Electric Energy Technology

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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.

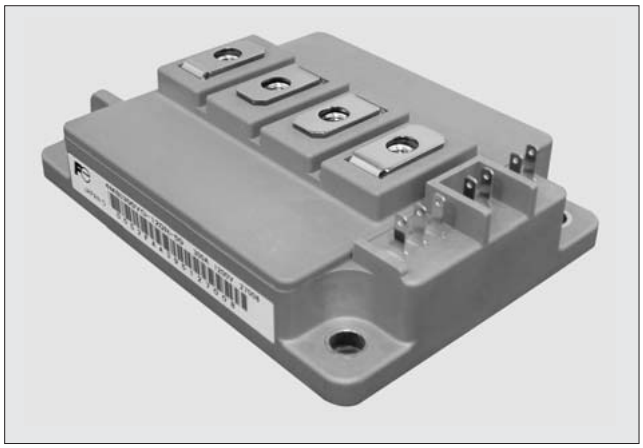
In the field of power distribution, Fuji Electric expanded its "F-MPC Series" of power monitoring systems with the addition of an insulation monitoring unit using Ior detection method, which have a simple configuration that uses a zero-phase current transformer (ZCT), and continuously monitors the insulation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

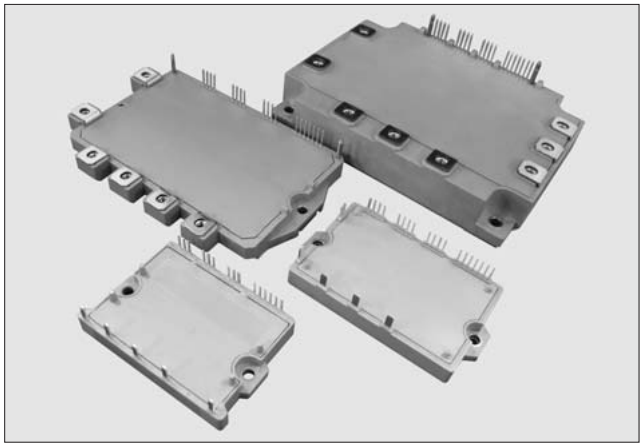


2 6th Generation IGBT-IPM "V-Series" IPM

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.)

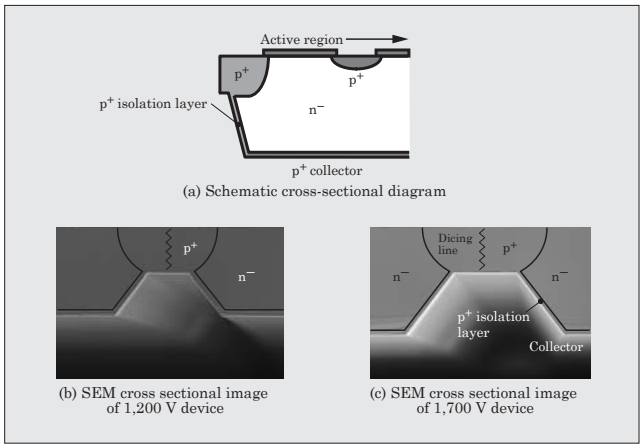
Fig.2 "V-Series" IPMs



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

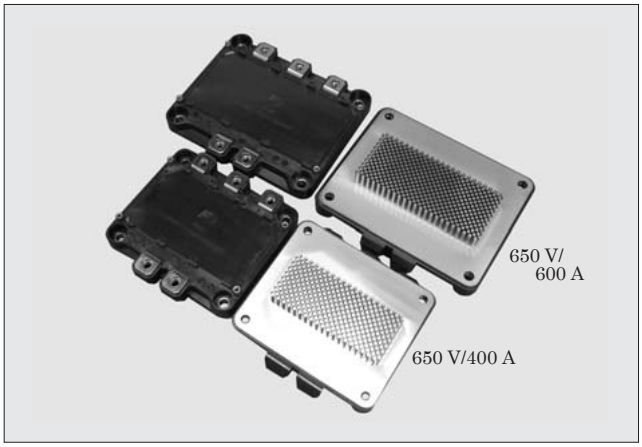


4 Direct Liquid Cooling IGBT Modules for Automotive Applications

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.

