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Technical Achievement and Outlook

Fuji Electric

Innovating Energy Technology

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The earth, formerly perceived as being infinitely large, has become to feel smaller with the progress of civilization and is now recognized as being finite. Human activities are known to be an ongoing threat to the planet, as is evidenced by global warming. For these reasons, the realization of responsible and sustainable societies is a common challenge for mankind. Through pursuing innovation in electric and thermal energy technology to create products that maximize the utilization efficiency of energy, Fuji Electric intends to contribute to the realization of responsible and sustainable societies. This special issue, "Technical Achievement and Outlook," is a compilation of our achievements for one year and also presents an outlook for the future. We believe that the key to building new societies can be found within these pages and sincerely hope that this issue will be even a little helpful to our readers.

Cover Photo:

Nga Awa Purua Geothermal Power Station in New Zealand, Abu Mega Solar Power Plant of The Okinawa Electric Power Company, Incorporated (photo courtesy of The Okinawa Electric Power Company, Incorporated), demonstration test system at the Kitakyushu Smart Community Project and a "FRENIC-VG Series" stack-type inverter

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President's Message

On the occasion of the "Technical Achievement and Outlook" edition, I would like to say a few words.

The nuclear power plant accidents and power shortages resulting from the Great East Japan Earthquake that occurred in March 2011 have caused Japan to question the state of Japanese society and economy. A review of energy policy, heightened awareness of energy conservation and an awareness of the necessity for measures to maintain a stable supply of electric power, and the like have prompted changes in our consciousness. In July 2012, the Feed-in Tariff (FIT) Scheme for renewable energy went into effect, and renewable energy focusing on photovoltaic and wind power generation quickly began to come into widespread use. In this way, I think this past year was one in each we took a step toward the creation of responsible and sustainable societies.

Fuji Electric adopted the new brand statement of "Innovating Energy Technology" in July 2012. This statement reflects the company's ongoing pursuit of innovation in electric and thermal energy technology in order to create products that maximize the efficient utilization of energy and to contribute to the creation of responsible and sustainable societies. Also, in October 2012, Fuji Electric entered into an absorption-type merger with Fuji Electric Retail Systems Co., Ltd., and has further leveraged this synergy by combining Fuji Electric's thermal energy technology with cooling and heating technology that has been cultivated in the vending machine business.

Fuji Electric's "energy-related businesses" consists of the following three core areas: (1) key components that are based on electric energy technology, utilize power electronics technology that freely manipulates electricity, and have been cultivated since the founding of the company, including power semiconductors, power electronics equipment, motors, and electric distribution and control devices, (2) plants and equipment that are based on thermal energy technology, such as large thermal and geothermal plants, various induction heating devices and vending machines that employ cooling and heating technology, and (3) solutions based on measurement technology and energy management systems (EMSs) for optimally controlling electric and thermal energy.

In support of such an "energy-related businesses," our research resources are focused on developing technology for the responsible and effective supply and use of electric energy, technology for utilizing energy without waste and technology for optimally controlling electric and thermal energy.

In particular, we are focusing on the development of power devices that use next-generation silicon (Si) material, such as silicon carbide (SiC) and applied products. We have developed and sold inverters that employ SiC devices to realize lower loss and smaller size than were obtainable with silicon. In addition to inverters, we are also accelerating the development of power electronics products such as power conditioners (PCSs) and the like, that utilize SiC devices to realize ultra-low loss and ultra-compact size. We are also developing and selling distinctive high-efficiency devices such as a PCS, having the world's highest level of

efficiency for use in photovoltaic power generation applications, that utilizes a reverse-blocking insulated gate bipolar transistor (IGBT) element, a proprietary Si device of Fuji Electric, and features integrated ancillary devices. In this way, through the synergy of power semiconductor technology and power electronics technology, we will continue to promote innovation in electric energy technology.

As a thermal energy technology, heat pump technology contributes greatly to energy conservation. Fuji Electric has combined thermal and electric energy technologies to develop a data center air conditioning system that uses heat pump technology to realize high energy-saving performance. We have also developed and sold vending machines that utilize a revolutionary hybrid heat pump system that introduces, as a heat source, outside air and the waste heat generated when cooling a product. This vending machine uses 75% less energy than the model prior to adoption of the heat pump, and contributes significantly to energy conservation. Furthermore, we increased the capacity of a binary power generation system that uses hot water in the range of 100 to 200 °C to generate electric power. Geothermal energy can be utilized even more effectively with a "hybrid geothermal power generation system" that uses hot water after having been used for geothermal power generation and returned to a reinjection well. Fuji Electric is also actively engaged in innovation for this type of thermal energy.

In the midst of an actualized shortage of electric power, efforts to realize smart communities aimed at the large-scale introduction of renewable energy and the effective utilization of energy have intensified. Fuji Electric is developing EMSs that optimize the supply and demand of energy, and is participating in smart community demonstration projects. In Kitakyushu City, we are advancing the development and demonstration of cluster EMSs (CEMSs), factory EMSs (FEMSs), building EMSs (BEMSs) and retail store EMSs (REMSs). Thus, during public demonstrations that use a CEMS and smart meters, dynamic pricing that varies the unit price of power according to the power demand has been adopted to realize a power savings effect which has been confirmed to be as much as 13% (maximum) during the summer months.

Meanwhile, with the aim of expanding global markets with a focus on China and other Asian markets, Fuji Electric is promoting the development of such products as general-purpose inverters and UPSs that meet the price and performance needs of local customers. In addition, we are promoting the creation of a global supply chain, and strengthening our efforts in integrated development and production under the assumption that design (local design), materials procurement and production will be carried out at overseas manufacturing bases in Thailand, China and so on.

Fuji Electric is committed to the pursuit of innovation in electric and thermal energy technology and to contributing to global society through energy-related businesses, while accurately assessing the needs of society. We sincerely ask for your guidance and encouragement.

KITAZAWA Michihiro
President and Representative Director

Contributing to Society Through Collaborative and Integrated Research and Development

Aiming to Innovate Energy Technologies

EGUCHI Naoya
General Manager of Corporate R&D Headquarters
Executive Officer, Fuji Electric Co., Ltd.

YABE Akira
Vice-President
National Institute of Advanced Industrial Science and Technology

Fuji Electric Co., Ltd., which "contributes to the creation of responsible and sustainable societies through our innovation in energy technology," and the National Institute of Advanced Industrial Science and Technology (AIST), which promotes green innovation by "bringing technology to society," have a long-standing collaborative relationship that includes the research and development of SiC. Fuji Electric Executive Officer Dr. Eguchi Naoya invited AIST Vice-President Dr. Yabe Akira to exchange opinions about the future of research and about ways of contributing to society.

SiC device development and other collaboration in the Energy Sector

Eguchi: AIST and Fuji Electric have a collaborative relationship in the energy sector, which includes SiC (silicon carbide) device development, and together have produced various successful results. Today, I will be speaking with Dr. Yabe, Vice-President and Director General of AIST, and have been looking forward to this opportunity tremendously. Welcome and thank you.

Under a policy of "through our innovation in electric and thermal energy technology, we contribute to the creation of responsible and sustainable societies," Fuji Electric is working to develop next generation technology. Having already made vast contributions to society with electrical energy technology and thermal energy technology, Fuji Electric intends to continue to focus on energy technology more and more in response to the energy and environmental problems of recent years.

Fuji Electric has cultivated core technologies and expanded its business in the three fields of electrical energy technology, thermal energy technology, and energy management technology for the optimal control of these types of energy.

Yabe: AIST was founded in 2001, facing the 21st century. The 15 research institutes of the former Agency of Industrial Science and Technology, Ministry of International Trade and Industry, which were separated by research fields into the Electrotechnical Laboratory, National Metrological Institute of Japan Mechanical Engineering Laboratory and so on, were combined together, and reorganized to one National Institute to focus on our mission. As a result, we are now able to focus not only on basic research, but also widely on applied research and actual proof research in cooperation with many companies. The failure to follow through and industrialize the results of R&D has been likened to a "nightmare" or a "death valley

of research and development" and the development of a methodology to overcome such difficulties is the mission given to AIST, and we are working towards that end.

Eguchi: Researches of AIST with an emphasis on practical applications are, from a corporate point of view, extremely welcome. Although the catchphrases of "industry-academia collaboration," "industry-government-academia collaboration," and "open innovation" have been in existence for some time, these had been advanced in form rather than substance. AIST addressed this directly. We are certain that such an initiative would be effective in invigorating Japanese industry. To take advantage of open innovation, we have sent people to AIST, where they engaged in joint R&D. I feel that they are really moving toward practical application, and the things Dr. Yabe spoke about are truly being carried out.

At AIST, Dr. Yabe, you oversee the environment and energy field, don't you?

Yabe: Research at AIST is separated into the six fields of: environment and energy; life science and biotechnology; nanotechnology, materials and manufacturing; information technology and electronics; geological survey and applied geoscience; and metrology and measurement science. The environment and energy field, which I oversee, is charged with an extremely important mission that encompasses energy problems, environmental problems and the like, and for that reason has many researchers, and the combined number of postdoctoral fellows and researchers sent from companies is nearly 1,700 people, which is approximately one quarter of the total number of researchers at AIST.

The environment and energy field is working on three major themes. One theme is the promotion of energy technology through the efficient use of renewable energy, energy savings and the like. The second theme is the promotion of the recycling of materials and the circulation of materials. And the third theme is the development of methods of evaluating energy and environmental technology.

New form of open innovation: Tsukuba Power-Electronics Constellation (TPEC)

Eguchi: We again recognize that the field overseen by Dr. Yabe is also a core field for Fuji Electric.

Presently, Fuji Electric is most focused on SiC technology for next-generation devices. Our research and development activities in this field have been conducted jointly with AIST, beginning with the exploration phase.

Yabe: Present-day inverters have been made compact in size, but an overwhelmingly more compact size can be realized by incorporating devices that use new materials such as SiC. Inverters for railroad and automotive applications had, until now, occupied a significant amount of space, but by using SiC devices, the inverter size and weight can be reduced to a fraction of their present values, and constraints on installation can be reduced dramatically. The widespread adoption of inverters is expected to result in energy savings that, roughly estimated, would be equivalent to approximately 6% of Japan's total energy consumption. For the purpose of mitigating Japan's energy problems, the practical application of SiC inverters would seem to be an extremely important technology.

In April 2010, AIST established the Advanced Power Electronics Research Center to conduct full-fledge research on practical applications of high-performance power conversion technologies that make use of wide-bandgap semiconductor materials such as SiC.

Also, AIST has continued to promote the "Industrial Transformation Research Initiative" as a new structure for industry-government-academia collaboration. Fuji Electric and ULVAC, Inc. have participated as a part of that initiative and from FY2009 through FY2011, "a study of SiC trial production and a system application demonstration" were carried out by the three parties jointly. Sample devices that incorporate basic SiC technology established thus far were manufactured and their high-performance and compact size appealed to various system manufacturers, and this, I think, is a major achievement.

Eguchi: The participants from Fuji Electric, in addition to R&D personnel, also include members who work on a production line on the factory floor every day. This approach was completely different from the past and was also very challenging for management. However, the results from FY2009 through FY2011 will certainly lead to practical applications, and this is extremely important, I believe, for Fuji Electric and for the future of Japanese industry.

Yabe: Our experience has also been very valuable. A new organization that takes this approach one step further is Tsukuba Power-Electronics Constellations (TEPC), which was founded in April 2012. TEPC has four main members of Fuji Electric, ULVAC, Inc., AIST and Sumitomo Electric Industries, Ltd., and operates with about 30 institutions in total. While watching from entrance to exit, collaborating from upstream to downstream, and at times working towards various goals as rivals, we approach practical application. In this way, we are summoning our full strength to advance energy savings to the extent

EGUCHI Naoya

Born in 1954. Joined Fuji Electric Manufacturing Co., Ltd. in 1980 (now Fuji Electric Co., Ltd.). Fuji Electric Systems Co., Ltd. Board of Directors in 2006. President of Fuji Electric Advanced Technology Co., Ltd. in 2009. Director and Managing Executive Officer of Fuji Electric Systems Co., Ltd. in 2010. Executive Officer of Fuji Electric Co., Ltd. in April 2011, and concurrently serving as General Manager of, Corporate R&D Headquarters.

possible throughout the world.

Eguchi: Until now, it had been difficult to gather together rival companies to accomplish a single task. However, in consideration of the situation in Japan now, the participants are aware of the importance of being a global leader in technology such as SiC, and the cooperation among companies is a tacit acknowledgement of such. I believe that the skills obtained here can certainly be shared among members and utilized in each company's business. We must lead the world with SiC technology. That is my desire.

Yabe: In terms of technology, we are now attempting to overcome the "death valley." At such a time, unless all parties quickly come together and cooperate to build one thing, we will be surpassed by the global competition. It is extremely important for there to be accelerated by open innovation.

Eguchi: SiC exhibits not only low loss and high breakdown voltage characteristics, but also has a high degree of potential capability for various applications such as for use in vehicle engines, and it would be too much for a single company to master all of these thoroughly. TPEC members include various companies whose expertise ranges from materials to applications, and from this collective wisdom, we expect that different ideas will emerge and be realized.

Fuji Electric is considering the use of SiC in all of its existing power electronic components. It is well known that SiC can be used to make devices that are lighter and smaller than devices made of silicon. We also found that SiC seems to be usable in devices having specifications ranked one-level below those of silicon devices, and in consideration of this, we estimate that the initial and running costs will be cheaper. As of October 2012, we began to build various components, such as uninterruptible power supplies (UPSs), power conditioners (PCSs), inverters, matrix converters and switching power supplies for servers all at once.

Yabe: That is a very encouraging story. SiC devices are rather difficult to develop and require complex technologies. It is not something that can be imitated with makeshift technology. Once achieved, such technology is expected to lead the world for a long time.

Eguchi: In our collaborative research with AIST thus far, we have been able to obtain data about how exacting the processes will be when building a mass-production line and the rate of return that can be expected for a given size of investment. The ability to perform analyses prior to full-scale mass-production is a groundbreaking approach from the perspective of realizing practical applications, and had not been possible in prior industry-government collaboration. On the basis of such data, Fuji Electric makes estimates and accelerates the construction of SiC-related mass-production facilities.

Yabe: I believe that analyzing the data necessary for practical application is an essential requirement in order to cross over the "death valley" and to lead the world.

Efficiently utilizing thermal energy with heat pumps

Eguchi: We have been talking about electrical energy so far, but under Fuji Electric's management policy of "through our innovation in energy technology, we contribute to the creation of responsible and sustainable societies," we are also paying attention to thermal energy, and are thinking about technology that can use thermal energy effectively.

Thermal energy, qualitatively speaking, is energy in its final stage, and a large portion of such is often discarded. According to a certain estimate, Japan uses approximately 20,000 Peta*1 joules of primary energy per year, and this is equivalent to about 480

*1: Peta : 10^{15}

million tons of oil. Of this amount, however, 45% will eventually be discarded as heat and this is a huge waste of energy.

Yabe: Thermal energy is my field of expertise.

Thermal energy is used in a significantly large quantity, and accounts for about half of the overall energy consumption at AIST for cooling, heating, cleanroom air conditioning and the like. In the last 5 years at AIST, we have realized a 15% reduction in total energy consumption. The majority of this reduction is a result of the effective use of thermal energy. AIST formerly made annual payments of about 4 billion yen for energy, and a 15% reduction corresponds to a savings of 600 million yen. Considering that 600 million yen can now be diverted to research expenses, I think that the efficient use of thermal energy is an important matter.

The effective use of thermal energy has been supported by the progress of heat pumps. Heat pump performance is measured by a coefficient of performance (COP) value that indicates, for a given consumption of electrical energy, the multiple of thermal energy that will be obtained, and the heat pumps available on the market today have COP values of around 6. Such a value means that, for example, if a 1 kW electric heater was previously required for heating, that same 1 kW of heat can now be obtained using a heat pump air conditioner of 170 W, that is one-sixth of the electric heater.

We have moved on from the era in which fossil fuels were used for heating and supplying hot water. In the present era, electrical energy, which is one form of energy, is intervening in major thermal energy applications, such as cooling and heating and supplying hot water. I believe this to be a huge innovation.

Thermal energy is an important energy for uses that include cooling and heating, but our ways of using thermal energy are still quite wasteful, and there is still room to reduce such usage.

Eguchi: You mentioned heat pumps, and in 2012, Fuji Electric, a manufacturer of vending machines, launched a model with advanced heat utilization. With a structure that utilizes heat from outside air as well as exhaust heat from a cooling chamber to adjust the temperature of a heating chamber, the energy consumption was reduced by 40% compared to the prior year's model. The energy consumption of vending machines has been reduced to one-fifth over the course of fifteen years, but the further reduction by 40% all at once in one year made us realize the tremendous effect of heat pumps.

Yabe: Heat pumps that produce thermal energy are a world-leading product from Japan, and their use in constructing systems such as vending machines is actually very important and is attractive energy-saving technology that should have appeal worldwide.

YABE Akira

Born in 1952. Completed PhD in Mechanical Science and Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology in 1979. Joined Mechanical Engineering Laboratory of Agency of Industrial Science and Technology, Ministry of International Trade and Industry. Head of Fluid Engineering Research Lab, Department of Energy in 1995. Head of Quantum Engineering Research Lab, Extreme Technology Department in 1997. Concurrently Head of Mechanical, Quantum and Molecular Engineering Special Research Laboratory in 1998. Head of Planning Office for Mechanical Engineering Lab in 1999. Served as Director for Advanced Manufacturing Research Center on Micro and Nano Scale Science and Engineering, National Institute of Advanced Industrial Science and Technology (AIST), Director of Chugoku Regional Research Center, Chief of Biomass Technology Research Lab, Chief of Research Collaboration Promotion Department in 2001. Served as the Vice-President of AIST since 2008. Concurrently Director General for Environment and Energy Research Fields. Presently, also serving as President of the Japan Society of Mechanical Engineers (JSME), as Member of Science Council of Japan, Chairman of Fine Bubble Industries Association (FBIA), Professor (Cooperative Chair) of Dept. of Mechano Micro Engineering, Tokyo Institute of Technology, Adjunctive Professor of Cooperative Graduate School of Kanazawa Institute of Technology, Director of Technology Research Associations of R&D Partnership for Future Power Electronics Technology (FUPET), FC-Cubic (Fuel Cell Cutting-Edge Research Center) and Photovoltaic Power Generation Technology Research Association (PVTEC).

Additionally, everyone is presently studying industrial-use high-temperature heat pump systems with the goal of future realization. The public still does not use waste heat very much, and often discards it. A waste heat system would pump this waste heat and raise its temperature up to 160 °C. At present, boilers are used in industrial applications, but because boilers require long pipes, they have the disadvantage of large thermal loss. Heat pumps can be individually installed at required locations, and are an effective technology for reducing global warming.

AIST would like to gather the collective wisdom throughout Japan and research and develop this technology.

Cultivating binary generation technology with geothermal technology

Eguchi: Now, AIST is hosting a technical symposium for unused thermal energy.

Yabe: Yes, that is correct. For about the past 30 years, AIST has been working on waste heat utilization and the use of heat pumps to boost tem-

peratures. In the case of renewable energies, there are maps that show where the wind is strong, but there are no maps that show unutilized heat, such as which factory is discarding what quantities of heat. If such a map did exist, we believe that there would be a greater possibility of using heat effectively within a factory or industrial complex, and are therefore intensifying our efforts.

Eguchi: From the viewpoint of using heat effectively, not only usage of heat as heat and conversion of heat to electricity in an intermediate process, but also binary generation using low temperature hot water and exhaust heat from a factory are conceivable.

If we also think about converting geothermal heat, having been discarded at low temperature, into electricity, then I think there is the potential to conserve even a little more energy with thermal energy.

Yabe: Fuji Electric has an impressive track record in geothermal power generation. Actually, an even better solution would be to generate power using warmed cooling water that has been discarded from a factory, but one difficulty would be the long time required to recover the capital investment. In the present era, however, such thermal energy must also be treated carefully, and if we consider whether the thermal energy should be used to generate electric power, or whether its temperature should be raised and then utilized, as well as the sorts of systems that would be able to use this energy, I think that such development would be very profitable.

Eguchi: For geothermal power generation, Fuji Electric has expertise in a flash method that generates electric power using steam extracted from hot water that flows out of the earth. We are using double-flash or triple-flash methods whereby, after extracting steam that is 200 °C or hotter, the pressure of the remaining water is reduced and low-pressure steam is extracted, and after extracting low-pressure steam, the pressure of the remaining hot water is again reduced and the low-pressure steam is used to generate electricity. This method is used at the Nga Awa Purua (NAP) Geothermal Power Station in New Zealand, and was awarded the top prize of the Japan Electrical Manufacturers' Association (JEMA) in 2012. The power generation capacity of a single turbine is 140 MW, which is the largest in the world for geothermal power generation. Recently, we are also advancing practical application of binary generation, which uses low temperature hot water to vaporize low-boiling-point media for use in generating electric power.

Yabe: Geothermal power is the type of renewable energy that is supplied most stably. It is unfortunate that geothermal power generation has not been able to become more popular in Japan. Everyone is now putting forth ideas for ways to use thermal energy more effectively, and I do hope that Fuji Electric continues its efforts in this area.

Eguchi: We want to increase activity in Japan where there is high potential for using geothermal energy. We are also working to spread the usage of geothermal power generation.

Initiatives for distributed energy

Eguchi: By the way, I have heard that AIST is conducting research into distributed energy network technology. Could you please elaborate on that?

Yabe: In the aftermath of the Great East Japan Earthquake, public opinion has increased for using renewable energy as much as possible. In response, AIST established a research center for renewable energy in Koriyama, Fukushima Prefecture. Demonstration testing of various types of renewable energy can be conducted there. We want to use this

facility as a testbed for studying how to handle input energy that fluctuates greatly.

While speaking with victims of the Great East Japan Earthquake, I was told that "After the large earthquake, there was no electricity for about 1 week, but the sun shone brightly. We would have been able to endure the cold only if at least community centers had electricity from solar power generators," and I realized that, separate from the economic issues, an energy system that provides a foundation for an autonomous lifestyle is also essential.

Accordingly, there are still many topics regarding distributed energy to be researched and developed, such as the establishment of energy bases for disaster prevention and techniques for handling a demand response system that uses energy effectively. We want to continue to focus on this field in the future.

Eguchi: Fuji Electric is also participating in the Kitakyushu City Smart Community Project, the centerpiece of which is demand response. A technique known as dynamic pricing, whereby the range of the price for electricity varies according to the temperature forecast for the next day, has been applied and a very interesting result has emerged. As the price of electricity increases, the usage of electric power decreases, and the peak demand for electrical power decreased as a result.

In consideration of such consumer psychology, it is conceivable that when the amount of solar power generation is increased, the price of electricity can be reduced to increase consumption significantly instead of storing that energy. In order to popularize renewable energy, a multi-faceted approach is necessary.

Yabe: As you say, demand response based on economics would also be an important key.

Eguchi: A comprehensively thought-out approach would be good, whereby in addition to an economic incentive to save on energy costs by conserving electricity, there would also be an incentive to help the environment by using clean energy to reduce CO_2 emissions.

Overcoming the "Death Valley"

Eguchi: Now that I think about it, the future of energy technology is often spoken about in the context of its relation to society.

Yabe: I mentioned this briefly before, but AIST's mission is to "bring technology to society," and we believe it to be extremely important that the things we research and develop will be useful to society. However, between the practical research stage and the product commercialization stage, there lies a "death valley" and then during the time until product commercialization and survival in the market, the tests and trials known as the "Darwinian Sea" are waiting.

Let me give an example. One of the inventions AIST is most proud of is carbon fiber. Carbon fiber was invented for the first time in the world in the 1950s by a researcher named Shindo at AIST's Kansai Center. Then in the 1970s, practical applications were realized in the fiber industry by Toray Industries, Inc. and others. Carbon fiber was commercialized and overcame the R&D "death valley," but from the perspective of a corporate operations department, it would be very difficult to enlarge the industrial scope of this invention with subsequent research and development. Fiber manufacturers expanded the market to fishing rods, golf shafts and airplanes, and grew the market to nearly 100 billion yen. This can be called an example of successfully having crossed the "Darwinian Sea."

We have witnessed research and development efforts in many countries, but most of the technology is unable to overcome the "death valley" and ends up forgotten.

What should be done to overcome the "death valley"? I think that a generic methodology might exist. Such a method would firmly identify the best application early on, feed back profitability calculations to the basic research department and focus on important research, and as in the case of SiC, manufacture and send out samples to show the product to the public is also an effective way to have the technology accepted by society. Seeing an actual product tends to make people also want to try and make it by themselves. In order to overcome the "death valley," we also intend to focus on open innovation.

Using roadmaps to evaluate practical research

Eguchi: It is important that researchers pay attention to whether a certain technology is used in society and survives. At AIST, the researchers are made aware of this, aren't they?

Yabe: After becoming an incorporated administrative agency, we have consistently made our researchers aware of this. And finally after 10 years, I feel that everyone's awareness has changed.

For biomass energy conversion systems that use a combination of biological processes and chemical processes to make ethanol from wood, AIST was the first in the world to make trial calculations of the profitability of such a system. That paper received an award at an academic conference, and now everyone has a shared view of the importance of realizing practical applications for technology.

Eguchi: How do you evaluate researchers with regard to their efforts toward realizing practical applications?

Yabe: We call it a roadmap evaluation. The roadmap of each project is drawn to show whether the technology will clear the "death valley" and be accepted by society, whether it is economically feasible, and also shows tasks to accomplish in order to realize practical applications. While looking at the roadmap, we make our evaluations based upon the progress to date.

Eguchi: That is a great approach, especially because basic research tends to lose sight of the exit and is also difficult to evaluate. By all means, please allow us to reference this roadmap evaluation.

Nurturing talent and technology through exchanging information

Eguchi: AIST has various researchers, both male and female, and working both in Japan and overseas, I believe.

Yabe: We have nearly 600 foreign researchers, and have signed comprehensive agreements with various institutions and laboratories throughout the world to create an information exchange network. In the environment and energy field, in order to prevent warming of the entire planet, cooperation with foreign countries is essential instead of efforts limited to Japanese-led initiatives. We are continuing efforts to encourage all countries to come together and establish international standards.

Eguchi: Fuji Electric is also anticipating globalization, and is increasing our number of overseas bases at a rapid pace. However, because our core research is based on Japan-led initiatives, our researchers are recruited and work in Japan, and foreign researchers only constitute a few percent of our total number of researchers. We plan to focus on power electronics as a core technology, and want to hire a broad range of researchers in the field, but I think assembling talent globally will not be easy.

Yabe: A significant portion of the research and development work for power electronics can be advanced by Japan, I think. However, speaking from the experience of having conducted research jointly with a research institute of the U.S. Department of Energy, oftentimes, during a discussion, a previously unconceived thought may arise, and will coalesce into a new idea. Discussing an idea, after having thoroughly thought it through, with a person having a different point of view is an approach to innovation,

and I hope you aim for this because it is an important part of globalization.

Eguchi: As for Fuji Electric, we have established a course in power electronics at the University of Tsukuba. We hope that, by taking this course, the number of young people interested in power electronics will increase.

Yabe: In the summer of 2012, AIST sponsored a 3-day "Tsukuba Innovation Arena (TIA) Power Electronics Summer School," and of the more than 100 attendees, half were graduate students and half were young company employees. Being able to study from the dual perspectives of materials/devices and applications, rather than just from a single perspective as is usually the case, I believe, provided these students with a comprehensive view. Additionally, Vice President Shigekane of Fuji Electric also spoke as a lecturer from the perspective of industrial applications for power electronics. I was impressed that everyone was listening intently with their eyes beaming. I think that this is also a way to cultivate talent.

Ultimately, human resource is important, and if such talented people can be nurtured and raised, then good technology will also emerge.

Eguchi: I agree. As in the case of AIST and the University of Tsukuba, an environment that provides the opportunity to study state-of-the-art technology with teachers and researchers is great. The aim in establishing a power electronics course at the University of Tsukuba is, through cooperation between the university, AIST and companies, to foster future engineers and researchers who have a true understanding of applied technology, from the device level to circuit applications. I think that the individuals who have studied here will play important roles in the future of power electronics.

Yabe: The young researchers at AIST too, while advancing their research and development in an environment where they are able to engage in serious discussions with Fuji Electric personnel, come to understand what is sought now and what are the important points for basic research. This mutual stimulation is beneficial, and I feel that the technology will grow as a result.

Reviving Japan with energy technology

Eguchi: Japanese companies seem to be losing their self-confidence nowadays. This feeling is especially acute among electronics manufacturers. Japan, however, possesses the technology to lead the world

in the field of energy and the environment. Putting that technology into practice would enable Japan to regain its vitality. We would like AIST to use its knowledge to lead us corporations and to direct Japanese technology along the same vector so that ultimately the entire nation of Japan will be revived.

Yabe: It is our dream that, through our TPEC activities, SiC power electronics technology will be introduced to the world, and will spread globally to promote energy savings. We all want to do our best for this purpose. What we can do, however, is to run the organization well to accomplish our mission, and when a technology has ventured into the world, for example, we could address the form of the relevant international standards, or how society should relate to the risks of the technology.

Japan possesses knowledge that can drive the global field of energy and environment. With everyone's cooperation, we want to make this a successful example. Thank you for your ongoing support.

Eguchi: We would like to deepen our cooperation in terms of technology and personnel, and in addition to reviving Japan, also want to contribute to solving global energy and environment-related problems. Thank you very much for your time today.

Achievements and Future Outlook

Innovations in Electric and Thermal Energy Technology

EGUCHI Naoya
General Manager of Corporate R&D Headquarters,
Executive Officer, Fuji Electric Co., Ltd.

1. Introduction

As part of the reconstruction of areas affected by the Great East Japan Earthquake, the construction of new communities is planned, and in April 2012, eight districts including Aizuwakamatsu-shi were specified by the Japanese Ministry of Economy, Trade and Industry as Smart Community Master Plan Special Districts, and the formulation of specific plans is underway. Additionally, the Feed-in Tariff Scheme for renewable energy began in July 2012, and renewable types of energy such as photovoltaic power generation and wind power generation are rapidly becoming prevalent.

Under these circumstances, in July 2012, Fuji Electric adopted a new brand statement of "Innovating Energy Technology." This statement reflects the company's ongoing pursuit of innovation in electric and thermal energy technology to develop products that maximize the efficient utilization of energy and to contribute to the creation of responsible and sustainable societies. To realize these goals, Fuji Electric is concentrating its research resources on the development of technology for supplying and using electric energy safely, securely and efficiently, technology for utilizing thermal energy without waste, and technology for optimally controlling those types of energy in order to develop systems and solutions that utilize distinctive components and technologies (see Figs.1 and 2). This paper presents an overview of these efforts.

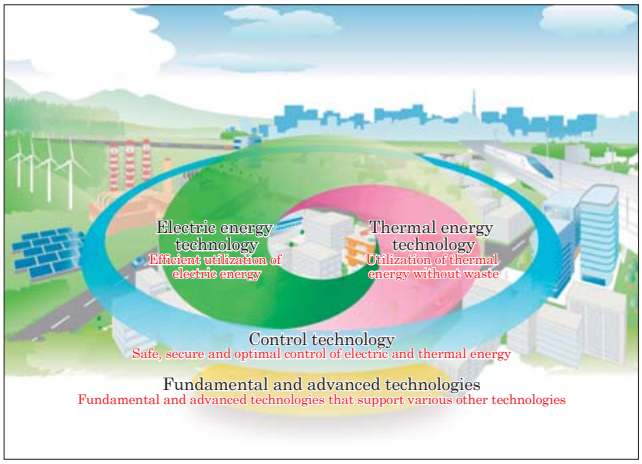


Fig.1 Fuji Electric's Technologies

2. Fuji Electric's Energy Technology

2.1 Electric Energy Technology

In the field of electric energy technology, Fuji Electric utilizes the synergy between power device technology and power electronics technology to develop component products and solutions that lead to energy savings.

With regard to power devices, Fuji Electric is developing insulated gate bipolar transistor (IGBT) modules, metal-oxide-semiconductor field-effect transistors (MOSFET), discrete devices and power ICs with the aim of realizing lower loss, lower noise, smaller size and higher reliability. For IGBT modules, in particular, a new process that forms a V-shaped groove on the backside of a device has been refined to develop an reverse-blocking IGBT (RB-IGBT) having a breakdown voltage of 1,700 V. Targeting the large capacity market, Fuji Electric expanded its series of 3.3 kV IGBT modules that use AlSiC as a base material. As a result of using this new base material, life spans of the heat cycle and the power cycle have been increased by several times. Additionally, for small capacity applications, Fuji Electric has developed a small capacity intelligent power module for use with inverter air conditioners. By combining an IGBT having a field stop type trench gate structure with a high-speed free wheeling diode, loss during light loaded operation, which accounts for approximately 80% of the time of air conditioner operation, was reduced by about 25%. For further optimization of IGBT module design, Fuji Electric performed coupled analysis of semiconductor devices, circuits and thermal structures. With this technique, the error in determining electrical characteristics was reduced to one-fourth compared to the conventional method and the error in determining thermal characteristics error was reduced to one-half.

Compound semiconductors made from SiC (silicon carbide) and GaN (gallium nitride) are being advanced by Fuji Electric as next-generation devices that dra-

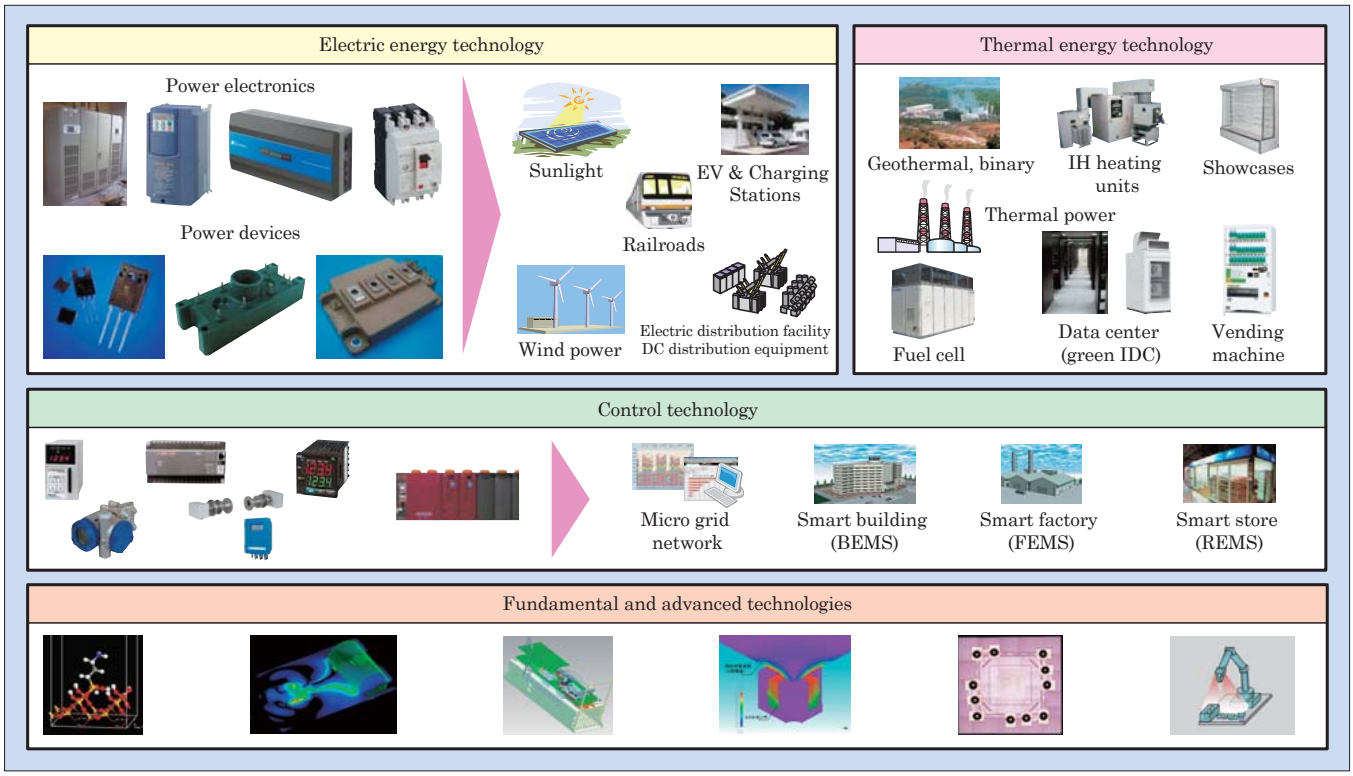


Fig.2 Fuji Electric's Technologies and products

matically reduce loss beyond the physical limits of the existing mainstream Si devices.

