Achievements and Future Outlook

Solutions That Create Customer Value Through Competitive Components, Systems and Use of IoT

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1. Introduction

Fuji Electric pursues innovation in energy and environment technologies and utilizes its world renowned semiconductors technologies as a core in order to offer distinctive components for power electronics equipment. Furthermore, we are enhancing our system products by combining measurement and control technologies with these components and using Internet of Things (IoT) technologies to collect data in order to provide customers with new value through data analysis that uses the latest mathematical techniques.

We set "promoting efficient R&D that creates customer value and increases sales and profits" as one of our R&D policies and have reformed our R&D activities. We have consolidated product development functions into the Development Division of each business group since FY2017. We have now completed the desired reorganization and have clearly established a system in which the Corporate R&D Headquarters is in charge of common fundamental technologies and advanced technologies. Moreover, for Design Review, which functions as stage gate review, to enhance its upstream processes, we have constructed a framework for verifying customer value while we also improved product planning capabilities by establishing a technology marketing department. We have also strengthened our advanced technologies and common fundamental technologies to create further competitive components and systems.

2. Solutions That Utilize IoT to Create Customer Value

IoT is a general term used to describe the concept of systems that collect and accumulate on-site data to create new value in cyberspace. Fuji Electric has been promoting utilization of IoT by treating it as techniques to improve productivity and quality and reduce costs from the viewpoint of users, as well as to expand business and reform business models from the viewpoint of vendors. In FY2017, we completed the basic development and cloud-migration development of an IoT platform that acts as the infrastructure for easily integrating field devices and analysis and optimization technologies (Data analytics). Specifically, we have developed IoT platforms with various functions, including an interface function useful for easily constructing