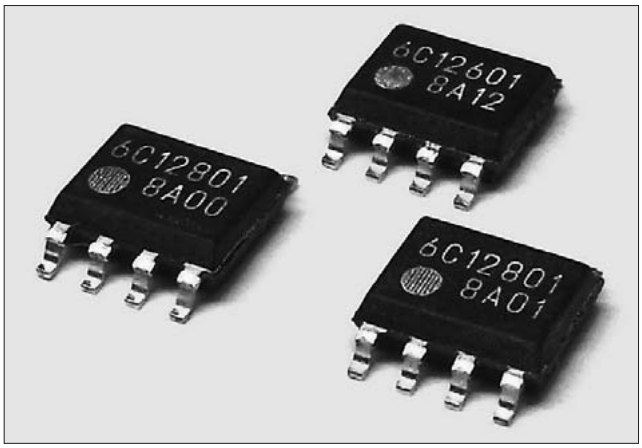
Fig.4 Direct liquid cooling IGBT Modules for Automotive Applications



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"

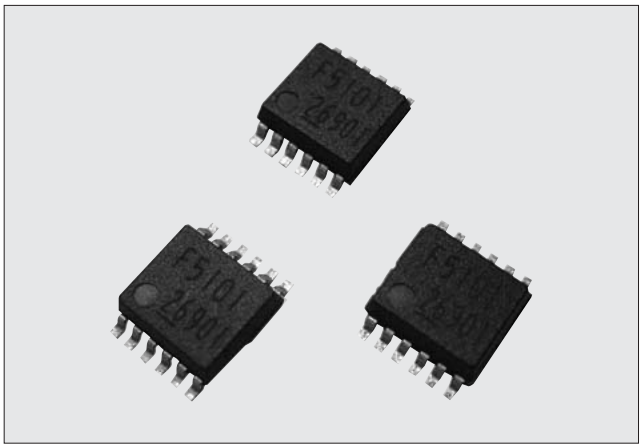


6 4th Generation High-Side IPS "F5101H" for Automotive Applications

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"

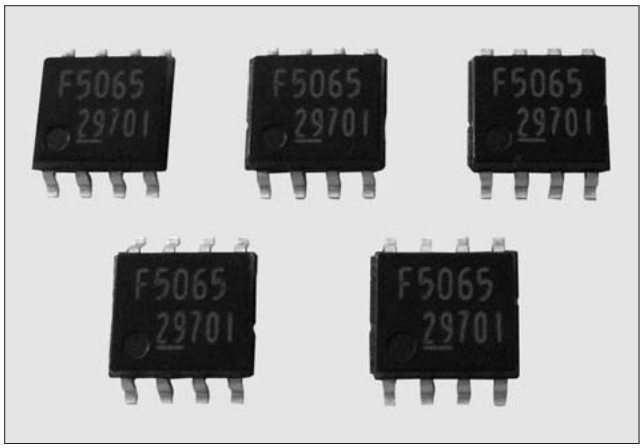


7 Low-Side IPS "F5065L" for Automotive Applications

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

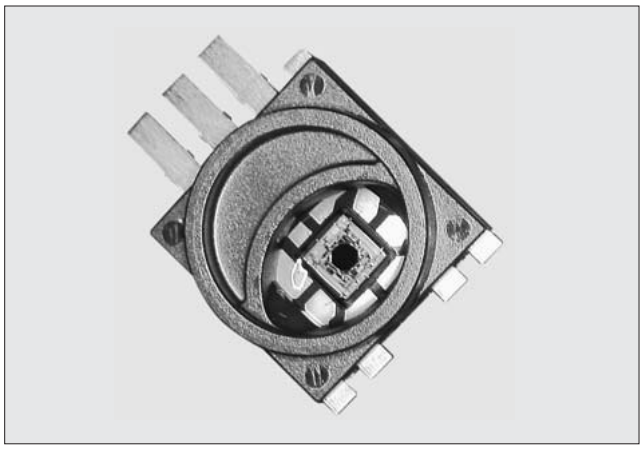
9 6th Generation Relative Pressure Sensor

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

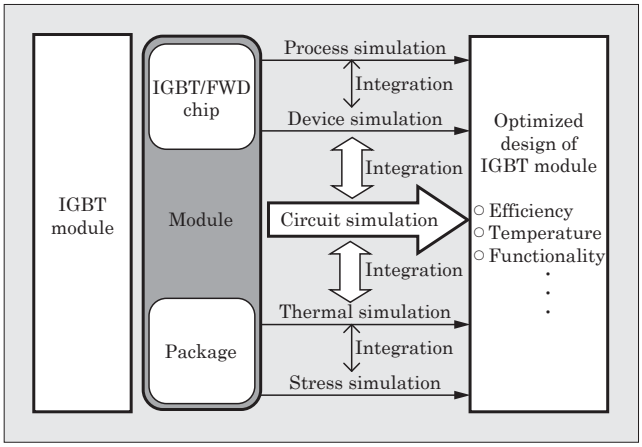
Fig.9 6th generation relative pressure sensor



