electric has developed the “FRENIC-Ace E3 Series” low-voltage inverter, which extends the functions of the “FRENIC-Ace” with a capacity of 0.1 to 22 kW.

The main features are as follows:

- (1) A built-in Ethernet interface, which was optional in conventional models, has reduced the size by approximately 27% compared to the conventional model, thereby saving space.
- (2) Equipped with a diagnosis function that evaluates the life expectancy of IGBTs to detecting inverter failure before it occurs, preventing long-term shutdown of equipment.
- (3) A traceback function that collects and stores the previous waveform data when alarms stop contribute to investigations on the causes of stops through data analysis and quick equipment recovery.



“S-Flow” Compact Ultrasonic Flowmeter for Small-Diameter Pipes

In the semiconductor manufacturing equipment and air conditioning equipment market, for which capital investment is robust, there is a growing need for small clamp-on type flowmeters that can measure fluid in small-diameter pipes without contact. In response to this need, Fuji Electric has developed the “S-Flow,” a small, palm-sized ultrasonic flowmeter.

The main features are as follows:

- (1) Capable of measuring with a high accuracy of $\pm 2.0\%$ R.D. (R.D.: Reading) in small-diameter pipes with an inner diameter of 8 to 32 mm
- (2) Small external dimensions of W120 × D42 × H65 mm (for pipe diameter $\phi 8$ mm), integrating the converter and detector to reduce installation space and installation cost
- (3) Easy installation without the need to apply grease during installation



“MONITOUCH V10 Series” Programmable Operator Interface

Programmable operator interfaces are widely used in the monitoring and operation of equipment and machinery at manufacturing sites. Fuji Electric has developed the “MONITOUCH V10 Series,” which achieves industry-leading* performance in all basic HMI functions (rendering, operation, communication, start-up, transferring, and custom code) and provides stress-free operation.

The main features are as follows:

- (1) Use of a quad-core CPU and thorough optimization of applications deliver stable operation and communication performance even on high-load screens.
- (2) Full compatibility with existing “MONITOUCH” allows customers to reduce development costs.
- (3) Adoption of the latest eMMC technology reduces start-up and transfer latency.

* Comparisons conducted with current models of major domestic and overseas HMI manufacturers using sample screens from our company (according to our research).



R211 subway car for New York City Transit
(Photo courtesy of Kawasaki Rail Car, Inc.)

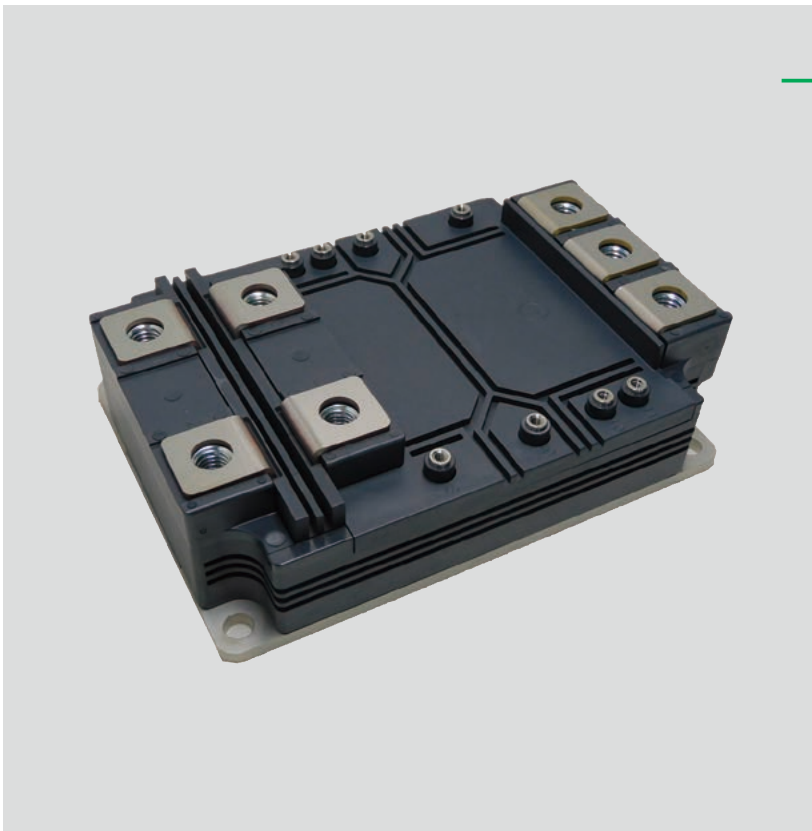
An Approach for Increasing Safety and Reliability in Fuji Electric's Door System

Door System for the railcars is critical safety and reliability because it is in direct contact with passengers. Fuji Electric designs some components of it for the overseas market locally, and it is necessary to guarantee the same level of safety and reliability.

As an approach for software, Fuji Electric expanded the scope of Capacity Maturity Model Integration (CMMI) activity, the standard to evaluate maturity of organization and management, to overseas subsidiaries. As a result of these activities, Fuji Electric, including overseas subsidiaries, received the certification of CMMI level 2.

Regarding hardware, Fuji Electric improved the reliability of Door System further by replacing the contact parts with highly reliable semiconductor switches, with the exception when usage of contact parts is a specified requirement.

Door Systems with the above measures were installed on New York City Transit's R211 cars, which started operations in March 2023.



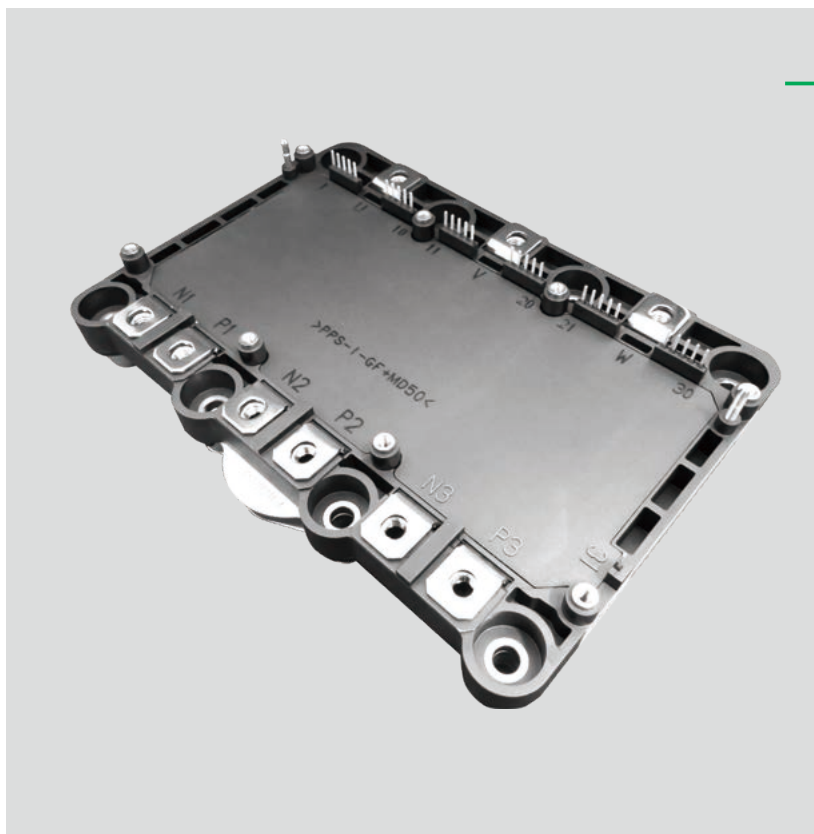
"HPnC" Industrial High-Capacity Module

As the market for solar, wind, and other renewable energies expands with the aim of achieving a decarbonized society, demand is increasing for higher efficiency, larger capacity, and reduced size in power conversion equipment. To meet this demand, Fuji Electric has developed the "HPnC" high-capacity industrial module

The main features are as follows:

- (1) A lineup of 2,300-V/1,200-A rated modules suitable for boosting the input voltage from 1,000 V DC to 1,500 V DC to increase power converter efficiency
- (2) Package terminal arrangement designed for easy multiple parallel connections, facilitating-capacity expansion of power converters
- (3) Use of the 7th-generation "X Series" IGBT chips to increase current density, helping downsize power converters

To further improve the efficiency of power conversion equipment, we are also developing a family product (rated at 2,300 V) using low-loss SiC-MOSFET chips.



“M675” Automotive Module for the Chinese Market

As society progresses toward decarbonization, the electrification of cars is advancing worldwide, and particularly in China, the need for electrified vehicles is increasing as a result of new energy vehicle (NEV) regulations. For the Chinese market, Fuji Electric has offered the “M653” direct water-cooled power module. We have recently developed the “M675,” a 750-V/820-A rated module for the Chinese market, with 30% improved output characteristics and 20% improved heat dissipation compared to the M653.

The main features are as follows:

- (1) Use of the “X Series” 7th-generation RC-IGBTs has reduced watt loss by 13%.
- (2) Enhanced internal fin structure of the cooling part has improved the heat dissipation by 20%. Combined with water jacket, usability is improved.
- (3) Main body size and fastening hole and water channel hole positions are the same as those of the M653, making it easy to perform replacements.



Turbine generator delivered by Fuji Electric

Start of Commercial Operations of Olkaria Geothermal Power Station (Unit 6)

The sixth power generation unit (86.9 MW) of the Olkaria I Geothermal Power Station began commercial operations in June 2022. Kenya Electricity Generating Company PLC ordered the unit from Fuji Electric through Marubeni Corporation. The Olkaria Geothermal Power Station is where Fuji Electric first delivered geothermal power equipment in Africa. Fuji Electric applied its corrosion-resistance technology developed over the years to the unit and optimized the plant layout and equipment to achieve the largest single-unit output in Kenya, where geothermal power generation is thriving. We worked with Kenyan civil engineering and architectural design firms and local construction companies to manage the project. We designed and procured a complete set of power generation equipment, including our own geothermal steam turbine, generator and condenser, as well as dispatched engineers to the site to work on the project.

The operation of this power station will contribute to the stable supply of electricity in Kenya.



120-kW hydrogen fuel cell system

Hydrogen Fuel Cell Systems for Factories and Facilities

The world is expected to see the arrival of a hydrogen society, which will contribute to the stable supply of energy and the realization of carbon neutrality. In preparation, Fuji Electric has started the development of a hydrogen fuel cell system as hydrogen power generation equipment for factories and facilities. This fuel cell system uses polymer electrolyte fuel cell modules that are mass-produced for automobiles. Since the amount of available hydrogen varies depending on the factory or facility, the system configuration allows the number of groups of built-in fuel cell modules to be changed easily so that the rated power generation capacity can be selected accordingly from 50 to 480 kW. Fuji Electric has produced a prototype fuel cell system that can operate for more than 10 years without replacing the fuel cell modules using our newly developed proprietary operating technology in addition to the fuel cell design technology cultivated so far. We are currently conducting demonstration tests for this system.



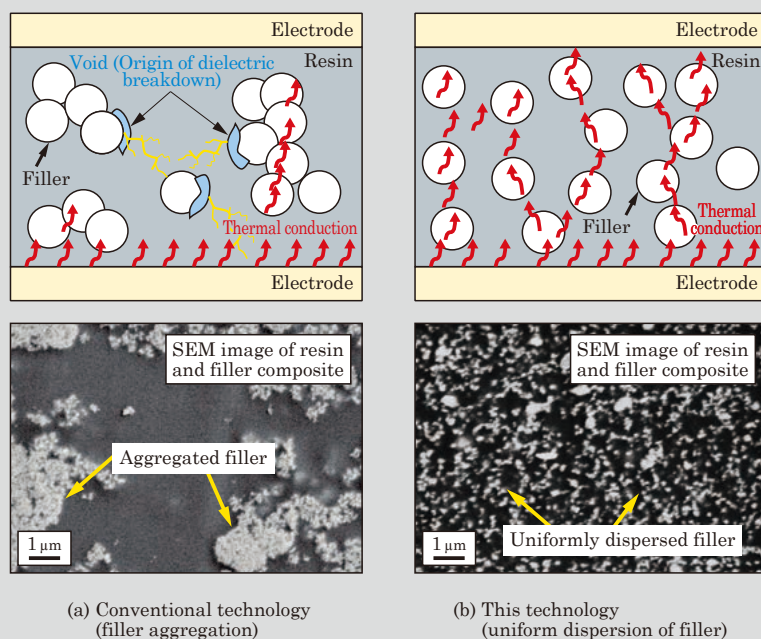
“Sustainable Vending Machine Series”

Against the backdrop of the SDGs and other factors, environmental measures are becoming increasingly important for beverage vending machines. Fuji Electric has thus developed the “Sustainable Vending Machine Series,” a series of environmentally friendly machines designed for energy saving and natural resources saving.

The main features are as follows:

- (1) Expanding rotational speed range in the cooling inverter compressor has improved cooling efficiency and optimal arrangement of additional vacuum insulation has reduced power consumption by up to 20%.
- (2) Improved sheet metal bending structure has reduced plate thickness while maintaining base strength, thereby saving natural resources (10% thinner than conventional models).
- (3) New packaging system that can be configured with minimal materials results in a 70% reduction in packaging materials
- (4) Cloud collaboration via multi-communication modules has optimized delivery plans and reduced lost sales opportunities.

Enhancing Performance of Electrical Insulation Composite with Filler

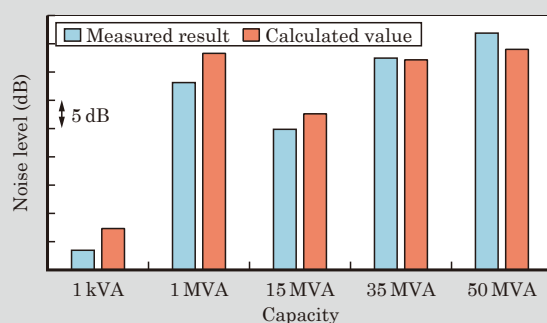
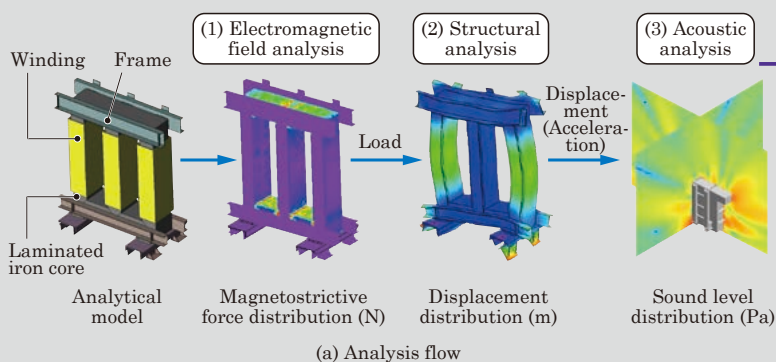


In recent years, as the size reduction of electrical equipment has accelerated, demand is increasing for insulating materials with high thermal conductivity and insulation property. As a way to achieve high thermal conductivity, it is effective to mix highly thermally conductive filler into base resin. However, to ensure high thermal conductivity while retaining insulation property, it was necessary to prevent the form of aggregated filler and voids, which can be the starting point of dielectric breakdowns.

To overcome this issue, Fuji Electric has developed a technology to control filler dispersion behavior and reduce voids in resin by improving compatibility between resin and filler by modifying the filler surface.

As a result of applying this technology to a varnish resin (unsaturated polyester) for the impregnation of stator coils of rotating machines, the thermal conductivity has improved from 0.3 to 1.0 W/(m·K) without losing insulation performance.

Laminated Iron Core Magnetostrictive Vibration and Noise Simulation Technology



(b) Noise level around the transformer

In recent years, urbanization around substations has progressed, and low noise is required for transformers and other substation equipment. The main cause of noise generated by the transformer is the vibrations caused by the magnetostriction, that is, the expansion and contraction of the electromagnetic steel sheet that makes up the laminated iron core during energization. We have developed a simulation technology to accurately estimate this magnetostrictive vibration and the associated noise. First, this simulation technology obtains the magnetostrictive force through electromagnetic field analysis, then uses structural analysis to calculate the displacement along with the vibrations caused by the magnetostrictive force, and acoustic analysis to calculate the sound level produced by the displacement.

The main features are as follows:

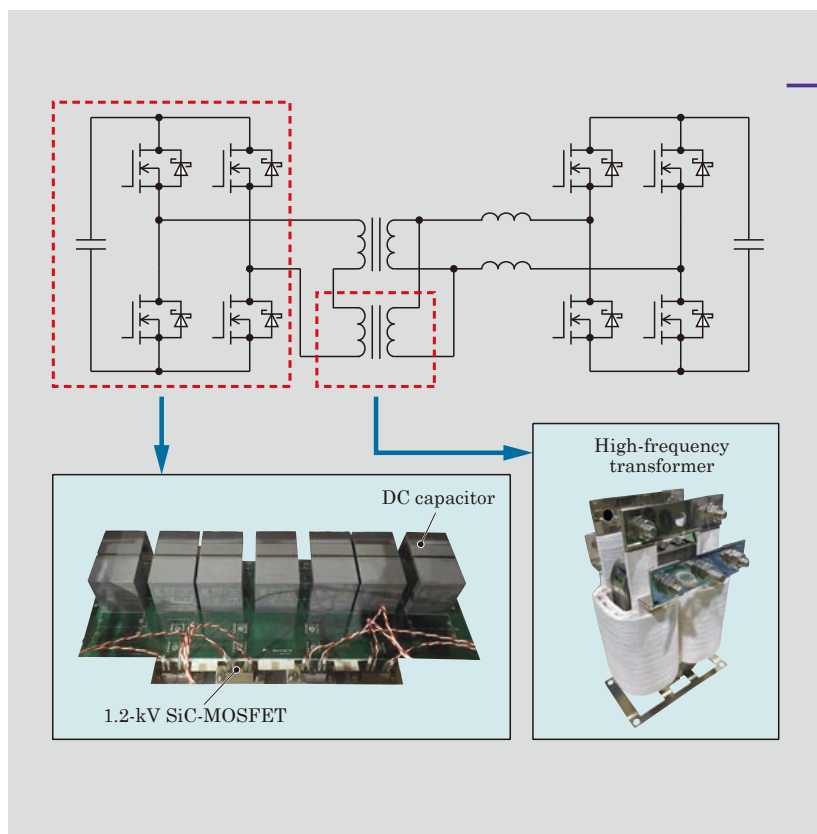
- (1) Capable of estimating the noise level with a high accuracy of ± 5 dB from the measured value.
- (2) Enables noise level estimation and structure examination to achieve low noise during the design phase, thereby reducing the time required for noise-related design work to a quarter of that required with conventional products.