For SiC Schottky barrier diodes, Fuji Electric has developed them in cooperation with the National Institute of Advanced Industrial Science and Technology. Fuji Electric is supplying samples, and using these devices, has begun mass production of industrial-use inverters for the first time in Japan. The loss is lower by 20% compared to the previous products. Moreover, with the aim of mass producing SiC-MOSFETs, Fuji Electric is also advancing the development of All-SiC modules, which maximally exhibit the properties of SiC devices.

All-SiC modules use copper pins instead of conventional wire bonding, and also utilize an insulating substrate containing Si_3N_4 (silicon nitride), which has good thermal conductivity, and a newly developed highly heat-resistant epoxy resin to ensure high heat dissipation and high thermal resistance. In addition, a low inductance structure was also used, and one-half footprint of the Si-IGBT module was realized (see Fig. 3).

Nine of these All-SiC modules were embedded into a three-phase three-level circuit to fabricate a prototype of a 20 kW power conditioner (see Fig. 4) for use in photovoltaic power generation, and a smaller size that is one-fifth that of conventional devices and a main circuit efficiency of 99% were demonstrated[1]. In this way, Fuji Electric has also developed circuit technology for applications that leverage the advantages of SiC devices, and has developed innovative products while utilizing the synergies among the three technologies of low on-resistance chip technology, package technology and circuit technology.

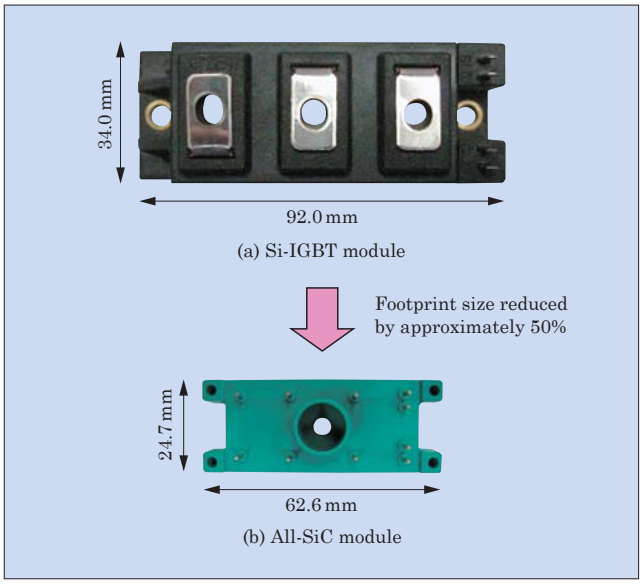
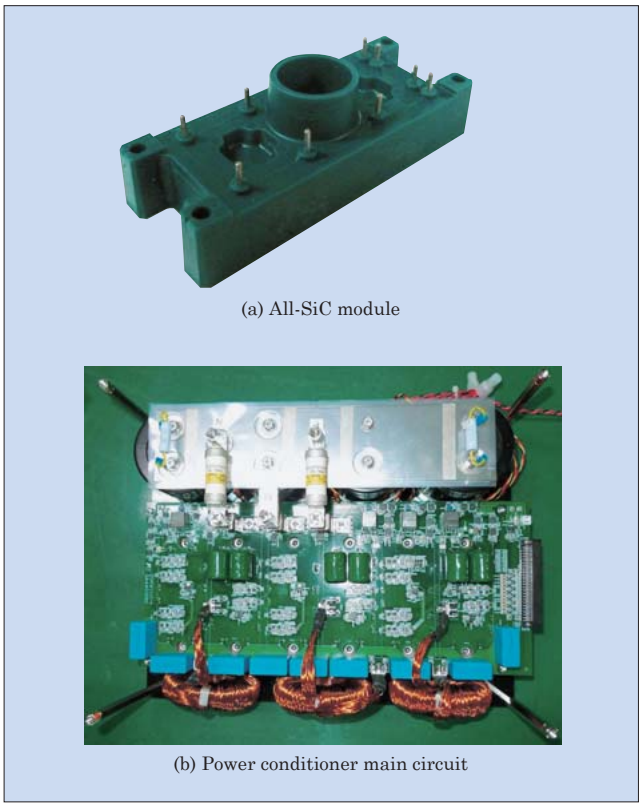


Fig.3 Footprint of All-SiC module

For power electronics equipment, Fuji Electric is advancing the development of low loss devices that maximally leverage the aforementioned power device characteristics.

With the start of the Feed-in Tariff Scheme for renewable energy, domestic Japanese mega solar facilities are rapidly increasing in number. Under these circumstances, Fuji Electric has applied its proprietary advanced T-type neutral-point-clamped 3-level conversion circuit technology to develop and launch a power conditioner that features significantly reduced switching loss, filter loss, and that realizes 98.5% conversion



(a) All-SiC module

(b) Power conditioner main circuit

Fig.4 Application to photovoltaic power conditioner

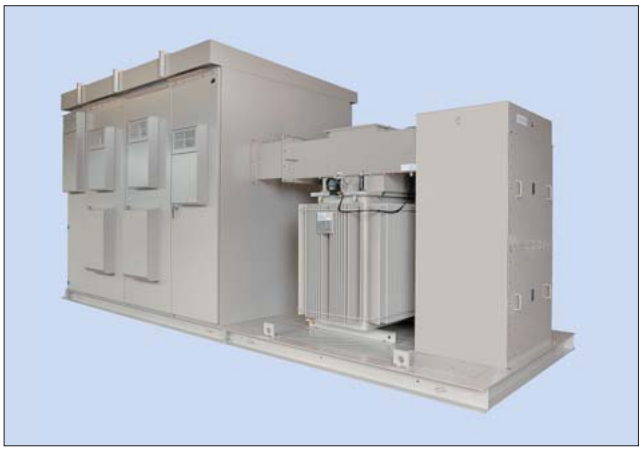


Fig.5 Power conditioner for use with mega solar

efficiency which is the world's highest class for use in 1,000 kW mega solar applications. The integrating of peripheral devices such as switchgears and transformers, and the packaging of basic functions enables onsite installation and assembly work to be performed in a shorter amount of time and construction costs to be reduced (see Fig. 5).

As a drive unit that can contribute to energy savings at large-scale facilities such as iron and steel plants, Fuji Electric has developed a stack-type high performance vector control-type inverter having a maximum output of 3,000 kW. The stack type configuration separates the inverter and converter functions, and direct parallel-connection technology for driving a motor can be applied when using multiple inverters in

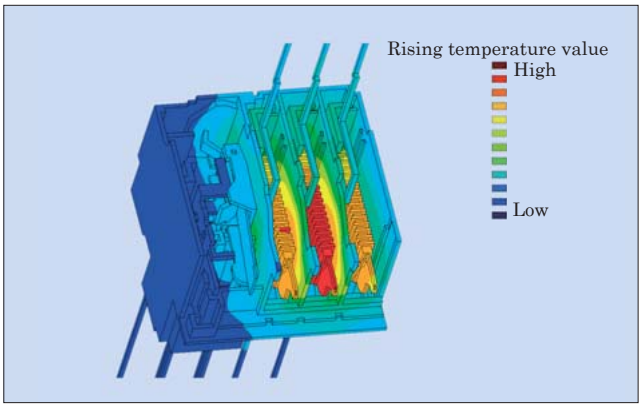


Fig.6 Coupled analysis of the amount of bimetal curvature and the electric current and electric heat.

parallel. In this case, continuous operation will be possible even if an inverter fails, and redundancy and an optimal combination can be realized according to the capacity of the customer's facility.

At factory production facilities, office buildings and commercial facilities, the importance of configuring space-saving, energy-saving and high-reliability distribution equipment and control systems is increasing. As power distribution and switchgear equipment that supports this need, Fuji Electric has developed 32 to 63 AF compact low-voltage circuit breakers and earth leakage circuit breakers for protecting small current circuits such as electric machinery and control panels. Additionally, as shown in Fig. 6, Fuji Electric developed a compact thermal relay by performing coupled analysis of electric current, heat transfer and amount of bimetal deformation to minimize the amount of heat generated by the heater and realize the industry's smallest class size. For higher voltage applications such as photovoltaic power generation systems, Fuji Electric has launched a series of 1,000 V DC nonpolar circuit breakers and switching devices. In addition, using an imbalance compensation algorithm for the earth capacitance, Fuji Electric has developed an Ior insulation monitoring unit for realizing a highly reliable distribution system and a power monitoring unit equipped with SD memory that facilitates the construction of stand-alone power monitoring systems.

2.2 Thermal Energy Technology

In the field of thermal energy, technologies that efficiently utilize high temperature heat, such as for thermal power generation and geothermal power generation, and technologies that efficiently utilize cold heat such as for data centers, vending machines and showcases, are being developed.

Fuji Electric delivered, for its first time, uniaxial combined cycle power generation systems to The Okinawa Electric Power Company, Incorporated as No. 1 and No. 2 units of the Yoshinoura Thermal Power Station, and these units were put into commercial operation in November 2012. A gas turbine from Siemens AG and an electric generator and steam turbine from Fuji Electric are arranged uniaxially, with

a clutch interposed between the electric generator and the steam turbine. Use of the clutch to optimize the starting of the gas turbine and the steam turbine enables the startup loss to be reduced. Compared to a conventional thermal power generation system that generates power with only a steam turbine, a combined cycle power generation system fueled by natural gas has such advantages as higher power generation efficiency, lower CO_2 emissions, and superior operability with easy startup and shutdown, and the use of combined cycle power generation systems has been expanding in recent years.

Fuji Electric has developed and launched energy-saving showcases for use in supermarkets. Refrigerated and freezer showcases blow out cold air from the front, blocking outside air as if a curtain were in place, and keeping the cold air inside. Thermal fluid simulation technology was used to analyze precisely the air curtain volume and flow, and the cold air blowing unit and the structure of the product display shelves were thoroughly reviewed to realize significant energy savings. Use of these showcases can lower the total power consumption per store for showcases and refrigeration by 30%.

Heat pump technology is a technology that significantly contributes to energy savings. Fuji Electric has developed an indirect outside air cooling system that indirectly introduces outside air and uses a heat pump to perform efficient air conditioning. This system is being used in data centers and the like that consume large amounts of electric power for air conditioning. Additionally, Fuji Electric led the industry in introducing a vending machine that employs heat pump technology to warm beverages using the waste heat generated while cooling products, rather than discarding that heat externally. Moreover, a hybrid heat pump method that takes in, as a heat source, not only the waste heat generated during product cooling but also the heat of the outside air, has also been developed (see Fig. 7). With this method, by controlling a proprietary electronic expansion valve at the same time that the compressor is being driven by the inverter, cooling and heating control is implemented corresponding to the load. As a result, Fuji Electric constructed energy saving technology that eliminates the need for a heater except when there is a high load, such as at the initial installation of the vending machine. In this way, although the installation of the heat pump already reduced the energy consumption by half, the hybrid heat pump method realized an additional energy savings of 30%.

In order to transfer cold and hot heat efficiently, Fuji Electric has developed an all-aluminum heat exchanger that transfers heat from a refrigerant to the air more easily than a conventional fin and tube heat exchanger, and that can significantly improve the heat exchange performance. The thermal transfer performance of this heat exchanger is improved with a perforated tubular structure having multiple refrigerant flow paths and corrugated-shaped fins that are integrally attached by solder (see Fig. 8). This heat exchanger is used in vending machines that employ the above-described hybrid heat pump method. Utilizing thermal technology having such features, Fuji Electric intends to develop a wide range of thermal energy management technology for factories, office buildings, data centers and the like, and to contribute to the energy savings of thermal energy as well as electric energy.

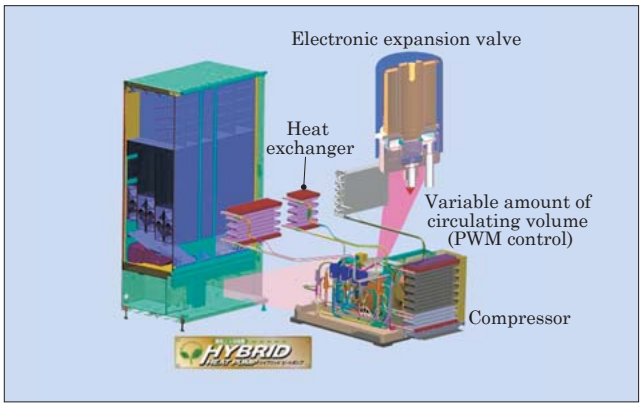


Fig.7 Hybrid heat pump method

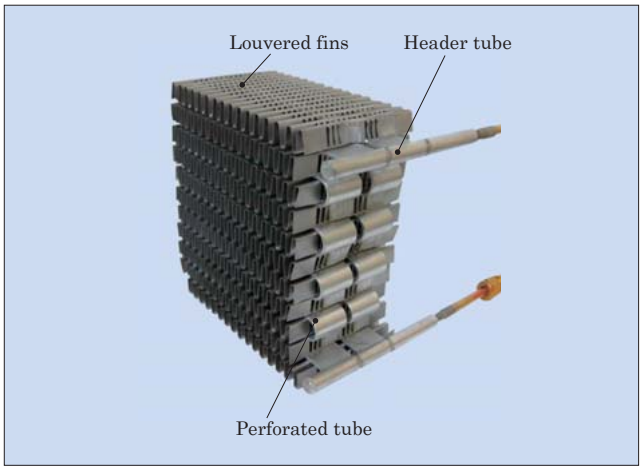


Fig.8 All aluminum heat exchanger

2.3 Control Technology

In order to create responsible and sustainable societies by fully utilizing electric and thermal energy technology, optimal control technology for electric energy and thermal energy storage, including electric power storage and heat storage, is indispensable. As such a control system, development and demonstration work is moving ahead for Fuji Electric's energy management system (EMS) that communicates demand side and supply side energy information bidirectionally to utilize energy efficiently based on that information and realize energy savings.

Fuji Electric is advancing the development of factory energy management systems (FEMSs), building and energy management systems (BEMSs) and retail energy management systems (REMSs) that visualize the energy consumption of energy consumers such as factories, stores and buildings, and introduce and opti-

mally control various energy-saving devices.

Common parts for constructing these EMSs were made into a platform and a mechanism that facilitates efficient system development was established. Each EMS has been developed in a smart community demonstration project, to be described later, and demonstrations of their effectiveness are already underway.

The concept of smart communities, which aim for sustainable development of the entire community, including the efficient usage of energy, cyclic utilization of resources, environmental protection and the like, has been attracting attention. This is a concept that greatly expands the idea of smart grids that aim to provide electric power grids with the ability to perform optimal control of the supply and demand control of electric power, expand the introduction of renewable energy, and reduce the consumption of electric power.

As mentioned below, many technologies and solutions are presented in organic combinations. These technologies and solutions address the challenges of supplying power using renewable energy, improving the efficiency of the supply of energy including thermal energy and adopting green technology. The implementation of energy saving buildings, factories and stores that use each EMS to control energy consumption optimally, ecofriendly transportation systems, safe and secure water supply and sewerage systems, wastewater treatment, and the like.

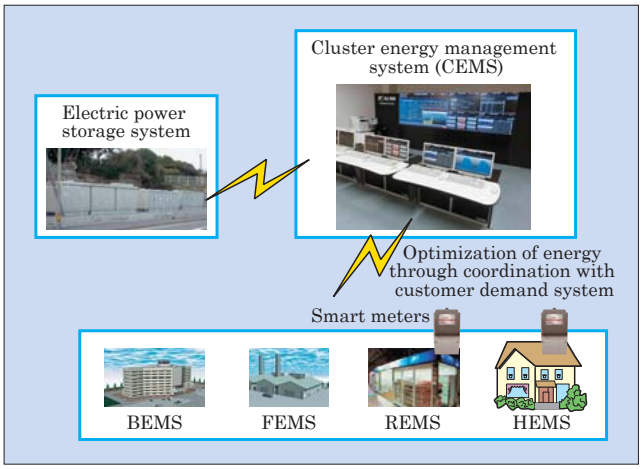


Fig.9 Kitakyushu Smart Community Creation Project

While participating in smart community demonstration projects, Fuji Electric is also developing these technologies. In Japan, Fuji Electric is participating in the development and demonstration of a cluster energy management system (CEMS) in Kita Kyushu City (see Fig. 9). Technical development such as optimal energy control with a CEMS, power stabilization by using storage batteries, supply and demand control through the use of smart meters, and optimal energy control for hospitals, factories and stores was carried out, and demonstration testing of these systems has begun. Through using a CEMS and a smart meter in a public demonstration to verify the effect on power consumption due to dynamic pricing, which causes the unit price of power to fluctuate according to power demand, a maximum peak cut of 13% was confirmed for the summer months.

The results of these demonstrations are consolidated as "a compact social infrastructure package," as depicted in Fig. 10, and their application to smart communities, industrial parks, islands, and other regions without electricity is being promoted. This package also includes power control solutions for maintaining power quality even when large quantities of renewable energy are introduced, energy-saving solutions based on an EMS, safe and secure solutions that utilize environment measurement technologies and ICTs, and service delivery solutions such as environmental measures.

2.4 Fundamental and Advanced Technologies

Fuji Electric is also advancing the research and development of fundamental technologies that com-

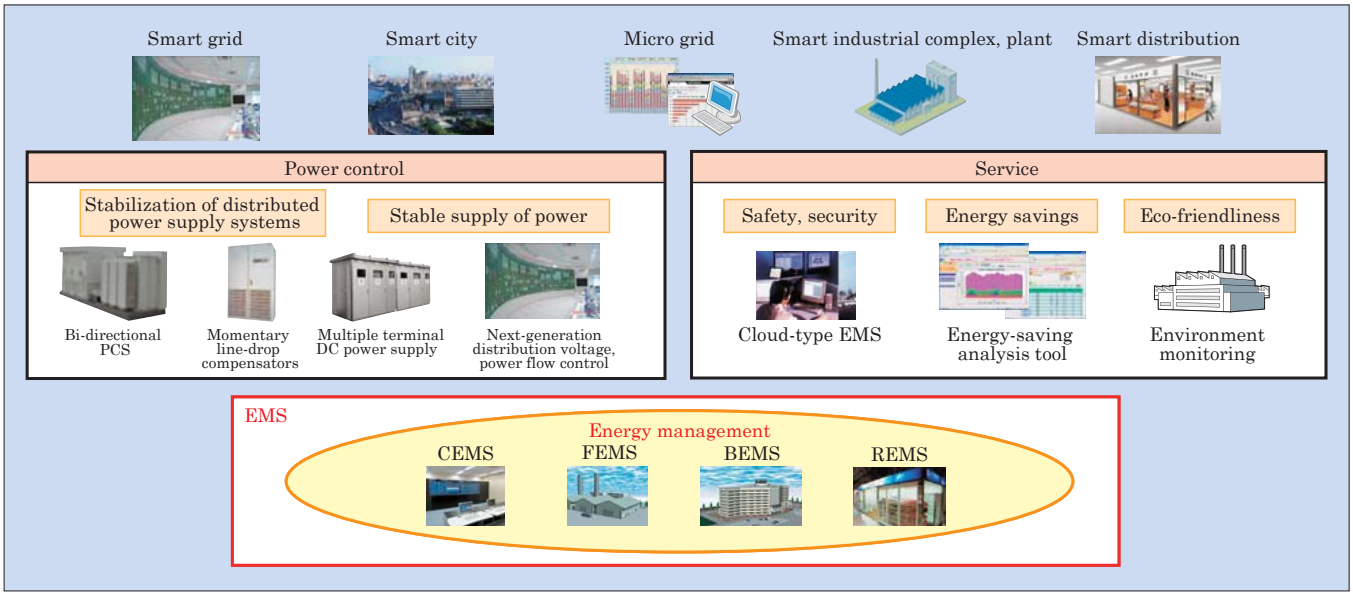


Fig.10 Compact social infrastructure package

monly support the electric and thermal energy technologies and control technologies described above. For materials technologies, to establish guidelines for the required physical properties of resins that are widely used in products, Fuji Electric is studying technologies that utilize molecular simulation techniques. The resins are analyzed in terms of their molecular structure and electron states, and molecular dynamics are used to analyze the effects of fillers that are mixed with the resins to realize higher heat resistance. This technique is applied to the development of materials for various devices, including semiconductor packages.

For insulation technology, Fuji Electric has developed partial discharge visualization technology that combines a high-speed camera and microscope to allow observation of small areas at high speed. This technique allows observation of details of the behavior of the insulation breakdown of foam caused by partial discharge with a gel, and has made it possible to clarify the discharge-generating mechanism, which heretofore had been unknown. Fuji Electric plans to apply this method to the development of high-voltage power semiconductor modules.

Fuji Electric developed a simulation technique that can be used at the design stage for the accurate evaluation of electromagnetic compatibility (EMC: the generation or reception of electrical or magnetic interference) characteristics (see Fig. 11). The application of this technique to product design has resulted in improved reliability of power electronics equipment and shorter development times.

Compliance with international standards is becoming increasingly important. As in the saying, "that which controls the standards controls the market," regardless of the excellence of a certain product, that product will not be able to capture its market, unless it meets global standards. Fuji Electric has established an in-house international standardization committee to strengthen its compliance of standards relating to power electronics products and smart communities.

Fuji Electric is participating in such committees as the International Electrotechnical Commission's TC22 (Technical Committee 22) (power electronics) and TC57 (power system management and the exchange of related information), and is actively involved in EMC functional safety, which will be standardized in the future, and energy efficiency standards and the like.

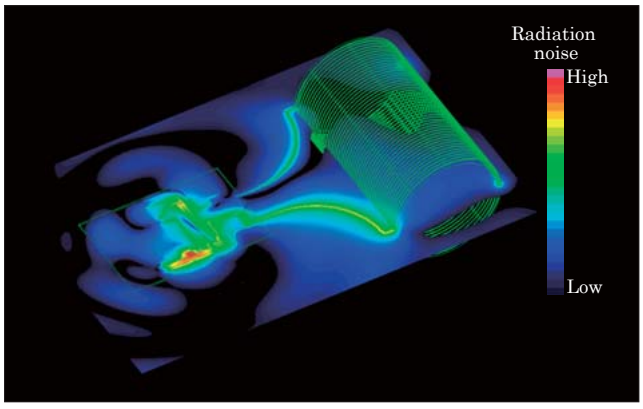


Fig.11 Example of EMC simulation (analysis of radiation noise)

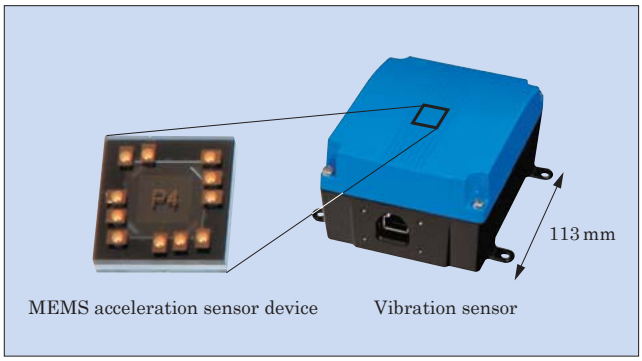


Fig.12 Vibration sensor based on MEMS technology

In terms of advanced technology, Fuji Electric is moving forward with the research and development of distinctive devices that utilize micro electro mechanical systems (MEMS) technology. By applying MEMS technology, Fuji has developed compact, low-cost acceleration sensor devices that can measure acceleration along three axes, the X-axis, Y-axis and Z-axis (see Fig. 12). Utilizing their advantages of compact size and low cost, these acceleration sensor devices are being verified in multi-point vibration measurement applications for large structures such as buildings and bridges, and in high-density applications for seismic measurement and the like, and there is a great deal of interest in these devices.

In addition, Fuji Electric is participating in the project of the Innovation Center for Medical Redox Navigation with Kyushu University, and is carrying out research and development of an optical scanner intended for use in medical devices, where small size is required. To drive the scanner, electrostatic attraction between electrodes fabricated with MEMS technology is used. Techniques to realize even further miniaturization are under development.

3. Postscript

This paper has presented an overview of Fuji Electric's focused research and development activities in the fields of electric and thermal energy and control technology.

Hereafter, building responsible and sustainable societies that are in harmony with their environments will be accelerated both in Japan and globally. To meet the requirements of such an era, Fuji Electric will continue to advance research and development, and to offer distinctive products and solutions in order to contribute beneficially as a good corporate citizen of the global community.

References

(1) MATSUMOTO, Y. et al. "Characteristics of the power electronics equipments applying the SiC power device." Proceedings of ICPERE 2012.

(Photo: provided by The Okinawa Electric Power Company, Incorporated)

The Okinawa Electric Power Company, Incorporated Opens "Abu Mega Solar" Business Service

A photovoltaic power generation plant for the Okinawa Electric Power Company, Incorporated's "Abu Mega Solar," which is the first mega solar (1 MW) plant in Okinawa main land, was completed and started operation in March 2012. This power plant is also a demonstrative site for the following purposes:

(1) To clarify effect of PV's power fluctuation on the grid line

(2) To compare actual outdoor performances of two kinds of solar cells, chemical compound (CIGS) and thin film (amorphous) silicon

Features of this plant are shown below:

(1) It has a supervisory and control function operated from both the site and head office of Okinawa Electric Power Company, Incorporated.

(2) It can control both active and reactive power of PV's output.

(3) A tilt angle of PV modules is adjustable.

Indoor Power Conditioner "PVI750-3/500"

The Feed-in Tariff Scheme for Renewable Energy, which was launched in July 2012, has created a construction boom in Japan for large-scale photovoltaic power generation facilities. The power generation capacity of many of these facilities is less than 2 MW, which capacity allows interconnection with medium-voltage lines. In addition, these facilities are constructed by combining multiple power conditioners from the perspective of maintainability.

Accordingly, Fuji Electric has commercialized the 500 kW PCS (600 V DC) that can be used in parallel by utilizing 3-level-conversion units. It achieves efficiency of 98.1% (exclusive of an internal power supply), which is 0.4 points higher than the products of other manufacturers of the same capacity in the 600 V DC class. Furthermore, the DC input voltage ranges from 310 to 750 V, thereby allowing photovoltaic panels to generate power at the operating point at which the maximum power is produced in JAPAN, where the temperature varies significantly throughout the year, even in both winter, when a photovoltaic panel voltage rises, and summer, when a photovoltaic panel voltage falls.

All-SiC module (1,200 V/100 A)

Inverter unit

Module mounting

Inverter for Photovoltaic Power Generation PCS Equipped with All-SiC Module

Fuji Electric and the National Institute of Advanced Industrial Science and Technology (AIST) have teamed up and have been carrying out research and development of SiC-MOSFET and SiC-SBD. SiC devices have advanced features that are high temperature operation, high frequency switching, etc. Fuji Electric has developed an ultra-small-size All SiC module with AIST's SiC-MOSFET and SBD. We have utilized a high heat-resistant jointing material, molding resin and low inductance wiring structure for the developed module that achieves the development of the module size that is 50% smaller than conventional Si modules.

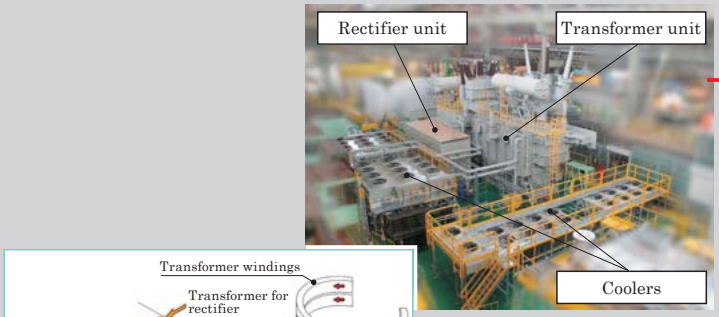
In addition, by adopting the module, we have developed an inverter specialized for power conditioners used with photovoltaic power generation outputting 20 kW. High frequency switching of 20 kHz and advanced t-type neutral-point-clamped (AT-NPC) 3-level circuits have helped us accomplish a capacity that is only 20% of conventional products using the same level of electricity as well as a maximum conversion efficiency of 99.0%. Some of our research efforts were carried out as part of a project of the joint research body "Tsukuba Power-Electronics Constellations (TPEC)."

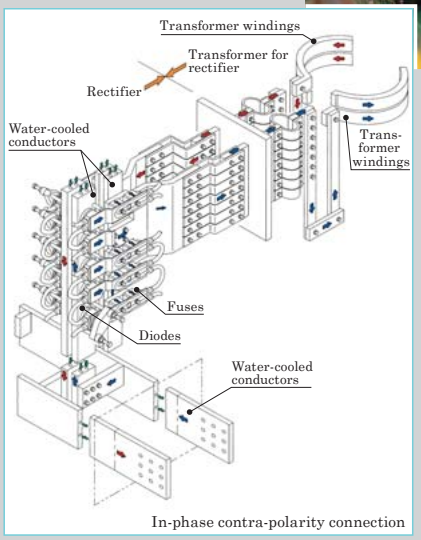
Direct Drive Permanent Magnet Generator of 3,000 kW Class for Wind Power Generation

Development has been made of a direct drive permanent magnet generator of the 3,000 kW class for wind power generation. With rotation speed of 15 min^{-1} at a voltage of 690 V, this generator is the largest permanent magnet generator for wind power in Japan.

Making full use of analysis technology at the time of the development has allowed us to incorporate many innovative design technologies and production enhancements to achieve weight savings and high performance. Some of the implementations include reducing total length by utilizing a concentrated winding coil, improving cooling capability through a new cooling system, and the achievement of a strong structure that can endure heavy loads. During factory testing, we were able to obtain good results, which satisfy our predetermined performance standards, such as a temperature rise of 115K or less and an acoustic noise of 80 dB or less under no-load.

Systems that make use of direct drive permanent magnet generators are superior to other types of systems concerning maintainability and operating efficiency. Sales of mass-produced generators are scheduled to start in FY2013.





World's Largest Single-Unit Capacity Transformer Rectifier Unit "S-Former" for Aluminum Smelting Facility

Fuji Electric completed manufacturing of transformer-rectifier units which are called S-Former and the units were successfully shipped in August 2012. The DC output rating of the units is 92 kA at 2,000 V DC and it is the world's largest single-unit capacity ever manufactured.

The transformers have been designed to be small footprint in size and to effectively deal with harmonics through the use of a hybrid insulation technology which appropriately arranges insulation materials corresponding to high temperature in the windings.

The rectifier stack has been developed as the world's first unit to be 2,000 V DC output.

The unit configuration uses Fuji Electric's unique in-phase contra-polarity connection technology to achieve the design which simultaneously eliminates magnetic fields and facilitates a high withstand voltage.

Stack-Type "FRENIC-VG Series" Inverter

In recent years, there has been increasing demand at large-scale facilities such as iron and steel plants for systemization that optimizes capacity and responsiveness, while at the same time, requiring easier installation and replacement procedures as well as less space usage. These customer demands can be met with the addition of a stack-type, which inherits the basic performance of the "FRENIC-VG Series," high-performance vector control inverters.

The main features are as follows:

(1) Improved storage efficiency with a slim structure, a width of 220 mm, allows to downsize cabinets (34% reduction over our previous products).

(2) Users can select either diode rectifiers or PWM converters to meet their applications.

(3) There are product lineups for various capacities up to 3,000 kW, and they employ a direct parallel connection method that makes them possible to operate with reducing operating capacity if one of the inverters breaks down.

(4) Easy stack replacement improves maintainability.

Standard-Type Inverter "FRENIC-Ace Series"

The Standard-Type Inverter "FRENIC-Ace Series" has been developed for driving motors of plant facilities, processing machinery, etc.

Its main features are as follows:

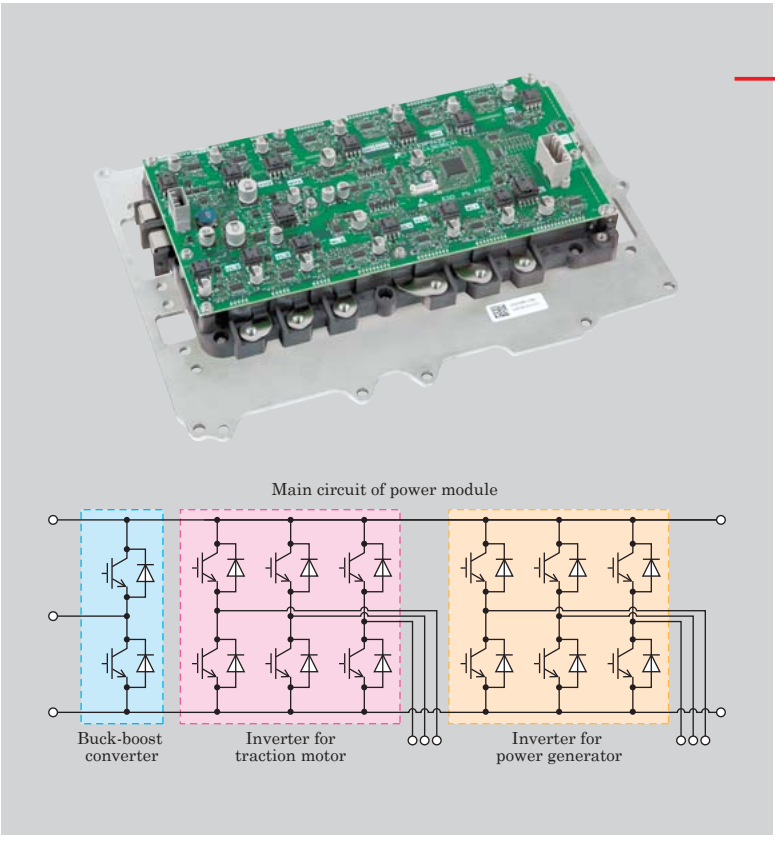
(1) Capacity series: 3-phase 200 V class 0.1 to 90 kW, 3-phase 400 V class 0.4 to 630 kW

(2) A size and cost of an inverter can be optimized by selecting up to four overload current ratings as well as selecting a current ratings or capacity which is suitable for a purpose.

