Fundamental and Advanced Technologies

Fundamental Technology
Advanced Technology

Outlook

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

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

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

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

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

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

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

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

As a sensing technology that creates new customer value, we have developed a high-sensitivity spectroscopic technology that applies birefringent Fourier spectroscopy. This technology achieves about 100-fold detection sensitivity of conventional spectroscopes and enables previously impossible measurements, such as on-line foreign object inspection of foods and chemicals and degradation measurement of concrete. In addition, we are also developing distinctive sensors that utilize MEMS technology, along with solutions that make use of the sensors.

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

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

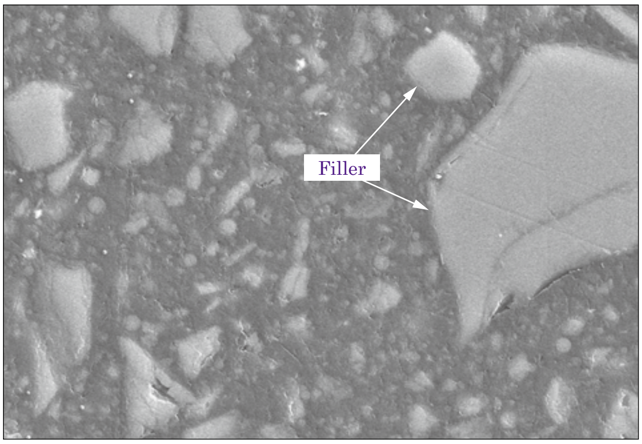
Fundamental Technology

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

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

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

Fig.1 Micro-structure of epoxy resin

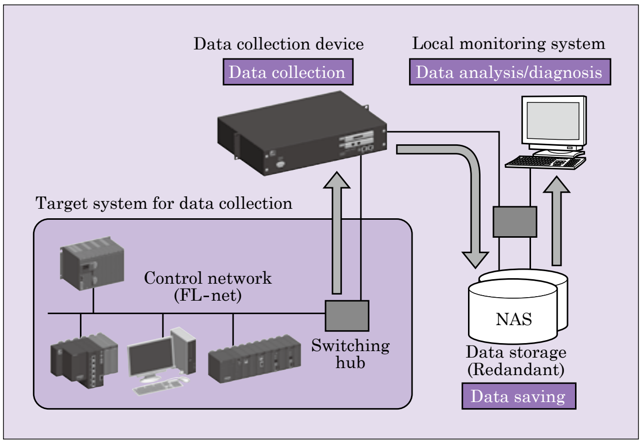


2 Data Collection Device That Supports Legacy Equipment for Industrial Plants

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

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

Fig.2 Configuration of data collection device

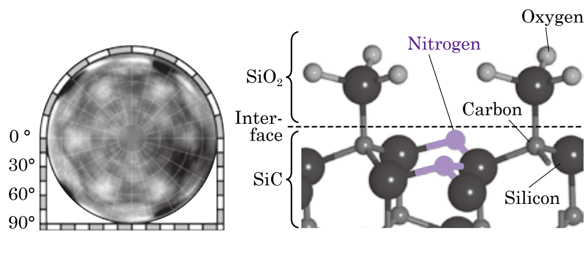


Advanced Technology

1 SiC Analysis Technology by Photoelectron Diffraction

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

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



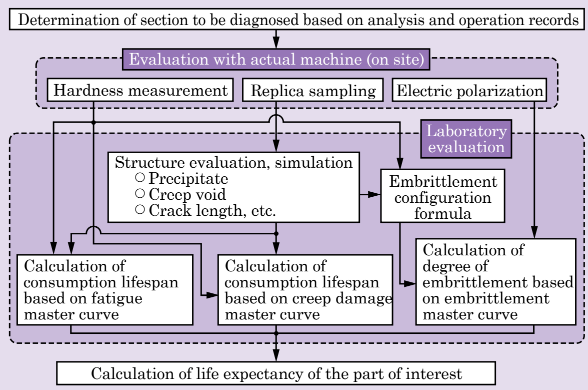
(a) Photoelectron diffraction pattern (b) Identified interface structure