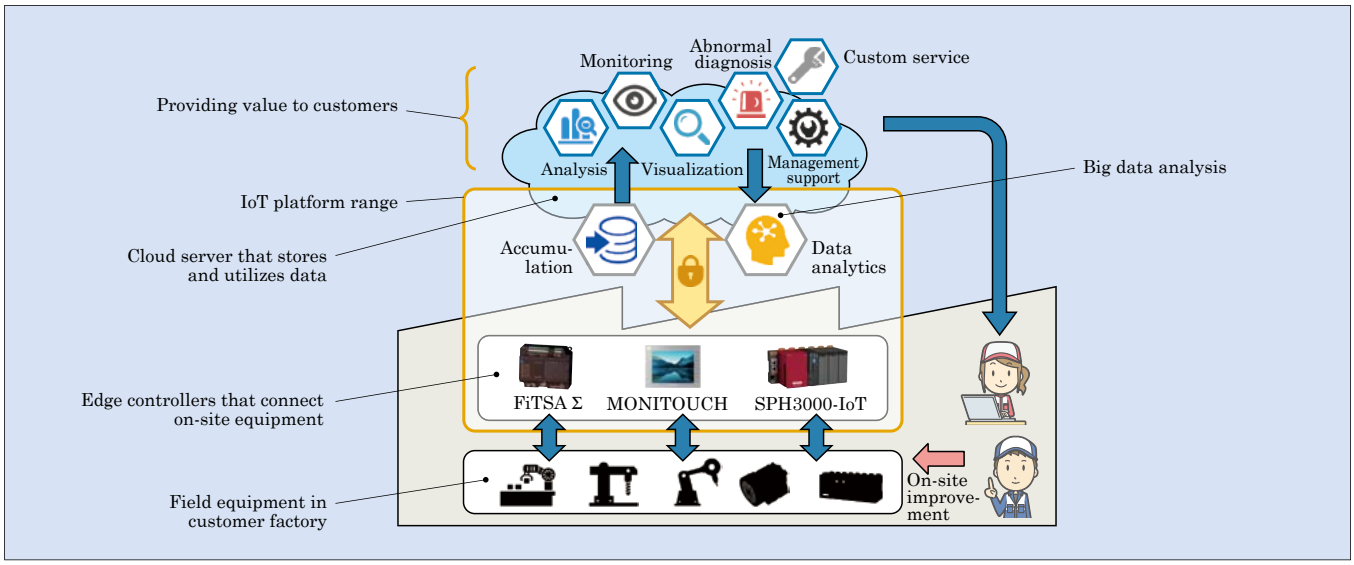

Fig.1 IoT platform

services based on general-purpose cloud technologies, communications functions that connect the cloud with edge controllers that collect and process data from on-site equipment, security functions, and a mathematical engine that diagnoses, forecasts and optimizes data (see Fig. 1). In addition to developing these platforms, we have used IoT in our factories and promoted projects for verifying the effectiveness of IoT solutions in customer fields. Performing these verifications, we have increased use cases for improving productivity, enhancing manufacturing quality, improving operation and maintenance efficiency, strengthening plant efficiency, and ensuring process quality traceability. Fuji Electric has adopted the motto "Small, Quick Start & Spiral-Up" to expand use of IoT and collaborated with our customers using quick start IoT to create customer value.

3. Synergy between Power Semiconductors and Power Electronics Technology

The rapid spread of electric motorization in the automobile field has been a motivating factor for us in the development of automotive discrete modules, automotive power semiconductor modules, and sealed high-voltage contactors (HVC) for automotive applications, as well as automotive power electronics equipment that utilize these components. For automotive power semiconductor modules, important features to create customer value are reduced switching loss, size and weight reduction and high power density. In this respect, we have developed a high-power, direct liquid cooling insulated gate bipolar transistor (IGBT) module for automotive applications that utilizes a reverse-conducting IGBT (RC-IGBT), which mounts diodes and IGBTs on a single chip; a cooling system that integrates a lightweight aluminum high-performance heat-dissipating water jacket; and packaging technology using lead-frame for internal wiring (see Fig. 2). These technologies have enabled us to achieve the development of a 6-in-1 IGBT module with a large rated capacity of 750 V/1,200 A.

Silicon carbide (SiC) has been attracting attention as a next-generation semiconductor material that achieves lower loss even at higher switching frequencies and higher operating temperature than conventional Si semiconductors. We have developed a trench-gate structure based SiC metal-oxide-semiconductor field-effect transistor (SiC-MOSFET) and SiC equipped Schottky barrier diode (SBD) as devices that achieve world-class performance and stability. We have developed an All-SiC module with a newly structured package that uses copper pin connections and resin molding technology. This newly structured module not only reduces internal inductance, but also makes high-temperature operation possible, thus enabling the development of high-speed and highly reliable SiC devices. We have expanded our product line-up of All-SiC modules that have a new structure: a 1,200-V/25- to 400-A rated module equipped with SiC trench MOSFET chip with a breakdown voltage of 1,200 V, and a 1,700-V/max. 270-A rated module equipped with newly developed SiC trench MOSFET chip with a breakdown voltage of 1,700 V (see Table 1).

As a power electronics product that makes use of this SiC-MOSFET module, which is characterized by its low loss, low heat dissipation and high operating temperature, we have developed the "FRENIC-eFIT" fanless environmentally-resistant inverter with a totally-enclosed self-cooled structure (see Fig. 3). It is expected to expand the range of applications in harsh environments and those susceptible to corrosive gases. We will use semiconductor modules that use SiC for various power electronics equipment that can create

Table 1 All-SiC module series

Package		Type 1B	Type 2B	Type 3LB
Dimensions (mm)		W 62 × D 20 × H 12	W 68 × D 26 × H 13	W 126 × D 45 × H 13
Rated voltage	Gate structure			
1,200 V	Trench	25 A, 50 A	75 A, 100 A	200 A, 300 A, 400 A
1,700 V	Trench	–	–	<270 A

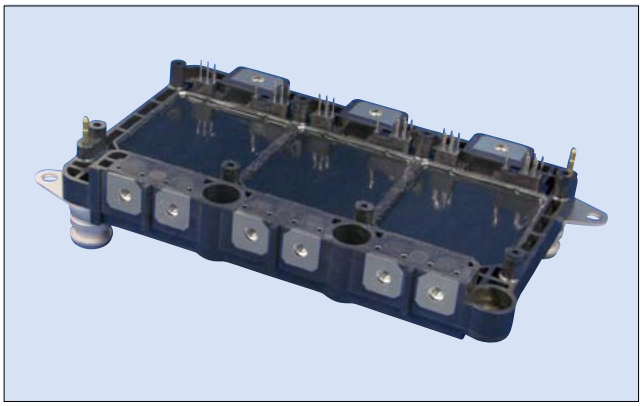

Fig.2 High-power, direct liquid cooling IGBT module for automotive applications

Fig.3 "FRENIC-eFIT" environmentally resistant inverter

added value.