(3) A feature rich customizable logic function makes it possible for customers to simplify surrounding circuits as well as construct an inverter designed for dedicated applications.

(4) This series contributes to energy-saving through featuring a sensorless driving method for synchronous motors as standard.

(5) Machine safety functions comply with functional safety standard IEC61800-5-2/61508.

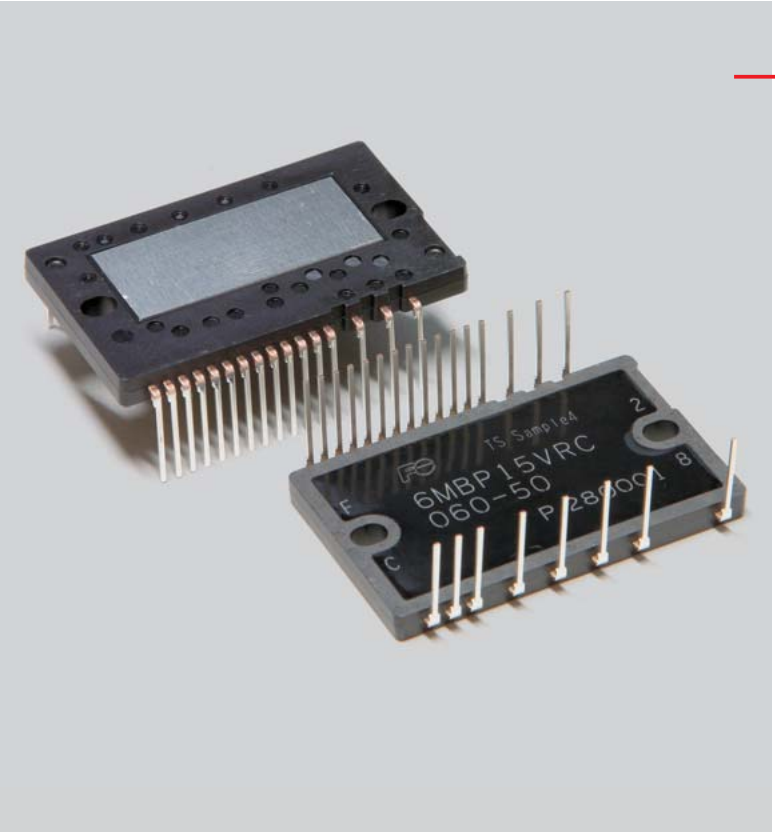


Intelligent Power Modules for Plug-In Hybrid Electric Vehicles

Mass production of intelligent power modules (IPM) for plug-in hybrid electric vehicles has started.

This module consists of separate inverters of a traction motor and power generator as well as a buck-boost converter. In order to achieve a compact and lightweight to realize the high output needed for plug-in hybrid electric vehicles, this IPM has been commercialized to combine a low-loss 1,200 V sixth-generation IGBT and FWD with a heat dissipation aluminum direct-water-cooling heat sink.

The mounted drive board incorporates several built-in protection functions, a fault detection function and a power supply circuit, which make it possible to use the CPU to have serial communication with the master ECU. Thermal fluid analysis was utilized to optimize the fin detail and coolant channel design in the aluminum direct-water-cooling heat sink in order to facilitate the effectiveness of heat dissipation. Furthermore, high durability of the insulating substrate soldering has been ensured by using high strength solder.



Compact Type IPMs for Inverter Air Conditioners

Among home appliances, air conditioners have the highest energy consumption ratio. In order to improve on energy saving performance, Fuji Electric has started mass-producing compact type intelligent power modules (IPMs) that have a built-in 3-phase inverter bridge circuit and control circuit.

By utilizing an optimized low-loss device, this IPM reduces loss during light load conditions, which occupy about 80% of yearly air conditioning usage, by about 25% in comparison with conventional devices.

In addition, thermal resistance has been reduced through the adoption of an insulated metal substrate with high thermal conductivity. Combining this with low-loss devices that facilitate effective loss reduction, temperature rises in the IPM can be suppressed, leading to an inverter that is smaller in size.

By utilizing this technology, Fuji Electric plans to start production in FY2013 to establish a product line-up of IPMs with a rated current of up to 30 A.

MCCB ELCB

"G-TWIN Λ (Lambda) Series" of Compact Low-Voltage Circuit Breakers and Earth Leakage Circuit Breakers

"The G-TWIN Λ Series" of compact molded case circuit breaker (MCCB) and earth leakage circuit breakers (ELCB) (32 to 63 AF) have been developed to provide comparatively low-current circuit protection for most machinery installations and control boards. This series reduce its installation area by narrowing the external width to 70% of that of previous products and comply with standards of many countries in the world as with existing "G-Twin Series," allowing to improve its adaptivity to miniaturization and global needs.

Silver and copper savings have also been realized through the adoption of a thermal over current detection mechanism and arc commutation breaking method. Furthermore, by adopting miniaturization technology for each component structure, we have secured enough mounting space for internal accessories which are necessary to configure control sequence. Thus all types of this series can be equipped with auxiliary and alarm contacts.

Fuji Electric is also currently developing models which serve downsizing needs of electrical facilities by employing a plug-in connection capability, leakage alarm function and correspondence to high voltage direct current.

Start of Commercial Operation of Ulubelu Geothermal Power Station in Indonesia

In February 2010, Fuji Electric contracted a full turnkey project of the geothermal power plant (55 MW×2 units), as a subcontractor of Sumitomo Corporation, with an Indonesian state-owned power company. This geothermal power plant is located at the Ulubelu region in the southern Sumatra.

The scope of Fuji Electric includes engineering work, supplying main equipment such as geothermal steam turbine, generator and control units and commissioning of the power plant.

The power plant commences commercial operation of the Unit1 in September 2012 and the Unit2 in October 2012.

This is the first large-scale geothermal power plant in Sumatra. The power plant is expected to provide stable supply of electrical power to southern Sumatra.

(Photo: provided by The Okinawa Electric Power Company, Incorporated)

Start of Commercial Operations of Unit 1 Yoshinoura Thermal Power Station for The Okinawa Electric Power Company, Incorporated

Fuji Electric, in partnership with Siemens AG, has delivered power generation facilities, consisting of a single-shaft combined-cycle-power-plant, to the Yoshinoura Thermal Power Station. This is the first time that this type of system has been employed, meeting the special environmental needs of The Okinawa Electric Power Company, Incorporated. The power station uses LNG as fuel, and with both Units 1 and 2 producing a respective 251 MW at generator terminal, Yoshinoura has become Okinawa's largest capacity power station.

Utilization is made of Siemens' 1,400 °C class gas turbine SGT6-4000F to create a shaft configuration that consists of the gas turbine, generator, clutch and steam turbine. This plant adopts a static frequency converter, which uses the power generator as a start-up motor, while dis-engagement is made of the steam turbine at gas turbine start up time via the clutch. This type of design minimizes energy loss during start up. Unit 1 started commercial operations in November 27, 2012, while Unit 2 is scheduled to begin commercial operations in May 2013.

Module-Type Data Centers

Developments in our IT-based society have created an accelerated need to integrate IT devices into a data center. Fuji Electric has developed the module-type data centers through employing "built in block system," which offers physical infrastructure such as housing-units, air-conditioning systems and power supplies as well as needed components for building and operating monitoring control functions etc. in the form of blocks. The result of this development has been the achievement of a stepwise architecture that minimizes investment burdens. In addition, we have been able to realize quick construction completion dates (three months) through the standardization of the housing-unit, air-conditioning system, power supply, etc.

The air-conditioning system used in the data center is a highly efficient indirect outdoor air-conditioning unit that combines indirect outdoor cooling with compression refrigeration cooling. The system's average yearly coefficient of performance for the Tokyo area has yielded a result of 10 or better, helping this system contribute to energy conservation.

"ECOMAX S Series" Display Cases for Supermarkets

Fuji Electric has developed the "ECOMAX S Series" refrigeration display case as a freezer unit with enhanced energy-savings capability.

We have improved cooling capability by utilizing blower speed distribution and internal temperature distribution of a front air-curtain as well as LED lighting, thus reducing 30% of power consumption per store (a hypothetical store with 24 display cases).

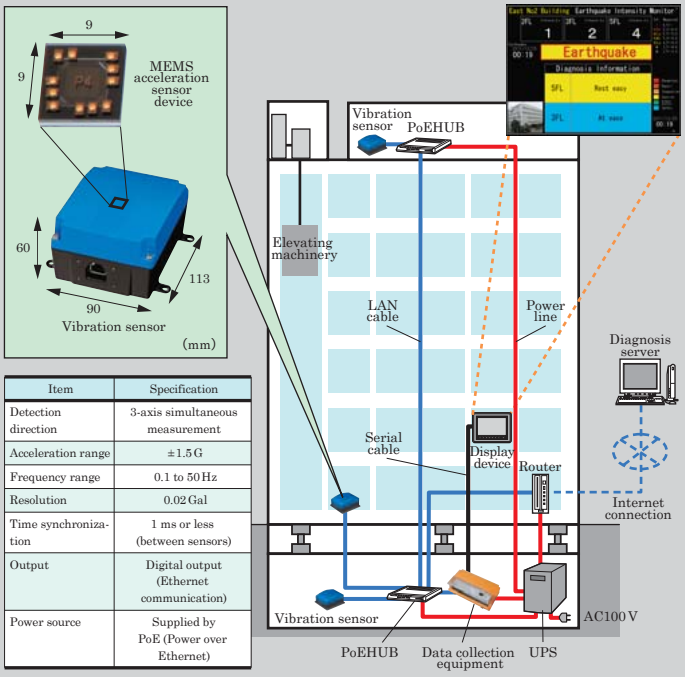
The design has been optimized to achieve cold airflow balance according to the unique technology employed in the air-curtain airflow guide configuration of the edge of shelves. By suppressing front air-curtain disturbances, increased isolation from outside air is achieved. Furthermore, cooling capability is also increased by decreasing the amount of frost formation on the heat exchanger by sucking outside air.

All showcases come standard with energy-saving LED lighting, which is an industry first. This results in a power consumption savings of 48% over conventional fluorescent lighting.

Peak-Shift Vending Machines for Coca-Cola (Japan) Company, Limited

In the aftermath of the Great East Japan Earthquake, the need to save electricity has increased with power shortages. Accordingly, Fuji Electric has developed a new peak-shift vending machine, in collaboration with Coca-Cola (Japan) Company, Limited. This new peak-shift vending machine uses electricity for intensive refrigeration during the nighttime when demand for electricity is comparatively low, thereby enabling the machine to provide cold drinks throughout the day for up to 16 hours without the need for extra cooling. Furthermore, since peak-shifts are possible, the machine also contributes to saving electricity during winter. Its main features are as follows: (1) a thermal storage technology makes full use of the thermal capacity of the drinks contained in the machine, allowing to maintain the optimum temperature of the next drink to be sold for a long time; (2) a highly advanced insulation technology that employs vacuum insulation materials allows the outside appearance and storage inside dimensions of the machine to remain unchanged while reducing heat intrusion to the inside of the machine by approximately 50% when compared with existing vending machines; and (3) the contents of drinks stored in the machine can be quickly cooled at a uniform temperature with a new structural airflow control technology.

Configuration of structural health monitoring system



Item	Specification
Detection direction	3-axis simultaneous measurement
Acceleration range	±1.5 G
Frequency range	0.1 to 50 Hz
Resolution	0.02 Gal
Time synchronization	1 ms or less (between sensors)
Output	Digital output (Ethernet communication)
Power source	Supplied by PoE (Power over Ethernet)

Vibration Sensors

Fuji Electric has created a vibration sensor that applies MEMS technology as a means to apply structural health monitoring to carry out soundness and safety tests for buildings, bridges, and other structures. The vibration sensor is capable of continuous micro-vibration measurements of around 0.1 Gal (1 Gal = 0.01 m/s^2) for unfelt earthquakes, structural diagnostics, etc. The sensor can be used to detect various abnormalities such as earthquake damage to buildings and deterioration of a structure due to aging. This newly developed vibration sensor also comes equipped with an acceleration sensor device that employs original MEMS technology. The adoption of this type of technology provides the ability to replace previously used servos as well as take advantage of a compact size and low-cost (about a 20% decrease), while performing multi-point measurements for various applications. The vibration sensor provides a wide range of applicable uses that include performing micro-vibration measurements for structural vibration and seismic motion of buildings and bridges, and even the ability to use the sensor to detect human motion, etc.

Demonstration System Created for Kitakyushu Smart Community

Since FY2010, the Kitakyushu Smart Community Creation Project has been making advancements in its efforts to realize a low carbon society. Fuji Electric has provided various energy management systems (EMSs), smart meters and electric power storage systems. Smart communities started attracting attention following the Great East Japan Earthquake as a countermeasure against the tightness of electricity supply and demand. In addition, since FY2012, demonstration testing of Japan's first dynamic electricity pricing has begun, which varies electricity rates based on supply and demand conditions.

Demonstration results verified a 10 to 13% peak-cut performance while important data was acquired to analyze demand fluctuations caused by rate changes. In addition, demonstration tests have begun with verification to ensure power quality, supply and demand balance, etc. by using a regional EMS system to handle the challenges of power systems that rely on introduction of high penetrating renewable energy.

Fuji Electric will continue the tests until FY2014 to confirm the effectiveness of regional EMS while accumulating operational know-how and developing the business throughout Japan and overseas.

Electric Energy Technology

Power Semiconductor Technology
Power Electronics Technology
Safety and Security Technology

Outlook

Power Semiconductor Technology

Energy saving is being requested more and more as the shortage of electric power becomes evident. Fuji Electric is advancing the development and commercialization of power semiconductors that incorporate distinctive technology and that can contribute significantly to energy savings.

In the industrial field, Fuji Electric has added 1,200 V/50 A, 75 A and 100 A 12-in-1 products for eco-friendly applications to expand its lineup of advanced T-type neutral-point-clamped (AT-NPC) 3-level circuit modules that incorporate a proprietary reverse-blocking insulated gate bipolar transistor (RB-IGBT) applied to an intermediate switch and that enable high efficiency power conversion. Moreover, a 1,700 V RB-IGBT device was also developed for higher voltages.

In the automotive field, for plug-in hybrid vehicles, Fuji Electric has developed intelligent power modules (IPMs) that combine 14 arms and a control board for driving two inverters and a converter. Employing low-loss 6th generation IGBTs and integrally fabricated direct water-cooled fins made of aluminum, these IPMs feature improved heat dissipation performance and support up to a 700 V system voltage and 400 kVA output.

In the consumer products field, for use in household inverter air conditioners, Fuji Electric has developed a small capacity IPM that contains a 3-phase bridge circuit and a control circuit. The use of a low-loss device optimized for air conditioner applications and a high heat dissipating aluminum insulating substrate results in products that have excellent energy efficiency. In regard to IC products, Fuji Electric has developed a 6th generation pulse width modulation (PWM) power supply control IC for use in power supplies for consumer and industrial devices. Fuji Electric is contributing to energy savings through utilizing 0.35 μm fine process technology, internalizing functions that had previously been provided with externally attached components and realizing ICs with low current consumption and low standby power (30 mW).

In the field of automotive discrete devices, for engine control applications to achieve low fuel consumption, Fuji Electric has expanded its lineup of low-side intelligent power switches (IPSs) which are equipped with a short-circuit and open-load detection function and are able to output the detected state thereof to a CPU. Application to exhaust gas recirculation (EGR) systems that use a stepping motor was made possible by housing a 2-channel chip rated at 2 amps in an SOP-8 package and optimizing the switching characteristics.

Meanwhile, as SiC (silicon carbide) devices, which have attracted attention as next-generation power semiconductors, 1,200 V SiC- metal oxide semiconductor field effect transistors (MOSFET) and SiC-Schottky barrier diodes (SBD) have been developed jointly with the National Institute of Advanced Industrial Science and Technology. Characteristics of Fuji Electric's devices are the simultaneous realization of low on-resistance and high breakdown voltage. Additionally, a new package that makes use of the low loss and high temperature behavior that is characteristic of SiC devices was also developed concurrently. The characteristic of this new package is that the currently mainstream features of aluminum wire bonding, soldered joints and silicon gel encapsulated structures have been replaced with copper pin connections, silver sintered joints and epoxy resin molded structures to realize power modules that have a compact size, low thermal impedance, high-temperature operating capability and high reliability. Fuji Electric has completed development and started mass production of a hybrid module using a SiC-SBD for application in high-efficiency inverters.

Power Electronics Technology

In the aftermath of the Great East Japan Earthquake, demand has been increasing for a stable supply of electric power and for energy savings. Leveraging the synergy between power semiconductor technology and power electronics technology, Fuji Electric is developing and commercializing high-reliability products that can contribute to energy savings.

In the field of variable speed equipment, Fuji Electric has responded actively to the requests of each application field. Fuji Electric released the "FRENIC-Ace Series" of high-performance, general-purpose inverters. A wide range of capacities, of up to 630 kW, allows the optimal unit to be selected according to the application, and customized logic functions able to support main applications have been strengthened to allow a finer response to the requirements of each application. Fuji Electric has newly added stack-type inverters to their "FRENIC-VG Series" of high-performance vector control inverters. In addition to inverters, Fuji Electric also provides diode rectifiers and PWM converters, and has standardized the width of these devices to 220 mm to improve board storage efficiency. A direct parallel connection function has been added to both the unit type and the stack type inverters. The range has been expanded up to 3,000 kW maximum, and up to 4 inverters may be connected in parallel without a coupling reactor. In addition, Fuji Electric has released the "FRENIC-MEGA GX-SiC Series" of inverters equipped with SiC devices. This was the first use in Japan of SiC, a material considered to be promising for next-generation semiconductors, in an industrial inverter. As a result, generated loss was reduced and the inverter efficiency was improved. Further energy savings can be expected when used in combination with a PM motor. Fuji Electric intends to continue to offer products that meet new market demands.

In Japan, as a result of the Feed-in Tariff Scheme for renewable energy that went into effect in July 2012, large-scale photovoltaic power generation plants that aim to sell power are being constructed and the demand for large-capacity power conditioners is increasing.

Fuji Electric has newly commercialized its "PVI 1000 Series" of power conditioners for large-scale photovoltaic power generation facilities. The PVI 1000 Series employs 3-level conversion technology using proprietary RB-IGBTs that were previously commercialized for uninterruptible power supplies to reduce conversion loss and is able to transmit the energy generated with solar panels efficiently. Moreover, power conditioners used in Japan often have a specified DC input voltage range of 750 VDC or less, which is classified as low voltage according to the technical standards for electrical equipment, but in consideration of deployment overseas, the PVI 1000 Series tolerates a DC input voltage of up to 1,000 VDC. Through acquiring international standard certifications, Fuji Electric plans to deploy this series to a wider geographical range. Additionally, the packaging of basic functions such as switchgears and transformers makes it possible to shorten the time required for onsite installation work and assembly work, and to lower construction costs.

In the field of uninterruptible power supplies, user needs vary according to the intended usage, installation environment, required capacity, usage voltage and so on, and there is demand to expand the product line to offer products suitable for each application.

Fuji Electric has newly commercialized a 2.4 kVA product line of its general-purpose mini UPS "EX 100 Series," in addition to the existing four capacity product lines. Moreover, Fuji Electric has responded to market needs by increasing the output effective power (kW) for high power factor loads.

In the field of power transformation, in order to support the stable and reliable supply of electric power, Fuji Electric has delivered 1,050 MVA transformers and 765 kV shunt reactors for main transformer substations both in Japan and overseas. In addition, Fuji Electric has delivered transformer equipment and power compensators for the new construction of the Hokuriku Shinkansen and has delivered various eco-friendly, safe and energy-saving devices for the renewal of existing transformer substations.

For electrical rolling stock, overseas, Fuji Electric continues to deliver a complete set of electronic devices for the Singapore subway system, while in Japan, Fuji has begun to deliver main circuit electronic devices for the new N700A Shinkansen bullet trains of the Central Japan Railway Company. For electric power control, under the problematic circumstances of a tight supply and demand of electric power, Fuji Electric has developed an AC/DC converter and an optimum operation control system that use large storage batteries to shift the power load during the peak hours of home demand.

For drive control systems, plant systems that were delivered during the 1980s and early 1990s are reaching their time for updating, but because a long-term shutdown of these plants is often not possible, partial updating is required. For the updating of programmable logic controllers (PLCs), Fuji Electric has developed a retrofit board capable of communicating with an old PLC and a new PLC, and that is being used for partial updating of several plants. For drive systems, Fuji Electric has shipped large-capacity water-cooled inverters for a hot reverse mill, 3-level inverters in steel bar rolling mills and a drive control system for a process line with using drive master controllers.

For industrial power supplies, Fuji Electric has received an order to expand the rectification equipment of the world's largest aluminum smelter; and for electric furnaces, has delivered and started operation of the first unit of a new self-commuted flicker compensator. In the field of industrial electric heating, targeting application to the industrial sector, Fuji Electric has prepared a lineup of general-purpose inverter heaters of up to 50 kW. In the field of facility electrical equipment, Fuji Electric has advanced product development aimed at improving the reliability, eco-friendliness and energy savings of power supplies, and has delivered uninterruptible power supply systems, vegetable oil-filled transformers and gas-free circuit breakers.

With attention being focused on electric vehicles (EVs), Fuji Electric has launched a ground-based quick charger that will improve the infrastructure for EVs and the like. As a follow-up to the capacity established in FY2011 (25 to 50 kW), Fuji Electric has commercial-

ized a unit equipped with a communication function and a stand-alone billing unit, and has expanded functions to meet the various needs of users. Although there is an increasing number of examples of installations at convenience stores and roadside train stations, in addition to use by local governments, Fuji Electric also aims to enter overseas markets for ground-based quick chargers. In terms of in-vehicle components, Fuji Electric is actively moving forward with the development of driving inverters and in-vehicle power supply devices.

Safety and Security Technology

In the Japanese market for electric distribution and control devices, it is increasingly expected that a change in the energy mix accelerated by reconstruction efforts in the aftermath of the Great East Japan Earthquake proceeds, and accordingly, technology is developed to supply and store electrical energy more safely and efficiently. Meanwhile, in emerging economies such as China and other Asian countries, the products with right specifications and prices are required corresponding to the expanding and diversifying market needs respectively. In such a market environment, Fuji Electric strives to respond quickly to changing market demands and to provide greater added-value to customers.

For factory production facilities, office buildings and commercial facilities, it is becoming more important to configure electric distribution equipment and control systems featuring space-saving, energy-saving and highly reliable. As electric distribution and switching devices responding such need, Fuji Electric has developed the "G-TWIN Λ (Lambda) Series" of 32 to 63 AF compact low-voltage circuit breakers and earth leakage circuit breakers with 70% external width realizing significantly smaller installed footprint comparing to previous models , suitable for the protection of small current circuits in such as machinery, control equipment and boards. Fuji Electric has also developed compact thermal relays by researching smaller size through reducing the part count, using thermoplastic materials in the housing, improving the heater design, and so on. The pin layout was also redesigned to improve operability and facilitate wiring.

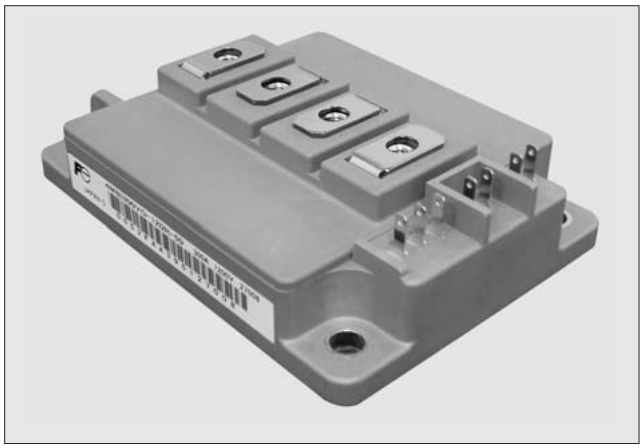
In the field of power distribution, Fuji Electric expanded its "F-MPC Series" of power monitoring systems with the addition of an insulation monitoring unit using Ior detection method, which have a simple configuration that uses a zero-phase current transformer (ZCT), and continuously monitors the insulation state of equipment to realize highly reliable power distribution systems at low cost.

1 Line-Up of IGBT Modules for AT-NPC 3-Level Circuits

A module for advanced T-type neutral-point-clamped (AT-NPC) 3-level circuits has been developed for use with power supplies. The uniquely developed RB-IGBT has been utilized as for bidirectional switching. Compared with conventional NPC 3-level inverters, the number of components that conduct current through all of the pathways has been reduced by 50%. High efficiency is now possible since conduction loss has been decreased. In addition, generated power loss has also been reduced by about 15% as compared with conventional NPC 3-level systems.

The main features are as follows: (1) the main inverter circuit utilizes an IGBT and FWD that has twice the blocking voltage of the neutral point switch, (2) anti-parallel connection of the RB-IGBT allows to perform neutral point bidirectional switching and (3) by applying a forward voltage that exceeds the threshold to the gate of the RB-IGBT, reverse recovery action is possible.

FIg.1 IGBT module for AT-NPC 3-level circuit

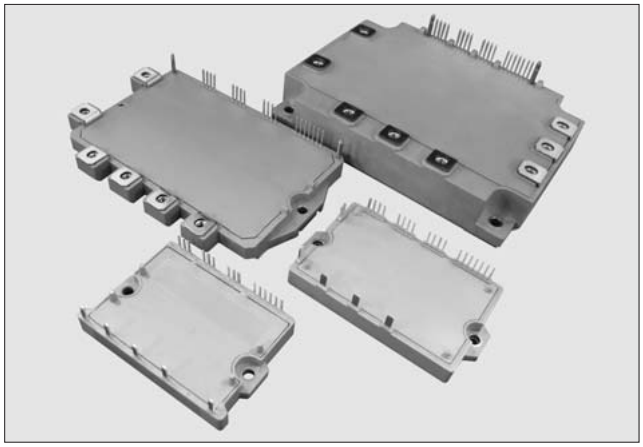


2 6th Generation IGBT-IPM "V-Series" IPM

In recent years, there has been strong demand for small-sized, highly efficient, highly reliable, and easy-to-use intelligent power modules (IPMs) that can be used with power converters such as servos amplifiers. Fuji Electric has developed and completed a full lineup of "V-Series" IPMs (V-IPMs) by applying "V-Series" IGBT chips and drive ICs, which are optimized for the IPM.

The main features are as follows: (1) rated voltage/Current: 600 V/20 to 400 A, 1,200 V/10 to 200 A, (2) reduction of total dissipation loss: 17% reduction (compared with R-IPM3), (3) equipped with functions to reduce dead time and identify alarm causes, (4) improvement of ΔT_c power cycle capability: The P631 package has twice the capability of the P612 package (ΔT_c = 80°C) and (5) planned systematization of low thermal resistance components for the P630 package (Thermal resistance reduction is expected to be at least 30% better than that of previous packages.)

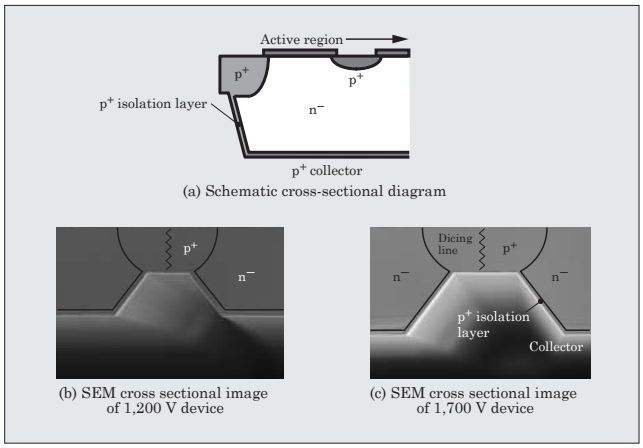
Fig.2 "V-Series" IPMs



3 1,200 to 1,700 V RB-IGBTs with V-Groove Hybrid Isolation Layer

Demand has been increasing in recent years for reverse blocking (RB) - IGBT modules that can be used as neutral point clamping devices in highly efficient power conversion circuits. Fuji Electric has been dedicated to developing RB-IGBTs that enable the efficiency improvement in power converters. By avoiding the difficulty in the case of forming through silicon isolation with existing thermal diffusion, 1,700 V RB-IGBTs, following 1,200 V, have been successfully developed. This has been achieved by adopting a hybrid isolation process that combines thermal diffusion on the surface with V-groove etching on the back. RB-IGBTs of 1,700 V can be applied in high power applications, such as wind power generation and vehicles. Recent advancements in hybrid isolation processes have allowed us to reliably manufacture 1,700 V RB-IGBTs. AT-NPC 3-level conversion circuits that use this type of device have successfully achieved energy loss reductions of 18% as compared with previous devices.

Fig.3 RB-IGBT structure and cross sectional images

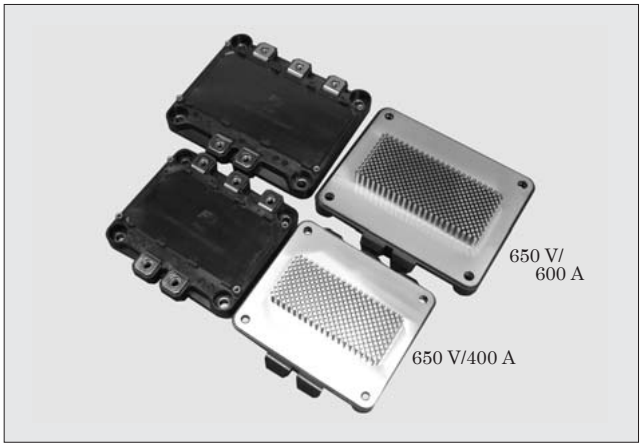


4 Direct Liquid Cooling IGBT Modules for Automotive Applications

New insulated gate bipolar transistor (IGBT) modules for automotive applications have been developed with direct liquid cooling system for the purpose of reducing size of inverter units used in hybrid electric vehicles and electric vehicles. Main features of the newly developed IGBT modules are as follows:

(1) Voltage and current ratings: 650 V/ 400 A and 650 V/600 A, 6-pack IGBT modules
(2) The 650 V/ 400 A and 650 V/600 A modules are designed for 20 to 30 kW and 40 to 50 kW power range motor drive, respectively.
(3) Squre pin fin and silicon nitride insulated substrate are adopted for the newly developed IGBT modules. Total thermal resistance has therefore been reduced by 60% compared with conventional indirect IGBT module with aluminum oxide insulated substrate.

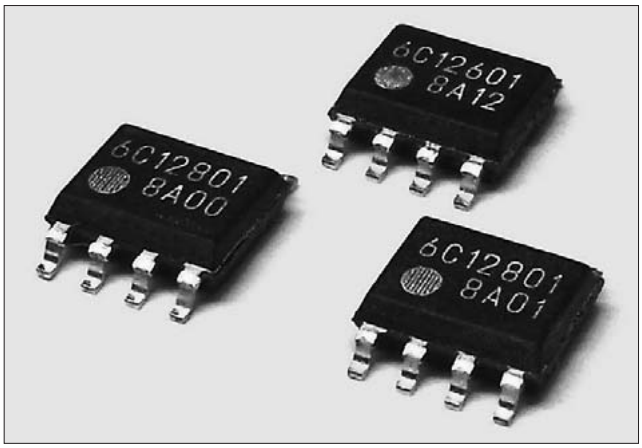
Fig.4 Direct liquid cooling IGBT Modules for Automotive Applications



5 6th Generation PWM Power Supply Controller IC "FA8A00 Series"

In recent years, electronic equipment such as home appliances and servers have increased to be used in continuous operation, and this has resulted in higher demand for systems with reduced standby power consumption. Furthermore, the power supplies for such electronic equipment are required to operate stably and include high accurate protect functions. To meet these needs, Fuji Electric has developed the 6th generation PWM (pulse width modulation) power supply controller IC "FA8A00 Series." Through adopting a newly developed X capacitor discharge function as well as reducing the amount of IC current consumption, the standby power of the power supply has achieved power levels of 30 mW or less, realizing a 66% reduction compared with conventional products. The main features are as follows: (1) reduced standby power consumption by using X capacitor discharge function, (2) built-in 500 V high voltage startup, (3) built-in AC input voltage compensation function for output current during times of overload and (4) reduced EMI noise by switching frequency jittering function.

Fig.5 "FA8A00 Series"

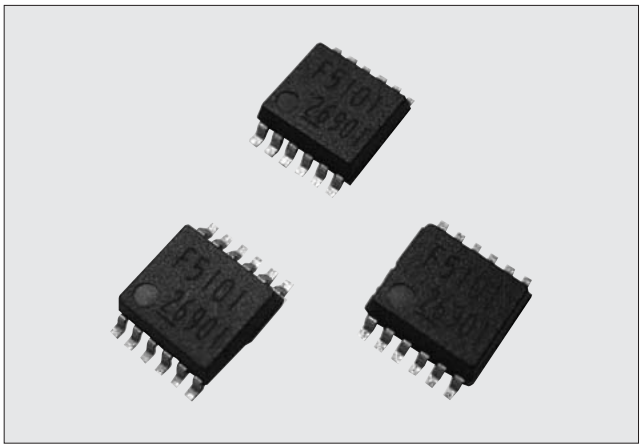


6 4th Generation High-Side IPS "F5101H" for Automotive Applications

There is an increased demand for small, highly reliable, low cost devices in automotive applications. To meet this demand, Fuji Electric has developed the 4th generation high-side IPS "F5101H" by changing the output stage power MOSFET from the planer structure to a trench structure, as well as by employing minute circuits for control and protection circuits and applying a multi metal layer technology. The product increases mounting efficiency, being equipped with two channels of IPS in a SSOP-12 package, which is the same size as existing SOP-8 package. The F5101H has the following features:

(1) Secures the same current capability as the 1-channel product due to optimized on-resistance
(2) Short-circuit protection through functions that detect over-current and over-temperature
(3) Low voltage operation (V_{cc} = 4.5 V)
(4) Incorporates an ST terminal for status output
(5) High speed turn-off function for inductive load by an output voltage clamp circuit

Fig.6 "F5101H"

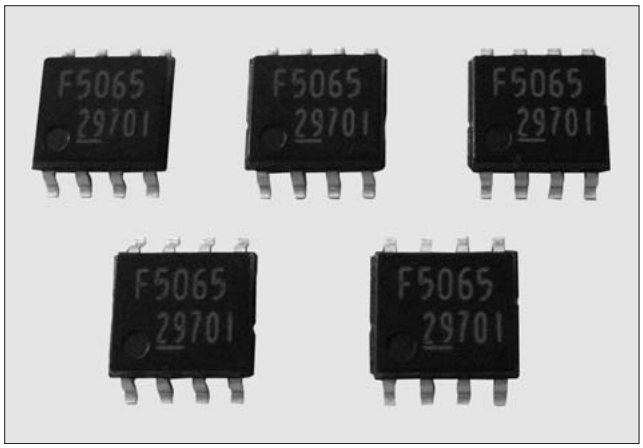


7 Low-Side IPS "F5065L" for Automotive Applications

Power management systems have been greatly increasing in scale due to the strict environmental regulations imposed on automobiles. As a result, power semiconductors are required to be smaller and have a higher level of functionality. Fuji Electric has developed the low-side IPS "F5065L" for automotive applications, integrating peripheral circuits in a power semiconductor.