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

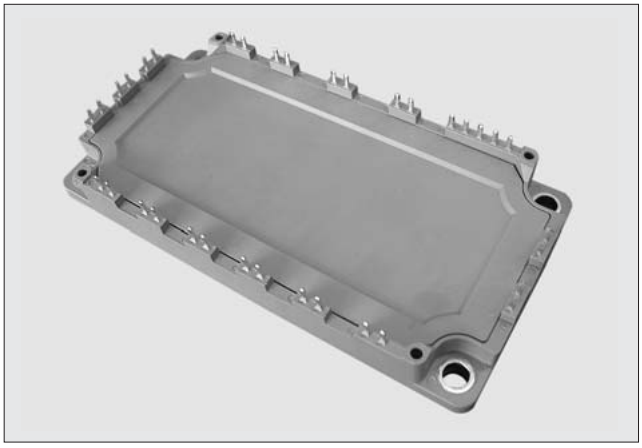


11 SiC-SBD Hybrid PIM

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.

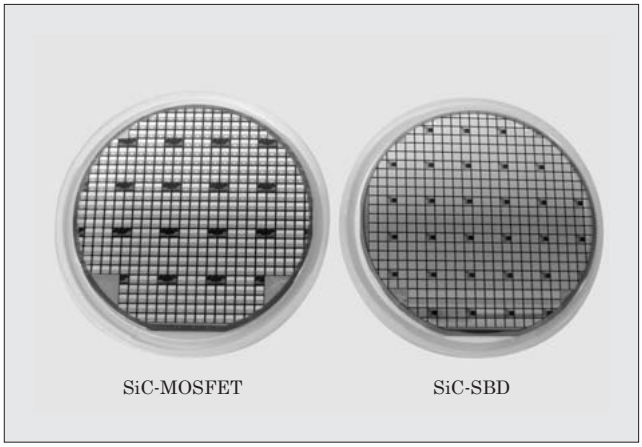
Fig.11 SiC-SBD hybrid PIM



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)."

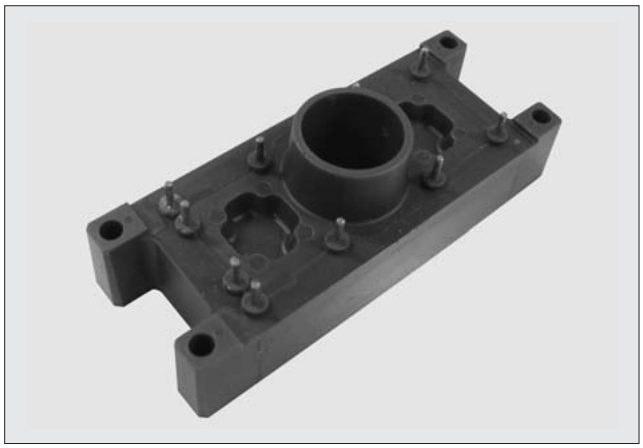
Fig.12 Developed SiC devices



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).

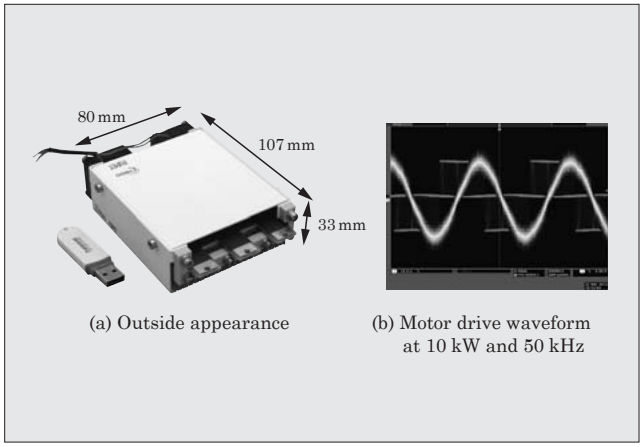
Fig.13 SiC power module package



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"