4. Industry Solutions Field

The factory automation (FA) field has continued to grow as a result of active investment in factory automation. Fuji Electric has been working to meet the various customer needs in this field by developing competitive components and systems by using technologies of power electronics, control, and measurement equipment as core technologies.

We have launched medium and high capacity industrial inverters, such as the “FRENIC4400VM6” and “FRENIC4800VM6” and delivered them to steel and nonferrous manufacturers in Japan. These products are not only characterized by basic performance improvements such as expanded output frequency and enhanced control functionality, but also improved ease-of-use through expanded user support functions.

We have contributed to factory automation that require precise control by providing our motion control technologies using distinctive components, such as the “SPH3000D” motion controller and the “ALPHA7” servo system, which has been continuously developed since FY2016.

A system example for the automobile industry field that uses these technologies is a tire testing machine that is compliant with the Worldwide Harmonized Light Vehicles Test Procedures (WLTP) (see Fig. 4). By fully utilizing electric inertia control in combination with driving technology and precision control technology, driving load can be controlled in various types of driving mode, ranging from light vehicles to 4-t trucks.

Fuji Electric has been promoting IoT application for manufacturing processing lines and has developed the “MICREX-OnePack[(1)]” facility information collection system. This product can collect and aggregate data from manufacturing equipment by one cycle, which help a data collection system to be compact and low cost.

In the process automation (PA) field, we offer components and systems that contribute to the stable operation of production equipment and the reduction of energy unit consumption rates by using technologies of

Fig.4 WLTP compliant tire testing machine

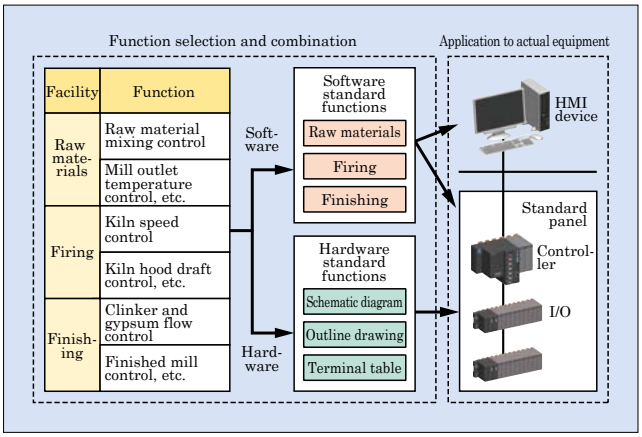

Fig.5 Monitoring and control system package for cement plants

drive control, instrumentation control and industrial electric heating as core technologies.

We have increased the functionality of the “MICREX-VieW XX” to enhance the stabilization of product manufacturing and facility operation and improve the usability of the monitoring functions. For the steel and nonferrous manufacturing field, we have replaced the large-scale monitoring and control system of steel plants with this system. For the cement industry, we have developed a monitoring and control system package for cement plants as an application platform that provides the functionality required in plant control (see Fig. 5). This package will encourage the engineering activities of partners and users all over the world. In addition, we are also continuing to supply various monitoring systems in the food and beverage and power generation fields.

5. Energy Solutions Field

For the energy solutions field, we have provided switchgear, transformers, power system protective relays, power system monitoring and control systems, and distribution automation systems for the social infrastructure and industry field. These products are mainly based on large-capacity power electronics technology, which are used for substation systems and power distribution systems, and energy monitoring and control technology. In addition, we are developing uninterruptible power systems (UPS), facility-use power supply equipment and air conditioning equipment for data centers. As the data center market continues to grow due to the advances in information and communications systems and cloud technology, demand is increasing for UPSs with high reliability in addition to high efficiency. For the North American market, we have developed the “UPS7400WX-T3U” large-capacity UPS, which employs a module control function to meet this demand (see Fig. 6). Having a capacity of 330 kVA per module, this UPS can incorporate multiple modules to meet capacity needs. In addition, it can control the modules so that the load current value of each module is within the maximum efficiency region, and it can be

Fig.6 “UPS7400WX-T3U” large-capacity UPS for North America with module control function

repaired while supplying power, allowing it to be flexibly adapted for customer facilities.