Since this product provides a status output terminal as well as short-circuit protection (over-current and over-temperature) functions and open-load detection functions, it can output the status of semiconductor devices and load to CPU. Furthermore, 2-channels are equipped with 1.9 A current capable chips in the SOP-8 package by lowering Ron value of the output stage power metal-oxide-semiconductor field-effect transistor (MOSFET). In addition, by optimizing switching characteristics, the product can be applied to exhaust gas recirculation (EGR) systems, which use a stepping motor.

Fig.7 "F5065L"



8 Absolute High Pressure Sensors

Engine control systems have been further advancing because of environmental and fuel efficiency regulations on automobiles. This advance has brought an increased demand for high-pressure sensors compatible with direct-injection engines and fuel pumps. Furthermore, efforts to improve safety and comfort have caused the demand of high-pressure sensors to increase significantly with respect to hydraulic control systems for braking, transmission systems, steering, etc. Fuji Electric has specialized in producing low-pressure sensors of 1 MPa or less, but in order to meet the increasing demand of our customers, we have successfully developed an absolute pressure sensor that can correspond to pressures up to 20 MPa. The high-pressure sensors have the following features:

(1) Output range/output voltage: 1 to 20 MPa abs, 0.5 to 4.5 V
(2) Temperature range: −40 to +135°C
(3) Output voltage precision: 1.5% FS (25°C), 2.5% FS (−40°C, 135°C)
(4) Minimum outer dimension: ϕ14 mm

Fig.8 Absolute high pressure sensors

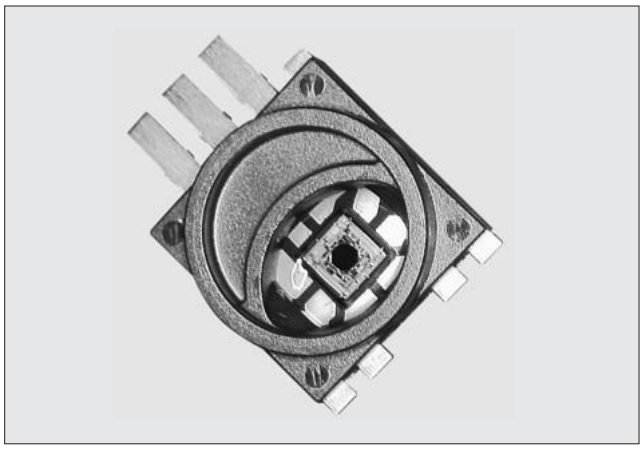
9 6th Generation Relative Pressure Sensor

Relative pressure sensors become employed in exhaust gas compliant automotive systems such as diesel particulate filter (DPF) system to eliminate soot deposits in exhaust gas as well as fuel-feeding system to prevent emission of fuel gas. Through applying our 6th generation small pressure sensor technology, we have developed a small, lightweight relative pressure sensor that adds a tolerance to the pressure medium of exhaust gas, fuel, etc.

The main features are as follows:

(1) Output range and output voltage: −80 to +10 kPa gauge and 0.5 to 4.5 V
(2) Temperature range: −40 to +130°C
(3) Output voltage precision: 1.5% FS (25°C), 2.0% FS (−40°C, 135°C)
(4) Outer dimensions: L15.6 × W11.5 × H6.6 (mm)
(5) Fuel tolerance: ASTM fuel-B, E10, E85, M15
(6) EMC specifications: built-in chip capacitor compliant with ISO7637 and ISO11452-4

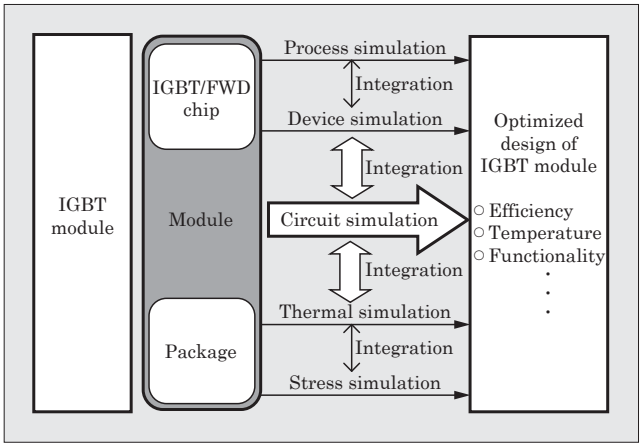
Fig.9 6th generation relative pressure sensor



10 Integrated Simulation Technology in IGBT Module Development

To meet the various demands for insulated gate bipolar transistor (IGBT) module design such as miniaturization, high efficiency and low noise, the importance of preanalysis through simulation has increased. Heretofore, Fuji Electric has performed device and thermal simulations separately for each component of IGBT module such as chip, package; now we have linked these simulations based on a circuit simulation, and established an integrated simulation system that enables the analysis of whole IGBT module. Through this we have improved the accuracy of simulations to one fourth for electrical characteristics of the IGBT module and to one half for thermal characteristics of the IGBT chip, as compared to previous simulations. This system contributes to speed up the development of IGBT module that meets the various demands of our customers.

Fig.10 Integrated simulation for device, circuit, and thermal analysis

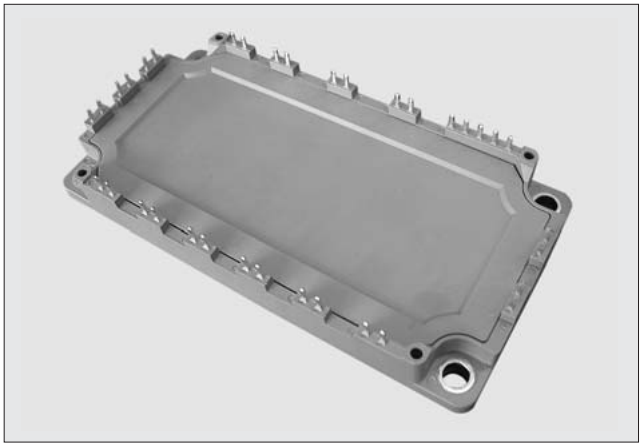


11 SiC-SBD Hybrid PIM

In recent years, there has been a pressing demand to develop power semiconductor modules with silicon carbide (SiC), which enables to meet the increasing demand for low-energy-loss power converters. Fuji Electric has developed a SiC-SBD hybrid power integrated module (PIM) that has achieved mixed-mounting of our latest "V-Series" IGBT and SiC Schottky barrier diode (SBD). The rated voltage and current of our product lineup includes 35 A, 50 A for 1,200 V and 50 A, 75 A and 100 A for 600 V modules. By applying this product, generated loss can be reduced by approximately 25% comparing with our new V-Series IGBT module.

In the future, we plan to expand our product lineup to include further capacity enlargements as well as to develop 2-in-1 and 6-in-1 SiC-SBD hybrid modules enabling significant generated loss reductions.

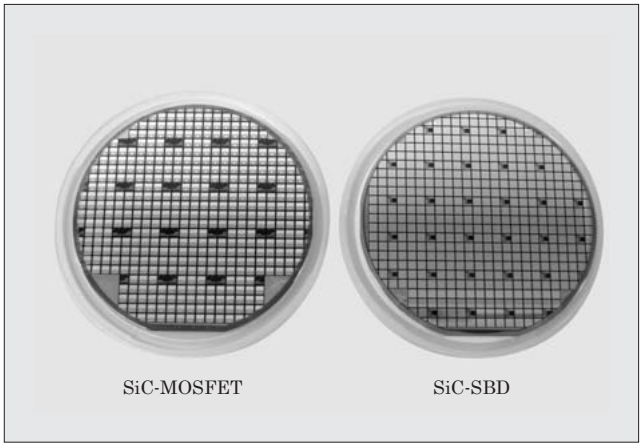
Fig.11 SiC-SBD hybrid PIM



12 SiC Device Development (SiC-MOSFET, SiC-SBD)

Fuji Electric and the National Institute of Advanced Industrial Science and the Technology (AIST) have teamed up to develop 1,200 V SiC-MOSFET and SiC-SBD devices. Compared with other companies, these devices have simultaneously achieved both a lower on-resistance and a higher avalanche capabiity. In particular, the SiC-MOSFET device is characterized by its high reliability, including its ability to realize almost no threshold voltage variation even after applying gate voltage at high-temperature. These developments are the result of our efforts to create power electronics that are compact and highly efficient, which cannot be achieved by using previous Si devices. In order to achieve high-temperature operation and a sufficient reduction in power-loss, which characterize SiC devices, we verified its superior performance and operation by mounting the device on our newly designed package. Meanwhile, some of our research efforts were carried out as a part of project of the joint research body "Tsukuba Power Electronics Constellations (TPEC)."

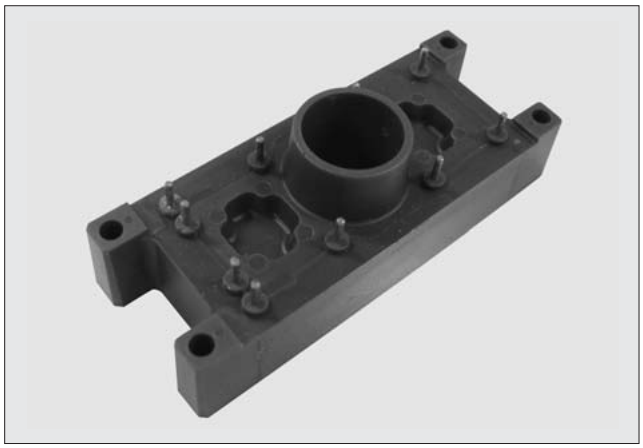
Fig.12 Developed SiC devices



13 SiC Power Module Package

Fuji Electric has developed a packaging structure and applied it to All-SiC power modules. The packaging structure is designed to take the benefit of the characteristics of SiC devices, including the ability to realize low power loss as well as operation at high frequency and at high temperature. This package serves as a replacement for traditional aluminum wire-bonding structures, making use of a printed substrate that employs Cu pins. There realized a structure that can connect multiple SiC-MOSFET and SiC-SBD chips collectively. In addition, the package optimizes electrical wiring patterns as well as utilizes an epoxy resin molding and an insulating substrate characterized by its thick copper bonding and low thermal resistance. The main features of these optimizations are as follows: (1) compact and high power density (footprint: less than 50% of previous structures), (2) high temperature resistance (maximum operating temperature T_{jmax}: 200°C), (3) high reliability (power cycle capability: at ΔT_j 150°C, more than 30 times that of previous structures) and (4) low inductance (about 25% when compared with previous Si modules).

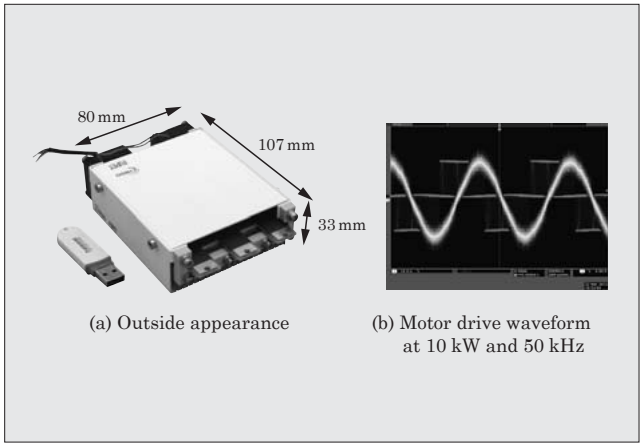
Fig.13 SiC power module package



14 Next Generation Ultra-High Voltage and Low On-Resistance SiC Device Technology and Ultra-High Power Density All-SiC Inverter

Fuji Electric has teamed up with the R&D Partnership for Future Power Electronics Technology (FUPET) and the National Institute of Advanced Industrial Science and Technology (AIST) to carry out collaborative research with regards to next generation MOSFET component technology, high growth-rate epitaxial technology, All-SiC inverters, and ultra-high voltage SiC-IGBT modules. A two-layer ceramic substrate module with a low inductance of 5 nH has been utilized in an All-SiC inverter to achieve a high power density of 40 kW/L, which is at least 10 times higher than conventional Si inverters. In addition, demonstration tests have also verified 3-phase motor drives at 10 kW and 50 kHz. In the future, we plan to expand our research into trench MOSFET component technology, which incorporates next generation low on-resistance technology, gate oxidation technology, and high growth-rate epitaxial technology. Furthermore, we are also working on a trial production of an ultra-high voltage SiC device that is expected as the key device of smart grid components.

Fig.14 All-SiC inverter



(a) Outside appearance

(b) Motor drive waveform at 10 kW and 50 kHz

15 SiC Products

Fuji Electric is advancing its development of SiC products in corporation with devices, packages and circuits. We have carried out research of device technologies in collaboration with the National Institute of Advanced Industrial Science and Technology (AIST), and led to the development of a low resistance MOSFET and highly reliable SBD. Packages equipped with these devices were developed to take advantage of a new structure dedicated to SiC devices, which can operate under a high current density and high temperature. An achievement of our SiC device development is the realization of a high conversion efficiency of 99% in power conditioners for photovoltaic power generation, equipped with a module dedicated to SiC devices and utilizing Fuji Electric's original advanced T-type neutral-point-clamped (AT-NPC) 3-level circuit. Furthermore, a lower cost was achieved by reducing power conditioner volume by 20% compared with previous products. Among devices using SiC-SBD, we started manufacturing a high efficiency inverter in FY2011, while we also began development in FY2012 of a newly designed, highly efficient, and compact "Direct-BBU" system used for data servers. Some of our research efforts were carried out as a part of project of the joint research body "Tsukuba Power Electronics Constellations (TPEC)."

Fig.15 Power conditioner for photovoltaic power generation

1 "FRENIC-MEGA GX-SiC Series" Using SiC Device

The "FRENIC-MEGA GX-SiC Series," which utilizes a next generation power semiconductor SiC-SBD device, was developed with the aim of realizing higher efficiency of inverters used for synchronous motor drives, which are used in air-conditioning systems and production equipment in factories. Its main features are as follows:

(1) Capacity lineup includes:
- ○ 3-phase 200 V class 5.5, 7.5 and 11 kW
- ○ 3-phase 400 V class 5.5, 7.5 and 11 kW

(2) Generated loss of the inverter: Reductions of 20 % or more by using SiC-SBD devices compared with conventional models.

(3) Construction of an ultra-high efficiency drive system: Motor drive in combination with the "GNP Series" and "GNS Series" of synchronous motors.

(4) Control method: Vector control with a speed sensor, vector control without a speed sensor, and V/f control for induction motor

Reference: FUJI ELECTRIC REVIEW 2012, vol. 58, no. 4, p. 212

Fig.16 "FRENIC-MEGA GX-SiC Series"

2 Direct Parallel Connection Technology for "FRENIC-VG Series"

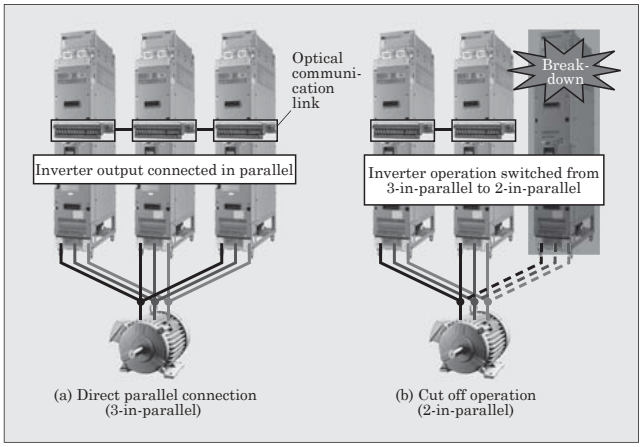
Fuji Electric has developed a direct parallel connection method used for its stack-type high-performance "FRENIC-VG Series" of vector control inverters, which are employed increasingly in electric motor control applications. Parallel connection of multiple inverters realizes the construction of a high capacity inverter system.

(1) Direct parallel connection is possible by mounting a dedicated end terminal in the inverter and by configuring an optical communication link.

(2) Running up to three inverters of the same capacity in parallel is realized. By connecting three 800 kW inverters in parallel, it is possible to expand capacity up to 2,400 kW (with a 150 % overload capacity) or 3,000 kW (with a 110 % overload capacity).

(3) When using a direct parallel system, even if one of the inverters breaks down, cut off operation is possible to keep running by using only the other normal inverters.

Fig.17 Configuration of direct parallel connection



3 Expanded Capacity "FRENIC-HVAC/AQUA" and Enhanced Option Card

Fuji Electric now offers an expanded lineup of its "FRENIC-HVAC/AQUA" inverters and performed enhancement of option card applied for air conditioning and water treatment systems. The main features are as follows:

(1) Newly added 45 to 90 kW (IP21/IP55) and 110 to 710 kW (IP00) models to previous 0.75 to 37 kW models, covering practically all air-conditioning and water treatment system application needs.

(2) Ease of compatibility with other systems is realized by incorporating control options (four types including a relay output card and resistance-temperature detector card) and communication options (six types including an Ethernet communication card and LonWorks communication card).

(3) A loader for PC applications is prepared, enabling easy setting of various functions and enabling to perform runtime monitoring.

Fig.18 "FRENIC-HVAC/AQUA" and option card

4 "FRENIC-Mini (C2) Series" of Compact Inverters

The "FRENIC-Mini (C2) Series" was developed as the next-generation model of the "FRENIC-Mini (C1) Series" of compact inverters. The main features are as follows:

(1) The series has a 3-phase 200 V (0.1 to 3.7 kW) input models, while development is also underway for 3-phase 400 V input and single-phase 200 V input models.
(2) Dynamic torque vector control function is mounted, providing a high starting torque output of 200% at 3 Hz.
(3) Switching operation is possible between two separate motors by recording their constant values.
(4) RS-485 communication interface is built-in as a standard, making it possible to carry out control operations from PC. The option touch panel also enables communication via a USB device.
(5) PID control function that has a Stop for Slow Flow Rate function suitable for the pressure control of pump is equipped.

Fig.19 "FRENIC-Mini (C2) Series"

5 "FRENIC 4400" of 3-Level Inverters, 1,300 kVA Output

The "FRENIC 4400" 3-level inverter is very highly rated as an inverter for medium-capacity AC motor driving equipment. A 1,300 kVA capacity model was developed as a new product in this series. The FRENIC 4400 is easy to utilize in all types of industrial plants such as metal rolling mills. It is currently being employed in steel bar rolling mill plants etc. in Japan and overseas.

The main features are as follows:

(1) The same high functionality and high precision were inherited from the previous models.
(2) Miniaturization has been achieved (reduced 40% in dimensions and 35% in weight) through a newly designed stack that utilizes an optimized IGBT module for 3-level PWM control as well as by optimizing initial charging circuits and snubber circuits.
(3) High reliability was realized by employing fiber optics and enhancing protective functions.

Fig.20 1,300 kVA output "FRENIC 4400"

6 CE-Mark Compliant "FRENIC 4600FM5e Series" of Medium-Voltage Inverters

Medium voltage inverters that can support variable speed driving in direct connection to medium-voltage electric motors are being used increasingly in order to achieve energy savings in fan and pump applications, etc. CE-Mark compliant "FRENIC 4600FM5e Series" medium-voltage inverters are being produced and delivered for use in European markets.

The inverter's main features are as follows:

(1) Compliant with EC directives: EN61800-5-1 and EN 61800-3
(2) Voltage lineup: 6 kV and 6.6 kV
(3) Capacity lineup: 470 to 7,000 kVA (converted capacity to 6.6 kV)
(4) Drive system: Variable speed driving capable of direct connection with a medium-voltage motor
(5) Efficiency: Approximately 97%
(6) Power supply power-factor: 0.95 or higher

Voltage lineup are being enhanced to include 3 kV and 3.3 kV.

Fig.21 "FRENIC 4600FM5e"

Power Electronics Technology

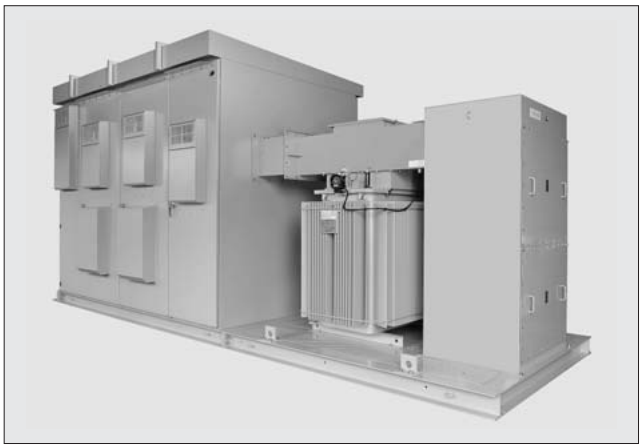
7 IEC Third-Party Certified PCS for Mega Solar Applications

Fuji Electric has developed a power conditioner (PCS) especially designed for expansion into quickly growing market for large-scale photovoltaic power-generation (mega solar) stations in Japan.

The "PVI1000-3/1000" substation PCS (1,000 V DC, 1,000 kW) is a PCS model exclusively designed for outdoor use. It has achieved a single-unit capacity of 1,000 kW and a maximum efficiency of 98.5%. IEC third-party certification was acquired for this PCS as part of our efforts to strengthen our overseas expansion.

Certification was acquired for the following standards:
(1) Safety standard: IEC62109-1
(2) EMC standard: EN55011 and IEC61000-6-2

Fig.22 "PVI1000-3/1000"



8 2.4 kVA Model Newly Added to "EX100 Series" Lineup

Fuji Electric has successfully produced the mini-UPS "EX100 Series" as a device that provides compatibility between energy savings and supply quality. The EX100 is equipped with automatic mode transfer (High-efficiency mode and Online mode). We have recently released the 2.4 kVA EX100 in order to expand the series' capacity lineup and to offer a wider range of product choices to our customers.

The unit's main features are as follows:
(1) The same I/O interface as previous models, meeting replacement demand
(2) Effective output: 2,200 W (1.3 times that of previous model)
Weight: 31.6 kg (17% less than previous model)
(3) Performance enhancement using automatic mode transfer

Fig.23 "PEN302J1RT/30"

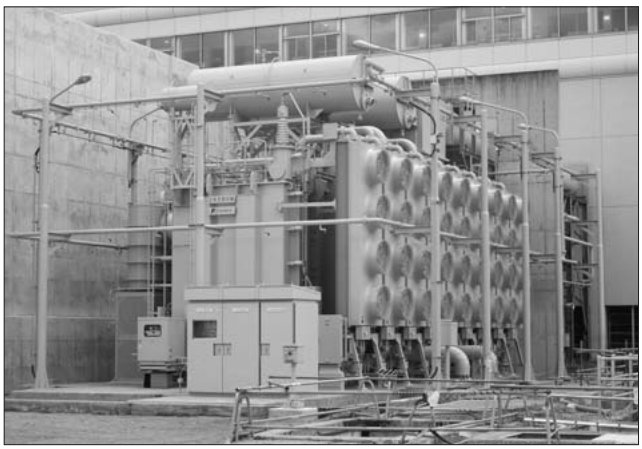
9 No. 2 Main Transformer for Haramachi Thermal Power Station of Tohoku Electric Power Co., Inc.

Fuji Electric has completed delivery and installation of the No. 2 main transformer for Haramachi Thermal Power Station of Tohoku Electric Power Co., Inc., which had suffered damage because of the Great East Japan Earthquake. With a rated capacity of 1,050 MVA, this transformer falls under the largest class of transformers made by Fuji Electric concerning capacity, size, and weight.

Since Tohoku Electric Power Co., Inc. is currently experiencing a severe power supply and demand situation, a quick resumption of operations at the Haramachi Power Station is desired. In order to help meet these demands, Fuji Electric created a special internal organization to oversee the delivery of the transformer, reducing manufacture time significantly from the usual 18 months or more to nearly 12 months. The time required for on-site operation was also shortened to the greatest extent possible, enabling to meet the desired deadline of installation by the end of October 2012.

Test runs at the plant have been underway, and commercial operation started at the end of March 2013.

Fig.24 1,050 MVA main transformer



10 765 kV, 400 Mvar Shunt Reactor for Kappa Substation of Eskom Holdings SOC Limited

Since 1986, Fuji Electric has delivered many 765 kV, 400 Mvar shunt reactors to Eskom Holdings SOC Limited, a South African national electric company. In November 2012, we successfully installed a bank (three single-phase units) of shunt reactors for Eskom's Kappa Substation, achieving a total delivery record of 45 reactors for the South African company.

The Kappa Substation was established to reinforce the power systems in southern regions such as Cape Town, where power supply and demand conditions are critically tight. With approximately 20 km of unpaved roads in the vicinity of the substation, transportation of heavy loads requires lots of caution. The region has no infrastructure for electric power and water supply, making cellular phone use also impossible. In addition to this, we carried out the installation work in the middle of winter, which caused us to have to discontinue the work temporarily. However, we were able to overcome all of these obstacles and successfully installed the reactors.

We look forward to providing more shunt reactors to multiple substations in the future, helping a stable supply of electricity in this region.

Fig.25 765 kV, 400 Mvar shunt reactor

11 Power Compensator for New Substation on Hokuriku Shinkansen Line (Between Nagano and Kanazawa)

Fuji Electric has delivered a power compensator (railway static power conditioner) for the new substation located in extended line (between Nagano and Kanazawa) of the Hokuriku Shinkansen.

The substation utilizes a Scott-connected transformer to convert 3-phase AC to 1-phase (phase M/phase T), feeding power into 1-phase railway trains.

However, the receiving side of the power often experiences large voltage variations due to the load variations of running trains and the unbalance in loads between the main and teaser transformers. As a countermeasure, a power compensator is connected to each single-phase between the phase M and phase T, making compensation for three-phase unbalanced loads and voltage variation through accommodating effective power between both transformers mutually. This has also given ability to provide reactive power compensation at the same time.

Since this compensator adopts a large-capacity IGBT and a new cooling method, we have successfully reduced the footprint by 68% of the conventional products.

Fig.26 Power compensator delivered to Japan Railway Construction, Transport and Technology Agency

12 66 kV Power-Receiving and Direct-Current Transforming Facility for Shiroi Substation of Hokuso-Railway Co., Ltd.

Fuji Electric has delivered a 66 kV two-line power-receiving direct-current transforming unit as part of relocated new facilities in the Shiroi Substation of Hokuso-Railway Co., Ltd.

The main features of the unit configuration are as follows:

(1) 66 kV SF_6 gas insulated switchgear (C-GIS)
(2) Rectification facilities (transformer + rectifier): 3,000 kW ×2 banks
(3) Power feed (DC breaker): 4 feeders + 1 spare feeder
(4) Transformer for high power distribution: 2,000 kVA×1 bank
(5) High power distribution (AC breaker): 4 feeders
(6) Operating control panel for main control

This transformer for rectifiers is a palm-fatty-acid ester transformer that uses eco-mark approved insulating oil. The insulating oil is highly biodegradable and helps to suppress global warming. It is environmentally friendly oil that has excellent cooling and insulating properties.

Fig.27 66 kV power-receiving and direct-current transforming facility

Power Electronics Technology

13 AC/DC Converter and Monitoring Control System for 1 MWh-Class Large Lead-Acid Batteries Used at Japanese National University

The utilization of large lead-acid batteries is being anticipated as one of the measures that can help secure a stable electricity supply-demand balance. In addition, it is also attractive to consumers as a method for reducing electricity cost by using peak-shift, and as such, installation of the battery units has been increasing in light of recent electric power circumstances.

Fuji Electric has supplied a Japanese National University with an AC/DC converter and monitoring control system used for 1 MWh-class large lead-acid batteries. The main features are as follows:

(1) Peak shift control by schedule settings to accommodate different time slots
Four types of operation patterns are recorded into the monitoring control system, providing the system to reduce the load of users through automatic control operation.
(2) AC/DC conversion (discharge: 125 kW, charge: 200 kW)
(3) Control considering the charging characteristics of the lead-acid batteries

Fig.28 AC/DC converter and monitoring control system

14 Electrical Equipment for N700A Shinkansen of Central Japan Railway Company

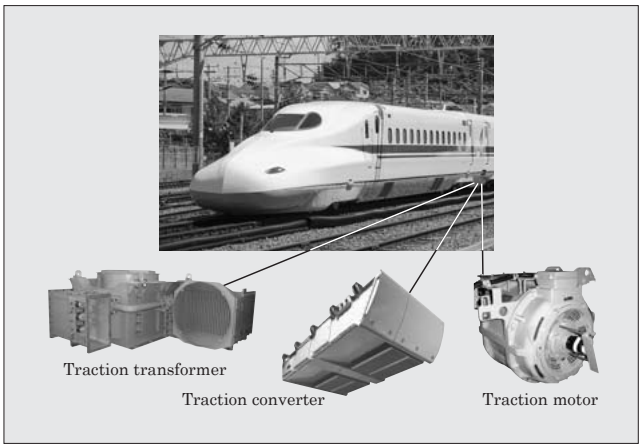
Central Japan Railway Company has manufactured N700A Shinkansen trains and started train operations in February 2013.

Fuji Electric is producing the electrical propulsion system (including the traction transformer, traction converter, and traction motor) for the N700A Shinkansen based on its power electronics technology and system control technology. Delivery of the equipment began in April 2012.

The propulsion system has the following features:

(1) All of its traction converters realize a low ambient noise and high efficiency through the utilization of a blowerless natural-ventilation method for equipment cooling. Its more compact and lighter weight design contributes environmental and energy-saving demands.
(2) The main components (power unit, etc.) are designed to share commonality with N700-Series components, thus helping to achieve a lower cost of product.

Fig.29 Electrical equipment for the N700A Shinkansen



15 Electrical Equipment for Increased C151A Trains in SMRT Singapore Subway

Fuji Electric has received an order to manufacture the electrical propulsion systems and auxiliary power units for increased C151A trains (78 trains of 13 cars) for the SMRT Singapore subway system. The electrical products are on the program to deliver over a period between January and August of 2013. The increased trains will run on the SMRT East-West Line and North-South Line.

The main features are as follows:

(1) The system utilizes the same specifications as existing SMRT C151A trains, and as a result, a high level of reliability was guaranteed through practical use of our existing experience and track record.
(2) The system was inspected at the time of delivery based on SMRT testing conditions and requirements, ensuring a higher degree of dependability as well as improving the usability and working efficiency of SMRT.

Fig.30 C151A Train (currently in-use)

16 Production of Rectifier for Electroplating Equipment (by Chinese OEM Maker)

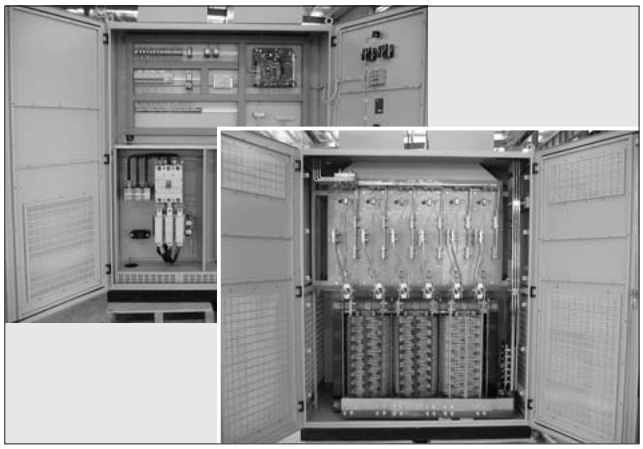
Fuji Electric has completed the production of rectifiers to be used in the electroplating equipment (two lines consisting of total 68 units) for a Chinese company. (A Chinese OEM manufacturer manufactured the rectifiers.) As a result, we have completed a series of ±2,000 to ±8,000 A rectifier units.

The main features are as follows:

(1) The units are equipped with a "LEONIC-M700P" control device, enabling compatibility with the network and maintenance tools of inverters used in industrial plants. Interfacing with a control PLC (programmable logic controller) employed the PROFIBUS-DP protocol.

(2) The system was designed to facilitate easier maintenance with the adoption of a 6-phase half-wave thyristor rectifier system for the main circuit, devising the air-cooling system to realize an output capacity of ±8,000 A.

Fig.31 Rectifier for electroplating equipment



17 Self-Commutated Frequency Converter

Fuji Electric has developed a 20 MVA self-commutated frequency converter that employs a water-cooled 3-level single-phase inverter.

The main features are as follows:

(1) Employment of self-commutated inverter enables to control effective and reactive power.

(2) The use of a high-performance digital control device enables constant frequency control and constant power control as well as high-speed control and switching of autonomous operation.

(3) Development of a compact water-cooled inverter, which employs 4.5 kV, 1.2 kA IGBT module, facilitated the construction of 3.3 MVA-capacity single-phase bridge as a single-unit.

(4) The height of the inverter board was minimized through an accommodating design inside the panel, which arranges longitudinal thin inverter units horizontally.

Fig.32 Self-commutated frequency converter

18 Static Flicker Compensator (STATCOM) for Jonan Steel Corporation

Fuji Electric delivered the first static compensator (STATCOM type) to Jonan Steel Corporation in May 2012. The 20 MVA STATCOM is composed of a multiplex transformer and inverter.

Flicker means the uncomfortable feeling that people have when the brightness of lighting continues to change (i.e., voltage variation). Flicker compensator is a device for improving voltage variation, which is the source of the flicker, in the system.

The main features of the device are as follows:

(1) Applying 3-level water-cooled inverter

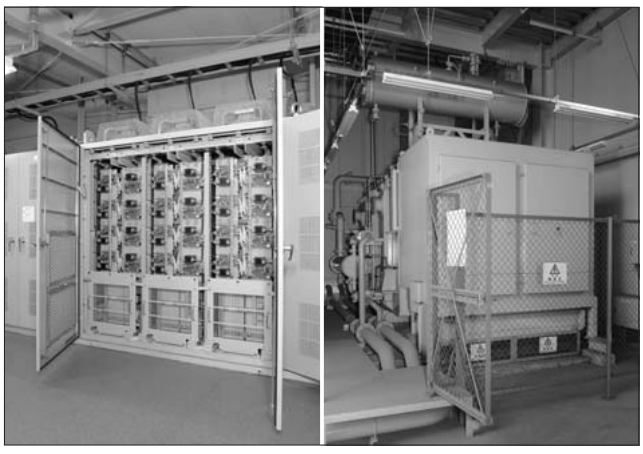
(2) Significant miniaturization of the device (installation area reduced by about 40%)

(3) More compact and lower noise transformer is used in the inverter

(4) Improved reliability and enhanced flicker compensating performance by applying a new control system

(5) Combined operation with already installed external-commutated flicker compensators

Fig.33 Static flicker compensator (STATCOM type)



19 IH Inverter Unit (50 kW)

The 50 kW unit has been newly added to Fuji Electric's lineup of induction heating inverters (2.5 to 20 kW) used in commercial kitchen and industrial appliances. The unit was designed especially to meet industrial specifications, and it expands the range of applications and uses through the adoption of an air-cooling system. The main features are as follows:

(1) With a power capacity of 50 kW, output frequency of 21 to 50 kHz, and a 3-phase 200 V input, this new unit can be used in a wider range of applications than previous 20 kW unit.
(2) By adopting an air-cooling system, the unit can be used for applications where water must be avoided.
(3) Expansion is easy to meet the larger capacity needs of applications by employing a system that connects multiple units in parallel.