Bi-Directional Isolated DC/DC Converter

In recent years, the application of a DC bus system using electrolysis equipment, fuel cells, and storage batteries for hydrogen utilization has been studied as part of efforts toward realizing carbon neutrality. In order to achieve the practical application of DC bus systems, power converters providing galvanic isolation as well as high conversion efficiency are required. To fulfill these requirements, Fuji Electric has developed a bi-directional isolated DC/DC converter for DC bus systems.

The main features are as follows:

- (1) High conversion efficiency over a wide range of loads achieved by using SiC power devices with a withstand voltage of 1.2 kV and dual active bridge (DAB) circuit configuration (rated efficiency 98.0% for 200-kW prototype)
- (2) Adaptable to a wide range of voltage fluctuations with Fuji Electric's proprietary modulation technology (Voltage range 400 to 800 V)

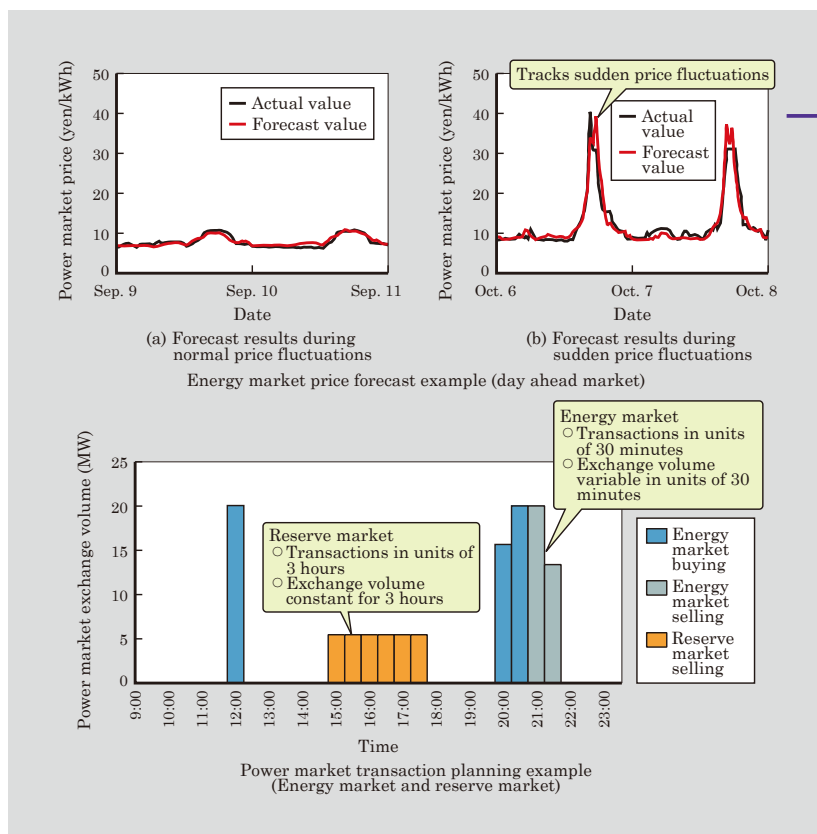


Energy Market Price Forecasting and Planning of Transactions Using Storage Batteries for the Power Grid

The establishment of the energy market has led to an increase in the need for storage batteries to be utilized in electricity utilities. In response to this need, Fuji Electric has developed a technology to forecast the power market price and create an exchange plan based on the forecast to maximize profits by effectively utilizing storage batteries.

The main features are as follows:

- (1) Power market price forecasting
 - Capable of forecasting with high accuracy by using a wide range of information, such as nationwide supply and demand information and inter-connection line information.
 - Capable of tracking sudden price changes by using short-term historical data.
- (2) Power market transaction planning
 - Enables simultaneous planning of transactions in existing energy markets with different transaction units and new reserve markets.



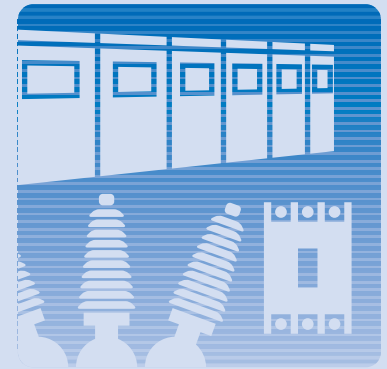
Power Electronics Energy

Energy Management

Transmission and Distribution Systems

Power Supply and Facility Systems

Electric Distribution, Switching and Control Devices



In the power electronics energy segment, Fuji Electric is committed to power electronics, substation, and energy monitoring and control technologies. Based on these core technologies, Fuji Electric offers components such as switchgear, transformers, protection relays, uninterruptible power systems (UPSs), power conditioning systems (PCSs), switchgears and controlgears, as well as energy solutions that incorporate these products. We provide one-stop solutions ranging from system building to maintenance services for power companies, material plants, and data centers in order to contribute to the construction of infrastructure that provides a stable supply of energy.

Energy Management

To achieve carbon neutrality, we offer solutions to expand the adoption of renewable energy and systems to stabilize power supply.

In the field of power transmission and distribution, we have developed a distribution automation system in consideration of business continuity plans (BCPs) that enables restoration of operations from power failures over a wide area. We also delivered a power supply system that stabilizes power supply by linking grid control functions with supply-demand functions. To accommodate the expansion of the supply demand adjustment market, we have provided control systems for storage battery PCSs that work in conjunction with higher-level planning systems. To accommodate the expansion of the adoption of renewable energy, we received an order for electric power storage battery system equipment for Japan's largest-scale self-consumption solar power generation plant. We have also developed a demonstration equipment for M-G sets [equipment for storing power generated from renewable energy in storage batteries and using the power to rotate a motor (M) that drives a synchronous generator (G) equipped with storage batteries]. This equipment is a countermeasure against the decline in power system stability due to factors such as reduced inertia caused by a decrease in the proportion of synchronous generators in the system.

Transmission and Distribution Systems

We provide our solutions business for the electric power, industrial, and transportation sectors to improve reliability, efficiency, and environmental friendliness through substation equipment and power electronics equipment.

In the field of substation equipment, we delivered a special 3-phase transformer that uses an innovative tank structure to reduce the installation footprint by 20% compared to conventional transformers. In the field of power monitoring equipment, we renewed our product offering according to customer needs and have been providing electric power remote monitoring equipment that features improved monitoring visibility and utilizes an open communication protocol that makes it easy to connect with customer-side systems. In the field of railway electrical equipment, we provided electrical equipment for stations on a Shinkansen line that improve reliability by distributing control devices to both primary and stand-by systems, adopting duplex configuration for general control equipment and using emergency generators to provide backup circuits that can supply electrical power even during power outages.

Power Supply and Facility Systems

Data centers and semiconductor plants in Japan and overseas not only require power supply systems that provide a highly reliable and stable power supply, but also space saving and shorter construction times. To meet these needs, Fuji Electric can provide high-voltage substation equipment, emergency power generation equipment, and UPSs that contribute to optimizing systems, reducing installation footprints and shortening construction periods.

For a data center, we provided high-capacity UPS systems that can supply up to 3,600 kVA by connecting UPSs in parallel with a single unit capacity of 1,200 kVA. This system has improved reliability by adopting duplex output buses and facilitates maintenance and inspections. For transformers, we developed and delivered FR3[®] transformers that use natural ester oil to meet the requirements of advanced data center operators to reduce the environmental load. Natural ester

oil is highly biodegradable and non-toxic and is capable of reducing the impact on the environment in the unlikely event of an oil spill. Its high flash point also simplifies auxiliary equipment such as fire extinguishing equipment and contributes to lowering entire installation costs.

For the computer and communications equipment at banking facilities and government offices, we have developed a 3-phase 200-V high-capacity UPS that improves operability, including start, stop and mode switching, while simplifying equipment renewal by allowing existing wiring to be reused.

In addition, we provided the power supply equipment of a semiconductor plant with high-speed circuit breakers that enable switching from commercial power to in-house power generation in one-half cycles in the event of a power outage or instantaneous voltage drop.

Electric Distribution, Switching and Control Devices

We offer power distribution equipment and switching devices to ensure the efficient and safe use of electric power in renewable energy-related facilities, electric equipment for buildings and facilities, and control systems for plant production lines, as well as control equip-

ment to automate and optimize production equipment and machinery.

In the field of control devices, we have renewed our lineup of operating and indicating devices. To meet the needs of the machine tool market, these devices adopt a thin and stylish design with minimal product protrusion from the surface of the panel. The surface of the push button is shaped to fit the operator's fingertip, improving not only the design aesthetics but also the feel of operation.

For switching devices, we have developed an AC contactor for elevator control panels that is suitable for the dynamic brake control circuits required by latest international standards for injection molding machinery and elevators. It contributes to enhancing the safety of equipment that uses electric motors.

In order to meet the growing environmental needs of the power distribution equipment market, we have developed a load break switch (LBS) using resin materials that are easily disposable and recyclable.

Moving forward, we will continue to contribute to society by releasing components to the market for electric distribution, switching, and control devices that meet the needs of the times.

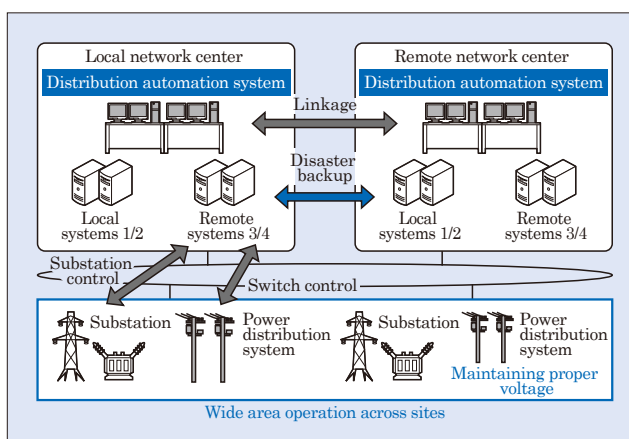
Energy Management

1 Distribution Automation System for Chugoku Electric Power Transmission & Distribution Company, Incorporated

Fuji Electric has replaced the distribution automation system for monitoring and controlling 6-kV and 22-kV power systems for Chugoku Electric Power Transmission & Distribution Company, Incorporated. The system has the ability to automatically restore accidental outage and generate data on equipment information at changing equipment. The main features are as follows:

- (1) By deploying a backup system at a location remote from the business site in consideration of the business continuity plan (BCP), the system can continue to operate even if the business site is damaged by a disaster.
- (2) The wide-area operation function provides a wide-area system diagram on a single screen and enables restoration operations after power outages that span across business sites.
- (3) For power distribution systems, which are becoming increasingly complex due to the expanded deployment of decentralized power supplies, it supports the optimization of power distribution system voltages through highly accurate system condition calculations that take into account small-scale power generation facilities and actual power generation.

Fig.1 System configuration diagram



Energy Management

2 Replacement of Power Supply System for Sumitomo Joint Electric Power Co., Ltd.

Fuji Electric has delivered a power supply system to Sumitomo Joint Electric Power Co., Ltd. designed to provide a stable supply of electric power to Sumitomo Group companies and to enhance power supply control. The main features are as follows:

- (1) It integrates grid functions for monitoring and controlling power systems and power plants with supply-demand functions for preparing and submitting power generation and demand plans and for trading on the wholesale power market into a single system to improve operability.
- (2) It prevents erroneous operations and reduces the burden on operators by automating procedures and accident restoration for grid functions, supply-demand balance planning and intraday market trading for supply-demand functions, and simultaneous supply-demand balancing control that links both grid and supply-demand functions.
- (3) By using the power industry's first multi-window system that supports one client and four monitors, it allows operators to register screen and button layouts to improve workability and usability.

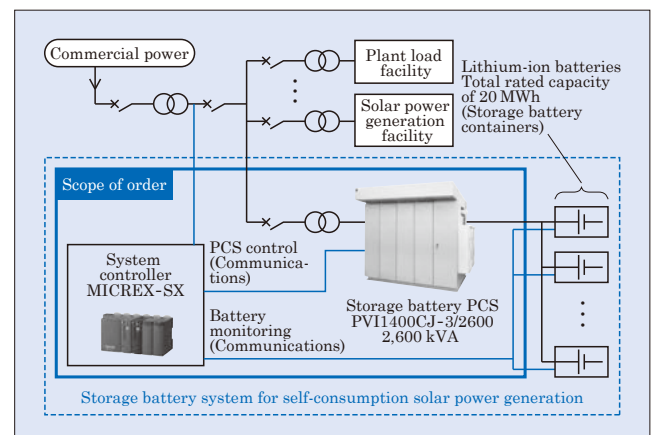
Fig.2 Power supply system



3 Received Order of Equipment for Storage Battery Systems Supporting Self Consumption of Solar Power

Fuji Electric received an order for a storage battery PCS (2,600 kVA), a system controller, and substation equipment from Tokyo Gas Engineering Solutions Corporation. They are used for Japan's largest-scale solar power plant for self-consumption installed in the Kumamoto Factory of Honda Motor Co., Ltd. The equipment will be co-located with a solar power plant (5.8 MW) on the factory premises to support the expansion of self-consumption of solar power by recharging surplus power on factory holidays and discharging it at night and during periods of cloudy or rainy weather. The PCS is designed to accommodate high voltage DC input, allowing the battery system to use high-power, high-capacity storage batteries. This allows the system to have a narrow footprint and flexibly arrange batteries, saving costs for the construction, including foundation work and installation. The system is scheduled to begin operations in April 2024.

Fig.3 Storage battery system

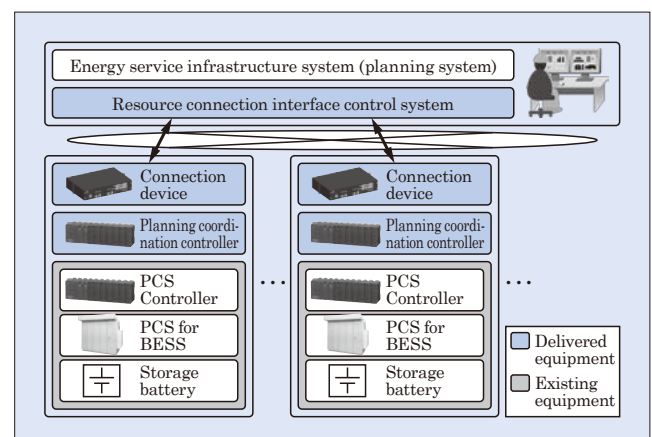


4 Control System of PCSs for BESS used in the Power Exchange Market

Fuji Electric has delivered to Sumitomo Corporation an energy service infrastructure coordination control system that is necessary for making its storage battery system to be used for the power exchange market. This system controls the recharge and discharge of PCSs for battery energy storage system (BESS) using the commands from the energy service infrastructure system as its target values. The main features are as follows:

- (1) The energy service infrastructure system and storage battery systems owned by customers can be easily associated by adding a resource connection system on the energy service infrastructure system and by providing a connection device and a planning coordination controller between them.
- (2) It uses an open communication protocol (OpenADR2.0b) that makes it easy to connect the existing electric power storage battery system to the energy service infrastructure system.

Fig.4 Overview of system configuration



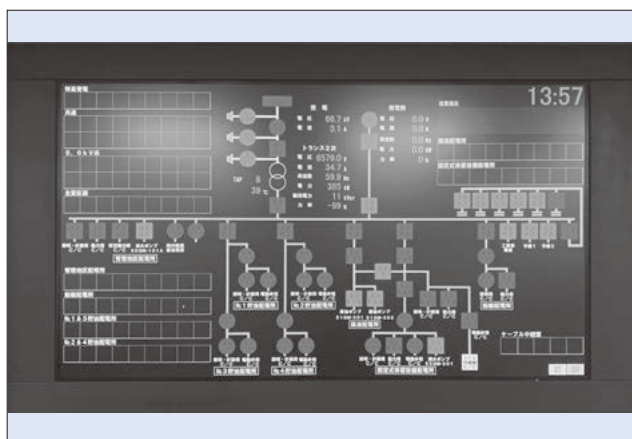
Transmission and Distribution Systems

1 Replacement of Electric Power Remote Monitoring Equipment for Shibushi Oil Storage Company, Ltd.

Fuji Electric replaced the aging electric power remote monitoring equipment for Shibushi Oil Storage Company, Ltd. The Shibushi National Petroleum Stockpiling Base is an important site for national oil storage. As such, it needed to be able to monitor the plant facilities during the replacement period. By replacing the existing system and the newly installed system together in stages, we completed the renewal work without interrupting monitoring activities. The main features are as follows:

- (1) It has greatly improved visibility by replacing the existing mosaic graphic panel with a 98-inch monitor.
- (2) It uses an OPC server to easily connect with customer systems.
- (3) A new operation support function saves labor in daily operation and restoration work when a malfunction occurs.

Fig.5 Electric power remote monitoring equipment



2 Delivery of Electrical Equipment for Stations on the Nishi Kyushu Shinkansen Line

The Nishi Kyushu Shinkansen Line connects Takeo-Onsen Station in Saga Prefecture to Nagasaki Station in Nagasaki Prefecture. It is a 66-km stretch of track that started operations on September 23, 2022. Fuji Electric supplied 7.2-kV enclosed switchboards, main control switchboards, molded transformers, emergency gas turbine generators, and other equipment for four of the five newly constructed stations, including the distributing station at Takeo-Onsen Station. Station electrical facilities are responsible for supplying power to equipment that supports various services at the station as well as to signaling facilities. Therefore, they are required to provide a reliable supply of power. The equipment's main features are as follows:

- (1) It improves reliability by distributing control equipment to both primary and stand-by systems and by adopting a duplex integrating controller system.
- (2) A backup circuit with the emergency generator can start feeding power in case of a power outage.