2 Life Expectancy Diagnosis Technology for USC Turbines

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

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

Fig.4 Flow of life expectancy diagnosis



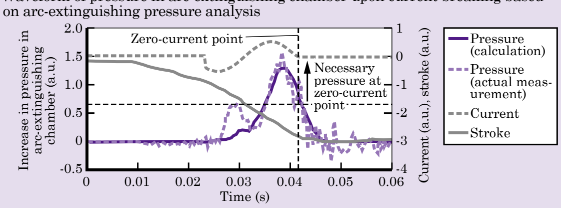
3 Current Breaking Technology in Gas-Insulated Switchgear (GIS)

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

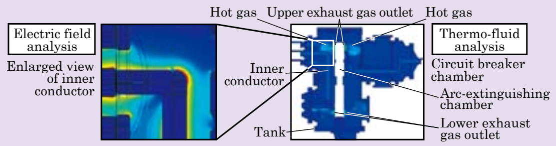
In the development of this current breaking technology, we have developed technologies, such as an arc-extinguishing pressure analysis that takes nozzle abrasion into consideration [see Fig.(a)], a high-precision electromagnetic field-thermo-fluid coupled analysis that takes into account the movement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

Fig.5 Developed technology for current breaking evaluation

(a) Waveform of pressure in arc-extinguishing chamber upon current breaking based on arc-extinguishing pressure analysis



(b) Technology to evaluate insulation performance upon current breaking by coupled analysis



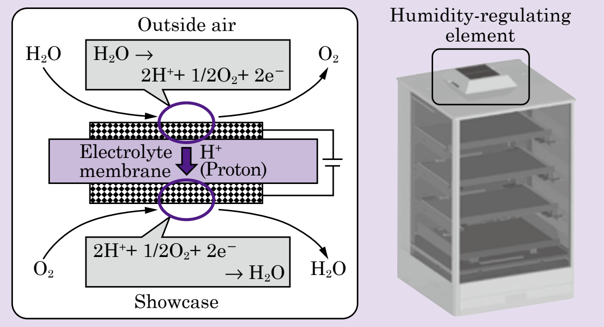
Fundamental and Advanced Technologies

4 Food Showcase with Humidity Adjustment Function

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

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

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



(a) Model of principle of humidity-regulating element (b) Showcase with humidity adjustment function

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

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

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

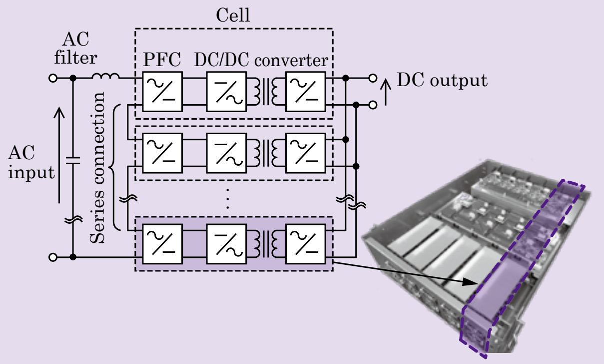
Conversion circuits (cells) composed of low withstand voltage switching devices are connected in serial (multi cell system), allowing the equipment to achieve high frequency operation.

(2) Miniaturization

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

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

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

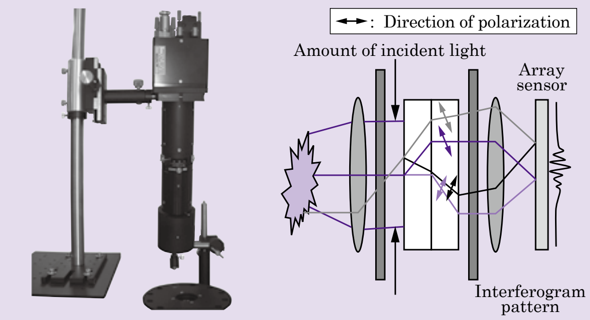


6 High-Sensitivity Spectroscopic Achieving Non-Contact and Non-Invasive Inspection

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

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

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



(a) High-sensitivity spectroscopic device for quality inspection (b) Birefringent Fourier spectroscopy

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Innovating Energy Technology