Fig.34 IH inverter unit (50 kW)

20 Medium-Voltage UPS Unit Using Lithium-Ion Capacitor for Yamanashi Factory

Production lines, such as producing semiconductors etc., may suffer great damage from a momentary voltage drop. Conventional low-voltage UPS systems can only work as backups for individual loads. In order to backup an entire factory, an uninterruptible power supply unit is needed.

A medium-voltage 2,000 kVA uninterruptible power supply unit has been installed at Fuji Electric's Yamanashi Factory. The system enables the consolidated backup of the production lines.

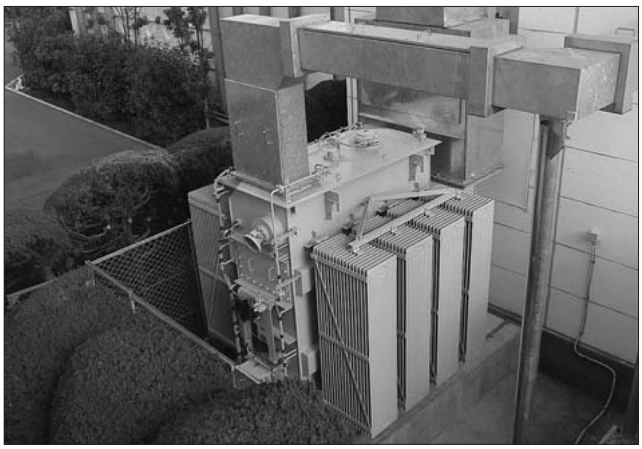
The system employs a lithium-ion capacitor (LiC) that is less than half the size of conventional lead-acid batteries. This has resulted in the miniaturization of the system. Furthermore, LiC capacitors only need to replace every 15 years. The system also contributes to decreased running cost and helps abate environmental burdens since it does not require detailed temperature regulation and reduces the amount of electricity used for air-conditioning.

Fig.35 Medium-voltage UPS unit using lithium-ion capacitor

21 Ecore Trans (Palm-Fatty-Acid Ester Oil Transformer)

Palm-fatty-acid ester (PFAE) contributes to global environment preservation and has excellent cooling and insulating properties. It is superior to conventional mineral oils and plant oils. The Ecore Trans (11 to 77 kV) applies PFAE as insulating oil. PFAE makes it a transformer that is both environmentally friendly and highly efficient. Since the commencement of sales, the number of orders for the Ecore Trans has been steadily increasing, especially for customers in the railway industry. In the near future, we are also planning to release a 6.6 kV model to meet private demand. PFAE has the following characteristics: (1) it is the first to adopt a saturated fatty acid molecular structure among insulating oils based on plant oils, and this ensures the oxidative stability and stable thermal stress characteristics; (2) as insulating oil for transformers, it has achieved a viscosity reduction of about one-sixth compared with previous products. In addition, it has superior cooling properties and is compatible with compact transformer designs; and (3) at the time of disposal, it can be reused as diesel fuel as is.

Fig.36 Ecore Trans (22 kV to 6,000 kVA)



22 Coin Billing System for Quick-Chargers

With the increasing popularity of electric vehicles (EVs), the number of installed quick-chargers has already exceeded 1,500 units. Most of these units are used free of charge. At the same time, a number of IT companies are installing fee-based charging infrastructures, which limits the use of the chargers by checking customer's IC card.

However, since these installation systems are incompatible, EV users have been forced to carry multiple IC cards, which have done much to detract from the convenience of the machines.

Fuji Electric has utilized its vending machine technology to develop coin billing system for the charger unit. Fuji quickly released a public-use system for charging service and enabled to use cash, thus increasing the convenience of EV users. In the future, we plan to continue developing products that exhibit the synergy effects of our manufacturing group, and to contribute to the spread of electric vehicles and the realization of a low-carbon society.

Fig.37 Quick charger equipped with coin billing system

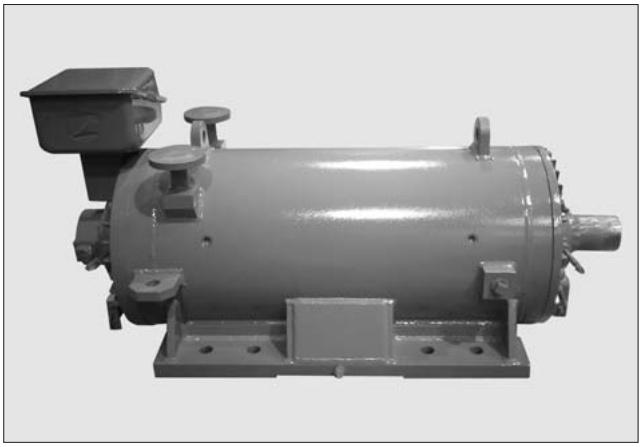
23 Electrical Equipment for Power Regenerating Servo Cushions Used in Large-Sized Press Machine

Fuji Electric has completed production and delivery of electrical equipment for power regenerating servo cushions for large-sized press machine at automobile steel sheet facilities. We achieved the development of a system that meets the requirements of press machine, i.e., providing high-speed and high-precision synchronous control of multiple cushion shafts. The main features are as follows:

(1) A large-capacity low-inertia servo motor (developed product)
- ○Rated capacity: 110 kW at 1,600 r/min
- ○Overload capability: 300% or higher for 10 s
- ○Moment of inertia: 0.19 kgm²

(2) High-speed and high-precision synchronous control of eight servo motors
- ○Drive system: "MICREX-SX SPH3000MM" and "FRENIC-VG" high-performance vector control inverter
- ○I/O refreshing capability: 250 μs at the max.
- ○Synchronous precision: ±1 μs or less

Fig.38 Large-capacity low-inertia servo motor



24 "GYB Series" of Medium Inertia Servo Motors

In order to meet the high-performance and ease-of-use requirements of the servo system market, Fuji Electric has developed the "GYB Series" of medium inertia servomotors in three different models ranging from 200 to 750 W.

The main features are as follows:

(1) The moment of inertia of the motor is twice that of previous "GYS Series" products. This results in a lower load moment of inertia ratio (load moment of inertia/motor moment of inertia), leading to improved control stability and a reduced setting time.

(2) Permanent magnet performance enhancement and simulation utilization have resulted in magnetic circuit improvements and an optimized skew structure, helping the motor achieve reduced cogging torque (50% less than previous models) as well as a larger torque range.

(3) Cooling and vibration-resistance properties have been improved based on an optimized structural layout obtained from simulations.

Fig.39 "GYB Series"

25 Renewal of Large-Capacity Synchronous Motor for Compressor Equipment at Mizushima Works of ASAHI KASEI CHEMICALS CORPORATION

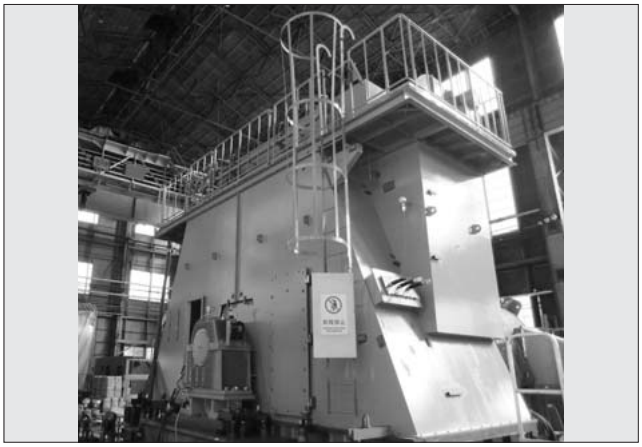
Fuji Electric has renewed a large-size synchronous motor for compressor equipment at the Mizushima Works of ASAHI KASEI CHEMICALS CORPORATION.

The specifications of the motor include an output of 7,700 kW, voltage of 6,600 V, frequency of 60 Hz, 34 poles and rotational speed of 212 r/min. This is a brushless three-phase synchronous motor structured totally enclosed fan cooled system with water-to-air heat exchanger and safety increase type explosion protection.

The renewal work includes working with existing machinery to form an integrated structure of the stator, instead of former two-block structure. Thus, it was possible to reduce the time necessary for on-site renewal as well as to improve the quality of the facilities.

In addition, we exchanged the rolling bearings with slide bearings to preserve the freedom of the longitudinal direction of the rotor. The renewed motor exhibits higher efficiency and better energy-savings effects compared with the former installation.

Fig.40 7,700 kW, 34P synchronous motor under factory test



26 Renewal of Stator of Power Generator Unit 1 for Chita Plant of JX Nippon Oil & Energy Corporation

From the perspective of preventative maintenance and long-service life of supplied facilities, it is recommended and proposed that customers, who have been operating industry-owned thermal power generators over a long period, should renew main component devices to meet their own preservation and maintenance plans.

In June 2012, Fuji Electric manufactured a new stator for power generator unit 1 of the Chita Plant of JX Nippon Oil & Energy Corporation, and completed the on-site replacement work within the construction period of the customer's periodic inspection.

This power generator first started operations in 1973 and had its rotor renewed in 2000. This renewal of the facilities is a continuous work since then. This time renewal of the stator includes quality improvements by employing Global Vacuum Pressure Impregnation insulation system of the stator windings. Moreover, installed is Coupling capacitor for online partial discharge measurement that can diagnose insulation degradation conditions of the stator winding during operation.

Fig.41 Transferring out of the former power generator stator and installation of the new power generator stator

27 Renewal of Emergency Power Generation Equipment at Joyo Reactor

Fuji Electric is continuing in its renewal work of the emergency power generation equipment for the experimental fast reactor Joyo of the Japan Atomic Energy Agency (JAEA). The work includes replacing the windings and renewing control equipment of unit 2 (2,500 kV). Nearly 40 years have already passed since the equipment was first delivered, and as a preventative measure against insulation degradation, renewal of the equipment has been ongoing, succeeding the replacement of the windings of unit 1 performed in 2009.

When the Oarai Substation was damaged due to the Great East Japan Earthquake in 2011, the emergency power generator of the equipment started automatically and was able to maintain functionality for the eight days required to temporarily restore the substation, thus playing a big role in the stability of Joyo's operations.

This has resulted in the system being highly rated with regard to operation at the time of an earthquake, and the importance of maintaining this functionality in the future has been confirmed. In addition to replacing the windings of unit 2, the control system is also scheduled to be updated during the early stages of the renewal work. Fuji Electric is currently working hard to get the system updated as soon as possible.

Fig.42 Emergency power generator of Joyo

1 Compact Thermal Overload Relay

A thermal overload relay is a protective device for the power supply and switching circuits in control panels and other machinery and equipment. The thermal overload relay is not only required to have advanced safety and protective functions, but also to have lower power consumption and more compact size in order to meet the energy-savings and space-savings demands of such machinery and equipment.

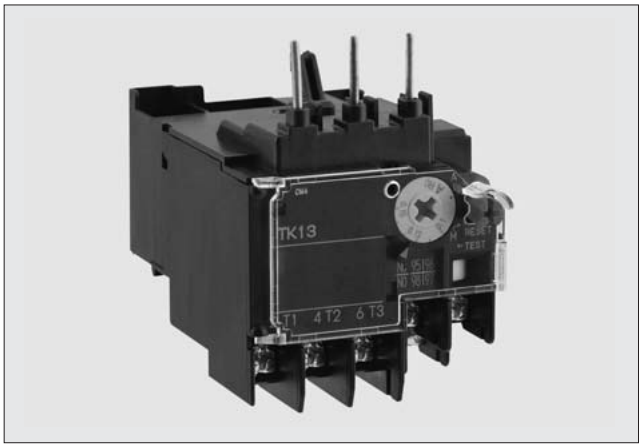
To meet these demands, Fuji Electric has developed a compact thermal overload relay that is globally compatible, being compact, economical and safe within a rated capacity of 26 A or less.

The main features are as follows:

(1) Enhanced electric motor protection functions due to standardization of the open-phase protection function.
(2) Improved operability and wiring work through revision of the terminal layout.
(3) Compatible with the "New SC Series" thermal overload relay, and easy to replace to a new one in existing magnetic contactors.

Reference: FUJI ELECTRIC REVIEW 2012, vol. 58, no. 3, p. 104

Fig.43 Compact thermal overload relay



2 "BW0 Series" 400 AF Molded Case Circuit Breaker

The 400 AF model of the "BW0 Series" of molded case circuit breakers was developed for emerging markets such as China and Southeast Asia. It is an enhancement of the series in combination with conventional 100 to 250 AF models.

The main features are as follows:

(1) Same outer appearance and installation size as the "G-TWIN Series" 400 AF, with unified exterior color (white-gray).
(2) Rated current: 250 to 400 A
(3) Rated breaking capacity (representative value):
440 V AC/36 kA
230 V AC/85 kA
(4) Compatible specifications: IEC, JIS and GB
(5) Accessories: Sharable attributes with the G-TWIN Series 400 AF including an auxiliary/alarm switch, shunt trip device, terminal cover, and external operating handle.

Fig.44 "BW0 Series" 400 AF

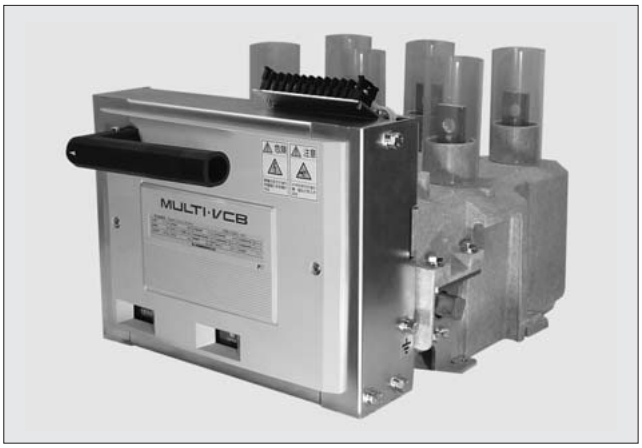
3 Fixed-Type Multi-VCB

High-voltage energy consumers often use high-voltage vacuum circuit breakers as main breaking devices, and most JIS cubicle-type high-voltage power-receiving units are equipped with devices that are mounted directly to the panel.

Fuji Electric has developed a panel fixed-type Multi-VCB as a highly-safe high-voltage vacuum circuit breaker that can be used in a various environments. The VCB was designed to cut down the life cycle cost including the cost needed at the time of maintaining, installing and renewing facilities. Its main features are as follows:

(1) Inspection work labor savings have been achieved by extending the inspection cycle as well as by reducing the number of locations that require lubrication.
(2) Enhanced insulation performance through revision of the configuration and materials of the main circuit.
(3) Improved installation workability due to simplification of panel cut.
(4) Easy renewal of facilities by adopting the same installation dimensions as currently existing products.
(5) Design in harmony with the environment based on compliant with the RoHS directive and providing recycling indications.

Fig.45 Fixed-type Multi-VCB



4 "F-MPC04E" Single-Circuit Power Monitoring Unit Equipped with SD Card

Fuji Electric has developed the "F-MPC04E" as a new single-circuit power-monitoring unit that has the capability of utilizing SD cards. Unlike previous models that adopted RS-485 communication technology, this model was designed for off-line interaction that does not require a network connection. Its main features are as follows:

(1) Various power monitoring data can be written to an SD card.
(2) SDHC cards, with a maximum memory of 32 GB, can also be used in the unit.
(3) Internal clock provides two methods of writing to memory, i.e., by 1-hour time intervals and designated intervals (1 to 30 minutes).
(4) Capable of storing data such as the maximum, minimum, and average current and voltage values.
(5) Clock function backup for power failure by using an electric double-layer capacitor makes replacement of batteries unnecessary (power holding capacity for seven days).
(6) Recorded data can be saved in CSV format, and graphing support tools used for data analysis are supported.

Fig.46 "F-MPC04E" equipped with SD card

5 "F-MPC Ior" Insulation Monitoring Unit Using Ior System

The "F-MPC Ior" insulation monitoring unit was developed based on the technology of Igr insulation monitoring devices (products developed in FY2011) in order to meet the need for continuous monitoring of the insulation situations of distribution plants. Compared with Igr systems that superimpose voltage signals as a benchmark in the system, Ior insulation monitoring systems facilitate a lower installation cost, to the extent that they are applicable to phased-wiring layouts, through a simple system configuration that combines with zero current transformers (ZCT) to standardize the voltage-to-ground of electrical circuits.

(1) Capable of monitoring two separate systems such as power and lighting.
(2) Corrective calculation of earth electrostatic capacitance unbalances.
(3) Combined ZCTs are compatible with "G-TWIN" breaker built-in type and general-use "EW Series."
(4) The unit equipped with RS-485 communication as standard, thus providing a common protocol with the "F-MPC Series," allowing for consolidated power monitoring and equipment monitoring.

Fig.47 "F-MPC Ior"

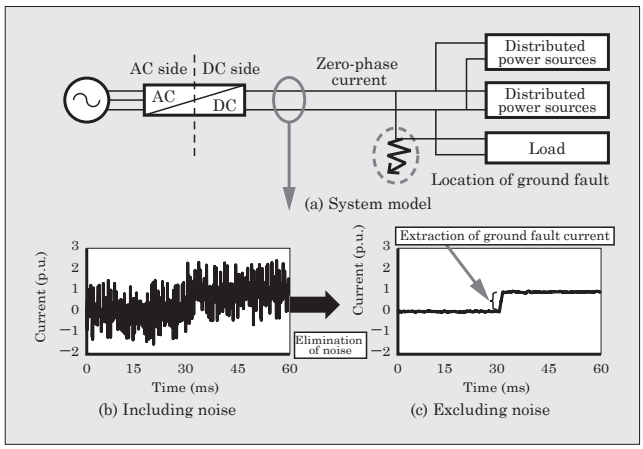
6 Grand Fault Analysis Technology for Direct-Current Distribution Systems

DC distribution systems that include photovoltaic power generators and storage batteries are becoming a popular distributed power source. As the popularity of these systems increases in the future, it will become necessary to develop system protection technology such as functions to detect ground fault current in DC distribution systems. Since ground fault current is affected by noises etc. that proceeds from power conditioners, grounding systems and resistance at the time of ground fault, it is very difficult to detect a precise current value.

Fuji Electric has developed ground fault analysis technology for DC distribution systems. In this method, it is possible to estimate ground fault current accurately by eliminating noise.

We plan to develop applications of this technology for DC distribution systems in the future.

Fig.48 Grand fault analysis results



Others

1 Restart of Construction for General Electric Company of Libya Benghazi and Misurata Combined Cycle Power Plants Project

Due to the political turmoil in Libya, the construction of two units of 245 MW steam turbine and generator for General Electric Company of Libya Benghazi and Misurata combined cycle power plants via Engineering Company, Korea were suspended in March 2011. In June 2012, it was confirmed in a site survey before dispatching technical field advisors to Benghazi and Misurata that there were no safety issues regarding the airport, transportation, power plants and accommodations. There was almost no damage to the power facilities, which were maintained based on preservation procedures; therefore, it was possible to restart the projects as long as workers were available. As a result, TFAs were redispatched to Benghazi and the commissioning resumed in October 2012. In addition, Misurata is expected to resume the construction in the first half of 2013.

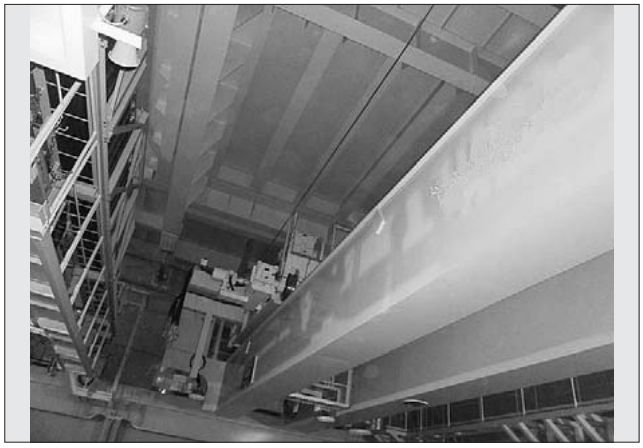
Fig.49 GECOL Benghazi combined cycle power plant

2 Overhead Traveling Crane for Vitrification Technical Development Facility

Japan Nuclear Fuel Limited is constructing a facility for technical development of vitrification. It will be used for developing technology to dissolve radioactive liquid waste, which is generated during the process of reprocessing used nuclear fuel, into glass in a melting furnace and converting it to solid waste.

Fuji Electric received an order for the design, manufacture, field installation and field test of two overhead traveling cranes via IHI Corporation. The field installation is currently being conducted. The crane body was manufactured by Ube Machinery Corporation. A robot arm is mounted on the crane and there are severe constraints on its arrangement because of a large amount of cables such as those for power and measurement control. For this reason, the crane body is combined with the power supply and control devices, which are manufactured by Fuji Electric. In the future, an operational test will be implemented.

Fig.50 Installation of overhead traveling crane



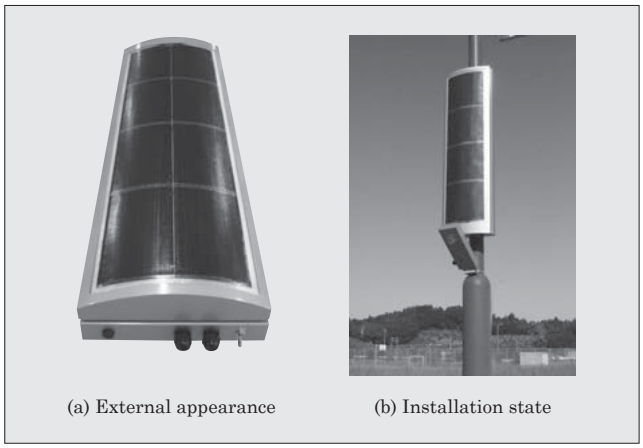
3 Low Voltage Application Products of Film Substrate Solar Cell

Along with focusing on component film solar cell businesses, Fuji Electric is co-developing low-voltage application products with customers for new application fields. Representative products include emergency power sources, small rechargers for portable devices, solar bags and various types of independent power sources.

An independent power source installed on a pillar is one of the typical products. The power source generates electricity from sunlight and charges a lithium-ion capacitor in the system rapidly.

Besides flexible film solar cells enable us to achieve lightweight systems, and applicability to various designs, they introduce easy installation features. Applications to street lights in parks and remote measurement hardware having difficulties of maintenance are expected.

Fig.51 Independent power source installed on a pillar



(a) External appearance (b) Installation state

Others

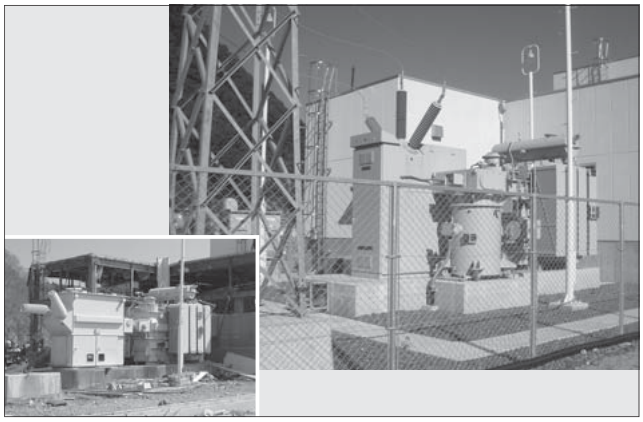
4 Restoration Works from Earthquake Disaster at Kuji Oil Storage Base of Japan Underground Oil Storage Co., Ltd.

All ground facilities of Kuji Oil Storage Base of Japan Underground Oil Storage Co., Ltd. suffered damage from the tsunami of the Great East Japan Earthquake. Restoration was urgent because crude oil was inside the underground bedrock. The following steps were taken to ensure safe operation of the base.

(1) Power supply to the underground facility and administrative building with a temporary power source
(2) Restoration of the receiving and distribution equipment and power supply to utilities facilities
(3) Restoration of the emergency power generation facilities and low-voltage switchgear for effluent treatment

The power-receiving equipment was a compact type C-GIS that uses a polymer insulator, and Fuji Electric aimed to improve earthquake resistance, reduce environmental impact (one-third the amount of SF_6 gas), save space, and reduce the field construction period. A digital type protection relay was used to provide greater reliability and energy-saving in view of maintenance. Currently, the emergency power generation facilities are under commissioning and Fuji will contribute to the complete restoration of the base.

Fig.52 66 kV receiving and distribution facility immediately after disaster and after restoration



Thermal Energy Technology

Thermal Utilization Technology
Cold Thermal Energy Control Technology

Outlook

Thermal Utilization Technology

One of the most significant topics in Japan in 2012 was the enforcement of the Feed-in Tariff (FIT) Scheme. Moreover, although not yet resolved, the comprehensive review of nuclear energy policy represents a significant turning point for energy policy.

Under these circumstances, geothermal and biomass power generation projects, for which commercialization appears promising as a result of FIT, are beginning to move forward. Meanwhile, as a result of the review of nuclear energy policy, plans for new facilities and for increasing the efficiency and for extending the service life of existing facilities have become active, even in the field of general thermal power generation.

Overseas, in developing countries, the trend toward infrastructure improvements such as ensuring power supplies, and in advanced countries, renewal demand for upgrading aging power supplies to the latest technology, remain strong.

In the field of geothermal power generation, Fuji Electric has completed plants in the United States, Indonesia and Nicaragua, shipped a power plant to Turkey, and is in the process of manufacturing a plant for the Philippines. Additionally, Fuji Electric is currently engaged in specific projects in Japan for binary power generation facilities for small and medium capacity applications.

In the field of thermal power generation, Fuji Electric has received many orders from Brazil and Vietnam, and is constructing or manufacturing plants for the United States, China, Vietnam, Pakistan, Indonesia, Oman and Libya. In Japan, Fuji Electric has completed the No. 1 plant of a high-efficiency gas turbine combined cycle (GTCC) station for the Okinawa Electric Power Company, and is advancing the trial operation of the No. 2 plant for the start of commercial operation in May.

In fuel cell and nuclear power fields, as well, Fuji Electric supplies distinctive technologies and services in order to meet the various needs of customers at home and abroad.

Fuji Electric will continue to contribute its accumulated technology and services to customers in order to utilize energy efficiently for the early realization of a low-carbon society and in order to ensure safe and secure power supplies.

Cold Thermal Energy Control Technology

Energy savings has been approached from various angles. Moreover, in the tight electric power situation that has existed since the Great East Japan Earthquake of March 11, 2011, there has been strong demand for strengthening energy-savings measures. In addition to reducing the consumption of electric energy, efforts to improve the utilization of electric power are also needed.

Fuji Electric's representative products that utilize cold thermal energy control technology include vending machines that heat and cool beverages and the like, showcases that cool and display products for sale in stores, and air conditioning systems for data centers and the like.

In the field of vending machines, Fuji Electric and Coca-Cola (Japan) Company, Limited have jointly developed and launched a long-term low-temperature insulating vending machine that does not require any power during the day. This vending machine cools beverages housed inside itself from 11:00 PM until 7:00 AM only, and does not cool the beverages during the interval from 7:00 AM to 11:00 PM. Such an operating mode results in significantly lower power consumption during the daytime hours of peak power usage, and thus this innovative vending machine can contribute greatly to society through the effective utilization of electric power. This performance was realized by utilizing thermal insulating structure technology and airflow analysis technology for beverage cooling.

Meanwhile, in the field of showcase technology, Fuji Electric has developed and launched the "Eco Max S Series" of showcases that, through improving the internal cooling efficiency and installing LEDs as a standard feature for the first time in the industry, enable a reduction in the total showcase and refrigerator power consumption per supermarket by 30% compared to ex-

isting showcases. This showcase series incorporates a proprietary air flow guide system to smooth the air flow of the front air curtain, and utilizes thermo-fluid analysis technology to realize optimal matching of the air flow of the air curtain and the cooling air flow from the rear of the refrigerator. Moreover, in addition to applications to supermarket showcases, Fuji Electric has begun to expand the market by utilizing energy-saving technology to develop showcases for convenience stores and overseas stores.

In the field of air conditioning, Fuji Electric has developed the "F-COOL NEO" of indirect external air-cooling type air conditioners that utilize heat pump technology, a core technology of cooling control, and has installed these air conditioners in data centers. Furthermore, in order to meet customer needs for short lead times, Fuji Electric began offering "build-in-block" type modular data centers.

In the future, Fuji Electric will continue to develop and deploy eco-friendly products that utilize thermal energy technology.

Thermal Utilization Technology

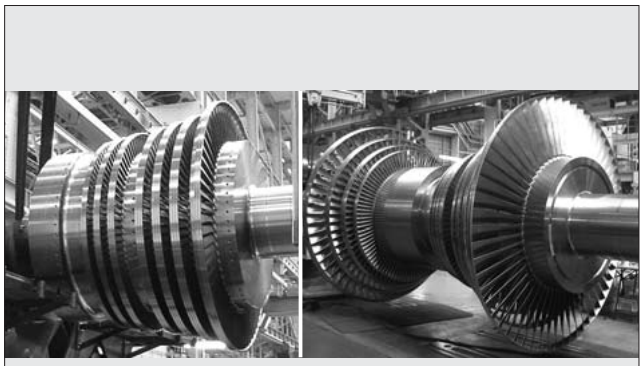
1 Power Facilities for Turkey Kizildere Geothermal Power Plant

In August 2012, the 60 MW steam turbine and generator for the Kizildere Geothermal Power Plant were shipped out. With this project Fuji Electric has newly entered the Turkish geothermal market.

This power plant adopts a triple-flash system. The steam turbine and generator are rotated with the steam with three different pressures (high, medium and low) to generate electricity. A back-pressure system is adopted for a high-pressure turbine which uses high-pressure steam, and a condensing system is adopted for a medium and low-pressure turbine, which uses medium and low pressure steam. This turbine system is tandem by coupling these two turbines to a single shaft.

The high-pressure steam is unique because it includes 16.7 weight percent non-condensable gas, which is extremely high concentration compared with other geothermal power plants. The final evaluation of consequence of the highly concentrated non-condensable gas will be performed based on the commissioning results. The equipment is currently being installed and the commissioning is expected to start from the spring 2013.

Fig.1 60 MW steam turbine



High-pressure turbine　　Medium and low-pressure turbine

2 Construction of Philippine Maibarara Geothermal Power Plant

In December 2011, we received an order for one 20 MW geothermal power plant from EEI Corporation, which is a major construction company in the Philippines. The scope of the supply includes a geothermal steam turbine, generator, condenser and auxiliary equipment such as gas extractor, cooling tower and hot well pumps.

An axial exhaust flow type was adopted for the turbine and a direct-contact type barometric-condenser was used for the condenser. In March 2013, the equipment was delivered by Free on Board (FOB) and installed at the foot of Mt. Makiling (Elevation: 200 m) located in Santo Tomas City, Province of Batangas, Island of Luzon, Philippines.

Fig.2 Progress of foundation work at the site

3 Hybrid Gas Extractor for Mori Geothermal Power Plant of Hokkaido Electric Power Co., Inc.

In September 2012, we completed the exchange construction to a hybrid system gas extractor for Mori geothermal power plant of Hokkaido Electric Power Co., Inc. This construction removed a gas compressor in operation connected directly with a steam turbine and exchanged it for three stages-style hybrid system (1st and 2nd stage of ejectors and 3rd stage of vacuum pump) newly. Currently, the machine is operated at the maximum steam amount (primary steam: 200 t/h) and noncondensible gas amount decreases to 3% from the planned amount 10%.

The purpose of this construction raises a condenser vacuum degree by changing the capacity of the gas extractor in 25 MW specifications (the generation output has been changed to 25 MW) from 50 MW specifications in consideration of the present maximum amount of steam (quantity of primary steam 200 t/h) and decrease in non-condensation gas (it decreases from 10% to 3%) and is to increase the generation output. As a result, a condenser vacuum degree rose to 8.4 kPa from 16 kPa and became able to increase by 20 to 30% of generation output.

Fig.3 Full view of vacuum pump for hybrid system

Thermal Utilization Technology

4 Shipping Turbine and Generator for US Biomass-Burning Power Plant

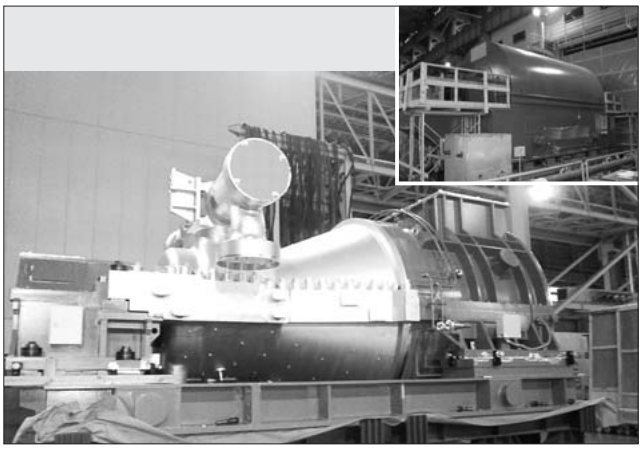
In September 2012, we completed shipping of a set of axial-flow-type single-cylinder condensing steam turbine and air cooling power generators for a newly constructed 75 MW class biomass-burning power plant in Berlin, New Hampshire, the United States.

In order to respond to a strong request from Babcock & Wilcox Construction Co., Inc. (BWCC) for shortening the construction period, a skid-type steam turbine and air cooling generator were adopted. The skid-type product of this class is the first machine of its type to be built by Fuji Electric.

BWCC remodeled the existing black-liquid collection boiler, which stopped operations in 2006, to a woody biomass-burning bubbling fluidized bed boiler, which generates power with a turbine and generator manufactured by Fuji Electric.

The power plant is expected to start selling electric power by the end of 2013.

Fig.4 Skid-type steam turbine and air cooling generator



5 Fuel Cell Equipment for Sewage Innovative Technology Demonstration Project (B-DASH Project)

The Feed-in Tariff Scheme in Japan for renewable energy has been started since July 2012. In the power generation field using sewage digestion gas, which is attracting attention, Fuji Electric's fuel cell equipment was adopt as a power generator for Sewage Innovative Technology Demonstration Project (B-DASH Project). The fuel cell equipment was installed in a sewage treatment plant in Osaka city in February 2012 and its demonstration test has been executed since April 2012.

It is expected to expand the market for sewage treatment plants including small-scale plants, as this fuel cell equipment can be operated by mixing digestion gas of lower yield with city gas.

Fig.5 Fuel cell equipment under demonstration test

6 Delivery of CE-Marked Fuel Cell Equipment to Germany

Fuel cell demonstration equipment with supply function of air containing low-concentration oxygen for fire prevention was delivered to Germany in 2010. Then CE-marked equipment with installation permission in the EU has been developed by using the demonstration equipment. The 1st. commercial CE-marked equipment was delivered to an automobile dealer in Germany in May 2012 and then has been running since August 2012. This equipment is the first CE-marked fuel cell product made in Japan for business use and has been completed by solving many subjects such as secure explosion prevention of flammable gas and EMC conformity.