Fig.6 7.2-kV enclosed switchboards for the distributing station at Takeo-Onsen Station



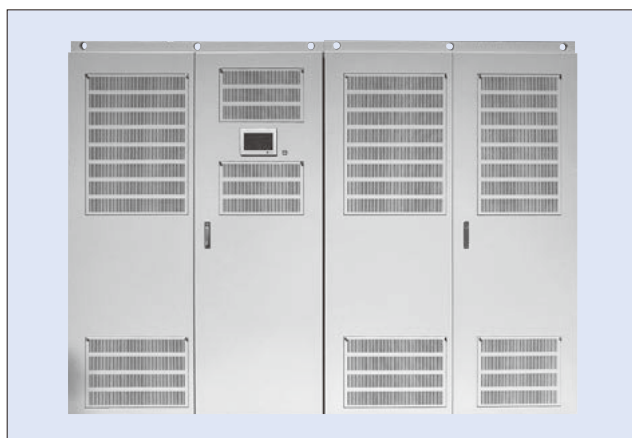
Power Supply and Facility Systems

1 "6000DX Series" 3-Phase 200-V High-Capacity UPS

UPSs with 200-V output are widely used in data centers and in computer and communications equipment at financial institutions and government offices. The power consumption of backup equipment has been increasing due to the increasing amount of data handled. As a result, demand is growing for UPSs with high capacities. To meet this need, Fuji Electric has expanded our 100- to 300-kVA lineup of its "6000DX Series" 3-phase 200-V high-capacity UPSs to include 400/500-kVA models. The main features are as follows:

- (1) It improves operability and maintainability by enabling UPS start and stop, mode switching, and other operations to be performed from the LCD touch screen on the panel.
- (2) It uses the external wiring layout that perfectly matches that of conventional models, enabling the on-site wiring of existing facilities to be reused without modification and also facilitating replacement.

Fig.7 "UPS6000DX-T3" (500 kVA)

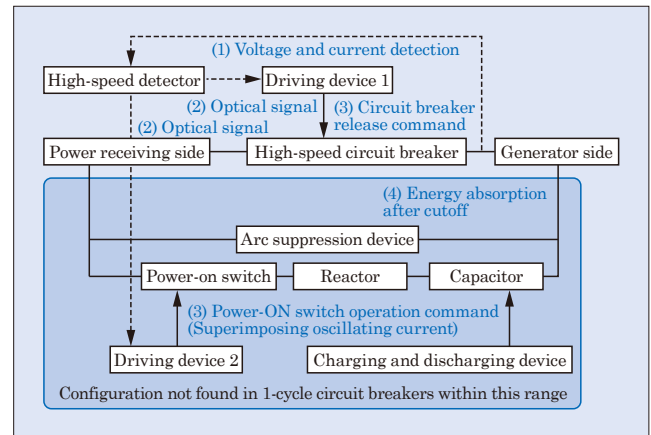


Power Supply and Facility Systems

2 1/2 Cycle High-Speed Circuit Breakers Delivered to Fuji Electric's Yamanashi Factory

In semiconductor factories, instantaneous voltage drops and even slight fluctuations in power supply voltages can cause defective products and manufacturing equipment failures. Therefore, critical equipment must be quickly disconnected from commercial power in the event of a power outage or instantaneous voltage drop. Fuji Electric's Yamanashi Factory operates its in-house power generation equipment in parallel with the commercial power supply at all times. In the event of a power failure or instantaneous voltage drop, critical equipment is disconnected from the commercial power supply and in-house power generation equipment operates independently to continue operations. We delivered circuit breakers that have reduced the break-time to 1/2 cycles (10 ms at 50 Hz), a half that of existing ones. We achieved this high-speed cutoff by combining the high-speed drive technology of 1-cycle circuit breakers with a commutation breaking method that has a proven track record in cutting off DC. This reduces the frequency of stoppages of manufacturing facilities due to instantaneous voltage drops and also helps prevent equipment failures.

Fig.8 Configuration diagram and operation sequence of high-speed cutoff

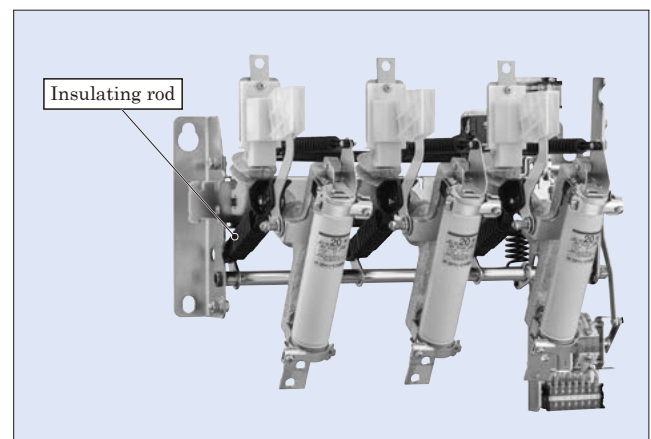


Electric Distribution, Switching and Control Devices

1 Load Break Switches with Improved Environmental Friendliness

In recent years, the "Plastic Resource Circulation Act" and other laws have required the use of resin materials with a low environmental burden in a wide range of fields. For load break switches used in industrial facilities, insulating parts made of difficult-to-recycle thermosetting resins need to be replaced with materials that are easily disposable and recyclable. Against this backdrop, Fuji Electric has developed load break switches with improved environmental friendliness by utilizing thermoplastic resin that can be recycled. We use thermoplastic resin for some of the insulating parts, including the insulating rod connected to the operating handle, by designing the structure after carefully examining the minimum insulation distance required for each material. Furthermore, we eliminated materials containing substances that fall under the RoHS Directive, thereby improving environmental friendliness from the standpoint of hazardous substances.

Fig.9 "LBS-6 A/200F"

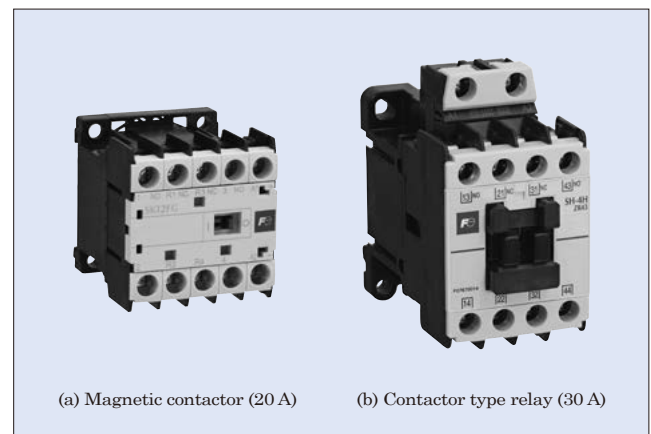


2 AC Contactors for Elevator Control Panels

China's elevating machinery test regulation "TSGT7007-2022" was issued with new H6.11 safety brake circuit (sealed star circuit) requirements added. Fuji Electric has released its AC contactors for elevator control panels that comply with the new requirements, based on an auxiliary relay, which is recognized as highly reliable by the Chinese market. The main features are as follows:

- (1) The configuration of 2A 2B contacts of the main circuit facilitates the formation of a star-closed-circuit, which is required to safely stop an elevator drive motor.
- (2) The lineup comes in rated currents of 20 A and 30 A and can be used for almost all elevator starting motors.
- (3) Applying proven pressure to the contacts as used for dynamic brake applications in Japan ensures high reliability.

Fig.10 2A 2B AC contactors



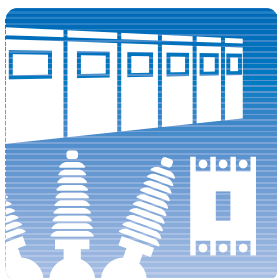
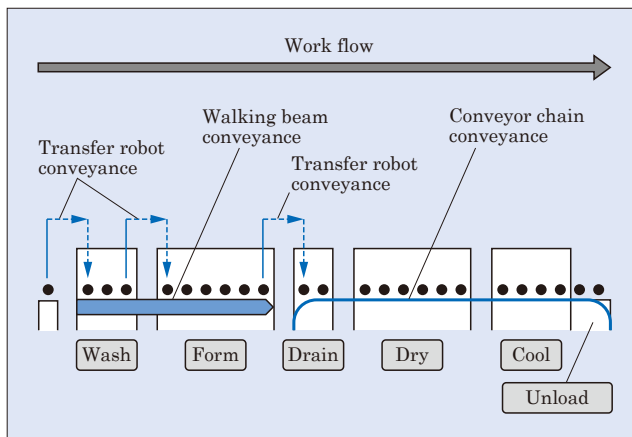
Electric Distribution, Switching and Control Devices

3 Replacement of Iron Core Production Line for Magnetic Switches Compliant with VOC Regulations

The revision and enforcement of the Air Pollution Control Act has increased the requirements to regulate the emissions of volatile organic compounds (VOCs). This has made it imperative to switch to materials with a lower environmental burden. Fuji Electric's iron cores for its magnetic switches had used VOC, namely dichloromethane, as the main solvent for anti-rust treatment, which needed to be switched over to a compliant anti-rust treatment. Against this backdrop, we have developed a new heat-drying technology that enabled the use of a non-VOC, easy-to-manage water-based treatment solvent. By renewing the production line that applies this new technology for anti-rust treatment, we reduced VOC emissions by 80% from the previous year. Going forward, we plan to apply this newly developed anti-rust treatment equipment to other products to further reduce VOC emissions.

Based on this accomplishment, this product was awarded honorable mention in the FY2023 Japan Electrical Manufacturers' Association Technical Achievement Award.

Fig.11 Configuration of anti-rust treatment equipment



Power Electronics Industry

Factory Automation
Process Automation
Information Solutions
Social Solutions
Field Services



In the power electronics industry segment, Fuji Electric has combined drive equipment, measurement instruments, and control equipment with artificial intelligence (AI) and the Internet of Things (IoT) to systematize them, providing solutions to support the advancement of digital transformation (DX). We thus contribute to automation, operational stability, and energy saving in the industrial, railway, and marine sectors.

Factory Automation

In the factory automation (FA) business, Fuji Electric has made contributions to automation, optimized operations at facilities, and energy saving by applying AI and IoT to drive equipment, such as inverters, servos, and rotating machines; measuring instrument, such as pressure transmitters and watt-hour meters; and control equipment, such as programmable controllers and programmable operator interfaces.

In the field of drive equipment, we have developed the “FRENIC-Ace (E3) Series” of high-performance, standard inverters equipped with an Ethernet interface, power cycle life diagnosis of insulated gate bipolar transistors (IGBTs), and a traceback function to contribute to the DX of FA systems.

In the field of measuring instruments, we have developed “S-Flow,” a palm-sized, clamp-on compact ultrasonic flowmeter for small-diameter pipes. When mounted, it does not need applying grease, allowing it to be installed even in clean environments such as semiconductor or food plants. We have also developed “HF Series” of flush-mount electronic watt-hour meters with a pulse output function, which contribute to the prevention of erroneous meter readings during electric rate transactions at commercial facilities and elsewhere.

In the field of control equipment, we have expanded our Abnormality Diagnosis Solution, which uses AI to detect and analyze processing abnormalities in the production process. We also developed a CPU module with a diagnostic function of the “SPH5000EC” Series for customers who require highly accurate diagnostic performance. In addition, we have developed the “MONITOUCH V10 Series” programmable operator interface, which delivers stress-free operation with re-

duced start-up time and no waiting time. Its compatibility with existing “MONITOUCH” facilitates equipment replacement.

Process Automation

In the process automation business, we offer reliable control of equipment, remote monitoring control, and anomaly sign detection by utilizing the know-how we have accumulated through a wide range of product line-ups and extensive delivery records.

In the field of drive control systems, we have developed and began application of a plant simulator that promotes DX in system verifications. In addition, in preparation for the replacement of DC motors, which were introduced to many steel rolling mills in Japan in the 1970s, we have added the new model to the existing product line. This is a DC-compatible induction motors with the same cooling system, mounting dimensions, and moment of inertia as the existing motors, which thereby reduces installation periods and costs.

In the field of process control systems, we have developed monitoring and control systems and an engineering support tool that allow customers to adopt new technologies to accelerate globalization and DX while maintaining system inheritability. We have also delivered our monitoring and control systems to small-scale wood biomass power plants and kiln waste heat generation facilities to contribute to the realization of a decarbonized society and to the safe and stable operation of customer plants.

Information Solutions

In the information solutions business, Fuji Electric is working to offer digital solutions and create new products. We are engaged in the information business through DX and carbon neutrality, including factory DX, new-normal offices, and digital transformation of government agencies.

For factory DX, we have developed manufacturing execution systems (MES) compliant with OPC UA, an open international standard designed for safe and reliable data exchange, enabling unitary management of production, inventory, and equipment data in the fac-

tory.

Social Solutions

In the social solutions business, Fuji Electric offers electric systems for railcars, ship and harbor systems, transportation equipment systems, and radiation management systems to contribute to safety, security, and energy saving of social infrastructures.

In the field of railways, New York City Transit's R211 cars started operations in March 2023 where Fuji Electric's door system is installed. As an approach for software development in this project, Fuji Electric, including overseas subsidiaries, received a certification of the Capacity Maturity Model Integration (CMMI) Level-2, the standard to evaluate maturity of organization and management. We are now working to maintain and improve the quality of our software.

In the field of ship and harbor systems, we have developed the onshore power supply system, which supplies the necessary power from land to the ship that docks and stops its engine in consideration of environmental improvement and CO₂ reduction, to contribute to the realization of a decarbonized society.

Field Services

In the field service business, Fuji Electric offers facility optimization solutions that utilize AI and IoT, in addition to conventional maintenance services such as periodic inspections and repairs.

To deliver predictive maintenance of switchboards, we have developed monitoring functions of partial discharge and local overheating in switchboards as part of the "Comprehensive Service for Smart Industrial Safety" we offer for customer equipment.

Factory Automation

1 "HF Series" Flush-Mount Electronic Watt-Hour Meters

Flush-mount mechanical watt-hour meters are typically used in buildings and commercial facilities, but they sometimes cause troubles, including billing issues due to erroneous meter readings and faulty wiring during installation. To address these problems, Fuji Electric has added a flush-mount model to the "HF Series" of electronic watt-hour meters. The main features are as follows:

- (1) Highly visible 6-digit digital display and built-in pulse transmitter to connect to data loggers help prevent erroneous meter readings.
- (2) Faulty wiring check assistance function prevents incorrect wiring.
- (3) Installation and wiring compatible with mechanical flush-mount watt-hour meters simplify replacement work.
- (4) The lineup is available in all four types of phase and wire systems, allowing it to be used for all watt-hour meters across an entire building.
- (5) Built-in battery allows measurement values to be checked even in the event of a power failure

Fig.1 "F7HF-RS23V" (3-phase 3-wire type with a pulse output function)

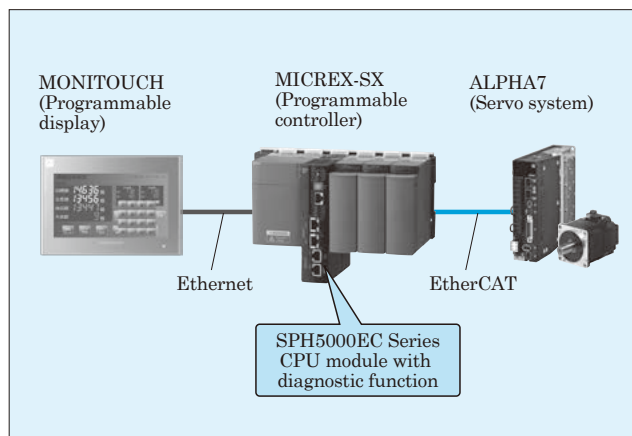


2 CPU Module with Diagnostic Function for the "SPH5000EC" Series

Machinery and equipment used in food packaging and metal processing are required to detect abnormalities in processed products and predict machine failures to stabilize and improve quality and improve operation rates. In response to these requirements, Fuji Electric has provided the "Abnormality Diagnosis Solution," which automatically detects abnormalities by utilizing analytics AI. This time, we have developed a module with a diagnostic function of which a single CPU can perform diagnosis and control designed for customers who require highly accurate diagnostic performance. The main features are as follows:

- (1) Capable of collecting data at a fastest cycle of 500 μs, allowing for very short time data change detection to improve the accuracy of abnormality detection.
- (2) Facilitates sensorless abnormality detection by aligning with the "ALPHA7" servo system and easy diagnosis results visualization by aligning with the "MONITOUCH" programmable display.

Fig.2 Example of the system configuration of a motion system



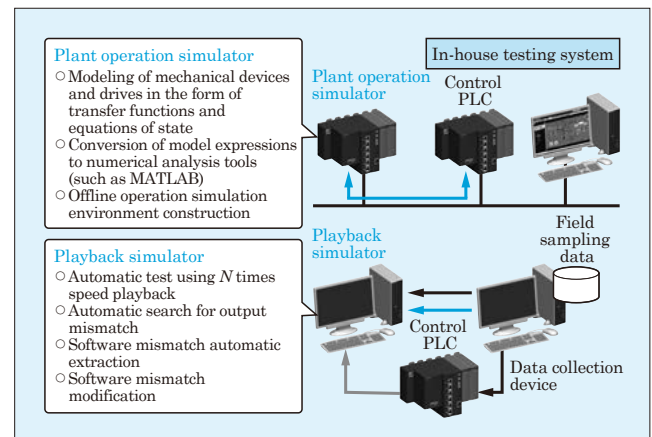
Process Automation

1 Plant Simulator for Industrial Plants with Motor Applications

For steel and non-ferrous metal plants and other industrial plants with motor applications, Fuji Electric has developed a plant simulator to debug control application software, increase on-site testing efficiency, and improve control system quality. The simulator enables even fine tuning of plants in a debugging environment by modeling mechanical plant devices, motors, and drive equipment and by creating a digital virtual plant. The main features are as follows:

- (1) Offline simulation of control conditions through the combination of a plant operation simulator with external numerical analysis tools, thereby improving software quality
- (2) A playback simulator verifies software execution using data from worksites to reduce on-site verification work, saving the software development period and costs.