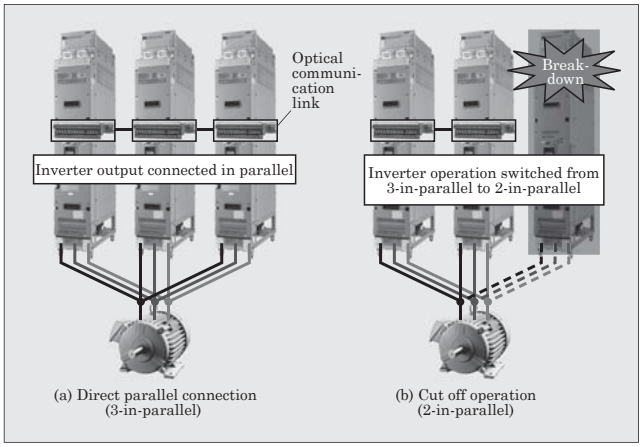
Fuji Electric has developed a direct parallel connection method used for its stack-type high-performance "FRENIC-VG Series" of vector control inverters, which are employed increasingly in electric motor control applications. Parallel connection of multiple inverters realizes the construction of a high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

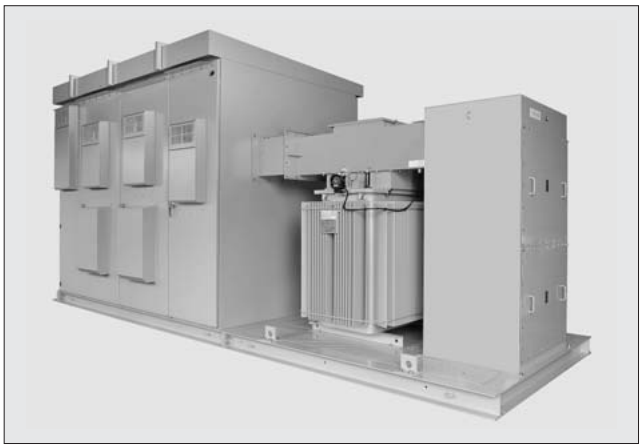
7 IEC Third-Party Certified PCS for Mega Solar Applications

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"

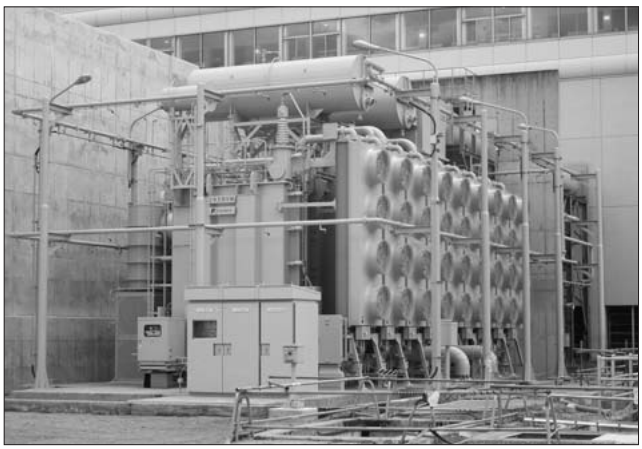
9 No. 2 Main Transformer for Haramachi Thermal Power Station of Tohoku Electric Power Co., Inc.

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

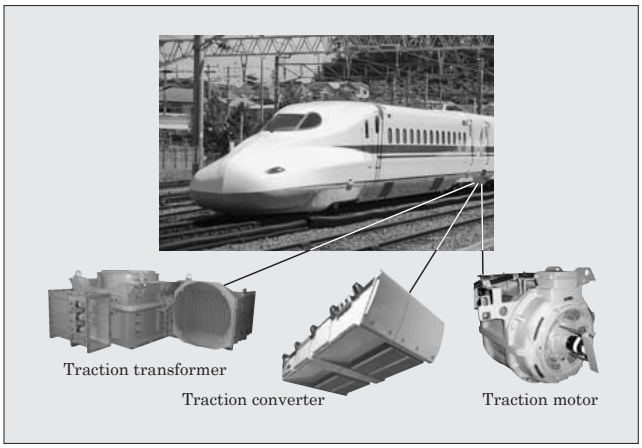
Central Japan Railway Company has manufactured N700A Shinkansen trains and started train operations in February 2013.