Hereafter we are going to expand the sales of low-oxygen air supply type equipment for data centers and warehouses in the EU.

Fig.6 Fuel cell equipment delivered to Germany

Thermal Utilization Technology

7 Fuel Cell Equipment Installation in Kawasaki Factory

In February 2012, fuel cell equipment was installed in Fuji Electric's Kawasaki factory. This equipment contributes as a co-generation system using normally city gas for fuel to energy saving and reduction of carbon dioxide emission in the factory.

This equipment can provide power to essential systems during electrical grid's outage. Moreover, it can also continue to generate power by stocked LP gas even when city gas supply is stopped. By these functions, power supply security of the fuel cell equipment is improved. In addition, high-temperature exhaust heat is used for air conditioning in the office building by introducing it to the absorption-type water cooling/heating apparatus, and low-temperature exhaust heat is used for preheating the water supply of the boiler in the factory.

Fig.7 Fuel cell equipment installed in Kawasaki factory

Cold Thermal Energy Control Technology

1 Energy-Saving Cup Type Drink Vending Machine "FX21"

Based on the concept of "environmental response" and "improvement of customer satisfaction," a full model change was conducted and the industry's top-class energy-saving high-performance machine, "FX21," was developed as a medium-cup-type drink vending machine. Compared to machines in FY2008, annual power consumption was reduced by 69%. The main features are as follows:

(1) Introduced a heat insulated structure with three layers by combining vacuum insulation material and resin foam and optimized the heater shape and operation control, and realized a high insulation and small-size hot water tank.
(2) By using resin for the part of the coffee extractor that comes into contact with the liquid, the machine is made highly insulated and small in size, and the need for a space heater was eliminated.
(3) Non-illuminated interface door was developed for the first time in the industry.
(4) With a new cup mixing system, the quality of beverages and efficiency of operation were improved.

Fig.8 "FX21"

2 Coffee Machine for Seven-Eleven Japan Co., Ltd.

While tasty coffee to customers is gaining attention, convenience stores are focusing on sales of coffee. Fuji Electric developed a one-cup coffee machine by utilizing the original paper drip extraction technology. The main features are as follows:

(1) Achieved good taste of fresh hand drip coffee by means of detailed extraction setting such as steaming time and air stirring, and uniform and optimal granularity using a new model coffee mill.
(2) Refined design with stainless exterior and space-saving compact-size safety design with cover on the ejection part.
(3) Achieved operability focusing on access from inside the counter such as ease of replacing paper from rear surface and making daily cleaning easier with an auto-rinse function.

Fig.9 One-cup coffee machine

3 Energy-Saving Display Case for Convenience Stores

Recently, there have been increasing needs for energy saving in the world of convenience stores in order to reduce environmental impact. Fuji Electric developed an open display case with reduced power consumption that meets the required refrigerating capacity by optimizing the blowout structure to improve cooling efficiency by means of controlling outdoor air infiltration and employing LED lamps.
The main features are as follows:

(1) Striving for optimization of blowout structure (air curtain) by controlling blowout opening structure at the optimum ratio of inner duct and outer duct, honeycomb angle and the rotation speed of fan, and reduced refrigeration capacity by 10% compared with machines in 2009.
(2) By installing LED lamps and optimizing the above-mentioned blowout structure, dew prevention heater capacity was reduced and power consumption was reduced by 35% compared with the machines in 2009.

Fig.10 Energy-saving display case for convenience stores

4 Refrigeration Showcase for Overseas

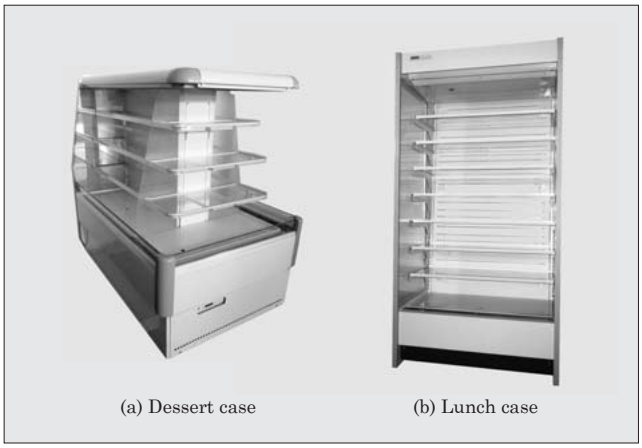
Recently, modernization of food distribution in China and South East Asia has been developing and the advance of Japanese convenience stores into overseas market has accelerated.

Under such circumstances, a separate placement type of showcases has become subject to a labeling system in China and enforcement of energy-saving management is underway. Fuji Electric developed a refrigeration showcase for overseas markets, which employs energy-saving technology.

The main features are as follows:

(1) In the control section, cost reduction and linkage with various energy-saving systems were realized with a structure combining a microcomputer basic unit, which is limited to the basic function, with an extension unit for improved function.
(2) By using feedback control to keep the number of rotations of the fan to be constant, maintaining the optimal air flow of air curtain from the cooling initial stage, and controlling the amount of inclusion of fresh air, cooling efficiency was significantly improved.

Fig.11 Refrigeration showcase for China



5 Plant Factory Unit and Growing Conditions Control System

Recently, there has been rapidly growing interest in plant factories that can stably produce farm products without using agricultural chemicals by artificially controlling the environment within the facility. Fuji Electric developed a plant factory unit by using a display case. This unit has doors with which cultivation with a high degree of hygiene in a semi-closed space is possible. The unit introduced in the demonstration building (not announced to the public) of Asahi Kasei Homes Corp. can be used as a wine cellar by providing two temperature zones. In addition, a control system for a cultivation environment for large-scale plants was developed. We achieved an environment suitable for growing plants by controlling the concentration of nourishing solution and CO_2 concentration using PLC. Furthermore, environmental information and facility operation information are gathered into the server and combined control is performed.

Fig.12 Wine cellar built-in plant factory unit

6 Air Conditioning Unit with Indirect Fresh Air Introduction for Data Centers

Recently, the calorific value of servers used in data centers has been increasing dramatically due to their high performance and high density. Because of this, introduction of a system using fresh air cooling is being promoted to pursue energy saving. Fuji Electric developed an air conditioning unit for data centers which uses the indirect fresh air introduction method. This unit is equipped with a built-in heat pump, and performs only heat exchange with fresh air. The main features are as follows:

(1) Providing cooling capacity of 25 kW/unit.
(2) By combining fresh air and cooling machine operation, it is possible to perform cooling throughout the year and achieve a coefficient of performance (COP) of 10 as the annual average.
(3) Because of the use of indirect fresh air, it is not necessary to take measures against corrosive substances (salt damage) and humidity adjustment.
(4) It is an independent and stand-alone facility that is easy to install and requires no auxiliary air conditioning.

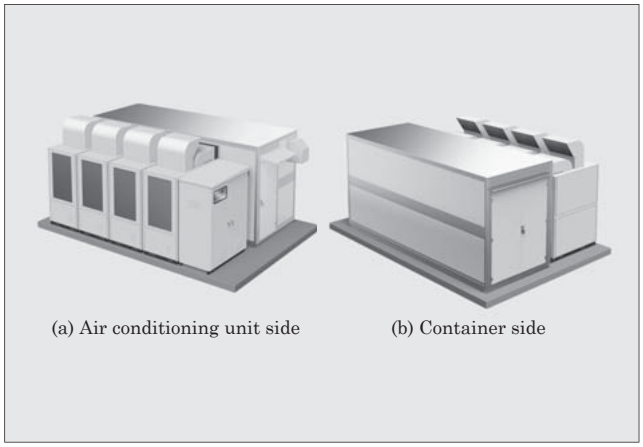
Fig.13 Air conditioning unit with indirect fresh air introduction (heat pump type)

7 Container Type Data Center for Fujitsu Limited

Recently, container type data centers have been attracting attention from the perspective of early construction and small start against the background of increasing demand for data centers. Under such circumstances, container type data centers using fresh air cooling are being commercialized in terms of energy conservation. However, in order to directly bring in fresh air, measures are required against fine particles and high humidity that exert a bad influence on ICT devices.

Fuji Electric developed an air conditioner that uses the indirect fresh air introduction method that resolves this issue. Air conditioning unit and container chassis, and power equipment are integrated as a package. This solution, a container type data center, which allows a short construction period and energy conservation, is jointly provided by Fujitsu Limited and Fujitsu Laboratories Ltd.

Fig.14 Container type data center



(a) Air conditioning unit side (b) Container side

Control Technology

EMS Technology
Measurement and Sensor Technology
System Control Technology

Outlook

EMS Technology

As smart community demonstration projects are being advanced throughout the world, Fuji Electric is developing and demonstrating various types of energy management system (EMS) technologies while also participating in such projects as the Kitakyushu Smart Community Creation Project and the Keihanna Eco-City Next-Generation Energy and Social Systems Demonstration Project. Fuji Electric has developed a factory energy management system (FEMS) and building and energy management system (BEMS) that are provided with functions for performing optimized control of multiple energy sources (electric and thermal power) and demand response. In addition, Fuji Electric has developed a power storage control simulator for verifying the optimality of the control system and its capacity, and that supports supply and demand control and planning with a grid, as well as a full-scale microgrid demonstration facility that performs energy optimization operation and grid connection with distributed power supplies and electric power storage systems. Furthermore, in accordance with the replacement demand for smart meters with built-in communication functionality, Fuji Electric is actively engaged in developing such products for major power companies.

In terms of power system distribution, Fuji Electric has contributed to the stable supply of electric power through continuing to deliver grid connection systems and centralized electric power generation supervisory and control systems for public utilities. Fuji Electric is also advancing the development of technology for international standardization and voltage control technology for distribution systems, and is working toward next-generation power system operation.

Measurement and Sensor Technology

In the field of measurement and sensors, Fuji Electric is advancing technical development to meet the need for more sophisticated flow and energy measuring instruments for the purpose of saving energy, environmental measuring instruments for the purpose of enhancing environmental protection and preservation, and monitoring instruments for the purpose of ensuring the safety and security of people's lives.

In the field of flow measuring instruments, Fuji Electric has developed a general-purpose type ultrasonic flowmeter for liquids that has a significantly improved tolerance to bubbles, and has also developed an advanced function type that adds 2-path system measurement and thermal energy computation functions. Additionally, Fuji Electric has developed a Foundation Fieldbus (FF) -compliant pressure/differential pressure transmitter and a combined sensor for mass flow rate measurement. As energy measuring equipment, Fuji Electric developed a clamp type electric power monitor that uses 920 MHz-band specified low power radio waves and that facilitates the construction of an electric power monitoring system.

For environmental measuring instruments, Fuji Electric has realized a laser-type gas analyzer able to measure multiple components, such as being able to measure carbon monoxide and oxygen at the same time, and has developed products that employ an instrumentation air purge system to improve their resistance to dust.

For monitoring equipment, Fuji Electric has developed an inexpensive and ultra sensitive vibration sensor that uses micro electro mechanical systems (MEMS) technology, and to demonstrate its effectiveness, has applied this sensor to a structural health monitoring system for assessing the soundness of buildings, bridges, and the like.

System Control Technology

In the field of system control, because equipment is deteriorating with age at various plants, distributed control systems (DCSs) and computer systems are being renewed and updated, one after another, in order to realize stable operation, improve manufacturing efficiency and expand capacity. Systems are required to make full use of existing hardware and software assets, and to be capable of responding flexibly to the facility operation conditions at minimum cost. For steel plants and waste incineration plants, Fuji Electric has

a proven track record of having delivered many systems for DCS updating and the like, and through the effective use of existing software assets, has realized improved quality assurance and shorter changeover times. In the updating of computer systems for control applications, virtualization technology is used to port the systems to new hardware without having to update the existing facilities, thereby enabling more efficient development and testing, and assuring quality. For the wide-area monitoring and control of city gas, Fuji Electric has constructed an IP telemetry system that flexibly supports differences in the installation location and communication means.

A controller is a common component that plays a central role in control systems and is being used in an increasingly wider range of applications. Fuji Electric's "MICREX-SX SPH3000MG" features Gigabit Ethernet networking functionality and is provided with a standard package for controlling multiple drive devices, enabling a maximum of 200 drive devices and their related I/O to be controlled via a network. The resulting reduction in the number of required engineering man-hours and the wire savings leads to a significant reduction in construction costs. The high-performance "SPH3000PN" with built-in PROFINET RT functionality can be connected directly to the PROFINET and supports global standards. For measurement systems, Fuji Electric plans to offer a high reliability control for monitoring and control systems before the end of FY2013.

For the purpose of environmental improvement, energy savings and crisis management for roads, Fuji Electric delivered tunnel remote control systems and SA/PA information terminals for the Shin-Tomei Expressway in FY2012. In addition, as cloud computing advances, Fuji Electric intends to accelerate cloud-based shared use across prefectural boundaries to reduce further the cost of local government systems.

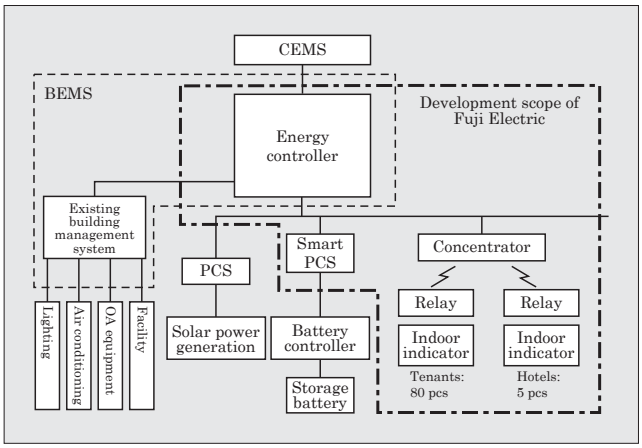
EMS Technology

1 Keihanna BEMS Demonstration Project

Fuji Electric is in charge of a building energy management system (BEMS) for Keihanna Plaza in the "Keihanna Eco City Next-Generation Energy and Social systems Demonstration Project" promoted by the Ministry of Economy, Trade and Industry and initiated the demonstration test in FY2012.

With the developed and delivered energy controller, information is gathered by linking to the existing building management system, and demand forecast from the weather information and energy usage performance, and solar power generation forecast are conducted, and an optimal operation plan for facilities is drawn up. The BEMS contributes to optimize regional energy balance in cooperation with a community energy management system (CEMS) with (1) demand response applied to building tenants and hotels and (2) smoothing demand in buildings with batteries. This demonstration project aims to reduce CO_2 emissions by 10% through energy management.

Fig.1 Keihanna Plaza BEMS overall system configuration



2 Fujitsu Limited Microgrid Demonstration System for Kawasaki Plant

Fuji Electric delivered a microgrid demonstration system to Kawasaki Plant, Fujitsu Limited. This system aims to reduce the receiving electric power and to carry out demonstration tests at the factory. It comprises a solar power generator (45 kW), storage battery system (approx. 80 kWh), power conditioner (50 kW), power distributor and remote operation equipment. This system is to have the following multiple control functions and will be able to conduct various demonstration tests.

(1) Receiving electric power regulating function and adverse current prevention function
(2) Discharge and charge control function
(3) Power stabilization function

Result of these demonstration tests verified to reduce the total amount of power reception by 5% and reduce peak power by 21% on average. Good results are expected for future demonstration tests.

Fig.2 Power conditioner unit

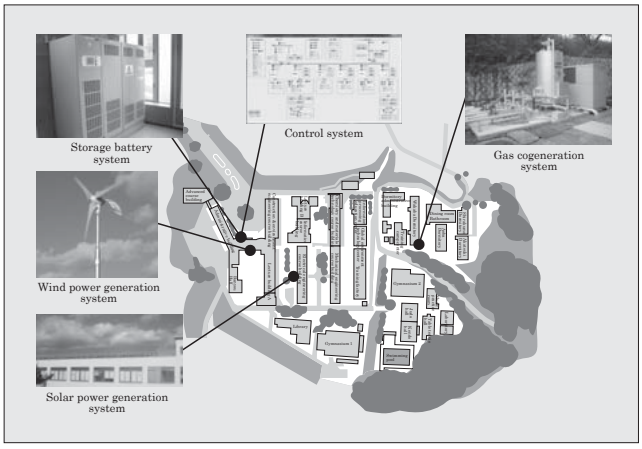
3 Smart Grid Real Scale Experimental Equipment for Fukushima National College of Technology

Smart grid real scale experimental equipment was delivered to Fukushima National College of Technology.

This equipment is experimental and research equipment for the purpose of developing human resources. At the same time, it is used as a routine dispersion type of power source and emergency power supply system in times of disaster.

Integrated control is performed for each system of gas cogeneration, solar power generation (existing), wind power generation, and storage battery. The gas cogeneration system efficiently utilizes waste heat, which is accrued along with power generation, in the hot-water system on campus by using a thermal energy storage technique. In addition, the simulator, which was delivered together with the main equipment, enables real-time simulation of the equipment and control system. A control algorithm such as storage battery control is expected to be developed by using the simulator and verified with the actual equipment.

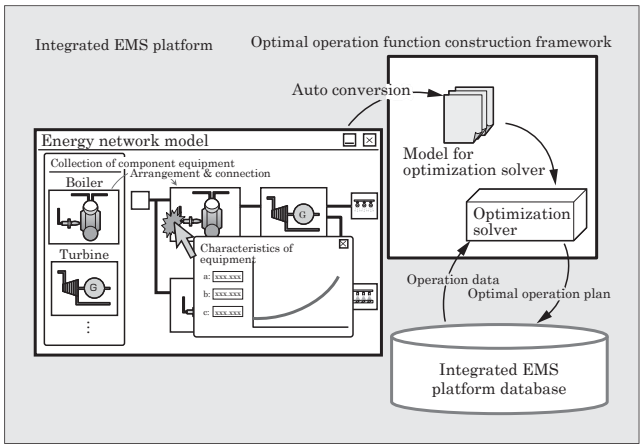
Fig.3 Configuration of smart grid real scale experimental equipment



4 Construction Framework of Integrated EMS Platform for Optimal Operating Function

Fuji Electric developed the optimal operating function as a construction framework for utility equipment such as electric power, heat, and gas equipment. It includes functional expansion of the integrated EMS platform for various industries, such as electric utilities steel, assembly, chemical, food manufacturing and food distribution. By arranging and connecting component equipment on the computer, the created energy network model is converted to the model format, which can be used for optimization solvers, and based on the device properties and operation data, optimization calculation is performed and the optimal operation plan can be drawn up. It is possible to perform maintenance easily when equipment structure or the equipment's characteristics are changed, although it was difficult up to now. The energy network model is installed in the integrated EMS platform and the model is similar to the Common Information Model (CIM) of international standard for power system, IEC61968 /IEC61970. In the future, Fuji Electric will strive to comply further with the standard by means of interconversion.

Fig.4 Optimal operating function construction framework

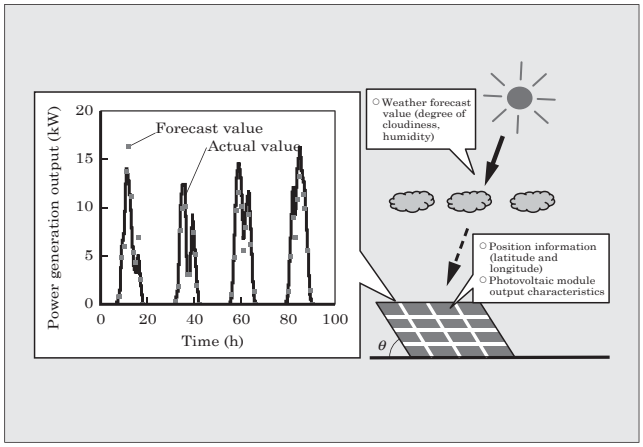


5 Forcasting Technology for Solar Power Generation

As an effort for a low carbon society, introduction of solar power generation systems are being promoted globally. However, the systems have negative effects on a power system because the outputs of them depend on climate. For that reason, technologies to stabilize the output of solar power generation are required. Fuji Electric is working on the development of a forecasting technology for the output as one of these technologies.

The main characteristic of this technology is that it can forecast the output every 30 minutes up to ahead of a few days at any place of the world by using position information of solar power generation facilities and surrounding weather forecast values and by considering output characteristics of photovoltaic modules. The forecast can apply to the supply and demand planning in power companies.

Fig.5 Example of the result of forecasting solar power generation

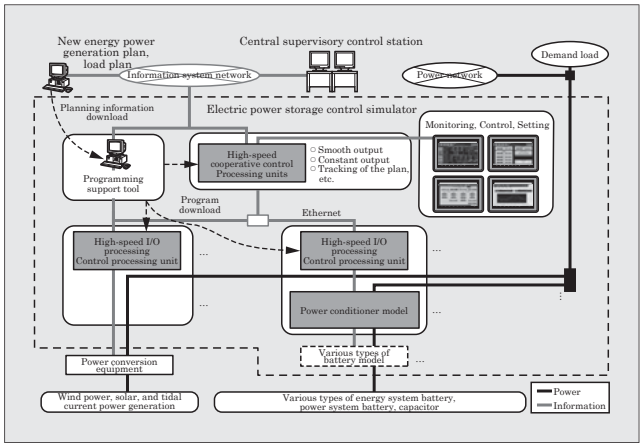


6 Electric Power Storage Control Simulator

Technology to control electric power storage is used to convert various types of large-scale natural energy such as solar power, wind power, and tidal current power to high quality and stable smart energy. This technology is also used to convert microgrids to ensure stable loads on power system. Research on this technology is rapidly progressing. Fuji Electric developed an electric power storage control simulator as an analysis support system based on its long time actual performances.

(1) in order to satisfy the need for power quality at power system interconnection, this simulator provides (a) capacity of electric storage equipment, (b) allocation of each type of electric storage equipment, (c) control algorithm for control system and control equipment, (d) control parameters and (e) data model, (2) support power generation plan and load plan of microgrid for system stabilization and (3) support establishment of optimal control algorithm and suitable parameters.

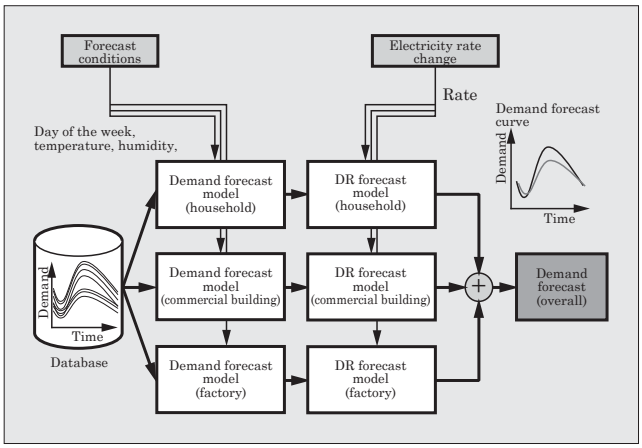
Fig.6 Electric power storage control simulator



7 Technology to Forecast Demand Response

Although adjusting the supply and demand has been performed at the power generation side only, it is becoming important to make adjustments at the demand side as well. By allocating changes in electricity rate and incentive points, demand response (DR), which prompts demand control and peak shift, is attracting attention. In order to integrate DR demand control into the system, it is necessary to forecast the demand change when the electricity rate is changed, and this forecasting technology has been developing. In concrete terms, the demand side is partitioned into several groups such as ordinary households and factories. After demand forecast is performed by using the demand database, the demand variation is corrected as a result of rate change. In the future, we expect to verify the forecast model by using data from a DR demonstration test, which started from FY2012 at the Kitakyushu Smart Community Project.

Fig.7 Configuration of demand response forecast model



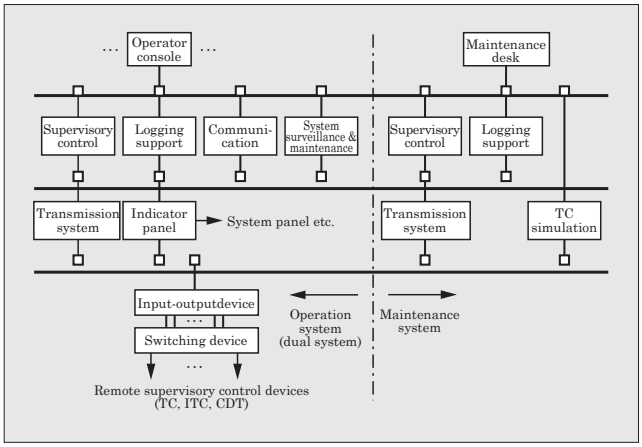
8 Nagano Power Supply Control Station System for Chubu Electric Power Co., Inc.

Full-scale update construction was carried out for the second time since the system was introduced in 1983 at the Nagano power supply station system for Chubu Electric Power Co., Inc. This system performs supervisory control of 128 electric power stations in the northern region of Nagano. The main features are as follows:

(1) As communication work became IP network, PMCN, which is the industrial protocol of The Japan Electrical Manufacturers' Association (JEMA) was introduced for data input and output with remote supervision control devices (TC, ITC and CDT) and there was linkage with a mainstay power supply system, other power supply systems, and power line automation systems.

(2) Operated the application software provided by a customer on the electric power middleware developed by Fuji Electric and achieved streamlining of system architecture.

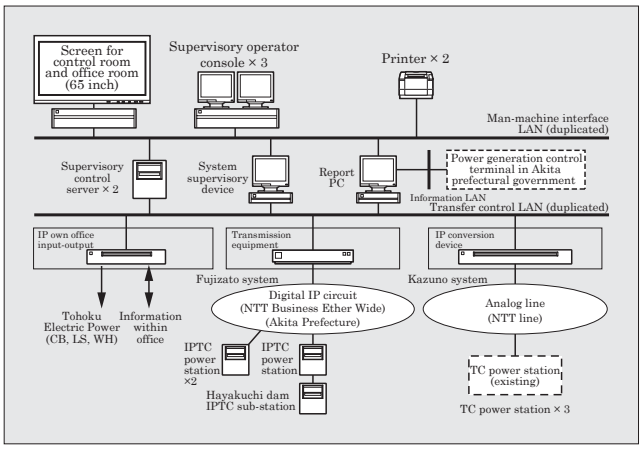
Fig.8 System configuration of Nagano power supply control station system



9 Odate Power Generation Office Centralized Supervisory Control System for Akita Prefecture

Renewal work for the Odate Power Generation Office integrated supervisory control device for Akita Prefecture was conducted. This device is a system to perform centralized supervisory control of six power-generating stations from the Odate Power Generation Office. The main features are as follows: (1) by duplicating the supervisory control server, transmission control LAN and man-machine interface LAN and configuring supervision operator console with three consoles, Fuji Electric achieved a system configuration with enhanced credibility, (2) three power generation stations of the Fujisato system were updated to be telecon compatible with IP (IPTC), and high functionality of infrastructure was achieved, (3) three power generating station of Kazuno system are equipped with an IP conversion device, for which the existing TC was diverted, in the Odate Power Generation Office and prepared for future upgrade to IP and (4) information service to terminals for power generation data control system, which was equipped outside, is achieved via report PC.

Fig.9 System configuration of centralized supervisory control system



⑩ Control Processing System for Maruyama Dam, Chubu Regional Development Bureau

Fuji Electric received an order for control processing system for Maruyama Dam from the Chubu Regional Bureaus of the Ministry of Land, Infrastructure, Transport and Tourism. The system started operation at the end of FY2012.

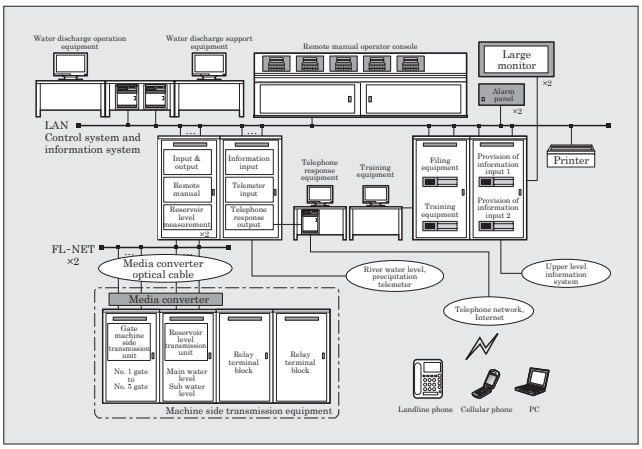
The main features of the equipment are as follows:

(1) In addition to discharge control of five spillway gates of the Maruyama Dam, it is possible to switch to the discharge control of two bypass gates that is built additionally along with the construction of a new Maruyama Dam.

(2) By linking a training equipment and remote manual operator console, it is possible to perform operation training close to the actual operation including operator console.

(3) In addition to response by telephone and reporting function with telephone response equipment, it is possible to send e-mail notifications.

Fig.10 Configuration of control processing equipment for management



⑪ Initiation of Flooding Test for Integrated Development Construction of Kyoto Prefecture Hatagawa Dam

Design, manufacturing and commissioning of main telecommunication equipment for a flood disaster prevention dam, which is built by Kyoto Prefecture, and water supply dam for Kyotamba-cho were completed. The main components of telecommunication equipment includes dam body observation equipment, measurement equipment, telemeter and discharge warning equipment, communication equipment, CCTV equipment, and control processing equipment for dam management.

These components equipment are under centralized management at the dam control office, and have a remote surveillance & control function and dam inflow forecast calculation function based on forecast precipitation from the Meteorological Agency. An energy-saving performance in dam management works and safe operation of the dam are realized.

The final adjustment test was carried out along with a flooding test in cooperation with Kyoto Prefecture, dam body contractor and discharge equipment contractor, and then construction was completed in March 2013.

Fig.11 Telemeter and discharge warning equipment and dam control station

⑫ Unit Type Digital Relay for Hokkaido Electric Power Co., Inc.

Fuji Electric developed the DUJ series of unit digital relays to install into digital relay equipment for power distribution substation of Hokkaido Electric Power Co., Inc. The main features are as follows: (1) reducing the size by about 60% compared to the existing equipment through functional integration by means of improving the CPU processing capability, employment of connectors for external terminal (excluding AC input section) and revising the substrate mounting form, (2) realizing improved accuracy using 16 bit AD converter and improved performance based on 4,800 Hz high-speed sampling, (3) improving maintainability by installing output terminal for testing, (4) by using dot matrix LED letter indicator, operability at stabilizing and visibility at status confirmation were improved and (5) noise-resistance performance conforms to JEC-2500 (2010).

Fig.12 "DUJ Series"

1 Dual Pressure Element (DPE) Sensor

When monitoring pressure and flow in the management of gas and oil wells, it is particularly important to measure the mass flow rate. Consequently, it is necessary to measure the differential pressure at the front and rear of the orifice installed in the piping and pressure (static pressure) in the piping simultaneously.

A DPE sensor consists of a compound sensor part that includes both the differential pressure and static pressure sensors, main body part that makes contact with the fluid, and a circuit part that includes functions for AD conversion and correction calculation.

The compound sensor (capacitance type) is based on MEMS technology and provides high sensitivity as well as superior stability and reproducibility. The pressure receiving unit of the main body part utilizes the same performance-proven structure as the "FCX-A III Series" to make it very reliable. Because the differential pressure and static pressure signals, which are processed by the circuit part, are externally output via serial transmission, the unit can significantly reduce power consumption and provide excellent interface compatibility. DPE sensors with these characteristics can be used in the harsh environments.

Fig.13 DPE sensor

2 Ultrasonic Flow Meter "FLR" and "FSV"

Since releasing its first ultrasonic flow meter in the 1970s, Fuji Electric's ultrasonic flow meters have been accumulating a steady track record in a wide range of fields, especially as related to the water treatment field and the steel and semiconductor industries. We have recently commenced sales of our successfully redeveloped "FLR" compact ultrasonic flow meters and "FSV" small ultrasonic flow meters.

The FLR has achieved an anti-bubble performance of approximately 60 times more than previous products, by adopting the implementation of digital signal processing (utilizing an advanced ABM method). The FSV has renewed its component configuration to include the latest technologies. In addition, it is expected to facilitate the release of high-end FLR models with expanded functionality for a diverse range of applications through future developments and enhancements. In particular, we are expected to add a variety of new functions such as a double measuring line method for 2-line synchronous measurement applications, HART communication for remote maintenance applications, and heat quantity calculation for energy savings applications.

Fig.14 "FLR" and "FSV"

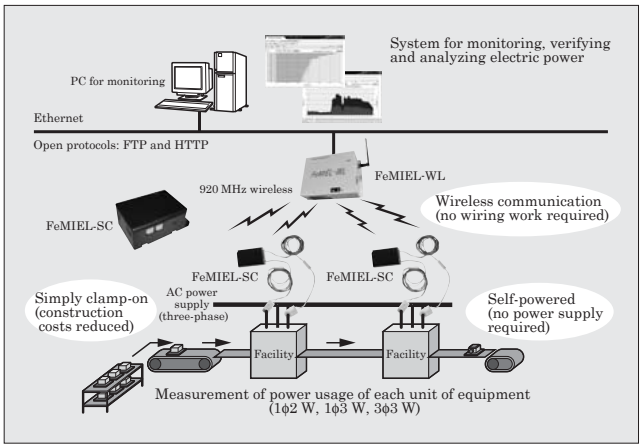
3 Clamp-On Type Power Measurement System

Fuji Electric has developed a clamp-on type power monitoring device and system to enable the easy construction of a power monitoring system.

The main features are as follows:

(1) 920 MHz specified low-power radio communication allows for data collection via wireless transmission.
(2) The implementation of a clamp-on current-sensor for measurement makes it unnecessary to have a dedicated power supply and power line (i.e., making it self-powered), since the power of the device is obtained from measured current.
(3) Installation can be made without switching-off the power, and connected simply by clamping to a power line.
(4) By collecting data via an Ethernet LAN (FTP, HTTP, etc.), the system can be combined with more sophisticated systems, enabling it to provide display of trends, reports, groupings, etc.

Fig.15 Clamp-on type power measurement system



4 Large-Scale Production of New Unit Type Electricity Meter

GE Fuji Meter has developed a new unit type electricity meter (rated current of 60 A, for a single-phase 3-wire model and three-phase 3-wire model). Production for the new unit began in July 2012. This meter is the result of the joint research of eight companies including the Kansai Electric Power Co., Inc. and Kyushu Electric Power Company, Incorporated.

A unit type electricity meter is used by combining a measurement unit and case unit. When the certificate expires, the measurement unit can be replaced with leaving the case unit to prevent workers from touching an energized part. Replacement work can, therefore, improve safety and reduce working hours. In addition, by changing the case unit material from glass and steel into plastic, the weight has been reduced by about 50% as compared with the conventional model.

Fig.16 New unit type electricity meter

5 Laser Gas Analyzer ($CO + O_2$)

Fuji Electric has developed a laser gas analyzer that utilizes two built-in laser elements in a single device, which can be used in applications including combustible gas recovery for steel industries and advanced combustion management for garbage incineration and sludge burning plants. The unit was released in June 2013.

By adopting a 2-laser method, we have achieved a significant price reduction on the unit compared with previous products. Some original technical specifications, such as usage of air for purge gas and improved anti-dust performance based on an automatic amplification-factor control function, are added to the unit. Since the laser elements can be changed according to application and measurement range, in the future it will be possible to make 2-components or 3-components measurements with all of the measuring devices in our product lineup.