Fig.3 Plant Simulator Overview



2 DC Commutator Machine Compatible Induction Motor

A number of special DC motors (800 line, 600 line) compliant with JEM 1109 were introduced to steel rolling mills in Japan in the 1970s. They are now due for replacement, but they have special dimensional specifications and unique cooling systems. To meet the demand for replacement, Fuji Electric has developed compatible induction motors and serialized all of them that are equivalent to the existing DC commutator machines with frame sizes of 802A to 818 and 620 to 624 and the "Low Inertia (D) Series." The main features are as follows:

- (1) Use of a cooling system equivalent to that of existing DC commutator machines (separately ventilated type) and matching of the interface dimensions of the motors saves the installation period and costs
- (2) With the same moment of inertia as that of existing DC commutator machines, it can be used for equipment that performs rapid acceleration and deceleration and frequent reversible operations.

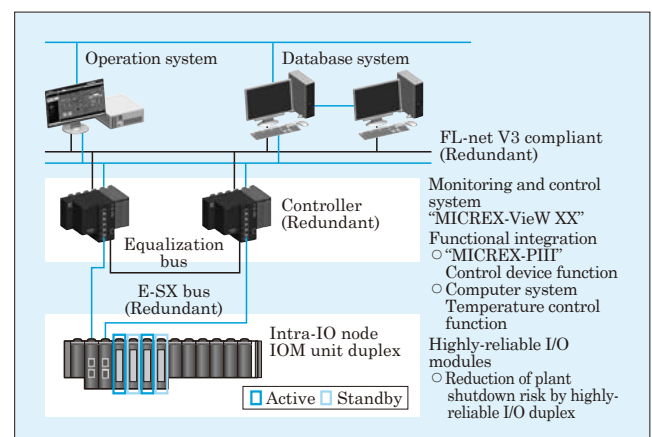
Fig.4 800/600 line-compatible induction motor for steel mill auxiliary



3 Replacement of the Monitoring and Control System for an Oxygen Production Plant

Fuji Electric has conducted replacement work on the monitoring control system of an oxygen production plant. The conventional system consisted of a mix of the "MICREX-AX" and the "MICREX-PIII," which have different architectures. In addition, the temperatures of some pieces of equipment were controlled separately by a computer system. This existing control system was entirely replaced by a new "MICREX-VieW XX" system and reliable I/O modules. The computer system was also integrated into the main control system to achieve a simple system configuration. In addition, the new system adopts a duplex configuration for both the monitoring and control system and the I/O modules to reduce the risk of plant shutdown. In the replacement work, we minimized the downtime of facilities by allowing the existing system to run in parallel with the new system during the changeover.

Fig.5 Monitoring and control system configuration



Process Automation

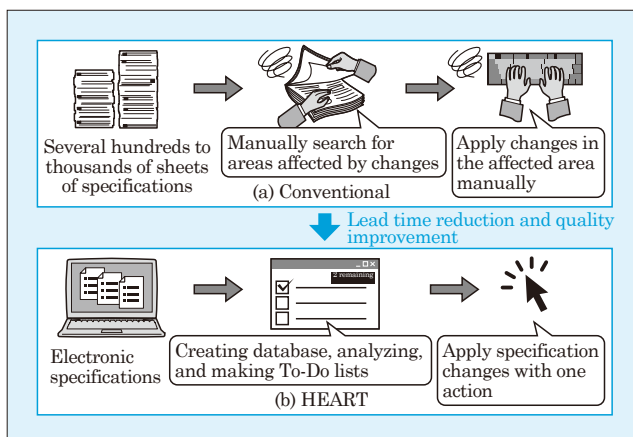
4 “HEART” High-Efficiency Engineering Support Tool to Accelerate DX

Specification changes in plant monitoring and control systems need manual work to search for changes to be made and reflect them, leading to challenges such as the prevention of quality degradation due to oversights and the reduction of work hours. To address these challenges, Fuji Electric has added following new functions to its “HEART” engineering support tool, which automatically generates controller software from control function specifications.

- (1) Creates a database of the software elements included in the specifications of the control function, analyzes areas affected by the changes in real time, and makes a To-Do list that indicates the areas to be changed
- (2) Jumping to the target specification page by clicking on a To-Do list item and checking the details before reflecting changes

These functions improve quality and shorten the work hours required when changes are made to specifications.

Fig.6 Using “HEART” to automate the reflection of changes in specifications

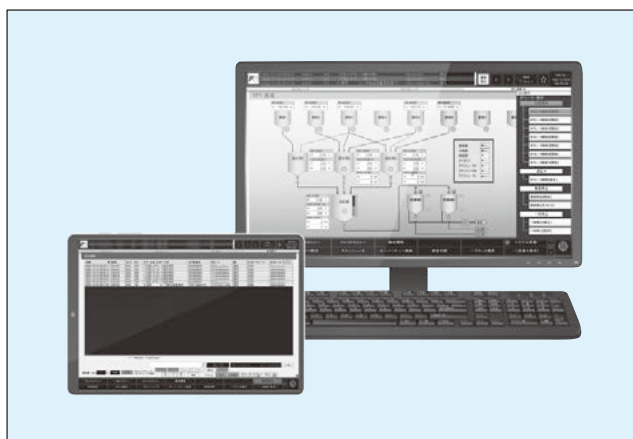


5 “MICREX-View FOCUS Evolution” Global Monitoring and Control System

In 1994, Fuji Electric launched the “MICREX-View FOCUS,” which is a monitoring and control system for small- and medium-scale plants. We have since delivered this product to many small- and medium-scale industrial plants in Japan. In December 2022, we developed and launched the “MICREX-View FOCUS Evolution,” which facilitates system construction, and to enhance its application in small- and medium-scale plants, including those outside Japan, we adopted the OPC UA international standard as a communication standard. The main features are as follows:

- (1) Easy engineering with drag and drop operations from catalogs in its tools.
- (2) Systems can be configured inexpensively through the use of general-purpose PCs and network equipment without using highly functional products such as SQL Server.
- (3) Duplex configuration is adopted for critical points such as controllers, system networks, and I/O buses to stable plant operation.

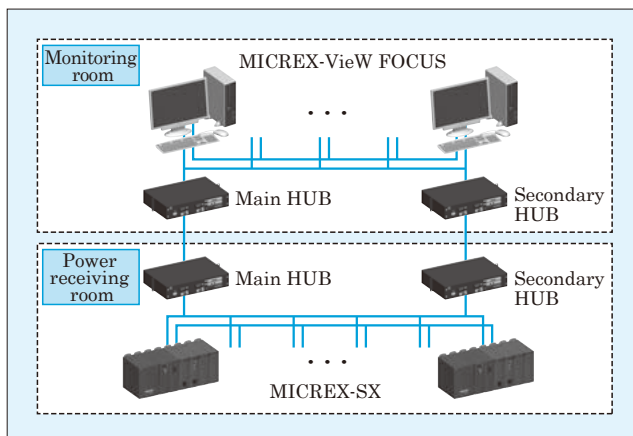
Fig.7 Graphic, alarm history screens examples



6 Replacement of the Supply Monitoring System for a City Gas Provider

Fuji Electric delivers remote monitoring and control systems to a number of gas suppliers who use them to provide a stable supply of city gas to factories and homes. In this project, we replaced an existing LNG satellite monitoring and control system including the “MICREX-View FOCUS” system delivered in 2005 with the new version system for a city gas provider. As it was necessary to monitor and control the plant equipment during the replacement period, we continued operating the existing system and started changing over the secondary system while keeping the main system active. As a result, we completed the replacement work without affecting plant operation. While both the shape and size of the symbols on the control screen remain the same as they were in the old system, the visibility of the screen and the processing speed have been improved in line with client PC updates, thereby improving operability for the customer.

Fig.8 Supply monitoring system configuration



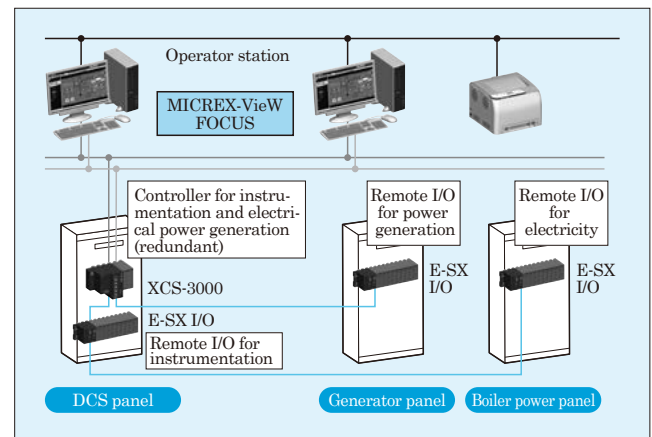
Process Automation

7 Monitoring and Control System for Small-Scale Wood Biomass Power Generation

The introduction of biomass power generation is progressing as part of efforts to realize a decarbonized society. Fuji Electric has developed a compact and highly functional monitoring and control system (DCS) for small wood biomass power plants of 2-MW class, which are expected to become more popular due to the low fuel security constraints. We have delivered this system to seven locations in Japan through plant manufacturers. The main features are as follows:

- (1) The integration of electrical, instrumentation, and power generation control into the monitoring and control system centralizes operations and reduces operator load.
- (2) A remote I/O system has downsized the control panels and saved wiring work.
- (3) Standard packaging of software through methods such as the integrated generation of operation screens and control logic reduces the price.

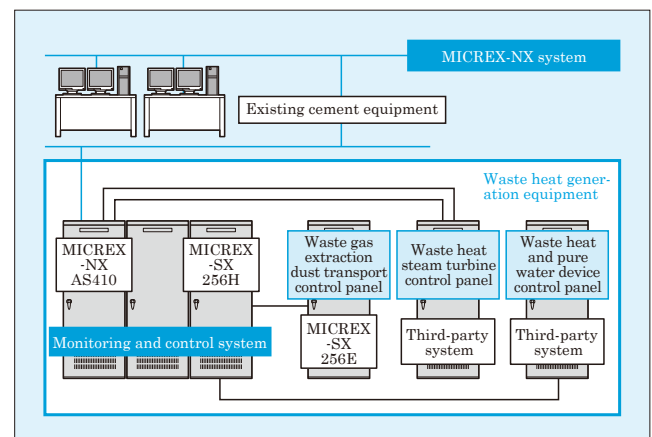
Fig.9 Monitoring and control system configuration



8 Delivery of a Monitoring and Control System for a Waste Heat Power Generation System

To reduce CO₂ emissions from cement facilities, Fuji Electric delivered a monitoring and control system for a kiln waste heat generation plant (rated output at generator terminal: 8 MW), which began operation in November 2022. In the kiln waste heat power generation plant, the heat of the gas discharged from the kiln combustion process of the existing cement facilities is recovered by the waste heat boiler equipment, and the steam generated by the heat is used in the turbine generator equipment to generate power. To reduce the burden on the operator accompanying the expansion, we added a waste heat monitoring and control function to the existing Fuji Electric "MICREX-NX System," a cement equipment monitoring and control system, thereby maintaining the same monitoring and operability as the existing system. The operation of this equipment can reduce CO₂ emissions by approximately 23,000 tons per year. We will use this delivery of a waste heat generation system as a case study to continue contributing to the realization of a decarbonized society.

Fig.10 System configuration diagram

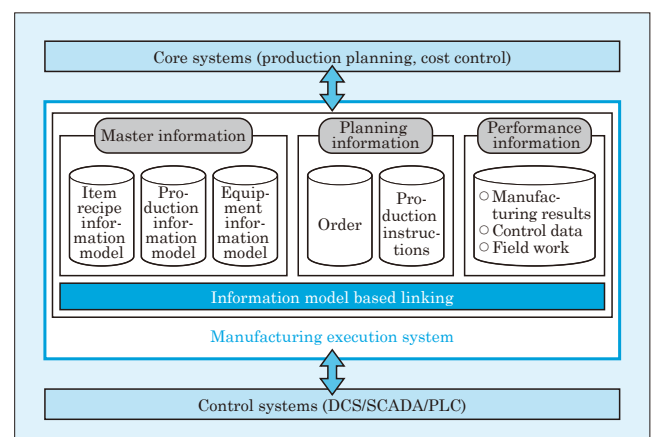


Information Solutions

1 Information Model-Based Manufacturing Execution System

To achieve factory DX, various types of field data must be collected, managed, and analyzed, then utilized for productivity improvement and quality control. For the integrated management of factory data, Fuji Electric has developed a manufacturing execution system based on an information model. The information model is a framework proposed by OPC UA to transfer information between systems. Based on this framework, we achieved unitary management of all factory data by linking together the master information (item recipes, production, and equipment), planning information, and performance information necessary for production. The adoption of an open architecture has made it easier to link information with external analysis tools and core systems, enabling the use of data to improve plant productivity and optimize production planning. We will continue to expand our capabilities and contribute to the realization of factory DX for our customers.

Fig.11 Manufacturing execution system configuration

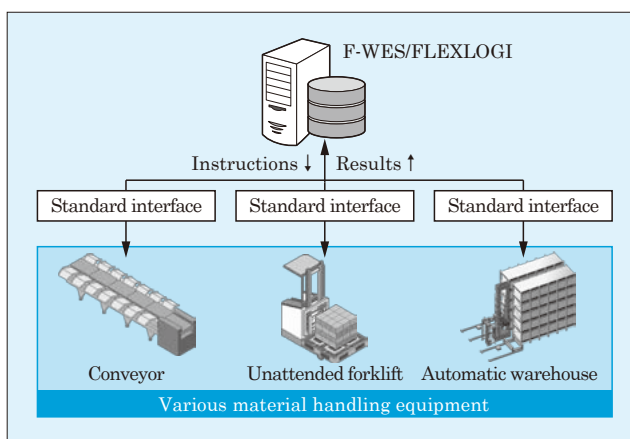


Information Solutions

2 “F-WES/FLEXLOGI” Standard Interface for Distribution Automation Equipment

Due to the labor shortage in recent years, the adoption of a diverse range of distribution automation (material handling) equipment has been increasing in the distribution industry to improve the efficiency of various operations. Fuji Electric has delivered the “F-WES/FLEXLOGI” warehouse management system to distribution centers and warehouses. However, the problem is that developing an interface for each piece of material handling equipment adopted increases the development period and cost, and also complicates the system. To address this problem, we have developed a standard interface that defines standard data linkage methods for each piece of material handling equipment, including conveyors and automatic warehouses. This interface makes it possible to link various types of material handling equipment to the warehouse operation management system without relying on the vendor of the material handling equipment. It also minimizes the development period and costs required for the adoption of systems. Furthermore, it unifies the data formats and operations associated with instructions to the material handling equipment, thereby supporting efficiency improvement through the adoption of material handling equipment.

Fig.12 Conceptual diagram of collaboration with various types of material handling



Social Solutions

1 Onshore Power Supply System

As a means of improving the environment and reducing CO₂ emissions in the ship and harbor system fields, onshore power supply systems have been attracting attention, which supply necessary power from land to ships that berth with the engine stopped. Fuji Electric has developed an onshore power supply system based on the “FRENIC-RHC-E Series” pulse width modulation converters. The main features are as follows:

- (1) Applicable to even a vulnerable power system of ports and ships because of the optimized design of harmonic filters to reduce the total harmonic current distortion THDi of the onshore system to 2.5% or less and the total harmonic voltage distortion THDv of the ship side system to 1% or less
- (2) Multiplex control to enable up to 4 parallel operations and accommodate a wide range of capacities up to 3 MVA. In the event of a converter failure, the system can disconnect only the corresponding converter to continue operation.

Fig.13 Pulse width modulation converter for onshore power supply systems



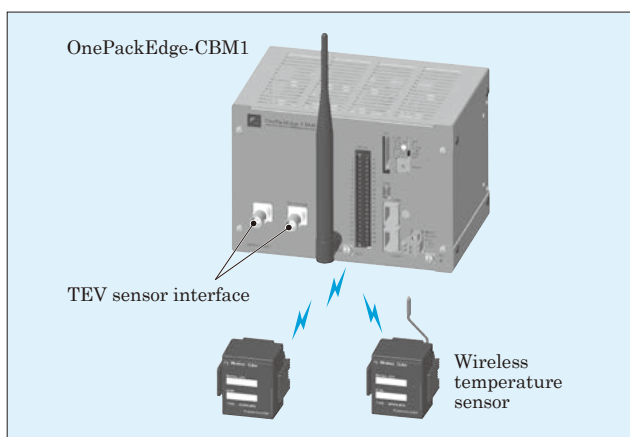
Field Services

1 Switchboard Deterioration Information Collection System for “Comprehensive Service for Smart Industrial Safety”

Maintenance including predictive maintenance is required to be more efficient by monitoring the deterioration trend of electrical equipment such as high-voltage switchboards. To address this demand, Fuji Electric offers the “Comprehensive Service for Smart Industrial Safety” to improve the efficiency of maintenance management through data collection, analysis, and diagnosis using IoT. As one of the functions to monitor switchboard deterioration, we have developed the “OnePackEdge-CBM1” information collection system, which monitors trends in partial discharge and local overheating. The main features are as follows:

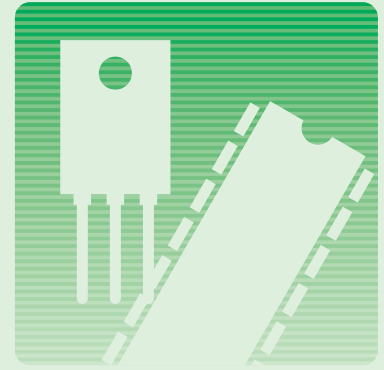
- (1) Trends in partial discharge and deterioration can be monitored by connecting two TEV sensors for either indoor or outdoor use.
- (2) Up to 32 wireless temperature sensors can be installed on switchboard components, such as busbars and cables, to detect local overheating caused by looseness of conductor connections and other factors.

Fig.14 Switchboard deterioration information collection system for switchboards



Semiconductors

Industrial
Automotive



Efforts to achieve a decarbonized society are accelerating as a means of solving the global climate change problem. The electrification of automobiles and the improvement of the efficiency of power electronics equipment for the stable and efficient use of energy are effective approaches to decarbonization, and Fuji Electric's power semiconductors are key devices that contribute to the achievement of this goal. Specifically, Fuji Electric has created products that meet the needs for higher efficiency, reduced size, higher reliability, and more, as well as numerous innovative technologies with a focus on power semiconductors typified by insulated gate bipolar transistors (IGBTs).