We are also working on the development of smart inverters for which Europe and North America are leading the industry ahead of other regions in response to the increasing importance of creating measures to solve power system problems due to the large-scale adoption of renewable energies. Fuji Electric has developed a power conditioning system (PCS) equipped with system support functions and an intelligent electronic device (IED) that enables communication connection via IEC 61850 communications. Furthermore, we have developed a distributed energy resource management system (DERMS) for verifying its remote monitoring and control functions performed between smart inverters and a DERMS via IEC 61850 communications. We have delivered this system to Tokyo Electric Power Company Holdings, Inc. The system is currently in validation in the “Research and Development Project on Technologies to Respond to Power System Output Fluctuations” commissioned by the New Energy and Industrial Technology Development Organization (NEDO) (see Fig. 7).

We have developed various products that contribute to reducing controlboard wiring work, including new screwless products such as “GT-Λ” molded case circuit breakers and earth leakage circuit breakers, “SK” magnetic contactors, “TK” thermal overload relays, “CP30F” circuit protectors, and spring terminals for relay and timer sockets. All models utilize an easy-to-use push-in mechanism that requires no special skills. All wiring gets connected by simply inserting the product. These products have also acquired major overseas standard certifications, such as IEC and UL (see Fig. 8).

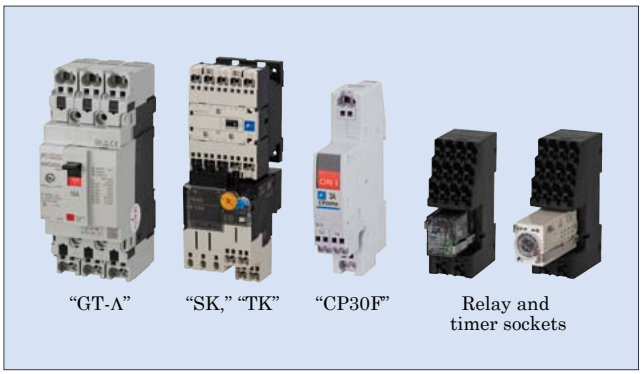

Fig.8 Push-in type labor-saving devices

6. Power Generation Field

In the field of power generation, in addition to thermal power and fuel cell technologies, we have been actively pursuing the use of renewable energies, such as geothermal, photovoltaic and wind, to help realize a low carbon society. We will deliver our complete power supply technologies to contribute to society.

We have delivered binary power generation facilities (Gross output: 4,990 kW) to Kyuden Mirai Energy Company, Incorporated. We received this order as engineering, procurement and construction projects (excluding civil work). Commercial operation of the facilities began on February 23, 2018 (see Fig. 9). This facilities effectively utilize hot water that has conventionally been returned to the ground without being used. Normal pentane has been used as a working fluid.

In the field of photovoltaic power generation, we received an order of photovoltaic power generation facilities with a rated capacity of 32.14 MW DC as the main contractor. Commercial operation of the facilities began in May 2018.

Furthermore, we participated in a NEDO project with the goal of developing a highly-efficient solid oxide

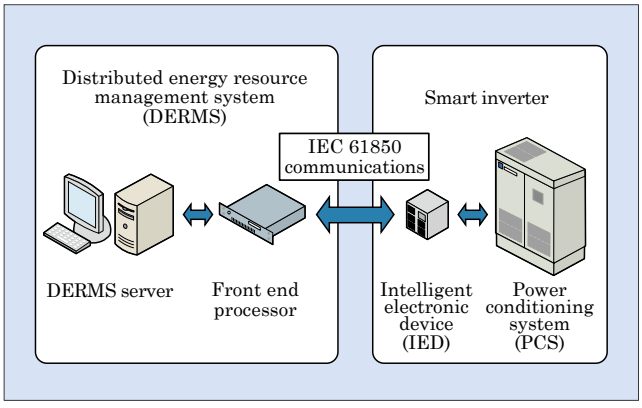

Fig.7 Smart inverter development

Fig.9 Binary power generation facilities

Fig.10 Solid oxide fuel cell (SOFC) system

fuel cell (SOFC) system. In the end, we developed a 50-kW class demonstration unit and evaluated it for a running time of 3,000 hours (see Fig. 10).