We have acquired ATEX and NEPSI explosion-proof certification in FY2013 so that we can expand sales to overseas oil and petrochemical markets.

Fig.17 Laser gas analyzer ($CO + O_2$)

6 Radioactive Contamination Inspection System for Monitoring Foodstuff

Fuji Electric has developed a radioactive contamination inspection system for monitoring foodstuff that is capable of high-speed 100% inspection of large-quantities of rice-bags. The system is compliant with the new radioactive cesium standard for foodstuff. The system improves sensitivity through increasing the number of high sensitivity gamma-ray detectors, and also implements ambient radiation (i.e., BG radiation) shielding using a shadow-shield structure. This has resulted in measurement processing times significantly faster than previous systems (60 seconds inspection has reduced to 10 seconds). Its main features are as follows:

(1) Measurement performance: Determination can be made at a precision of 99% for standard values of less than 100 Bq/kg (Measurement lower limit: 25 Bq/kg or less; Screening level: 50 Bq/kg)
(2) Processing capacity: For 30 kg rice bags, inspection can be made of 360 bags per hour (when BG is 0.1 μSv/h)

In the future, inspection of general foodstuff will also be possible by changing software, further helping to achieve food safety and security.

Fig.18 Radioactive contamination inspection system for monitoring foodstuff

Measurement and Sensor Technology

7 New Gas and CO Alarm Annunciator for City Gas Consumers

Fuji Electric has developed a newly designed gas and CO alarm annunciator for city gas consumers that is approximately 20% thinner and realizes about a 40% reduction in power consumption compared with previous models.

In order to improve the visibility of the display lamp, we have newly adopted a prism that can suitably diffuse the light of the lamp. For the alarm tone, we have adopted a sweep tone to enable tone changes from low to high frequencies. By revising the lamp and tone of the alarm, we have enhanced the hazard perception capability to users, which is the primary role of alarm annunciator. In addition, we have also been able to improve alarm reliability in the following ways: implementation of gas detection employing newly developed decision logic, improvement in suppression of false alarms for various gases other than city gas and carbon monoxide, and enhancement of failure diagnosis functions.

This product contributes to help for gas utilities to "achieve their goal of realizing a safe and secure society."

Fig.19 New gas and CO alarm annunciator for city gas consumers

8 "PXE" Low-Cost Compact Temperature Controller

Fuji Electric's temperature controllers, especially high-quality and low-cost "PXR Series," have acquired support from large amount of users throughout the world, with over three million units being sold in China, Southeast Asia, the United States, and Europe.

In recent years, there has been increasing demand for low-cost units in the Chinese and Southeast Asian markets. To meet this demand, Fuji Electric has recently released the low-cost "PXE" temperature controller, which has achieved a significant reduction in size while maintaining the market-proven high-quality of previously sold products. Its main features are as follows:

(1) the unit contributes to miniaturization with a front face thickness of 1.6 mm (80% reduction from previous units) and a depth of 61 mm (24% reduction from previous units), (2) developed as a product line of low-cost models with the same basic performance as previous products, (3) since the unit can be powered by a PC, parameter settings can be easily carried out via a single cable connection and (4) long warranty period (3-year product warranty).

Fig.20 "PXE"

9 Foundation Fieldbus (FF) Transmitter

The Foundation Fieldbus communication protocol has been popular in Europe and the United States in the measurement and control fields as a means of communication control that supports bi-directional communication. It enables direct connection of control monitoring systems with measurement and control equipment. In recent years, an increasing number of utilizations of the protocol have been adopted in some of the world's largest class plants in Southeast Asia, the Middle East, South America, etc.

Based on these trends, Fuji Electric has added an FF communication function to its "FCX-A III Series" of transmitters, which have a reputation for high-precision, high-reliability, and low power consumption. The lineup also meets customer requirements, incorporating specifications that include resistance to hydrogen permeation as well as corrosion-resistant material. In addition, since the lineup enables to bring out explosion-proof and intrinsic safety, it can be applied to a wide range of fields such as the petroleum, petrochemical and natural gas fields, which often require the adoption of FF specifications.

Fig.21 FF Transmitter

Measurement and Sensor Technology

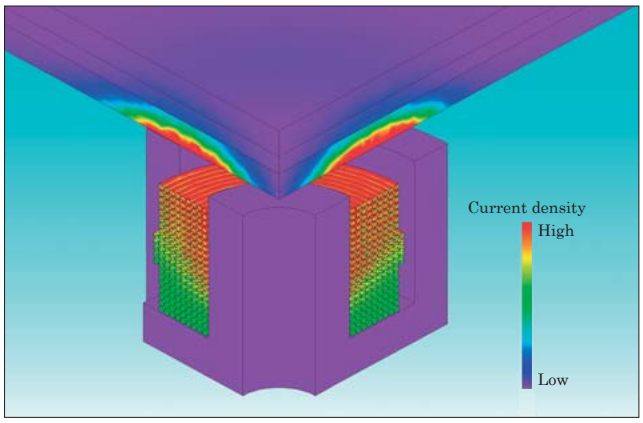
⑩ Enhanced-Precision of Electromagnetic Behavior Analysis in High Frequency Regions Used for Coin Identification

Eddy current sensors, which utilize coils, are used in a wide range of applications such as the verification of metallic material. In recent years, there has been a tendency that the verification target is diversified into a composite material consisting of multiple metal layers, and as a result, there is increasing demand for high-performance material verification capabilities.

Fuji Electric has developed a metallic material verification sensor to meet these needs, utilizing the difference in depth of penetration of the magnetic flux in high frequency regions. By combining the compensation acquired through equivalent circuit analysis with an electromagnetic field analysis technique, which has conventionally been based on the finite element method, we have been able to establish an analytical method that takes into account the amount of stray capacitance, which has induced problems during high-frequency excitation (500 kHz and up). This has enabled to greatly improve analysis precision.

In the future, we will continue to apply this analysis technology with our optimized design technology in order to develop techniques for carrying out material discrimination in composite materials that have a complex layer composition as well as for identifying foreign coins that are composed of composite materials.

Fig.22 Example of current density distribution analysis of the coil sensor (1/4 model)



System Control Technology

① "MICREX-SX SPH3000MG" Controller with Gigabit Ethernet

The "MICREX-SX SPH3000MG" is a high-performance and large-capacity controller equipped with the "SX-Net," which is a gigabit Ethernet-based control level network. Its main features are as follows:

(1) SX-Net has 128 K words of common memory area, which consists of broadcast transfer areas of maximum 64 K words per controller. The updating capability of the data is 8 K words per ms, which provides high-efficiency and large-capacity communication.
(2) The SPH3000MG also has the "E-SX Bus" and allows high-speed I/O updating, application execution and the SX-Net high-precision synchronous data exchange within 1 ms (minimum) cycle. Thus even between distributed multiple controllers, it is easy to build a high-precision synchronous control system.
(3) SPH3000MG is also equipped with a general purpose Ethernet port as in the Fuji's existing controllers and is flexibly applicable to various system configurations.

Fig. 23 "MICREX-SX SPH3000MG"

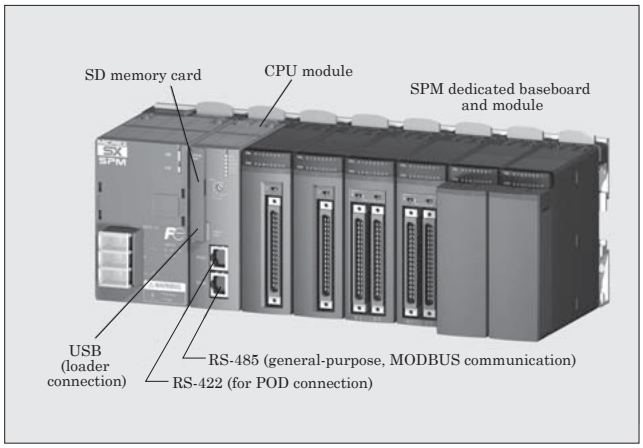
② "MICREX-SX SPM Series" of Programmable Controllers for Asian Markets

Fuji Electric added the "MICREX-SX SPM Series" to its lineup of programmable controllers for sale in Asian markets.

In the field of small-scale machine control, when performance is short with an existing small programmable controller, a conventional model of the "MICREX-SX SPH Series" makes a system more expensive and higher performance than required. However, the development of the SPM Series has helped to achieve a competitively priced product by filtering out certain functions, maintaining the same exact computing power as the SPH Series. Its main features are as follows:

(1) The SPM Series has the same programming tools as the SPH Series, ensuring the compatibility and reuse of software assets.
(2) Non-volatile RAM is utilized for data retention memory (no battery required).
(3) The CPU module is equipped with an RS-485 port, allowing for easy connection with the "ALPHA5 Smart."

Fig.24 Eight slot-based "MICREX-SX SPM" system



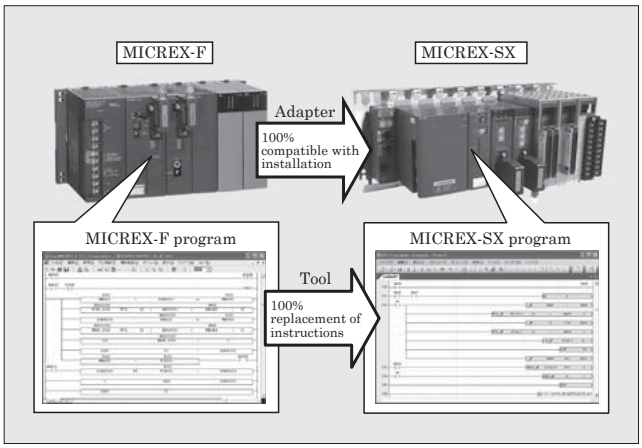
3 Replacement Tools and Adapter for "MICREX-SX"

A tool that completely converts application instructions of older "MICREX-F Series" models into those of the "MICREX-SX Series" of main controllers has been developed and released to the market. By developing a function to convert between differently represented instructions, migration can now be made from the MICREX-F Series to the MICREX-SX Series. This tool has allowed customers to smoothly transfer software assets and significantly reduced the design costs for the migration.

In conjunction with this tool, an adapter has also been developed to absorb differences between hardware externalities. Conventional I/O terminals can be reused as is, and since removal and rewiring of I/O signal lines is not required, the amount of time required for wiring work can be reduced dramatically.

Fuji Electric's replacement tool and adapter meet the demands of today's market, which requires effective utilization of customer assets as well as enhancement of functionality or replacement of long-term-use devices.

Fig.25 Example of replacement using the tools and adapter



4 "MICREX-SX SPH3000PN" Controller with Built-In PROFINET

Fuji Electric has developed a high-performance "MICREX-SX SPH3000PN" controller with built-in PROFINET RT, which is a global open network. The main features are as follows:

(1) Uniqueness of data is ensured and construction of high-speed control system is enabled by executing applications and synchronizing I/O data refreshing time among PROFINET I/O slave modules.
(2) I/O data of 4,096 words, connection of 128 slave stations, I/O communication at a rate of 2 to 512 ms for I/O data refreshing, and communication among controllers via general-purpose Ethernet overlapping are enabled.
(3) The support tools enable to reduce engineering efforts, allowing programs to be written in conjunction with the label name of the PROFINET I/O slave station.

Fig.26 "MICREX-SX SPH3000PN"

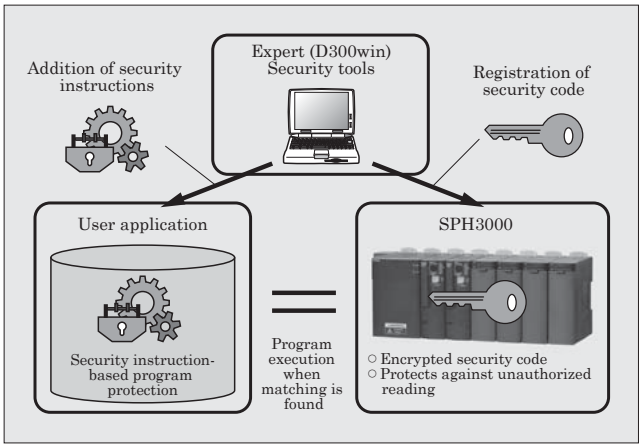
5 User Application Protection Installed in "MICREX-SX SPH3000"

A user application protection function was added to the "MICREX-SX SPH3000" in order to prevent unauthorized use of application programs. A security code, which is managed by the user, creates an association between programs and the controllers used to execute the programs, allowing a program to be executed only when this associative combination matches. By adding this restriction, unauthorized copying of programs and replication of the user's system can be prevented.

This protection function can be used in combination with traditional password-based functions used to prevent the display and reading of programs, and as a result, users can protect applications in a more robust manner.

The protection function also provides the ability to set an execution period for the program, ranging from 1 hour to 365 days, and enables to respond to the provisional operation and sample deployment of user system.

Fig.27 User application protection



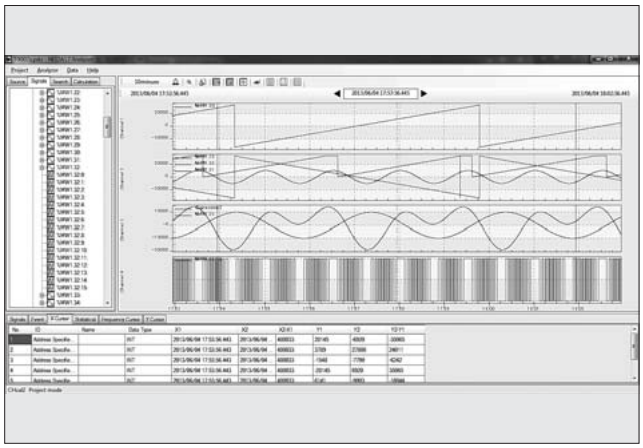
6 "f(s) NISDAS7" Package Software Supporting Data Collection and Analysis

In order to meet the need for predictive maintenance including the stabilization of equipment operation, high efficiency operation, and lifespan prediction, Fuji Electric developed the "f(s) NISDAS" support package software for data collection and analysis in 2002, and since then, we have supplied approximately 250 sets of the software to our customers. Recently, we have released "f(s) NISDAS7" as a new version of the software, incorporating many functional enhancements and providing compatibility with the latest personal computer environments. The main features are as follows:

(1) New functions: Newly added features include an innovative display and operating method, data management capabilities, panoramic display, and cursor function for statistical value
(2) Improved convenience through software enhancements

Chart comments, chart cursor function, data calculation function, Boolean display function, and data collection capabilities have been integrated into the software.

Fig.28 Example of chart from "f(s) NISDAS7"



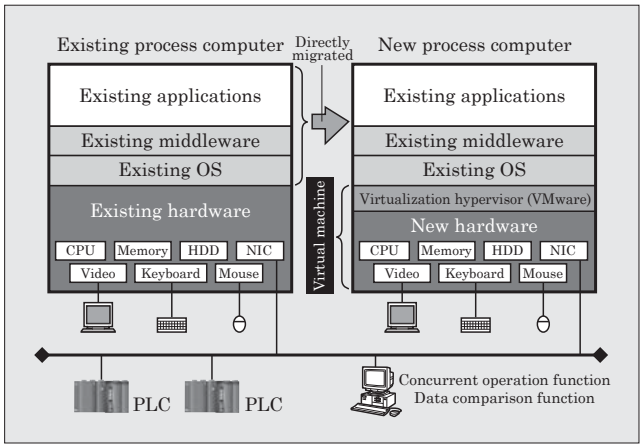
7 Replacing Process Computers by Using Virtualization Technology

The process computers (control computers) used in industrial fields need to be replaced periodically due to hardware degradation and expansion difficulties. Replacing to the latest hardware, operating system and middleware is very expensive due to costs associated with the conversion and operation test involved in the migration of existing applications.

Fuji Electric has utilized virtualization technology to develop a system that can be installed on new hardware without the need to change the existing system. This system ensures high quality, and also reduces development cost and time. It has the following features, which facilitate operation test and contribute to higher efficiency.

(1) Simultaneous operation of the old and new computer (concurrent operation)
(2) Efficient comparison of the output results of the old and new computer

Fig.29 Configuration of virtualization system



8 Administrative Cloud Mall for Citizen Information Services

With the growing interest in cloud computing implementations in local governments, Fuji Electric has developed an administrative cloud mall for resident information services as a new cloud service for local governments.

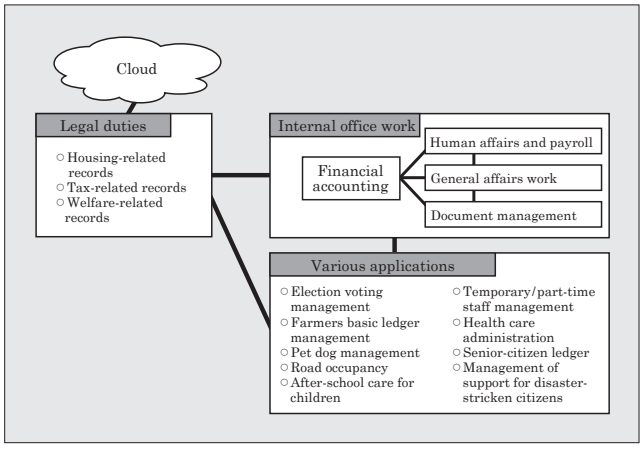
This service provides a cloud-based service that allows sharing of resident information packages, which previously needed to be installed individually, among multiple local governments and municipalities.

The main features are as follows:

(1) Housing-related records: Management of resident records
(2) Tax-related records: Management of local taxes
(3) Welfare-related records: Management of national health insurance, etc.

In addition, greater coordination can be made between various applications and the functions of internal office work, for which document management services have already been in operation.

Fig.30 Outline of administrative cloud mall for citizen information services

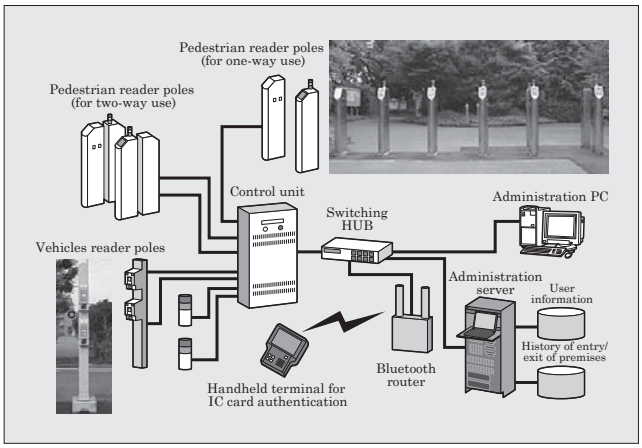


9 Entry/Exit Management System Capable of Counting Occupants

In the aftermath of the Great East Japan Earthquake, there has been growing demand for a system that can immediately discern the number of occupants on premises. Fuji Electric has developed this entry/exit management system to meet these needs. This system can immediately discern when people enter the premises of a building and also count the number of occupants on the premises. The system works by keeping track of when people (including pedestrians and vehicles) enter or exit the premises of a building by making real-time verification of the IC card data of company employees, etc. by using non-contact card readers or handheld terminals.

The control device is composed of an MPU and general-purpose remote PIO device for use in a remote monitoring and control system (telecontrol) to authenticate by checking the user information managed with server and information read from the card reader. We have also developed software to be used with the server for managing (registration, recording, storage and reference) the information of people who enter or exit a premises, resulting in an entry/exit management system that can easily count the number of occupants on a premises.

Fig.31 Configuration of entry/exit management system



10 New Tomei Expressway Remote Monitoring and Control System

In March 2012, Fuji Electric supplied the Tokyo Branch Office of the Central Nippon Expressway Company Limited with a remote monitoring and control system. This system consists of two types of equipment: (1) intelligent substations (intelligent slave station for Internet protocols) installed in the tunnels of the New Tomei Expressway opened in April 2012, (2) highway information terminal (including an earthquake early warning system) installed at service areas and parking areas.

The Intelligent substation incorporates a function for displaying the information recorded inside the slave station. The expressway information terminal equipment provides information regarding expressway traffic jams, etc. as well as URL information that can be accessed via a communication function in mobile phones that use FeliCa. The system also links to earthquake early warnings and displays earthquake magnitude information on its terminal screen for service area and parking area users. In addition, it is also possible to provide the information to public-address systems for notification by loudspeakers.

Fig.32 Intelligent substation and expressway information terminal equipment

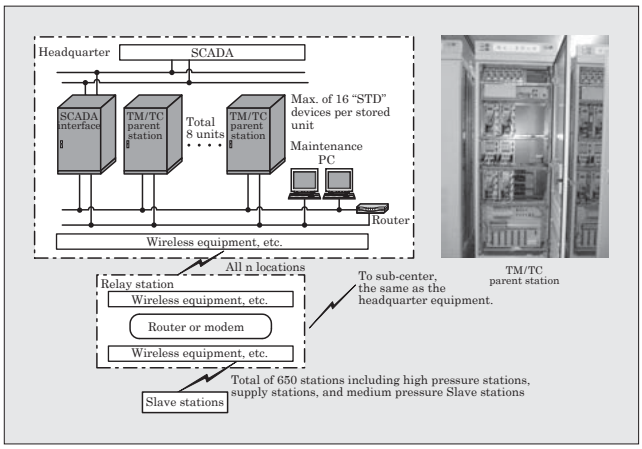
11 TM/TC Wide-Area Monitoring and Control System for Osaka Gas Co., Ltd.

Fuji Electric has supplied Osaka Gas Co., Ltd. with a TM/TC wide-area monitoring and control system. The system utilizes IP Telemeter "STD" hardware, which has a proven track record at power companies. We have also developed software used in the system, taking into consideration the differences in installation locations such as central monitoring rooms, radio relay stations and slave stations, as well as the differences that exist in communication methods such as those that use satellite channel, terrestrial radio channel and NTT digital circuit.

The system is a critical communication system for approximately 600 locations including high and medium pressure governor stations located throughout the supply areas of Osaka Gas Co., Ltd. The system is based on performing remote monitoring and control via a SCADA system in the central monitoring rooms (in both main and sub centers).

We have completed the delivery and testing of the system and are currently in the process of migrating from analog to digital lines.

Fig.33 System configuration diagram



System Control Technology

12 Renewal of Blast Furnace Blower Control System for Ironworks

Fuji Electric has renewed the blast furnace blower control system at an ironworks.

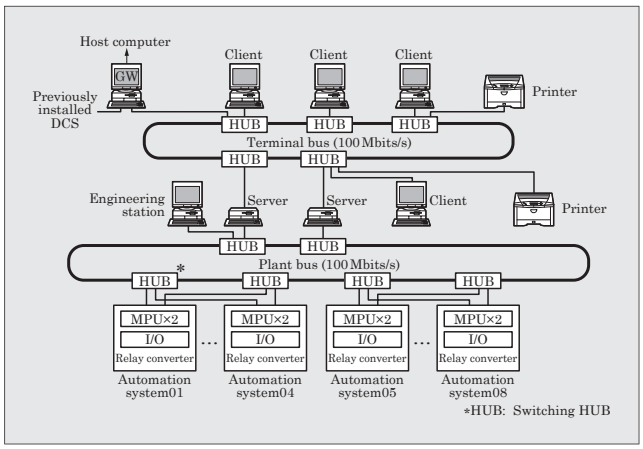
The renewal work of the control system required to complete within the short intervals of the furnace shutdown. This was accomplished by repeating detailed preliminary surveys as well as by repeatedly replacing and restoring signal branch board installations and switchover of old and new control systems.

The system's main features are as follows:

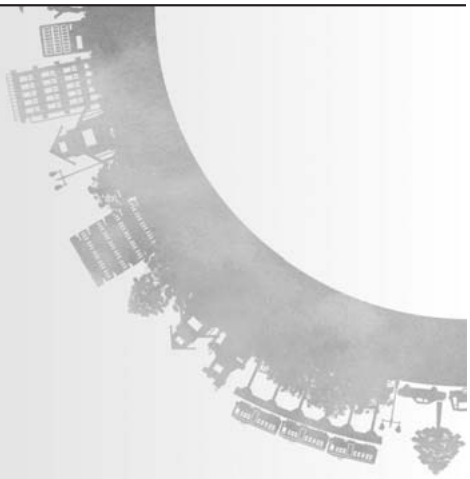
(1) Highly-reliable system meeting the blasting demands of the blast furnaces of integrated ironworks. The system achieves stable blowing through the combined control of multiple turbine blowers.

(2) The control system can flexibly respond to operations at times of periodic maintenance of each facility and device, blast intervals, inspections, etc. by carrying out operation though variously combining the blast furnace, blower and control system.

Fig.34 Blast furnace blower control system



Fundamental and Advanced Technologies



Design and Manufacturing Support Technologies
Materials Technology
Incubation Technology

Outlook

In July 2012, Fuji Electric adopted a new brand statement, "Innovating Energy Technology," which reflects its ongoing "pursuit of innovation in electric and thermal energy technology in order to create products that maximize the efficient utilization of energy and to contribute to the creation of responsible and sustainable societies." Underpinning the realization of this goal is design and manufacturing support technology. Design and manufacturing support technology is being developed in close cooperation with the departments that actually develop products.

Fuji Electric has newly developed a spectroscopic analysis method based on radiated light and infrared light, and with the addition of various types of microscopic analysis has established comprehensive techniques for analyzing gate oxide interfaces, crystal defects and the like. These techniques have been used in such applications as the development of SiC (silicon carbide) devices, which are currently the focus of attention as next-generation semiconductor devices, and are making positive contributions. Additionally, Fuji Electric aims to increase the efficiency of materials development through using molecular dynamics calculations and first-principle calculations to develop materials design technology for designing resin material structures and additives used in semiconductor interface structures and semiconductor packages. To increase the reliability of semiconductor devices, Fuji Electric has developed micro strain distribution measurement and evaluation technology for the contacts in semiconductor packages. In addition, so that these advances can be applied to improve insulation in semiconductor modules and to increase the breakdown voltage, Fuji Electric has established technology for visualizing partial discharge inside a module, and has clarified the mechanism by which partial discharges are generated.

For the purpose of deploying power electronics products in the global market, Fuji Electric has developed a virtual test environment that can be used directly with actual product programs. This virtual test environment enables the development and verification of customized products according to customer needs at overseas sites and the like that lack verification equipment. Additionally, Fuji Electric has developed magnetic field analysis technology for high-frequency transformers, which are a key component in high-frequency insulated-type transformers, the use of which is being advanced to realize the objectives of miniaturization and lighter weight, and this technology is being utilized to improve performance, and to shorten the development and design cycles. With the growing demand for earthquake resistance, Fuji Electric has developed an earthquake-resistant-housing design tool for distribution boards, and has established design technology for safe and secure electric equipment in response to various requests for earthquake resistance. Especially in the power electronics field, compliance with international standards has become increasingly important, and Fuji Electric has strengthened its compliance by establishing an in-house international standardization committee. Externally, Fuji Electric is actively involved in the assessment of standards for electromagnetic compatibility (EMC: the generation or reception of electrical or magnetic interference) and efficiency measurements.

As materials technology unrelated to electronic and thermal energy, Fuji Electric is advancing the development of high density magnetic recording media materials and photoconductive materials. As magnetic recording media for hard disk drives, for which larger capacities are continuously sought, Fuji Electric has optimized the organization and microstructure of each recording layer, and has commercialized 3.5-inch aluminum disk media having a storage capacity of 1 TB per disk, and 2.5-inch glass disk media having a storage capacity of 500 GB per disk. For photoconductors, demands are increasing for lower price, longer life and higher performance. Fuji Electric has responded to such requests by developing functional materials capable of reducing costs by 15% or more while realizing the same level of performance as before, and resin materials that enhance wear resistance by 20% or more, and has applied these materials to new products.

As incubated technologies, mostly various measurement technologies have been developed. Battery-free wireless sensing technology for measuring temperature and humidity has been developed, and application to a wide range of fields, such as data centers, showcases and the like is anticipated. Additionally, laser-based multi-composition multi-analysis technology capable of analyzing aerosols, for which the impact on health is a concern, has been developed. Furthermore, Fuji Electric is applying micro electro mechanical systems (MEMS) technology to advance the development of optical scanners for controlling the direction of laser light, a promising medical device application and the development of miniaturization and black-boxing of signal processing units for sensors.

Fuji Electric will continue to strive to research and develop advanced technology that leads to innovative electric and thermal energy technology and measurement and control technology.

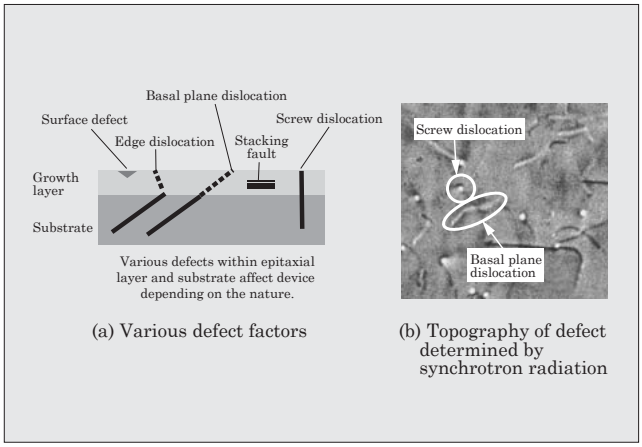
Design and Manufacturing Support Technologies

1 Analysis Technology Supporting Development of Next-Generation Power Device

Development of silicon carbide metal-oxide-semiconductor field-effect transistor (SiC-MOSFET) and silicon carbide insulated gate bipolar transistor (SiC-IGBT) as a high-voltage and low-loss power device is underway. Control of atomic defects of gate oxide interfaces, substrates and epitaxial layers is a common material issue with these devices.

Fuji Electric specifies the type of defects and position on substrate and epitaxial layer by topography analysis in addition to spectroscopic analysis with synchrotron radiation and infrared radiation, and nanoscopic analysis with a transmission electron microscope. There are various types of defects that can occur on an SiC substrate ranging from a large-scale plane defect to an ultra-microscopic dislocation (basal plane dislocation and screw dislocation). X-rays are irradiated on these defects and the structural abnormality at the atomic level is clarified from the difference in diffracted light. By using this technology, the influence that each defect has on the device is clarified and a more reliable SiC power device is realized.

Fig.1 Topography of defect by synchrotron radiation

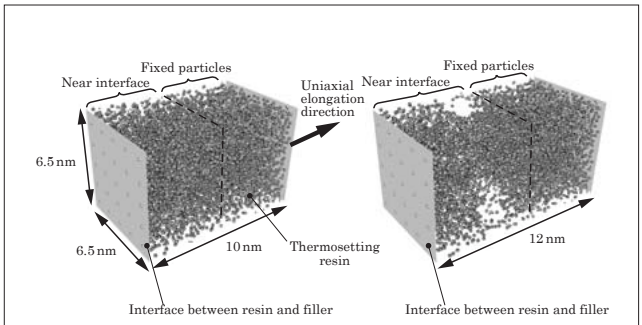


(a) Various defect factors (b) Topography of defect determined by synchrotron radiation

2 Analysis Technology of Material Properties Based on Molecular Simulation

In order to obtain a guideline which satisfies the material properties of resins that are necessary for improvement of products, analysis technology by using molecular simulation is being developed from the viewpoint of molecular structure and electronic state. Currently, Fuji Electric aims to obtain a heat-resistant resin available at a high temperature and is analyzing the behavior of a nanocomposite resin consists a of thermosetting resin and inorganic filler, whose material properties depend on the filler. It was revealed that the glass transition temperature of the resin adjacent to the filler was increased as cross linking reaction progresses by using molecular dynamics calculation. Furthermore, the result from the calculation of the uniaxial elongation near the interface shown in the right figure suggested that the modulus of elasticity near the interface was greater than that of the bulk resin. In the future, through the study on analyzing the oxidization of resin and adhesion of resin to an inorganic material, Fuji Electric will contribute to bring well-balanced resins in material properties.

Fig.2 Uniaxial elongation model of an interface between thermosetting resin and filler



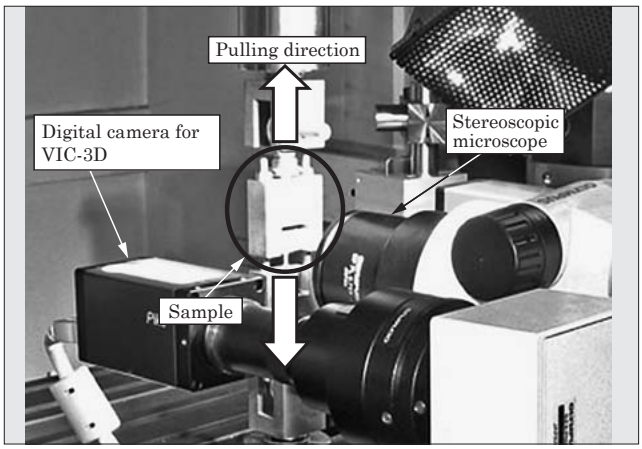
(a) Before uniaxial elongation (b) After uniaxial elongation

3 Technology for Evaluating Micro Part Skew Distribution to Improve Reliability of Device Design

Reliable device designs in areas such as the junction between the chip and substrate are drawn up mainly by stress analysis using the finite element method. In order to determine the behavior when deterioration such as cracks occurs, it is necessary to know data such as the skew distribution of minute joints and stress intensity factor. For this reason, Fuji Electric has developed skew distribution technology for minute sections.

By surface treatment that provides a luminance difference at the target section and by processing stereoscopic microscope images with the digital image correlation method, Fuji Electric has developed skew distribution evaluation technology with 10 times of the resolution and accuracy comparing the existing technology. Furthermore, from the result of this measurement, it was enabled to calculate the stress intensity factor of the tip of a crack directly. Consequently, the error of stress analysis was reduced by one-fifth compared to before and more reliable device designs became possible. In the future, this technology will apply to ensure reliable designs of new products.

Fig.3 Structure of evaluation device

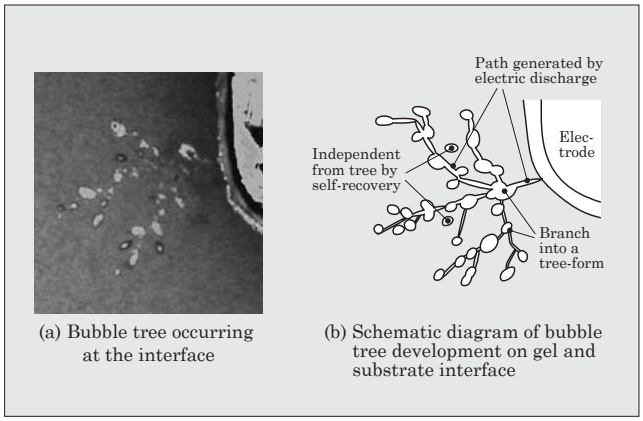


4 Partial Discharge Visualization Technology for Power Semiconductor Module

A higher withstanding voltage is required to achieve high-efficiency power electronic equipment used in wind power generation facilities, electric railroads and mega solar systems. For power semiconductor modules, an issue to overcome is how to improve the insulation performance at the interface between a silicone gel used as mold resin, and ceramic substrate.