Industrial

Fuji Electric has expanded the application of its 7th-generation IGBT technology, which is well known for its use in industrial modules, and promoted the expansion of its lineup of products with low loss and guaranteed high-temperature operation, completing the creation of a lineup of 7th-generation IGBT standard modules. Furthermore, as part of recent efforts toward achieving a decarbonized society, we have promoted a new lineup of the "HPnC" high-capacity modules to meet market demands in line with the expansion of electric railways and renewable energy markets for solar and wind power, among other sources. Such demands include increases in the capacity of power conversion equipment and reductions in the size and weight of equipment. The HPnC greatly reduces internal inductance and is a package suitable for high-speed switching and multiple parallel connections. In this way, it contributes to the reduction of size and increase in power density of equipment.

In addition, we will complete the creation of a lineup of the 7th-generation intelligent power modules (IPMs) with built-in drive and protective functions for applications such as FA, machine tools, and air conditioning equipment to contribute to increased efficiency, reduced size, and higher reliability in power conversion equipment. In addition to the conventional package lineup, we have established a new lineup of small "P639" packages that employ the 7th-generation IGBT and reverse-conducting IGBT (RC-IGBT) technology. Through these

products, we will further increase efficiency and reduce size, thereby contributing to space-saving as a result of smaller equipment.

At the same time, we are expanding the application of SiC devices, which are expected to be the next generation wide-bandgap (WBG) devices. We will also follow up with a lineup of SiC modules equipped with the 2nd-generation SiC metal-oxide-semiconductor field-effect transistors (SiC-MOSFETs), contributing to increased efficiency and reductions in the size and weight of power conversion equipment.

In terms of IC products, we have developed the "FA6C60 Series" of 4.5th-generation LLC control ICs designed to reduce costs for power supply systems. In conventional products, a series regulator composed of an external circuit supplied power to the IC. By contrast, this series incorporates this circuit into the IC to reduce the number of power supply components, thereby contributing to the reduction of costs for power supply systems.

Automotive

In the automotive field, we have developed and released power modules that incorporate three-phase inverter bridge circuits for inverters used in motor control for electrified vehicles (xEVs). Two types of newly developed products are described below.

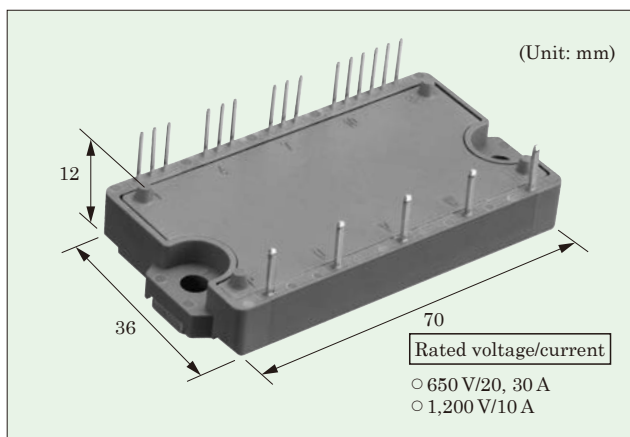
We have developed the "M675" for the Chinese market, where xEV demand is increasing as a result of the new energy vehicle (NEV) regulations. This product features improved output performance and heat dissipation while maintaining the same main unit size and fastening hole and water channel hole positions as the previously released "M653." In addition, it has been designed to be high-performance and easy to replace. Furthermore, we have developed a series of extended models that has the same profile as the currently mass-produced M660 (190-kW motor capacity), but with a current rating that corresponds to a motor capacity of 150 kW. Like the M660, this product uses the RC-IGBT chips, and the resin molding and lead frame structure enable high power cycle capacity. Both products use a direct liquid cooling system with a closed-type cooler, which improves cooling efficiency to reduce size and increase power density.

Industrial

1 Lineup of “P639” 7th-Generation IGBT-IPMs

Intelligent power modules (IPMs) are used to save power and space in power conversion equipment, and further reductions in loss and size are required. By applying 7th-generation technology, Fuji Electric has reduced the losses of the 7th-generation IPMs by 10% compared to that of the 6th-generation IPMs and has increased the allowable chip temperature during continuous operation from 125°C to 150°C. With these improvements, the 7th-generation IGBT-IPM has reduced package size even under the same current conditions. We have developed a new lineup of the “P639” 7th-generation IGBT-IPMs, which are 27% smaller than the existing package, the “P629.” For these products, we employed an RC-IGBT chip featuring integrated IGBT and FWD chips to reduce the thermal resistance in addition to the footprint size. Due to this feature, the “P639” lineup can help reduce the size of power conversion equipment without enhancing the heat dissipation performance.

Fig.1 “P639”

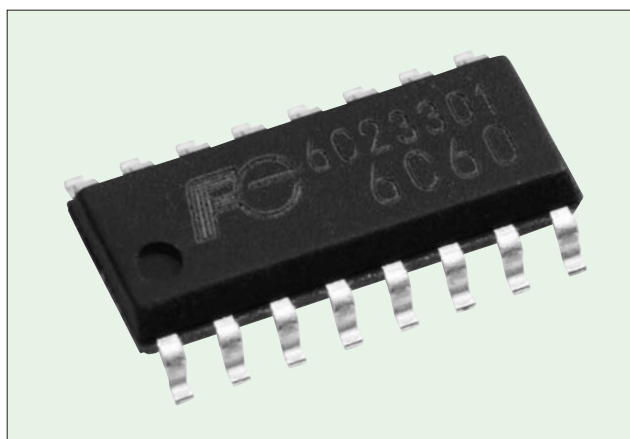


2 “FA6C60 Series” 4.5th-Generation LLC Control ICs

LLC current resonant circuits are widely used for power supplies used in flat-screen TVs and LED lightings, for which standby power and cost reductions are required. In response to this demand, Fuji Electric has developed the “FA6C60 Series” 4.5th-generation LLC control ICs. The main features are as follows:

- (1) Its burst control suppresses sudden changes in the output current at the start of switching under light loads by adjusting the ON width using a soft start function, preventing transformers from making audible noise. The ON width can be configured optimum with the state setting function, also lowering standby power.
- (2) This control IC includes input power supply circuits for driving MOSFETs and controlling PFC, which were previously attached externally, to reduce power supply components, saving costs.

Fig.2 “FA6C60 Series”

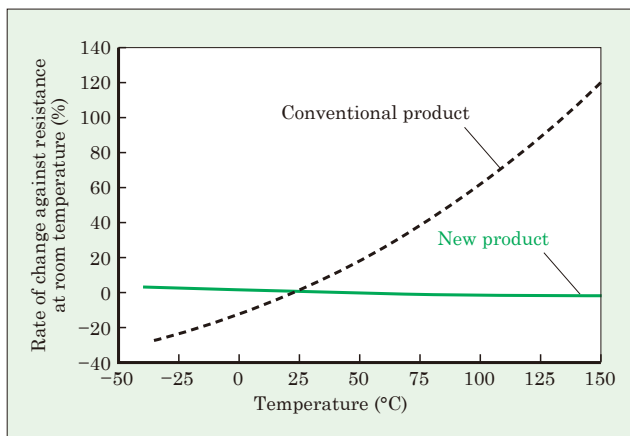


3 Built-in Gate Resistor Chips for High-Power Modules

High-Power semiconductor modules are required to inhibit both short circuit oscillation and turn-on loss at high temperatures. Therefore, for the gate resistor driving the semiconductor chip in the module, not only the resistance value must be optimized, but the resistance increase must also be suppressed as the temperature rises. In response to these needs, we have developed a gate resistor chip to be built into modules with a low temperature change rate for the resistance value by combining Poly-Si resistor manufacturing technology with a Si substrate with low specific resistance. The main features are as follows:

- (1) A rate of change within $\pm 2.5\%$ (conventional products: up to 120%) with respect to the resistance at room temperature in the range of -40°C to $+150^{\circ}\text{C}$
- (2) Capable of adjusting the optimum resistance value without changing the semiconductor chip size by changing the dimensions of Poly-Si
- (3) Can be manufactured in the Si power semiconductor manufacturing process

Fig.3 Temperature dependence of resistance



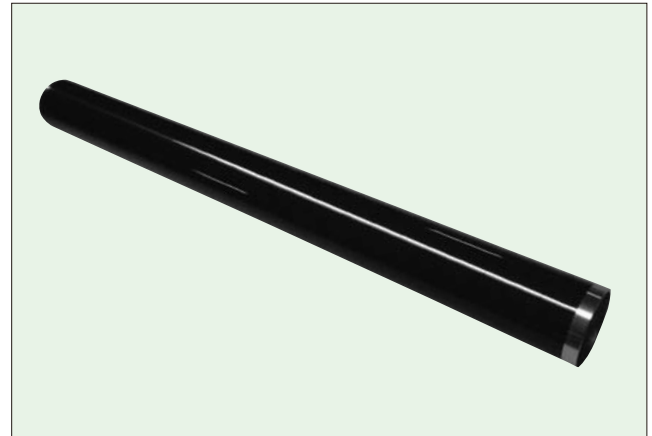
Industrial

4 Highly Durable Positive Charging Organic Photoconductors for Fast Printing

Photoconductors are key components responsible for image quality in electrophotographic printers and copiers, which are seeing advancements in size reduction, speed, and colorization. In addition, since a color machine requires accurate color reproducibility, it must suppress the fluctuations in characteristics over long periods of time. In particular, as the equipment becomes smaller and faster, improving the surface potential stability against the retention of the discharge generation gas has become a challenge.

Fuji Electric has improved the ability to transport charges generated by exposure light by combining multiple high-mobility charge transport materials, thereby achieving a printing speed of 1.5 times that of the conventional product. In addition, we optimized the amount of additive to fill the space of the photosensitive layer, and improved the gas resistance twofold. As a synergistic effect of these improvements, the stability of the surface potential has improved, and small, medium-speed color machines are able to retain color reproducibility for about three times longer.

Fig.4 Positive charge organic photoconductor



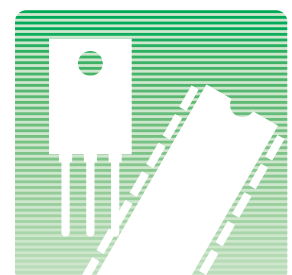
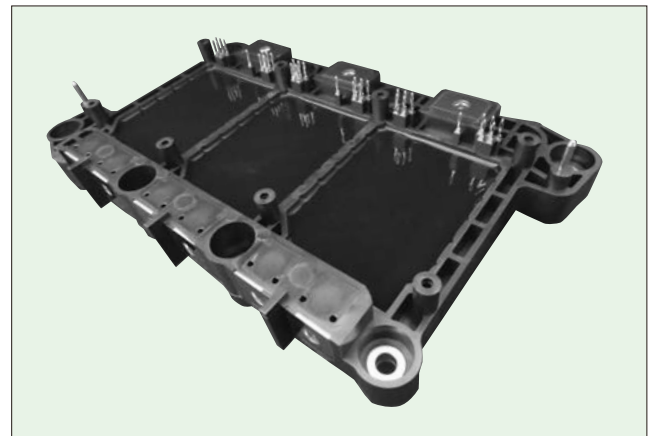
Automotive

1 Expansion of the “M660” Automotive Power Semiconductor Modules

In recent years, as the lineup of electric vehicles has expanded rapidly, and power modules are required to accommodate various inverter capacities. For this reason, Fuji Electric has expanded its “M660” lineup of automotive power semiconductor modules (with a motor capacity of 190 kW), which is currently in mass production. We have changed the chip size and redesigned the internal structure to enable the same package as the 190 kW product to support 150 kW (rating: 800 A/750 V). The main features are as follows:

- (1) Use of RC-IGBT chips has reduced size and loss.
- (2) Closed-type direct water cooling system has downsized the cooling unit.
- (3) Plastic molding and lead frame connection has increased high power cycle capability.

Fig.5 “M660” (150 kW)



Power Generation



Renewable Energy and New Energy Solution Services

As efforts toward the realization of a decarbonized society become a global trend, in Japan, the basic policy for achieving a Green Transformation (GX) was approved by Cabinet decision in February 2023.

To reduce greenhouse gas emissions and achieve carbon neutrality by 2050, suggested policies include “promoting renewable energy in harmony with local communities” and “utilizing nuclear power with safety as the top priority” while ensuring a stable supply of electricity.

In the power generation segment, Fuji Electric is steadily promoting the transformation of our business portfolio and accelerating our contributions to society. For example, we are promoting the introduction of renewable energy sources, such as geothermal, hydroelectric, solar, and wind power, in harmony with local communities; decentralized power sources, such as energy storage systems; and power supplies with high resilience; as well as making efforts to further ensure safety in nuclear power generation. We are also expanding our efforts to bring to market the products necessary for realizing a hydrogen society.

Renewable Energy and New Energy

In the field of geothermal power generation, in which Fuji Electric enjoys a leading share of the market, we are making continued efforts to leverage our track record of our project experience in Japan and in countries in the Asia and Africa regions, as well as in Iceland, New Zealand, the United States, and other promising regions. In 2024, the Tauhara Geothermal Power Station in New Zealand is scheduled for completion as the power station with the world’s largest output of a single unit. In Japan, the Appi Geothermal Power Station owned by Appi Geothermal Energy Corporation is also scheduled for completion. In addition to promoting ongoing projects in Japan and overseas, we will aim to increase the number of orders we receive. We will thus strengthen our efforts in binary geothermal power generation facilities equipped with locally sourced major equipment in Japan and develop stronger relationships with local companies overseas, thereby enhancing our presence.

In the field of hydropower generation, nearly 20 replacement and renovation projects are scheduled to be completed in FY2023. In these projects, we are promoting initiatives such as the improvement of power generation output through the use of the latest technology, as well as the application of the “hybrid servo system,” an environmentally friendly hydraulic turbine control mechanism designed with local communities in mind. Going forward, we will continue to actively work on projects to replace aging equipment and renovate power generation equipment for long-term use. We will also expand the scope of our products and services to promote pumped storage generation, which plays an important role as a regulating power source, as well as digital transformation (DX) in equipment operation and maintenance.

In the field of solar and wind power generation, companies and local governments in Japan are introducing self-consumption power generation equipment and constructing regional microgrids. Meanwhile, Fuji Electric is proposing solutions that best meet diversifying and complex needs by combining our strengths, such as our output stabilization technology that uses storage batteries, and our expertise on collaborative operation with existing power generation equipment that we have cultivated at our own factories. March 2023 saw the completion of a regional microgrid with solar power generation equipment designed for regional use, contributing to the expansion of the introduction of renewable energy.

In the field of fuel cell power generation, we are promoting the development of a hydrogen fuel cell power generation system that is highly responsive, durable, and capable of continuous power generation by utilizing system design technology cultivated in phosphoric acid fuel cells and control technology that intermittently operates multiple battery modules. We will launch it in FY2024 to contribute to the realization of carbon neutrality.

Solution Services

In the field of maintenance and replacement, we are aiming to provide more high value-added offerings in response to the trend toward decarbonization, responding

to the need for improved equipment reliability due to the tight electricity supply demand balance, and providing a wide range of service options such as deterioration diagnosis and remaining life assessment to improve equipment utilization. In Japan, we are working to minimize the risk of the shutdown of existing thermal power stations and to provide solutions that will contribute to the increase of power output. Outside Japan, we are actively proposing maintenance, replacement, and increased power output solutions by leveraging our extensive delivery record of geothermal power generation equipment.

In the field of nuclear power, we are making use of Fuji Electric's unique technologies, which are mainly focused on remote handling, radiation measurement, and radioactive waste treatment processes, such as remote cutting and advanced solidification. Using these technologies, we are continuously contributing to the safe resumption of operations of nuclear power stations in

Japan, as well as to radioactive waste treatment and decommissioning, and next-generation innovative reactors (including high-temperature gas-cooled reactors, fast reactors, and fuel production for fast reactors), which are currently attracting attention. In FY2022, we also worked on applying SIAL[®], an advanced solidification technology, in radioactive waste and decommissioning, as well as the development of multi-nuclide analysis to meet the need for rapid and accurate quantitative measurement of radionuclides.

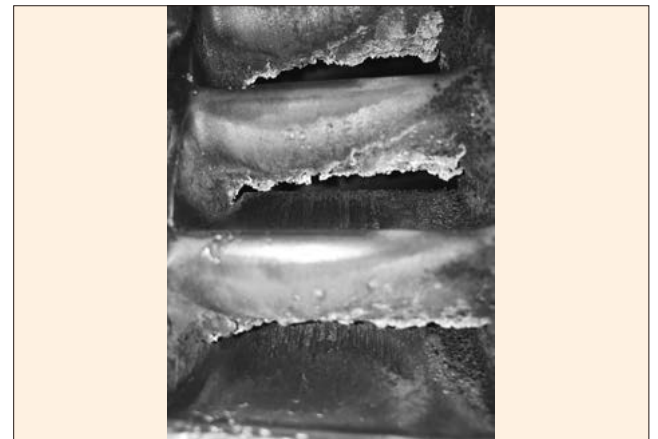
We will continue our efforts aimed at a virtuous cycle between the economy and the environment, from the supply of highly efficient and environmentally friendly clean energy to the provision of services such as monitoring, maintenance, and management of a safe and secure energy supply.

Renewable Energy and New Energy

1 DLC Coating on Geothermal Turbine Blades as a Scale Countermeasure

Geothermal steam, which is an energy of geothermal power generation, contains large amounts of silica and other impurities. When silica is deposited on the blade surface of a turbine in the form of scales, the deposition narrows the steam flow path and causes reductions in power output. For this reason, when a drop in power output caused by scale adhesion is observed, the blade surface needs washing with high-pressure water or other means. Fuji Electric has developed a DLC coating technology to suppress scale adhesion on the surface of geothermal turbines. Using real steam from a geothermal power plant, we demonstrated that the amount of adhering scales can be reduced to a tenth or less. We also confirmed that the DLC coating was effective in reducing scale adhesion caused by geothermal hot water. Going forward, we will continue to develop coating technology for pipes and valves that come in contact with geothermal hot water.