7. Food and Beverage Distribution Field

In the food and beverage distribution field, we took advantage of the technology we cultivated in cup vending machines to create a full-fledged drip coffee machine for overseas markets (see Fig. 11). By acquiring UL and NSF standard certifications, we have demonstrated a high-degree of safety, and we have been expanding this field of our business to markets all over the world including the United States and Asian countries such as China.

In Japan, we have partnered with Asahi Soft Drinks Co., Ltd. to develop a vending machine that makes it possible to sell cold beverages of subfreezing temperatures. These beverages utilize a supercooling phenomenon that “freezes through shock” and provide experience such as seeing a product freeze in front of one’s eye and enjoying snow-cone like texture in one’s mouth. Vending machines can help delivering effects to encourage consumption instead of simply selling things. Moreover, Fuji Electric is combining its expertise in IoT, mechatronics (system technology) and cooling and heating technologies to develop new products and services based on the 3 keywords of convenience, labor savings and energy savings in order to deal with labor shortages and reform the way people work in the distribution and retail industries in Japan.

Fig.11 Drip coffee machine for overseas markets

8. Fundamental and Advanced Technologies

Fuji Electric continues to implement research and development into fundamental technologies that commonly support the various technologies mentioned above and advanced technologies that contribute to future products. With respect to common fundamental technologies, we are engaged in experiments, evaluations, analysis and simulations related to the fundamental technologies of electromagnetism, insulation, electromagnetic compatibility, thermal fluids, machinery, resins and metallic materials. With respect to advanced technologies, we are engaged in research into semiconductor materials that can support future developments beyond SiC, as well as computational science that can predict material property and deterioration phenomena.

In the field of material technology, we have developed simulation technology that can predict the progress of corrosion in geothermal turbines through the use of a multi-phase field method (see Fig. 12). This technology can be used in product design and predictive maintenance in that it enables the uniform handling of ion diffusion and metal dissolution in corrosive fluids and can respond to various corrosive environments and corrosive modes. In addition to these applications, we will also apply the technology to make use of experiments and computation science in analysis of solid insulation and semiconductor interfaces.

In order to reduce the number of prototypes, we have developed a model-based design technology and are promoting innovative reforms in the design process stage of product development. We have established and confirmed the performance enhancements of a multi-purpose optimization technique for the temperature and sound properties of power electronics equipment through parametric 3D-CAD shape transformation and

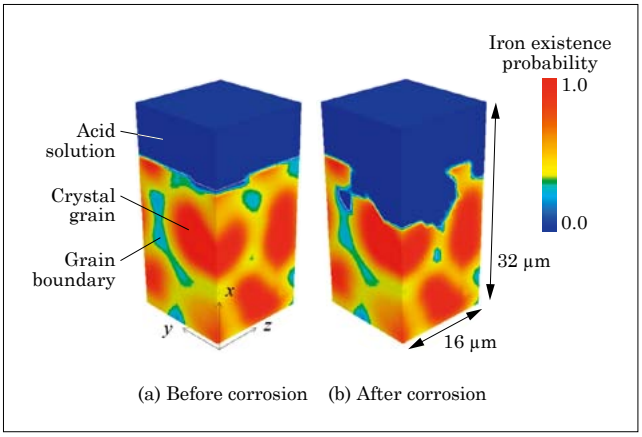

Fig.12 Simulation technology for predicting progress of corrosion

automation of analysis settings. In the future, we will apply this technique to product development through front loading.

In the field of thermal energy technology, we are currently developing a device for effectively generating high-temperature steam of 150 °C to effectively utilize conventionally unused low-temperature exhaust heat. For this development, we have developed a technology capable of two-stage compression in a single compressor to supply steam of high temperatures that cannot be achieved by conventional heat pumps that use 120 °C exhaust heat.

9. Postscript

In this paper, we have briefly introduced several of Fuji Electric's initiatives in technical development: technologies for safely and efficiently using electric energy while pursuing innovation in energy and environment technologies, technologies for effectively using thermal energy to contribute to energy savings, and solutions technologies for optimally controlling the above mentioned energies and connect them via IoT to increase added value. Fuji Electric has initiated the process reform in new product development and is constructing research and development system, which helps plan products that contribute to creating customer value and facilitates the research and development to contribute to these products.

In this way, we will pursue technical innovation and provide our customers with high-value-added, environmentally friendly products and systems to contribute to the creation of a responsible and sustainable society.

References

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

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Innovating Energy Technology