Fuji Electric has developed partial discharge visualization technology to monitor a micro area at high speed by means of combining a high-speed camera and microscope. Bubbles are generated by partial discharge at the interface and a bubble tree is formed as the bubbles move. This phenomenon was observed and the discharge occurrence mechanism at the interface, which used to be unknown, was clarified. In the future, Fuji Electric will improve the insulation performance of the interface and contribute to the development of power semiconductor modules.

Fig.4 Bubble tree occurring at interface between silicone gel and ceramic substrate

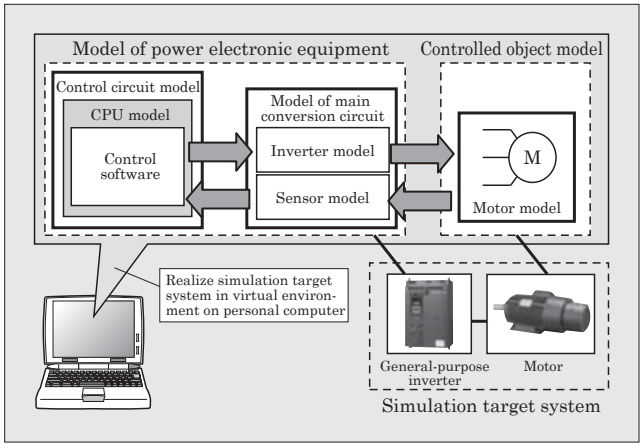


5 Virtual Test Environment for Power Electronics

Fuji Electric has developed a virtual test environment for power electronic equipment in order to enhance its competitiveness in the global market. It is possible to develop and verify customized products according to the customer requirements at overseas bases where there is no verification equipment, and promptly provide products that customers are satisfied.

In the virtual test environment, in addition to main conversion circuits and control circuits for the main body of the equipment, controlled objects such as a load were constructed in virtual environment on a personal computer, and a verification environment without using an actual machine was built. In addition, a simulator that simulates directly a CPU applies to the control circuit model, and this links to an electric and physical system simulator. As a result, a program of the actual products can apply to the control software that becomes the core of the control, which enables to perform verification more promptly.

Fig.5 Configuration of virtual test environment



6 Chassis Earthquake-Resistant Design Technology for Switchboards

Fuji Electric has complied with standards such as those of The Japan Electrical Manufacturers' Association (JEMA) and The Japan Electric Association (JEA) and has been implementing earthquake-resistant designs for chassis of switchboards by using the standard seismic intensity with the local seismic coefficient method. Since the Great East Japan Earthquake in 2011, further detailed earthquake-resistant designs have become necessary. There used to be such issues with previous earthquake-resistant designs that the center of the board is uniformly regarded as the center of gravity, and off-position of gravity toward the depth direction of switchboard is not considered.

For this reason, Fuji Electric developed a tool to determine earthquake-resistant designs with which structure, load and gravity can be set arbitrary by dividing internal equipment into several units. As the result of this development, it has become possible to draw up earthquake-resistant designs by complying with "Guideline for earthquake-resistant design and construction of building equipment" (The Building Center of Japan) with improved accuracy and in a short period. In the future, Fuji Electric will rapidly respond to each type of requirement for earthquake resistance and contribute to the installation of safer and more secure electrical equipment.

Fig.6 Example of switchboard employed an earthquake-resistant design

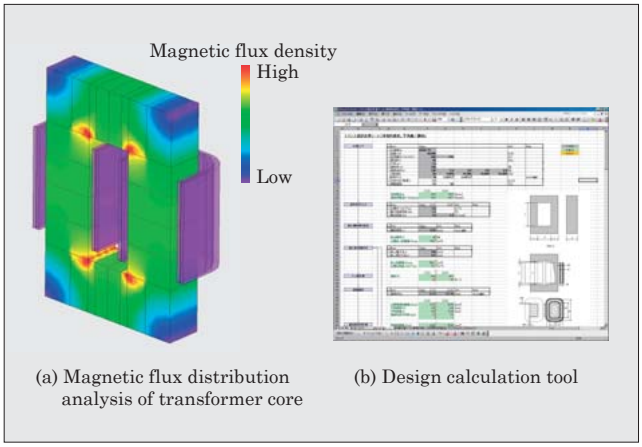
Design and Manufacturing Support Technologies

7 Magnetic Field Analysis Technology of High-Frequency, High-Voltage Transformer

Recently, high-frequency isolated converters have been widely adopted to reduce the size and weight of isolated type power electronic equipment. Fuji Electric has developed magnetic field analysis technology for high-frequency, high-voltage transformer, which is a core part of such equipment.

This technology is equipped with a circuit coupled and heat coupled analysis function considering the actual working status of the power electronic equipment. For material properties used for the transformer, Fuji Electric's original database, which has been accumulated over many years, is used. In addition, a design calculation tool was developed to calculate various design elements of transformers by using magnetic field analysis and to pursue limit design. With this tool, it is possible to predict performance more accurately in the design of high-frequency, high-voltage transformer. This is used to shorten the development and design period and to improve performance and quality further.

Fig.7 Example of magnetic field analysis for high-frequency, high-voltage transformer

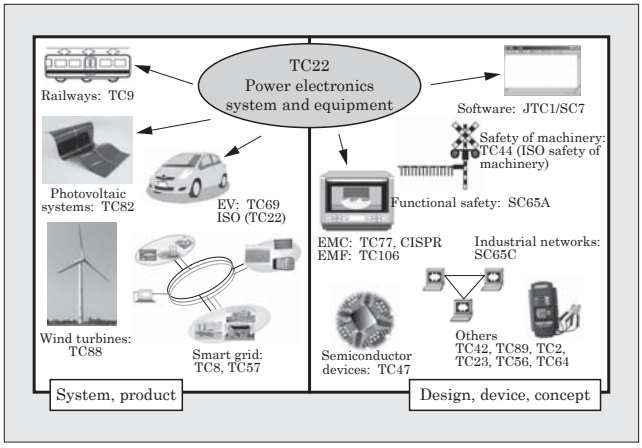


8 Corresponding to International Standards

Fuji Electric is carrying out activities to propel its main product power electronics devices as a member of TC22 (power electronics systems and equipment), SC22G (drive) and CISPR (EMC) in the technical committees of the International Electrotechnical Commission (IEC) and conducting technical development to correspond to standards. While developing efforts with the in-house committee in order to carry out activities smoothly, Fuji Electric is contributing to the industry. The main development items are shown below:

(1) Participated in the measurement campaign of the drive EMC specification and indicated the validity of the limit value.
(2) For drive efficiency specification, while considering the characteristics of measuring instruments, established an appropriate method to measure efficiency.
(3) Established an EMC measurement method for high-capacity solar light power converters and offered various arguments for amendment in an international discussion

Fig.8 International standards related to power electronics



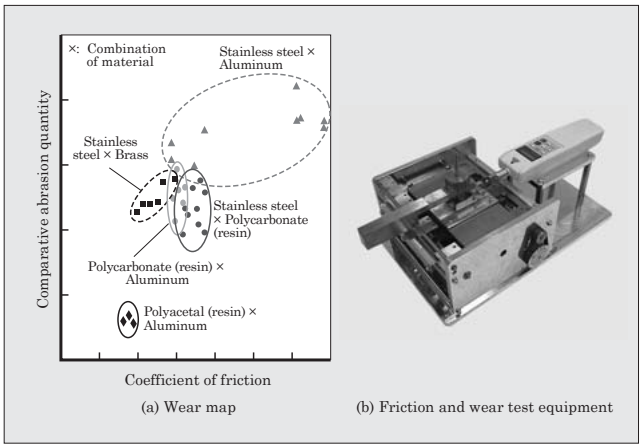
9 Improved Reliability of Machine Design by Tribology

Friction and abrasion on the contact section must be reduced to improve the reliability of product groups with rotating machines and sliding portions such as rotational machine. To meet this end, it is necessary to enhance design technology related to tribology (friction, abrasion and lubrication).

Fuji Electric has obtained the wear map of resin and each type of metal in the case of dry friction (without lubricant) and derived empirical formula to determine the correlation between the coefficient of friction and abrasion loss by using surface roughness, surface energy, material strength, and material hardness.

By applying this empirical formula, the reliability of product groups with sliding portions can be improved. Furthermore, Fuji Electric strives to expand the technology scope to fluid friction (with lubricant) and enhance design technology.

Fig.9 Wear Map and friction/wear test equipment



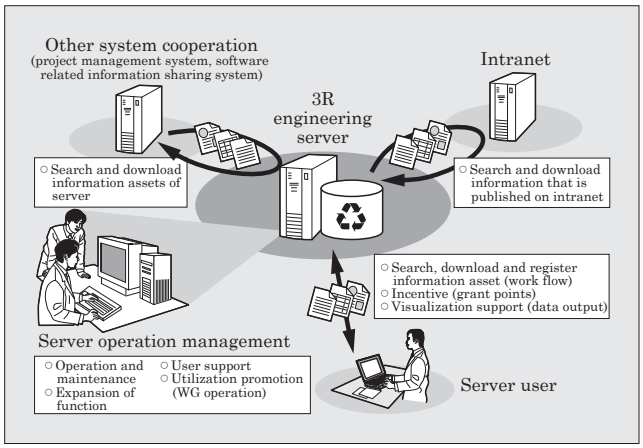
Design and Manufacturing Support Technologies

10 Construction and Operation of 3R Engineering Server

As one of the measures to improve business, Fuji Electric is working on productivity improvement centering on "reuse" of information assets. A 3R engineering server is a system with which all employees register and utilize information assets accumulated in-house such as knowledge, technology and know-how, and this system began operating in May 2010. Employees use an advanced search engine to search information assets registered in the server or information which are published on the intranet, and they are able to utilize these assets for the business.

In 2012, an "Incentive function" to promote utilization and a "Visualization support function" to enable users to browse the utilization state of individuals and divisions and a list of registered assets were developed and provided to the users. Fuji Electric continues to reflect the opinions and requests of users in the system and develop activities for system improvement toward a more user-friendly system and utilization promotion.

Fig.10 Service and operation management that 3R engineering server provides

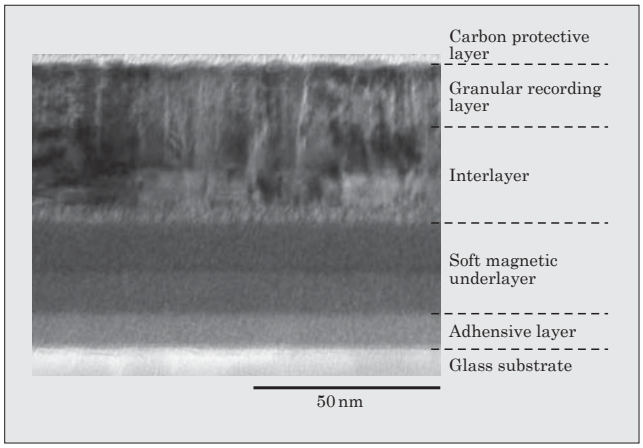


Materials Technology

1 Perpendicular Magnetic Recording Media with Ultra-High Density

Since higher recording capacity is continuously required for hard disk drives, Fuji Electric has commercialized 3.5-inch aluminum disk media with the capacity of 1 TB per platter and 2.5-inch glass disk media with that of 500 GB per platter. Low noise characteristics together with high writeability have been achieved by the optimization of the materials and the microstructures of multilayered granular magnetic layers and interlayers. In addition, the reduction of the magnetic spacing has been realized by applying a new lubricant material with enhanced bonding with a protective layer. Furthermore, along with the development of the advanced evaluation technology, such as the experimental evaluation of the recording performance by using hard disk drives and the improvement of the detection capability of nano-sized defects for higher recording density, Fuji Electric promotes further capacity improvement in order to overcome the competition against the semiconductor memories.

Fig.11 Cross-section TEM image of perpendicular recording media

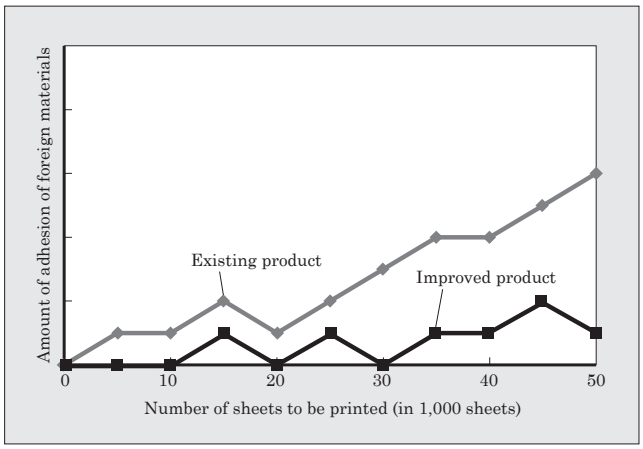


2 High-Durability, Negative Charging Type of Organic Photoconductors

In the digital printing field, devices with various functions are coming on the market each day along with the diversification of market needs. As a result, a wide range of products for peripheral components, such as a charging roller and cleaning blade, which come into contact with a photoconductor have been developed. For this reason, a photoconductor with excellent matching property with a peripheral component with a wide variety of properties and qualities are in demand.

Fuji Electric is developing a high-durability organic photoconductor that matches with these members. In order to increase durability against physical load to the photoconductor due to each member, development and formation of new material was adjusted and toughness of the layer, strength against anti-creep property and anti-cracking property were improved. As a result, the mechanical property of the photosensitive layer was improved and the amount of foreign materials that adhered, which is attributable to damage on the photosensitive layer caused by each type of contacting member, was reduced.

Fig.12 Amount of foreign materials adhering to surface of photoconductor in printing test



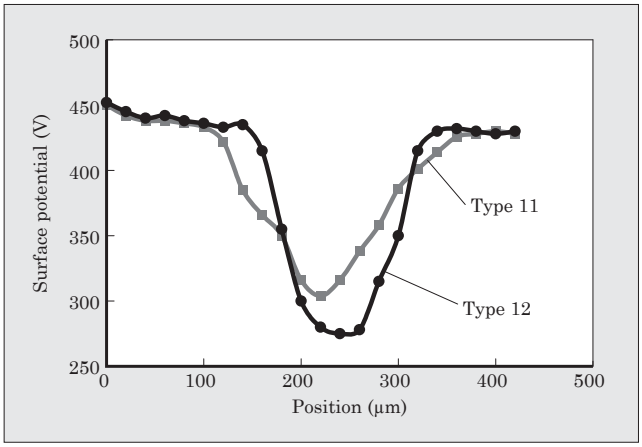
3 High Response and High Sensitive Double Layer Organic Photoconductor for Positive Charging

Electrographic imaging devices have become high-speed, high-resolution and colorized and there is a strong demand to reduce their size and price. Organic photoconductor (OPC) must satisfy requirements at a high-performance for sensitivity, responsiveness, durability, resolution, reliability and cost.

Fuji Electric has been launching on the market the multi layer OPC for negative charging (Type 8B) which can hardly achieve both high-speed and high-resolution and the single-layer OPC for positive charging (Type 11), which can relatively easily to achieve both. To meet increasing technical demands, Fuji Electric has newly gathered its own technologies and developed the ultra-sensitive double layer OPC for positive charging (Type 12) with excellent responsiveness, resolution, durability and reliability.

The figure shows a comparison of the electrostatic latent image of two types. Compared to the Type 11, the Type 12 has a sharper curve in surface potential and it is clear that image quality with higher resolution can be obtained.

Fig.13 Electrostatic latent image of positive charging OPC



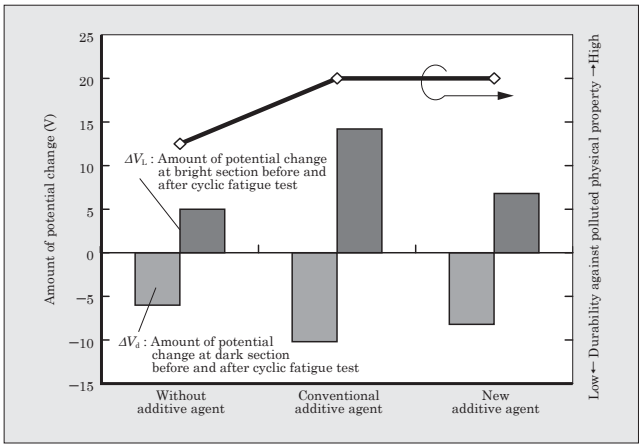
4 Durability Enhancement of Photoconductor Using New Additive Agent

There is an increasing demand for more durable photoconductors due to a trend toward reducing the environmental impacts of printers and plain paper copiers (PPCs) on which a photoconductor is installed. These products need to be made smaller, consume less energy, and made recyclable. In addition, photoconductors are required to have durability for plasticizers, which are included in peripheral attachments such as electrified rollers, and substances that derive from the surrounding environment.

Fuji Electric designs optimal additive agents in the development of functionality materials for photoconductors by considering a design that is not easily influenced by external factors, and increases the flexibility of the design by combining with film-forming material.

New additive agents can provide photoconductors with a more flexible design by improving the stability of the electrical potential with a small amount of potential change under a high-temperature and high-humidity environment under the same conditions while maintaining crack-tolerance property.

Fig.14 Durability-enhancing effects of photoconductor using new additive agent



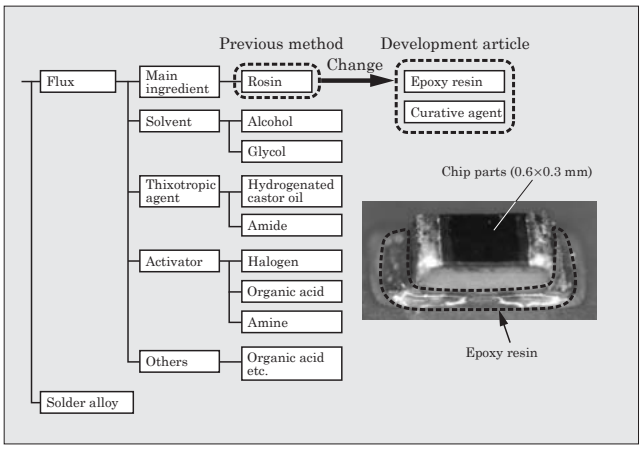
5 Epoxy Resin Cream Solder for Reinforcement of Joints for Microchip Parts

An effective way to implement high-density printed circuit boards and to reduce the size of devices is to use microchip parts (0.6×0.3, 0.4×0.2 mm). However, because the solder bond section of microchip parts is reduced, the bond strength becomes weaker.

Fuji Electric has developed cream solder flux that can reinforce the bond strength by changing the existing flux ingredient from rosin resin to epoxy resin. This is used to reinforce the solder bond section by using heat processing when joining with solder and by hardening the epoxy resin at the same time. The soldering properties such as wetting are equivalent to the original rosin resin by adding an appropriate activator.

In the future, Fuji Electric will optimize reflow conditions of this flux in order to apply to actual products, and promote its application to new products.

Fig.15 Material composition of cream solder and example of joint of microchip parts



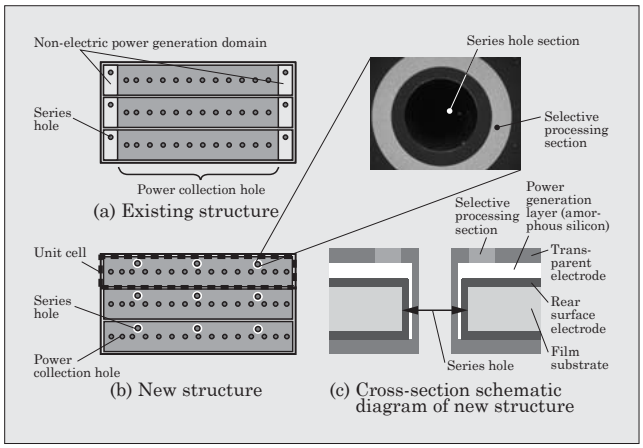
Materials Technology

6 Low-Loss Series-Connection Technology for Film Substrate Photovoltaic Cells

Fuji Electric has developed technology for selective laser processing to remove thin transparent electrode layers on amorphous silicon generation layers without causing thermal damage to the generation layers. This technology is used to process the groove of the ring shape by using an excimer laser all at once.

The photovoltaic cells of Fuji Electric have a unique series-connection structure. The photovoltaic cells, which are divided into units, are electrically connected through series holes and power collection holes. With this processing technology, it has become possible to align freely the series hole (Fig. (b)), which used to be aligned to both ends of the unit (Fig. (a)). As the result, the current that flows into the metal electrodes is divided and the output of the cell has been improved by 5% due to a decrease in resistance loss. Furthermore, it has become possible to change the non-electric power generation domains of both ends of the unit into the generation domains, thereby further improving output by 5%.

Fig.16 Low-loss series-connection photovoltaic cells using selective laser processing



Incubation Technology

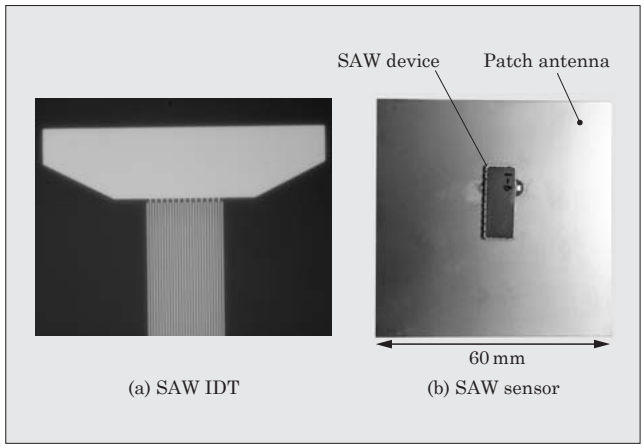
1 Batteryless and Wireless Sensing Technology

Fuji Electric has developed sensing technology that does not require a power line and a battery for a visualization sensor used in data centers and display cases. This technology utilizes a mechanism in which the propagation time when surface acoustic wave (SAW) propagates on a piezoelectric substrate is in proportion to each type of physical quantity (temperature, humidity, and pressure) on the substrate surface. The main features are as follows:

(1) Simple structure composed of SAW sensor installed in the antenna and transceiver with processing circuit.
(2) Battery is not required because radio waves (2.45 GHz) from the transceiver are converted to SAW by inter digital transducers (IDT).
(3) Possible to have multiple channels because multiple SAW sensors can be processed concurrently with one transceiver.

The sensor under development can detect temperatures in the range of −5 to +55°C with an accuracy of ±0.35°C or better and a maximum communication distance of 6 m was achieved.

Fig.17 SAW IDT and SAW sensor



2 MEMS Optical Scanner

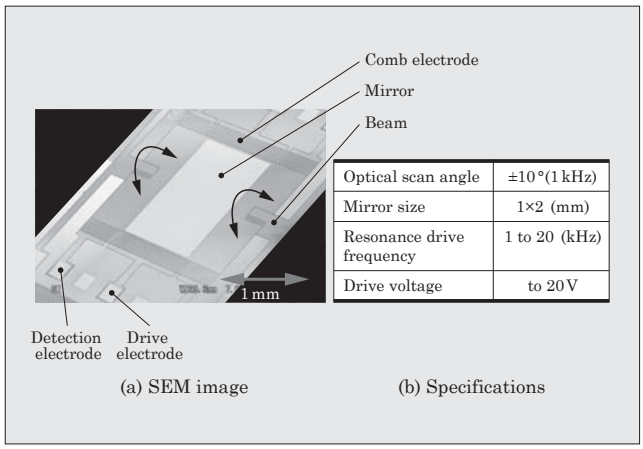
Fuji Electric has been participating in the project of Innovation Center for Medical Redox Navigation, Kyushu University since 2010 and is developing a MEMS optical scanner (device to control the direction of laser beam). in order to apply to medical equipment that requires miniaturization.

Fuji Electric is planning to miniaturize the size of MEMS optical scanner rotating the mirror by electrostatic force between movable electrode and fixed electrode, formed by using silicon microfabrication technology.

For design, fabrication and characterization, Fuji Electric has developed simulation technology that integrated electronics and mechanics, 3D chip stacking technology with through silicon via (TSV) and low temperature bonding technology using micro bumps.

In the future, Fuji Electric aims to apply these technologies to products such as optical measuring equipment and projectors.

Fig.18 Uniaxial MEMS optical scanner



Optical scan angle	±10°(1 kHz)
Mirror size	1×2 (mm)
Resonance drive frequency	1 to 20 (kHz)
Drive voltage	to 20 V

(b) Specifications

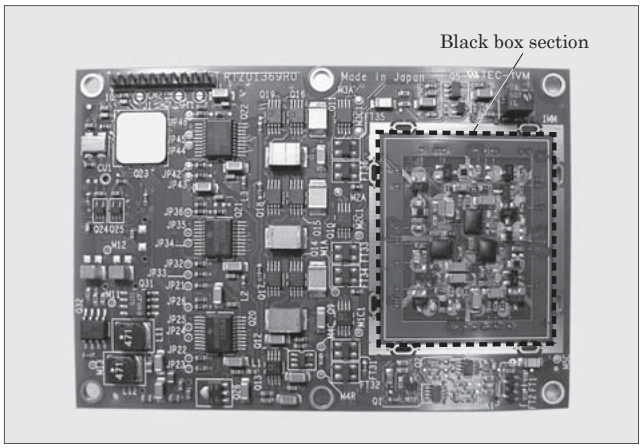
Incubation Technology

3 Black Box Technology for MEMS Sensors

Fuji Electric is carrying out research and development on various types of sensors by applying micro electro mechanical systems (MEMS), which make it possible to differentiate Fuji Electric's products from those of competitors in areas such as size and performance. MEMS sensor signal processing section (analog circuit) is one of the core technologies and a measure is required to prevent competitors from imitating the circuit section for global deployment. In order to achieve this, Fuji Electric is working to develop technology to apply an intelligent micro module (IMM) by using an interposer such as a silicon substrate to the low-noise circuit section, which is used for a MEMS sensor, and create a black box. Through this, obfuscation of circuit section is achieved, and it will be possible to reduce the product's size by 40% compared with the existing surface ratio.

Fuji Electric has applied this technology to vibration sensors and completed development in FY2012.

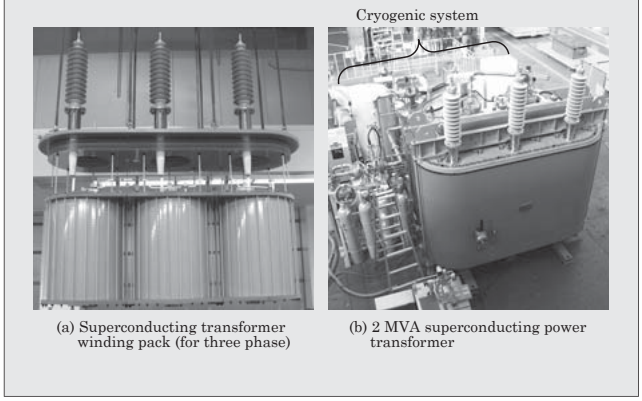
Fig.19 Application example into vibration sensor



4 66 kV/6.9 kV-2 MVA Three-Phase Superconducting Power Transformer

Fuji Electric aims to realize stable and efficient power supply systems and carried out research and development on a superconducting power transformer as a part of "Technological Development of Yttrium-based Superconducting Power Equipment." The project was a joint collaboration mainly with Kyushu Electric Power Company, Incorporated and International Superconductivity Technology Center and was entrusted by New Energy and Industrial Technology Development Organization (NEDO). The five-year project was completed in February 2012. In this project, Fuji Electric aimed to implement a 66 kV/6.9 kV 20 MVA-class superconducting power transformer to develop several elemental technologies such as a fault current limiting function and reduction for AC losses of superconducting windings. Finally, we have developed and evaluated a 66 kV/6.9 kV 2 MVA-class superconducting power transformer comprising the developed technologies. The achievement has reflected to the design of a 20 MVA-class superconducting power transformer.

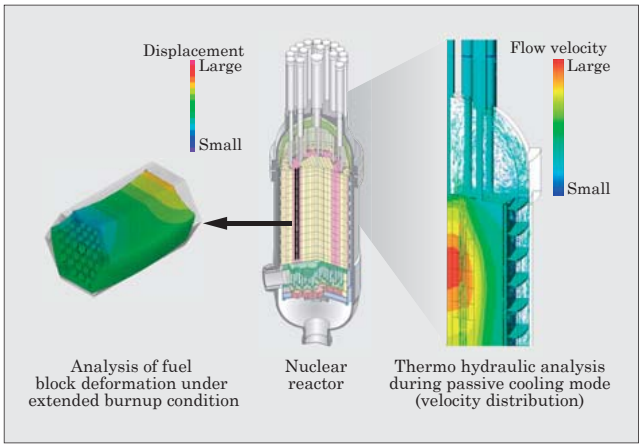
Fig.20 66 kV/6.9 kV-2 MVA three-phase superconducting power transformer



5 Modular High Temperature Gas-Cooled Reactor with Fully Passive Safety Features

A modular high temperature gas-cooled reactor (modular HTGR) is a next-generation nuclear reactor that has features as follows: (1) it has fully passive safety features, such as that it can be cooled by natural phenomena after an emergency shutdown; and (2) it can supply high temperature heat to realize various heat applications, such as hydrogen production and process heat for chemical plants. Toward the goal of commercialization of the modular HTGR, Fuji Electric is pursuing its R&D effort to achieve the enhancement of passive safety features, higher outlet temperature and higher fuel burnup of the HTGR reactor. Some of these are performed as cooperative research work with Japan Atomic Energy Agency. Relating to the enhancement of the passive safety features, the development of design technology for temperature behavior and structural integrity evaluation of the reactor components during a passive reactor cooling mode are being performed. As to higher outlet temperature and higher fuel burnup of the reactor, development of the evaluation technology for the fuel block deformation by neutron irradiation and thermal expansion, resulting core bypass flow rate fraction and so on are also performed.

Fig.21 Example of fuel block deformation analysis and thermal hydraulic analysis results



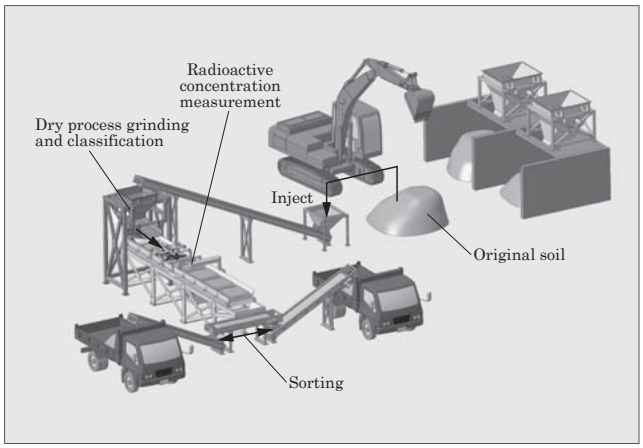
Incubation Technology

6 Dry Decontamination and Volume Reduction Facility for Contaminated Soil

Fuji Electric has developed a facility to separate highly contaminated soil from soil that was contaminated by the accident of Fukushima Daiichi Nuclear Power Station due to the Great East Japan Earthquake. In the contaminated farmland, the top layer of soil down to a depth of a few centimeters is removed to decontaminate. This soil is temporarily placed in an interim storage location, and then finally disposed. However, a wide area of land requires decontamination and a large area is needed to store the entire amount of removed soil. The original soil to be disposed is not contaminated entirely and if highly contaminated soil can be separated from less contaminated soil, it will be possible to reduce the amount of soil that needs to be stored.

This facility is used to reduce the volume of contaminated soil by separating highly contaminated soil from less contaminated soil by means of a dry process grinding and classification. In addition, the total amount of low-contamination soil is 100% verified and its safety is confirmed. The aim is to reduce the space needed for storing contaminated waste and guaranteeing safety and security related to the reuse of processed soil.

Fig.22 Facilty for dry decontaminating and reducing the volume of contaminated soil



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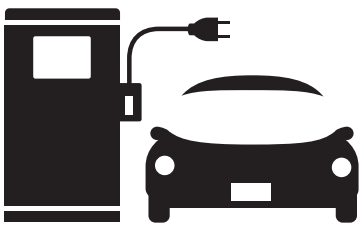
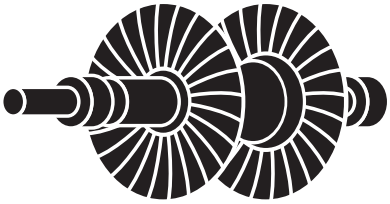
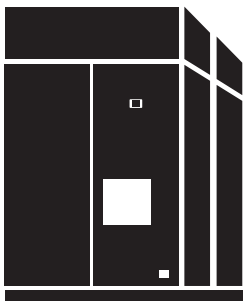
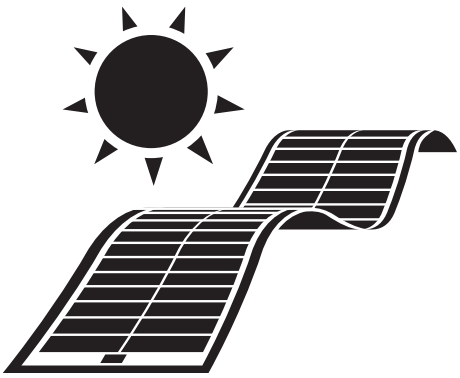
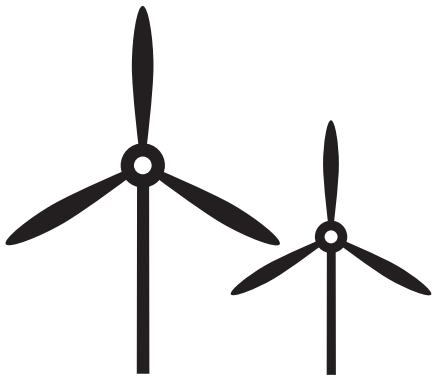
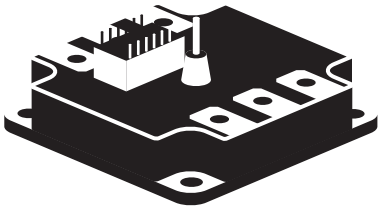
Innovating Energy Technology

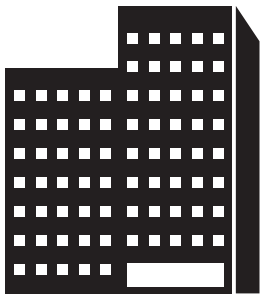



Fuji Electric will meet the demands
of a new age with our energy technologies.







"Energy creation" to produce clean energy,
"energy conservation" to reduce wasteful energy consumption and
"energy management" to make the most of both the above approaches.
Fuji Electric will contribute to the creation of sustainable societies
through our unique technologies that freely control electricity.

Fuji Electric

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Fuji Electric Korea Co., Ltd.

Sales of power receiving and distribution/control equipment and drive control equipment

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URL http://www.fujielectric.co.kr/

Shanghai Fuji Electric Transformer Co., Ltd.

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Fuji Electric Power Supply (Thailand) Co., Ltd.

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Fuji Electric India Pvt.Ltd.

Sales of drive control equipments and semiconductor devices

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Innovating Energy Technology

Through our pursuit of innovation
in electric and thermal energy technology,
we develop products that maximize energy efficiency
and lead to a responsible and sustainable society.

Fuji Electric