Fig.1 Scale adhesion to the turbine blade surface



2 Commencement of Commercial Operation of the Yufutsu Biomass Power Plant, Yufutsu Energy Center, LLC.

Fuji Electric delivered key equipment including a steam turbine, generator, and condenser to Yufutsu Biomass Power Plant Unit #1 owned by Yufutsu Energy Center, LLC. through TAKUMA Co., Ltd. The plant began commercial operation in March 2023. The main features are as follows:

- (1) The highest power generation output of 74,950 kW in dedicated biomass combustion plants in Japan.
- (2) Fuels for the plant include wood chips, palm kernel shells (PKSs), and unused wood such as forest residue from Hokkaido, thereby contributing to global warming countermeasures and the local production and consumption of energy.
- (3) Use of a single-casing non-reheat turbine and a brushless excitation air-cooled generator achieves high efficiency and high reliability.

Fig.2 Steam turbine and generator for the 75-MW biomass power plant



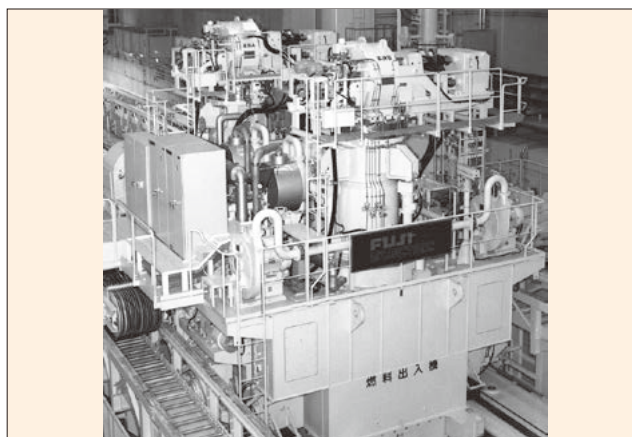
Solution Services

1 Completion of Fuel Unloading at the Prototype Fast Breeder Reactor Monju

At the prototype fast breeder reactor Monju, fuel unloading, the first stage of the decommissioning plan, was completed in October 2022. As Fuji Electric had supplied the fuel handling facility system, it provided technical support for the entire fuel unloading operation and made a significant contribution to the completion of this task, which is one of the most important steps in the first stage of decommissioning. The fuel handling facility system is composed of the ex-vessel fuel transfer system and many other systems. The fuel handling facility system requires advanced technology to remotely and safely handle fuel assembly in an environment where visibility is obscured by liquid metal sodium, which is the coolant of the fast reactor. Despite this, the long-term fuel assembly unloading and handling operation was completed successfully.

By actually operating the fuel handling facility system, we were able to obtain a large amount of data. We will utilize this data in the development of the next fast reactor.

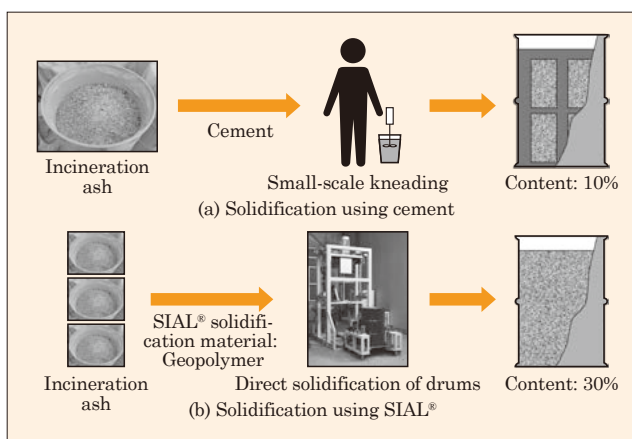
Fig.3 External appearance of the ex-vessel fuel transfer system



2 Applying SIAL®, an Advanced Solidification Technology, to Radioactive Waste

Low-level radioactive waste generated at nuclear facilities is solidified in drums with solidifying materials such as cement and disposed underground. Fuji Electric is focusing on geopolymer that can solidify a larger amount of waste, and is working with Jacobs to develop SIAL®, which has a proven track record overseas, for application in Japan. Cement can solidify only a small amount of incineration ash, a waste material, because it can contain substances that affect cement solidification, whereas geopolymer, which has a different chemical structure, is expected to be able to solidify a large amount. In solidification tests using waste that simulates incineration ash, we confirmed that SIAL® can solidify more than three times as much as cement can do. Going forward, we will conduct demonstration tests using radioactive incineration ash stored at the Tsuruga Power Station of the Japan Atomic Power Company to contribute to radioactive waste disposal.

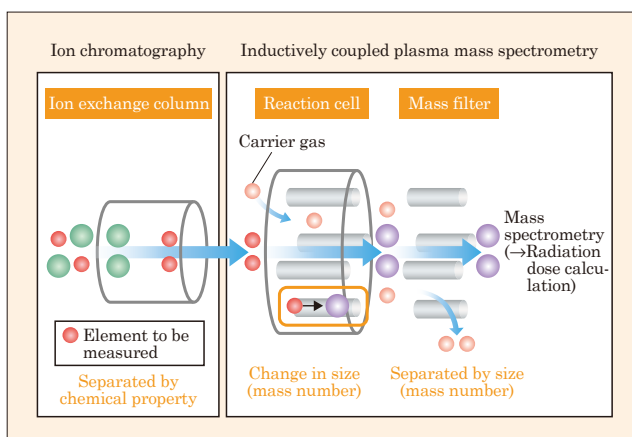
Fig.4 Comparison of waste solidification methods



3 Inductively Coupled Plasma Mass Spectrometry for Analyzing Radionuclide

Low-level radioactive waste generated at nuclear facilities is solidified in drums using cementitious materials and then disposed. Radionuclides contained in the waste are regulated in type and amount, and they have to be analyzed before being disposed. However, for some radionuclides, the long time required to measure the radiation dose has been an obstacle to smooth disposal. With a focus on inductively coupled plasma mass spectrometry as a new method for measuring radionuclides, Fuji Electric has developed a rapid measurement technology for chlorine 36 in preparation for the decommissioning of the Tokai Power Station operated by the Japan Atomic Power Company. The elements to be measured were conventionally separated and analyzed in advance through a complex pretreatment procedure. This method simplifies the pretreatment procedure through the combination of ion chromatography. This can shorten the measurement time to 1/30 of what was previously possible.

Fig.5 Principle of the developed radiation dose measurement method



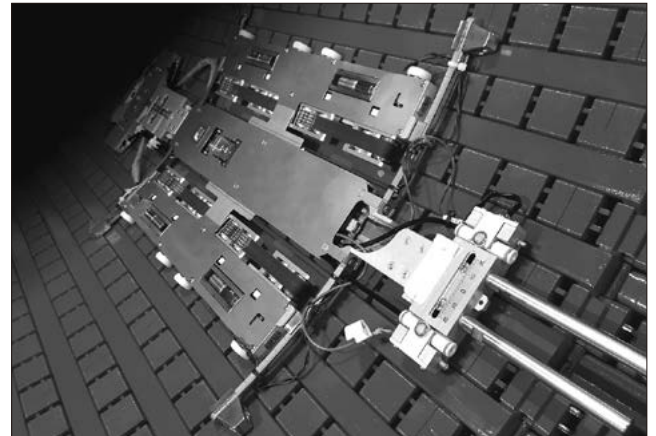
Solution Services

4 Generator Inspection Robot

Precise inspection of generators must be carried out on a regular basis in order to ensure stable operation of a power plant. The problem, however, was that these inspections were costly and took long periods of time to pull out the rotor. To address this problem, Fuji Electric has developed a generator inspection robot that runs through the narrow gap between the generator stator and the rotor without pulling out the rotor, enabling users to plan optimal maintenance work by understanding the accurate status of the generator. The developed generator inspection robot is available in two types, the standard type and the advanced type, which can perform the following inspections, respectively.

- (1) Standard type (15 mm thickness)
Stator and rotor visual inspections and iron core defect inspections
- (2) Advanced type (19.8 mm thickness)
All of the standard type inspection items, and stator wedge loosening inspections

Fig.6 Generator inspection robot



Food Distribution



Vending Machines
Store Distribution

With the shift of COVID-19 to Category 5, the food distribution market is facing a strong need to respond to environmental issues (SDGs and carbon neutrality) and the declining birthrate and aging population, which are fundamental social issues.

Vending machines

As a result of customers striving to achieve their 2030 environmental targets, as well as the recent rise in electricity prices, customer requirements for energy saving have reached unprecedented levels. There is a strong demand for the saving of natural resources, not only for the power used in operations, but also in installation and management. To meet these needs, Fuji Electric has developed the “Sustainable Vending Machine Series,” which promotes environmental measures such as energy saving and the minimization of natural resource consumption. In this series, we have developed a new inverter cooling unit equipped with a control system that can be flexibly applied in vending machines of different sizes with different capabilities while further improving the efficiency of heat pump operation. Furthermore, we have strengthened the insulation of the housing to reduce the amount of power consumption by up to 20%. To reduce the machine weight, we have also devised a bending method for the sheet metal used for the bases of vending machines to reduce the thickness of the plate while retaining its strength. In addition, we have reduced the packaging materials of the vending machine in order to save natural resources during installation.

In terms of functionality, we have developed “dynamic pricing buttons” that can be used to automatically change the prices of products. These buttons receive instructions from an external communication device to automatically change the information displayed by the LEDs in the product selection buttons, such as the price. The price display has changed from the con-

ventional three digits to four digits to allow high price items to be sold. It also enables the additional display of text such as “Highly recommended!” and “Discount” for customers to promote the products that the vendor wants to sell. This function can eliminate the need for manual price changes and point-of-purchase (POP) advertising for individual vending machines, thereby enabling significant improvements in operational efficiency.

Store Distribution

In the store distribution field, Fuji Electric has developed a refrigerated showcase with a built-in cooling unit for improved energy saving. This showcase makes it possible to take full advantage of the characteristics of the refrigerant by employing an electronic expansion valve in the cooling circuit while controlling the inverter compressor with high efficiency in response to internal load fluctuations. By combining these compressors with electronic expansion valve control, we have reduced the amount of power consumed by approximately 32% compared to existing models.

In the store distribution field, the “Act on Rational Use and Proper Management of Fluorocarbons,” which came into effect in 2015, requires refrigerants used in refrigeration and air conditioning equipment to have low global warming potential (GWP). We are also planning new developments to achieve further reductions in the impact we have on the environment.

Going forward, we will strike a balance between meeting the needs of society, such as through energy saving and carbon neutrality, and meeting the needs of customers in terms of labor saving and resource saving. Fuji Electric will continue to strive to develop products to remain a pioneer in the retail and distribution industry.

Vending machines

1 “Dynamic Pricing Buttons” for Vending Machines

Fuji Electric has developed “dynamic pricing buttons,” which allow the display of prices and promotional information to be changed remotely to increase sales and reduce the disposal of products sold at vending machines. The product selection button displays the price with its internal LEDs, and the displayed content can be changed remotely in real time using an external communication device. The main features are as follows:

- (1) Functions to bring attention to products the vendor wants to sell by displaying text such as “Highly recommended!” and “Discount” to contribute to sales growth
- (2) Automatic changing and display of prices of beverages that are about to expire to promote sales, thereby contributing to the reduction of food loss
- (3) A function to display product temperature zones, which eliminates the need for physical cold or warm signs, making vending machine operations more efficient when changing products

Fig.1 “Dynamic pricing buttons”



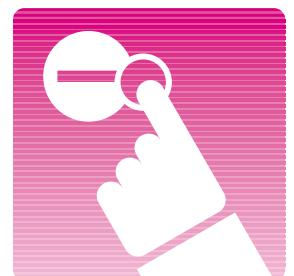
Store Distribution

1 Refrigerated Showcase with a Built-in Cooling Unit Equipped with New Cooling Unit Control Capability

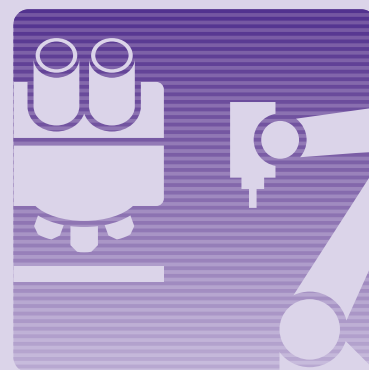
Fuji Electric is developing a refrigerated showcase with a built-in cooling unit designed to save energy, thereby meeting the needs of customers who are working toward the realization of a sustainable society. This time, we have developed a refrigerating showcase with a built-in cooling unit that maintains the internal refrigeration temperature range (3°C to 8°C) through a new cooling unit control feature. The main features are as follows:

- (1) Inverter control of compressor rotational speed according to internal temperature changes has reduced power consumption by approximately 22% compared to conventional machines.
- (2) Control of temperature differences between the inlet and outlet of the cooler with an electronic expansion valve improves the heat exchange efficiency, reducing the amount of power consumption by approximately 10% compared to conventional machines.

Fig.2 Refrigerated showcase with a built-in cooling unit



Fundamental and Advanced Technologies



Fundamental Technology
Advanced Technology

Fuji Electric is engaged in research and development of fundamental and advanced technologies to create new customer value through the realization of green transformations (GX) and digital transformations (DX).

A DC bus system is a promising GX technology to efficiently use decentralized power supplies, such as storage batteries and fuel cells, and a water electrolyzer to produce hydrogen, which is expected to become widely used. To improve energy conversion efficiency, we have developed bi-directional isolated DC/DC converters. By using a new conversion circuit system, we have demonstrated that high conversion efficiency can be maintained over a wide load range, and development is in progress to achieve DC bus systems.

With regard to the switchgear used in substation equipment, we have developed a technology to use built-in heat-absorber plates to cool high-temperature gas generated in short circuit arc accidents. This technology eliminates the need for an accessory structure for discharging hot gas to the outside, thereby improving the flexibility of switchgear in terms of where it can be installed.

We have been developing insulation technology to further reduce the size and weight of electrical equipment. For example, we have developed a technology to control the dispersion of fillers in insulating resin to prevent the decrease in withstand voltage caused by the aggregation of fillers when highly thermally conductive fillers are mixed with the resin. In the future, the technology will be applied to sealing materials for power semiconductors and substation equipment.

We have developed a 3.3-kV trench gate SiC superjunction metal-oxide-semiconductor field-effect transistor (SJ-MOSFET) chip to further reduce loss in power semiconductors. Compared with conventional trench gate MOSFETs, the total loss at 175°C has been reduced by half. Furthermore, for the vertical GaN-MOSFET, which we aim to put into practical application in the future, we expanded the chip area by combining a miniaturized active region achieved using ion implantation technology with multilayer wiring electrodes, thereby succeeding in increasing the output current to 1 A at

maximum.

For the first time in the industry, we have developed a highly accurate scale generation prediction technology for complex geothermal steam properties, which was designed to be applied in geothermal power generation equipment. The use of this technology contributes to the efficient maintenance by assisting the formulation of appropriate maintenance plans for geothermal power generation equipment and preventing sudden failures.

To further reduce the power consumption of refrigerated and frozen showcases widely used in food sales, we are developing a functional coating technology that reduces the energy required for defrosting by preventing frost formation on heat exchangers installed in showcases.

Among DX we have developed is a technology to meet the requirements from electric utility companies that participate in the energy market, which has been opened as electricity deregulation. The technology is to forecast the price of electricity in the power market and create an exchange plan based on the forecast to maximize profits by effectively utilizing storage batteries. This allows the use of a wide range of information, such as nationwide supply and demand information, to improve prediction accuracy and track sudden price fluctuations based on short-term historical data.

We have developed a multi-factor authentication technology to enhance the security of web application softwares. The technology enables the combination of conventional password authentication with one-time password or client certificate authentication to enhance security.

We have developed a moving image recognition artificial intelligence (AI) technology with the aim of reducing the amount of labor required for monitoring work using cameras in places such as railway station platforms. The technology is capable of recognizing and tracking moving people and objects from recorded video footage in real time, and automatically determining their status.

We have developed an optimum production scheduling technology to improve production planning efficiency

in factories. Using optimization AI, optimum scheduling can be performed in a short amount of time by simply inputting conditions such as connections between processes and time information for manufacturing lines, thereby contributing to improvements in productivity and labor saving in factories.

In terms of model predictive control of programmable controllers used in process automation sites, we have developed a technology for automating the adjustment of control parameters, which previously depended on the experience of skilled workers. This allows plant operations to be performed in a stable manner while simultaneously reducing engineering costs.

In addition to technologies that contribute to customer DX, we have also developed technologies that support DX in research and development.

To achieve low noise in transformers, we have developed a simulation technology to estimate the noise caused by the magnetostriction of electromagnetic steel sheets for cores. By linking together magnetic field analysis, structural analysis, and acoustic analysis, the vibrations and noise caused by magnetostriction can be accurately estimated.

We have developed a software execution infrastructure that can streamline the development of software for Internet of Things (IoT) systems. This makes it easy to

port software between edge controllers with different hardware and operating systems, thereby reducing the labor hours required for development.

We have developed a technology to predict the fatigue life of electronic parts used in transportation machinery and other equipment that is subject to various vibrations from the outside. This enables designs that prevent accidents and failures, as well as the shortening of development periods as a result of the reduction of reliability testing processes. We are also developing technology to provide new customer value. We have developed a small, high-precision electric current sensor that uses no magnetic core. This sensor will contribute to the reduction of size and cost of the equipment in which it is used.

We are developing a technology to automatically clean the inside of counter fixtures that are being introduced in convenience stores. Furthermore, we are developing components that suppress food adhesion, as well as a technology that enhances the cleaning effect of hot water.

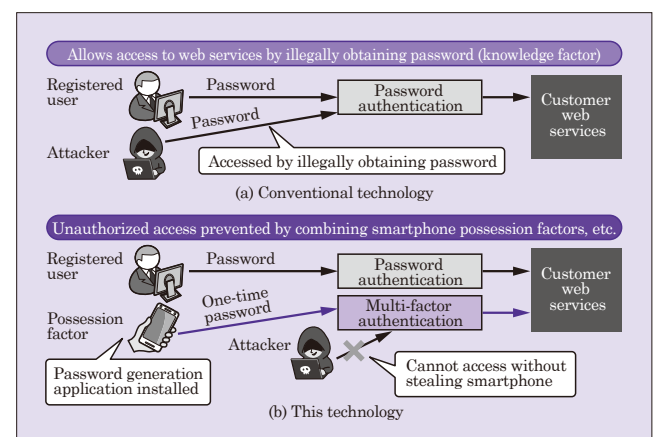
Fuji Electric will continue to strengthen such fundamental and advanced technologies and contribute to the creation of a sustainable society through the energy and environmental fields.

Fundamental Technology

1 Web Application Multi-Factor Authentication Technology

With the advancement of IoT and DX, the threat of cyber-attacks has increased, and there is a need to strengthen the security of products and systems. Seen in many web applications, single-factor authentication methods, such as password authentication, are particularly easy to use, but when using such methods, it has become difficult to prevent fraud caused by spoofing. As such, strengthening authentication is an urgent challenge. To address this issue, Fuji Electric developed a multi-factor authentication technology that enables authentication using one-time passwords, client certificates, and other factors in addition to passwords. We have implemented this technology using open source software, converting necessary functions into a platform to eliminate the need for application modification, thereby facilitating the introduction of the technology into existing systems. We will promote the application of this technology to enhance the security of web applications.

Fig.1 Multi-factor authentication example (one-time password authentication)



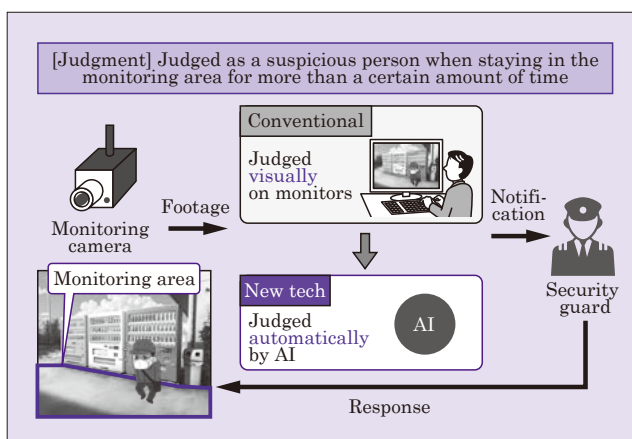
Fundamental Technology

2 Status Monitoring Technology Using Moving Image Recognition AI

Monitoring operations using cameras need labor saving and reliable surveillance with reduced oversights and fewer judgment errors. Fuji Electric has developed a moving image recognition AI technology that recognizes and tracks people and objects in footage in real time and automatically determines the status of each object. When used to detect suspicious people, the AI determines that there is a suspicious person and notifies security staff if the person stays within a predetermined monitoring area for more than a certain amount of time. In this way, by automating monitoring work with AI, this technology enables labor saving and prevents oversights in monitoring operations. Moreover, by applying the expertise of monitoring personnel in the judgment rules, monitoring can be carried out in a consistent manner.

We will promote the application of this technology to contribute to the creation of a safe and secure society.

Fig.2 Example of application in the monitoring of suspicious people

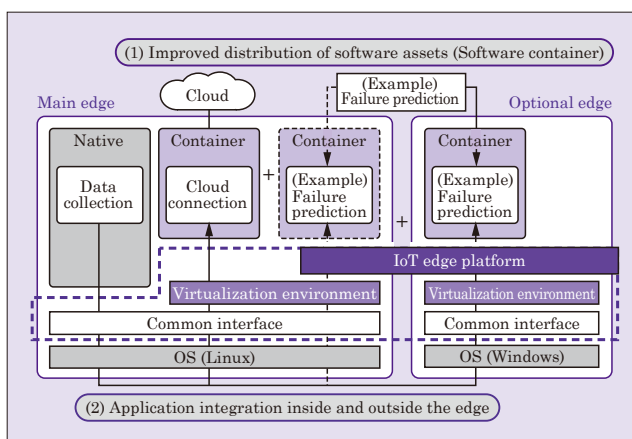


3 IoT Edge Platform

IoT systems are shifting from cloud-centric configurations to field-based edge-centric configurations designed to improve security, reduce traffic, and provide high-speed responses. At the same time, the extension of functions on systems that have already been installed has led to the issue of processing performance degradation due to the limitations of the hardware available for maintaining existing functions. To address this issue, Fuji Electric has developed an IoT edge platform with the following features:

- (1) Adopt of software containers and virtual environments improves the distribution of existing assets, including software with different operating systems, reducing development costs.
- (2) A common interface can associate the platform with applications inside and outside the edge regardless of the operating system to distribute processing and improve performance by adding edge devices.

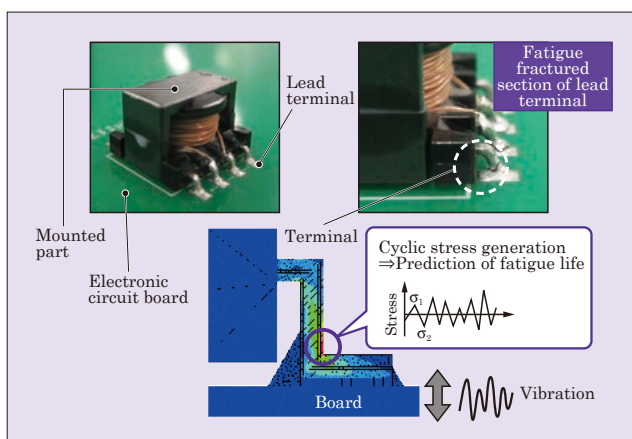
Fig.3 IoT system configuration example



4 Fatigue Life Prediction Technology for Electronic Parts

In the products that are subject to various external vibrations, such as transportation equipment (cars, railcars, and ships), a fatigue failure of an internal electronic component can occur, leading to serious accidents. The precautions against it are thus needed. To address this problem, Fuji Electric has developed a technology to predict the fatigue life of electronic circuit boards, which had been difficult to predict in the past. Damage caused by vibrations often occurs in places where stress especially increases, such as bent lead terminals of the parts mounted on electronic circuit boards, and it is important to understand this stress accurately to achieve life prediction. In response, by formulating the fatigue characteristics of the material by taking into account the concentration of stress due to bent shapes, and by developing a method capable of estimating the stress at bent sections with high accuracy, we have achieved life prediction for lead terminals of electronic parts. Using this method, the lifespan can be predicted with half of the error of the conventional method, thereby contributing to the improvement of reliability of electronic equipment and shorter development periods.

Fig.4 Lead terminal fatigue failure due to vibrations

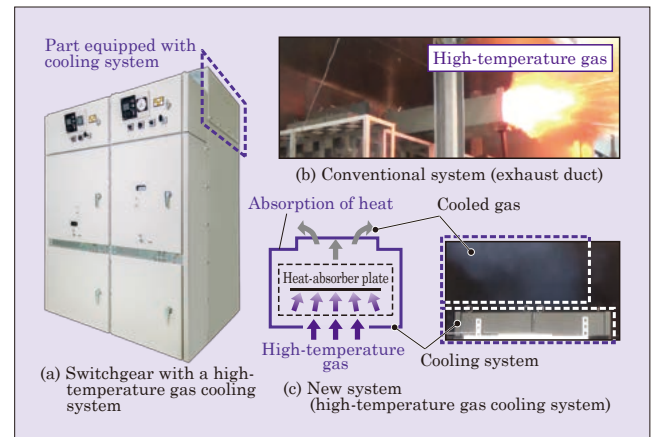


Advanced Technology

1 High-Temperature Gas Cooling Technology to Increase Flexibility in Selecting Switchgear Installation Sites

For switchgear used in substation equipment, the safety of the surroundings must also be ensured for when short circuit arc accidents occur. Until now, in case of short circuit arc accidents, switchgear installed indoors discharged high-temperature gas through the exhaust duct. However, there is a limited number of places where high-temperature gas can be discharged outdoors in chemical factories to prevent the occurrence of secondary disasters due to the ignition of chemical substances, and therefore, switchgear installation sites have been restricted. Fuji Electric has developed a technology to cool the gas temperature by proactively bringing the high-temperature gas generated in short circuit arc accidents into contact with heat-absorber plates. By equipping switchgear with a cooling system using this technology, it becomes possible to safely treat the gas generated during accidents inside the switchgear.

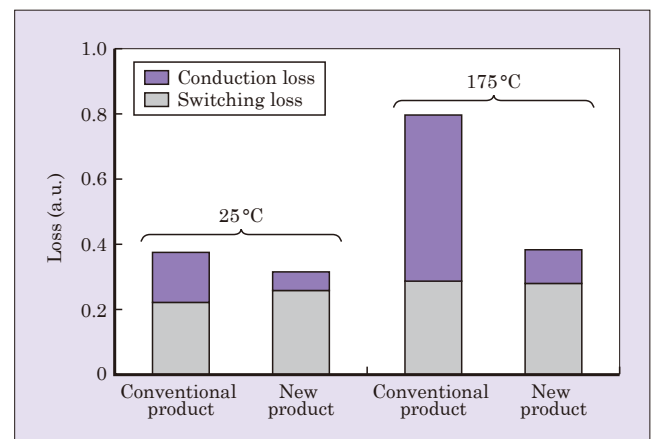
Fig.5 Differences in characteristics at the time of internal short circuit arc accidents



2 3.3-kV SiC Super-Junction MOSFET

Demand for low-loss SiC power semiconductors is increasing with the aim of using energy efficiently. Fuji Electric participated in the joint research body Tsukuba Power-Electronics Constellations (TPEC) and developed a 3.3-kV trench gate SiC super-junction (SJ) MOSFET chip, which is expected to further reduce losses. We evaluated the switching loss of the developed product and estimated the total loss in synchronous rectification. The trench gate SiC SJ-MOSFET has a slightly larger switching loss than the conventional trench gate SiC-MOSFET, but the conduction loss is smaller. As a result, the total loss per chip of the developed product was reduced by approximately 50% at 175°C compared to the conventional trench gate SiC-MOSFET.

Fig.6 Loss comparison between the conventional trench gate type and SJ-MOSFET

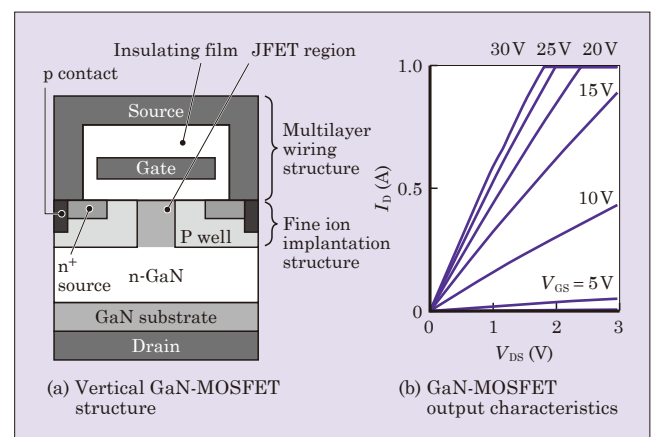


3 Vertical GaN-MOSFET with Currents of Several Amperes

Vertical MOSFETs with gallium nitride (GaN) are expected to be next-generation power devices that feature lower loss than silicon carbide (SiC). The development of GaN devices needs microstructure fabrication to reduce loss and area expansion to increase currents. Fuji Electric has increased the area of the chip by combining fine active region fabrication using ion implantation technology with corresponding wiring electrodes, thereby increasing currents up to 1 A. This operating current is the world's maximum as that of vertical GaN device fabricated using ion implantation technology, which is essential for high reliability.

In the future, we will further increase operating currents to enhance device performance that surpasses SiC-MOSFETs.

Fig.7 Vertical GaN-MOSFET structure and electrical properties

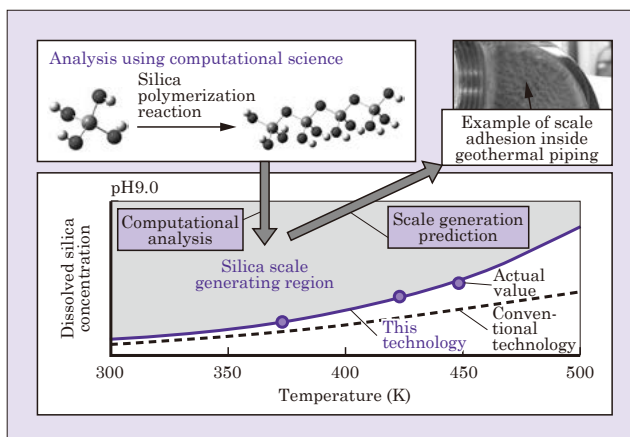


Advanced Technology

4 Technology to Predict Silica Scale Generation with Computational Science

Silica scaling results in flow rate reduction or improper performance in power generation. To preserve the power generation capacity, maintenance work is required to remove scales. Therefore, the prediction of the silica scale generation quantity is required, but conventional empirical prediction equations are not practical because they are not applicable when the properties of geothermal fluids change. To address this issue, Fuji Electric has developed the first non-empirical scale generation prediction technology in the industry, taking into account the pH and temperature dependence of geothermal fluids with computational science. This technology reproduces the polymerization process of silica scale generation from dissolved silica to generate scale, taking into account the type and concentration of impurities in the geothermal water, which are different for each geothermal power plant, thereby enabling highly accurate predictions. By planning maintenance schedules appropriately based on this newly developed scale generation prediction technology, it is possible to avoid reductions in power generation and sudden shut-downs of geothermal power generation facilities.

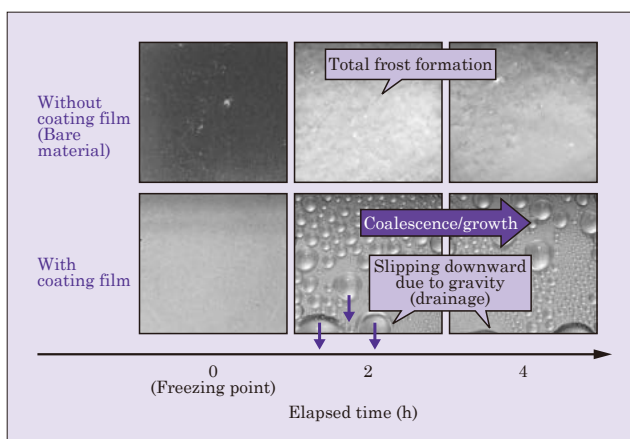
Fig.8 Prediction of silica scale dissolution curves



5 Frost-Free Technology for Heat Exchangers Using Functional Coating

To realize a decarbonized society, there is an increasing demand for energy saving in the use of refrigerated and frozen showcases in stores. When frost forms on the heat exchanger in showcases, the heat exchange efficiency decreases, and power consumption increases. To address this issue, Fuji Electric has worked with Kansai University to develop a frost-free technology that prevents frost formation by applying a special functional coating to heat exchangers. On the surface of the coating film of the functional coating, water remains in a supercooled state in which it does not freeze even at temperatures below 0°C. When applying functional coating to aluminum material, which is the main material used in heat exchangers, we confirmed that the water droplets caused by condensation on the surface remained unfrozen for more than 6 hours at -6°C, the temperature required for refrigerated showcases. We also confirmed that the water droplets grew over time and slid down due to their own weight. In the future, we will promote applications of this technology to actual showcases, thereby contributing to energy saving.

Fig.9 Observation results at -6°C cooling

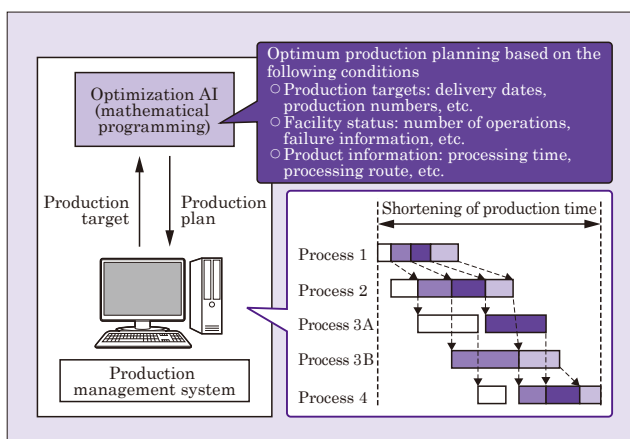


6 Optimum Production Scheduling Technology

Factory production plans used to be prepared by skilled workers who took time to consider various conditions, and even in cases that necessitated a change of plans due to sudden factors such as equipment failures, it was not possible to respond quickly. In addition, this method of developing plans was based on past experience and was not necessarily optimized. To address these issues, Fuji Electric has developed a technology to automate and maximize the efficiency of production scheduling by applying optimization AI (mathematical programming). The main features are as follows:

- (1) Ability to perform scheduling in time spans of several seconds to 10 minutes can quickly respond to sudden changes in plans.
- (2) Optimum scheduling can be achieved by simply providing manufacturing line conditions, such as process times and connections between processes, and scheduling objectives, such as production time reduction and production leveling.

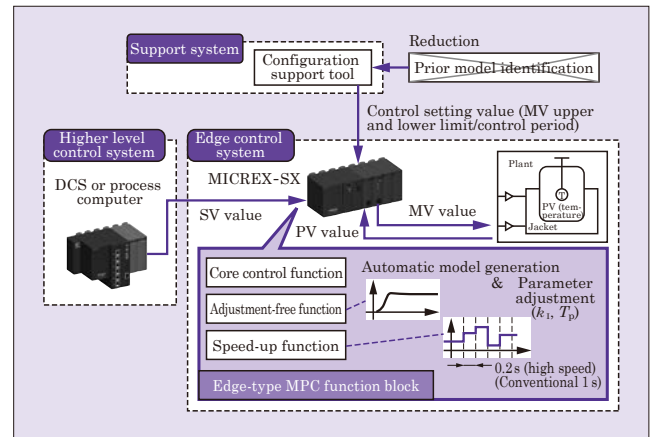
Fig.10 Production management system configuration



7 Edge-Type Model Predictive Control Technology with Automatic Model Creation

- The “MICREX-SX” programmable controller can incorporate an edge-type model predictive control (MPC) function to highly increase control precision by performing optimization while predicting the future response of the plant. Fuji Electric has developed an adjustment-free function and a speed-up function designed to stabilize operations and reduce engineering costs at plants. The main features are as follows:
- (1) Ability to automatically create plant models online using the controlled variable and the manipulated variable measured during operation can automatically adjust control parameters, such as gains and time constants, thereby reducing prior model identification tests that were required in the past.
 - (2) Control period sped up from the conventional 1 s to 0.2 s further improves control accuracy and response speed.

Fig.11 Example of edge-type model predictive control system

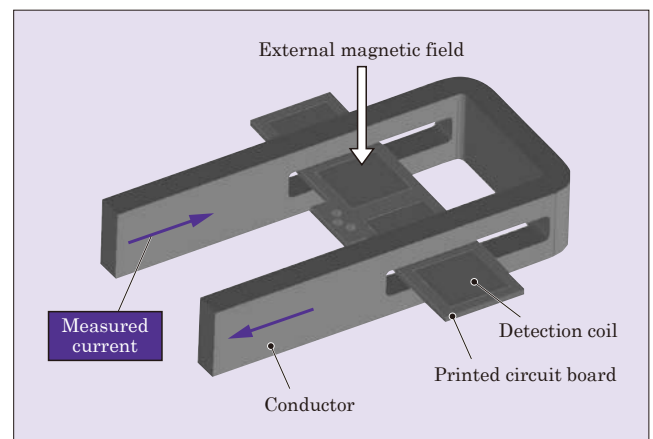


8 Technology of Current Measurement with Coreless Coils on a Printed Circuit Board

High-precision current sensors used in power monitoring are large and expensive because they use a magnetic core. To address this issue, Fuji Electric has developed a small, high-precision current sensor that uses no magnetic core. Equipping smart meters and other equipment with this current sensor will help reduce their size and costs. The features are as follows:

- (1) Use of detection coils formed on a printed circuit board eliminates the need for magnetic cores, thereby reducing size and cost.
- (2) Detection coils placed on both the left and right sides with respect to the energizing direction of the measured current offset the effect of the external magnetic field while detecting the magnetic field caused by the measured current, thereby achieving high accuracy.
- (3) A board with multiple coils placed in a through hole in the center of the conductor to suppress the effect of the magnetic field of the measured current fluctuating due to the displacement of the board position, thereby stabilizing current measurement.

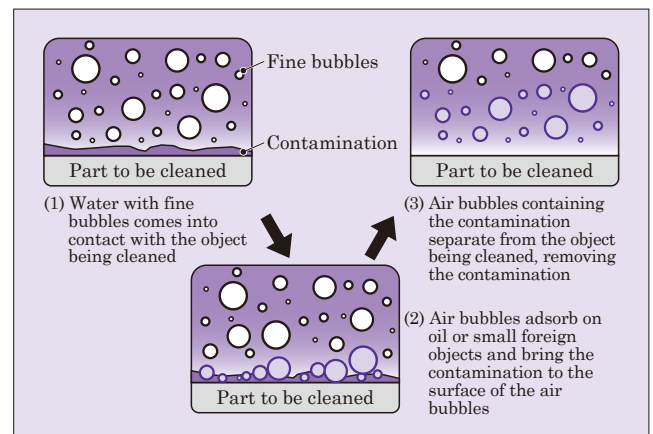
Fig.12 Coreless current sensor structure diagram



9 Automatic Cleaning Technology for Food Equipment Parts

The retail industry needs sanitation management in accordance with HACCP to ensure food safety and security. Counter fixtures in convenience stores, such as coffee machines, need washing to maintain sanitation conditions, and disassemble internal parts to clean with a dishwasher poses issues in terms of securing human resources and working hours. To address these issues, Fuji Electric is developing a technology to automatically clean parts that come into contact with foodstuff. For example, we are promoting the use of fine bubbles for the removal of coffee oil that adheres to coffee machines. As a result of hydrophobic interaction, the bubbles adsorb on coffee oil, which does not mix with water, thereby reducing the amount of residue to less than half of the amount achieved by using the method of only pouring hot water. Going forward, we will further improve the cleaning power of this technology by optimizing the bubble diameter and other factors.

Fig.13 Cleaning Mechanism using fine bubbles



FUJI ELECTRIC REVIEW vol.69 no.2 2023 Detailed Contents

Preface	69
Contributing to the Creation of a Responsible and Sustainable Society Through Our Innovation in Energy and Environment Technology	

Through Our Innovation in Energy and Environment Technology, We Strive to Create New Customer Value and Resolve Social Issues While Addressing the Changes in the Market Environment	70
---	----

Highlights	72
-------------------	----

- M-G Set Demonstration System Combined with Renewable Energy and Storage Battery
- Special Three-Phase Transformer for Minamiota Substation, TEPCO Power Grid, Incorporated
- Delivery of a High-Capacity UPS System to a Data Center
- Deployment of FR3® Transformers in the Data Center Market in Japan
- Redesigned “Command Switch”
- “FRENIC-Ace (E3) Series” High-Performance, Standard Inverters
- “S-Flow” Compact Ultrasonic Flowmeter for Small-Diameter Pipes
- “MONITOUCH V10 Series” Programmable Operator Interface
- An Approach for Increasing Safety and Reliability in Fuji Electric’s Door System
- “HPnC” Industrial High-Capacity Module
- “M675” Automotive Module for the Chinese Market
- Start of Commercial Operations of Olkaria Geothermal Power Station (Unit 6)
- Hydrogen Fuel Cell Systems for Factories and Facilities
- “Sustainable Vending Machine Series”
- Enhancing Performance of Electrical Insulation Composite with Filler
- Laminated Iron Core Magnetostrictive Vibration and Noise Simulation Technology
- Bi-Directional Isolated DC/DC Converter
- Energy Market Price Forecasting and Planning of Transactions Using Storage Batteries for the Power Grid

Power Electronics Energy	81
---------------------------------	----

Energy Management	82
--------------------------	----

- ① Distribution Automation System for Chugoku Electric Power Transmission & Distribution Company, Incorporated
- ② Replacement of Power Supply System for Sumitomo Joint Electric Power Co., Ltd.
- ③ Received Order of Equipment for Storage Battery Systems Supporting Self Consumption of Solar Power
- ④ Control System of PCSs for BESS used in the Power Exchange Market

Transmission and Distribution Systems	84
--	----

- ① Replacement of Electric Power Remote Monitoring Equipment for Shibushi Oil Storage Company, Ltd.
- ② Delivery of Electrical Equipment for Stations on the Nishi Kyushu Shinkansen Line

Power Supply and Facility Systems	84
--	----

- ① “6000DX Series” 3-Phase 200-V High-Capacity UPS

- ② 1/2 Cycle High-Speed Circuit Breakers Delivered to Fuji Electric’s Yamanashi Factory

Electric Distribution, Switching and Control Devices	85
---	----

- ① Load Break Switches with Improved Environmental Friendliness
- ② AC Contactors for Elevator Control Panels
- ③ Replacement of Iron Core Production Line for Magnetic Switches Compliant with VOC Regulations

Power Electronics Industry	87
-----------------------------------	----

Factory Automation	88
---------------------------	----

- ① “HF Series” Flush-Mount Electronic Watt-Hour Meters
- ② CPU Module with Diagnostic Function for the “SPH5000EC” Series

Process Automation	89
---------------------------	----

- ① Plant Simulator for Industrial Plants with Motor Applications
- ② DC Commutator Machine Compatible Induction Motor
- ③ Replacement of the Monitoring and Control System for an Oxygen Production Plant
- ④ “HEART” High-Efficiency Engineering Support Tool to Accelerate DX
- ⑤ “MICREX-VieW FOCUS Evolution” Global Monitoring and Control System
- ⑥ Replacement of the Supply Monitoring System for a City Gas Provider
- ⑦ Monitoring and Control System for Small-Scale Wood Biomass Power Generation
- ⑧ Delivery of a Monitoring and Control System for a Waste Heat Power Generation System

Information Solutions	91
------------------------------	----

- ① Information Model-Based Manufacturing Execution System
- ② “F-WES/FLEXLOGI” Standard Interface for Distribution Automation Equipment

Social Solutions	92
-------------------------	----

- ① Onshore Power Supply System

Field Services	92
-----------------------	----

- ① Switchboard Deterioration Information Collection System for “Comprehensive Service for Smart Industrial Safety”

Semiconductors	93
-----------------------	----

Industrial	94
-------------------	----

- ① Lineup of “P639” 7th-Generation IGBT-IPMs
- ② “FA6C60 Series” 4.5th-Generation LLC Control ICs
- ③ Built-in Gate Resistor Chips for High-Power Modules
- ④ Highly Durable Positive Charging Organic Photoconductors for Fast Printing

Automotive	95
-------------------	----

- ① Expansion of the “M660” Automotive Power Semiconductor Modules

Power Generation	96
-------------------------	----

Renewable Energy and New Energy	97
--	----

- ① DLC Coating on Geothermal Turbine Blades as a Scale Countermeasure
- ② Commencement of Commercial Operation of the Yufutsu Biomass Power Plant, Yufutsu Energy Center, LLC.

Solution Services	98
--------------------------	----

- ① Completion of Fuel Unloading at the Prototype Fast Breeder Reactor Monju

FUJI ELECTRIC REVIEW vol.69 no.2 2023 Detailed Contents

- ② Applying SIAL®, an Advanced Solidification Technology, to Radioactive Waste
- ③ Inductively Coupled Plasma Mass Spectrometry for Analyzing Radionuclide
- ④ Generator Inspection Robot

Food Distribution	100
--------------------------	-----

Vending machines	101
-------------------------	-----

- ① “Dynamic Pricing Buttons” for Vending Machines

Store Distribution	101
---------------------------	-----

- ① Refrigerated Showcase with a Built-in Cooling Unit Equipped with New Cooling Unit Control Capability

Fundamental and Advanced Technologies	102
--	-----

Fundamental Technology	103
-------------------------------	-----

- ① Web Application Multi-Factor Authentication Technology
- ② Status Monitoring Technology Using Moving Image Recognition AI

- ③ IoT Edge Platform
 - ④ Fatigue Life Prediction Technology for Electronic Parts
- Advanced Technology** 105
- ① High-Temperature Gas Cooling Technology to Increase Flexibility in Selecting Switchgear Installation Sites
 - ② 3.3-kV SiC Super-Junction MOSFET
 - ③ Vertical GaN-MOSFET with Currents of Several Amperes
 - ④ Technology to Predict Silica Scale Generation with Computational Science
 - ⑤ Frost-Free Technology for Heat Exchangers Using Functional Coating
 - ⑥ Optimum Production Scheduling Technology
 - ⑦ Edge-Type Model Predictive Control Technology with Automatic Model Creation
 - ⑧ Technology of Current Measurement with Coreless Coils on a Printed Circuit Board
 - ⑨ Automatic Cleaning Technology for Food Equipment Parts

Overseas Subsidiaries

* Non-consolidated subsidiaries



Fuji Electric website
<https://www.fujielectric.com/>

America

Fuji Electric Corp. of America

Sales of electrical machinery and equipment, semiconductor devices, drive control equipment, and devices

URL <https://americas.fujielectric.com/>

Reliable Turbine Services LLC

Repair and maintenance of steam turbines, generators, and peripheral equipment
Tel +1-573-468-4045

Fuji SEMEC Inc.

Manufacture and sales of door opening and closing systems
Tel +1-450-641-4811

Asia

Fuji Electric Asia Pacific Pte. Ltd.

Sales of electrical distribution and control equipment, drive control equipment, and semiconductor devices

URL <http://www.sg.fujielectric.com/>

Fuji SMBE Pte. Ltd.

Manufacture, sales, and services relating to low-voltage power distribution board (switchgear, control equipment)

URL <http://smbe.fujielectric.com/>

Fuji Electric (Thailand) Co., Ltd.

Sales and engineering of electric substation equipment, control panels, and other electric equipment

URL <http://www.th.fujielectric.com/en/>

Fuji Electric Manufacturing (Thailand) Co., Ltd.

Manufacture, sales, engineering and service of low-voltage inverters, instrumentation and sensors, switchgear, gas insulated switchgear, PCS, UPS
Tel +66-2-5292178

Fuji Tusco Co., Ltd.

Manufacture and sales of Power Transformers, Distribution Transformers and Cast Resin Transformers

URL <http://www.ftu.fujielectric.com/>

Fuji Electric Vietnam Co., Ltd. *

Sales of electrical distribution and control equipment and drive control equipment
URL <http://www.vn.fujielectric.com/en/>

Fuji Furukawa E&C (Vietnam) Co., Ltd. *

Engineering and construction of mechanics and electrical works
Tel +84-4-3755-5067

Fuji CAC Joint Stock Company

Provide the Solution for Electrical and Process Control System
URL <http://fujicac.com/>

PT. Fuji Electric Indonesia

Sales of inverters, servos, UPS, tools, and other component products
URL <http://www.id.fujielectric.com/>

P.T. Fuji Metec Semarang

Manufacture and sales of vending machines and their parts
URL <http://www.fms.fujielectric.com/>

Fuji Electric India Pvt. Ltd.

Sales of drive control equipment and semiconductor devices
URL <http://www.ph.fujielectric.co.in>

Fuji Electric Consul Neowatt Private Limited

Development, manufacture, engineering, sales and servicing of UPS, Stabilizers, Active Harmonic Filters and other component products
URL <https://www.india.fujielectric.com/>

Fuji Gemco Private Limited

Design, manufacture, sales, and engineering for drive control systems
Tel +91-129-2274831

Fuji Electric Philippines, Inc.

Manufacture of semiconductor devices
Tel +63-2-844-6183

Fuji Electric Sales Philippines Inc.

Sales of energy management systems, process automation systems, factory automation systems, power supply and facility systems, and power generation
URL <https://www.ph.fujielectric.com/>

Fuji Electric (Malaysia) Sdn. Bhd.

Manufacture of semiconductor devices
URL <http://www.fujielectric.com.my/>

Fuji Electric Sales Malaysia Sdn. Bhd.

Sales of energy management systems, process automation systems, factory automation systems, power supply and facility systems, and vending machines
URL <https://www.my.fujielectric.com/>

Fuji Furukawa E&C (Malaysia) Sdn. Bhd. *

Engineering and construction of mechanics and electrical works
Tel +60-3-4297-5322

Fuji Electric Taiwan Co., Ltd.

Sales of semiconductor devices, electrical distribution and control equipment, and drive control equipment
URL <http://www.fujielectric.com.tw/>

Fuji Electric Korea Co., Ltd.

Sales of power distribution and control equipment, drive control equipment, rotators, high-voltage inverters, electronic control panels, medium- and large-sized UPS, and measurement equipment
URL <http://www.fujielectric.co.kr/>

Fuji Electric Co., Ltd. (Middle East Branch Office)

Promotion of electrical products for the electrical utilities and the industrial plants
Tel +973-17 564 569

Fuji Electric Co., Ltd. (Myanmar Branch Office)

Providing research, feasibility studies, Liaison services
Tel +95-1-8382714

Representative office of Fuji Electric Co., Ltd. (Cambodia)

Providing research, feasibility studies, Liaison services
Tel +855-(0)23-964-070

■Equity-method Affiliates

Fuji Furukawa E&C (Thailand) Co., Ltd. *

Design and installation contracting for electric facilities construction
Tel +66-2-308-2703

Europe

Fuji Electric Europe GmbH

Sales of electrical/electronic machinery and components
URL <https://www.fujielectric-europe.com/>

Fuji Electric France S.A.S

Manufacture and sales of measurement and control devices
URL <https://www.fujielectric.fr/en>

Fuji N2telligence GmbH *

Sales and engineering of fuel cells and peripheral equipment
Tel +49 (0) 3841 758 4500

China

Fuji Electric (China) Co., Ltd.

Sales of locally manufactured or imported products in China, and export of locally manufactured products
URL <http://www.fujielectric.com.cn/>

Shanghai Electric Fuji Electric Power Technology (Wuxi) Co., Ltd.

Research and development for, design and manufacture of, and provision of consulting and services for electric drive products, equipment for industrial automation control systems, control facilities for wind power generation and photovoltaic power generation, uninterruptible power systems, and power electronics products
Tel +86-510-8815-9229

Wuxi Fuji Electric FA Co., Ltd.

Manufacture and sales of low/high-voltage inverters, temperature controllers, gas analyzers, and UPS
Tel +86-510-8815-2088

Fuji Electric (Changshu) Co., Ltd.

Manufacture and sales of electromagnetic contactors and thermal relays
URL <http://www.csfe.com.cn/>

Fuji Electric (Zhuhai) Co., Ltd.

Manufacture and sales of industrial electric heating devices
URL <http://www.fujielectric.com.cn/fez/>

Fuji Electric (Shenzhen) Co., Ltd.

Manufacture and sales of photoconductors, semiconductor devices and currency handling equipment
URL <http://www.sz.fujielectric.com.cn/>

Fuji Electric Dalian Co., Ltd.

Manufacture of low-voltage circuit breakers
Tel +86-411-8762-2000

Fuji Electric Motor (Dalian) Co., Ltd.

Manufacture of industrial motors
Tel +86-411-8763-6555

Dalian Fuji Bingshan Vending Machine Co., Ltd.

Development, manufacture, sales, servicing, overhauling, and installation of vending machines, and related consulting
Tel +86-411-8754-5798

Dalian Fuji Bingshan Control Systems Co., Ltd.

Energy management systems, distribution systems, and related system engineering
Tel +86-411-8653-6010

Fuji Electric (Hangzhou) Software Co., Ltd.

Development of vending machine-related control software and development of management software
URL <http://www.fujielectric.com.cn/fhs/>

Fuji Electric FA (Asia) Co., Ltd.

Sales of electrical distribution and control equipment
Tel +852-2311-8282

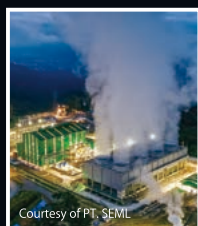
Fuji Electric Hong Kong Co., Ltd.

Sales of semiconductor devices and photoconductors
URL <http://www.hk.fujielectric.com/en/>

Hoei Hong Kong Co., Ltd.

Sales of electrical/electronic components
URL <http://www.hoei.com.hk/>

Power Electronics as a force for social good.



Courtesy of PT. SEMI

Geothermal Power
Plants



Power Conditioning
Systems



Uninterruptible Power
Systems



Power Semiconductors



Inverters



Vending Machines

Contributing to the creation of a sustainable society

FE **Fuji Electric**
Innovating Energy Technology

FUJI ELECTRIC REVIEW is made of
environmentally friendly paper certified by
the Forest Stewardship Council® (FSC) and
printed with vegetable ink.