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)

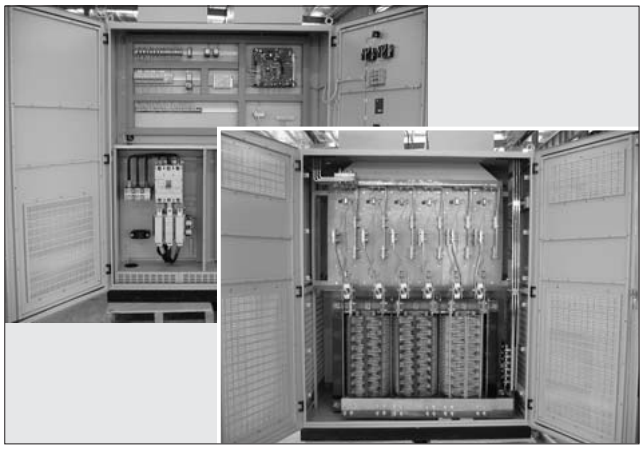
Fuji Electric has completed the production of rectifiers to be used in the electroplating equipment (two lines consisting of total 68 units) for a Chinese company. (A Chinese OEM manufacturer manufactured the rectifiers.) As a result, we have completed a series of ±2,000 to ±8,000 A rectifier units.

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

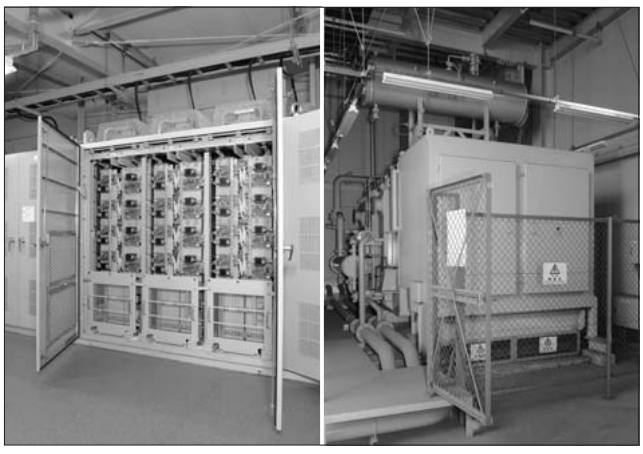
(2) Significant miniaturization of the device (installation area reduced by about 40%)

(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.

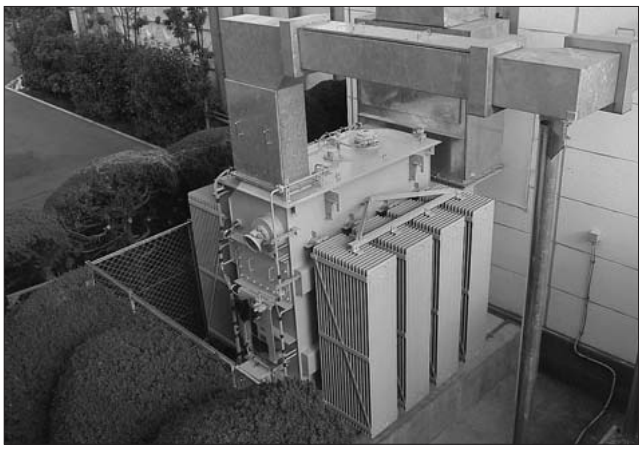
The system employs a lithium-ion capacitor (LiC) that is less than half the size of conventional lead-acid batteries. This has resulted in the miniaturization of the system. Furthermore, LiC capacitors only need to replace every 15 years. The system also contributes to decreased running cost and helps 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

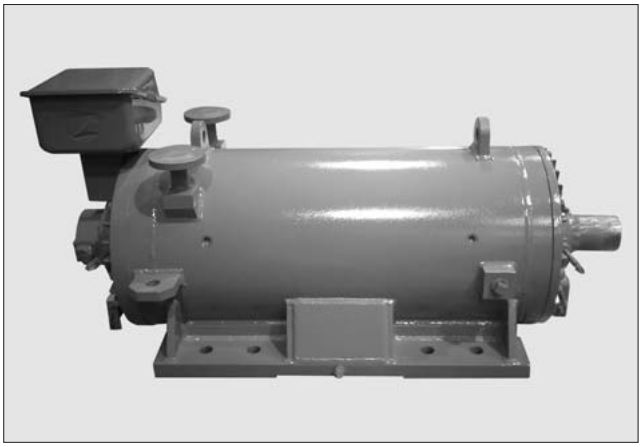
23 Electrical Equipment for Power Regenerating Servo Cushions Used in Large-Sized Press Machine

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

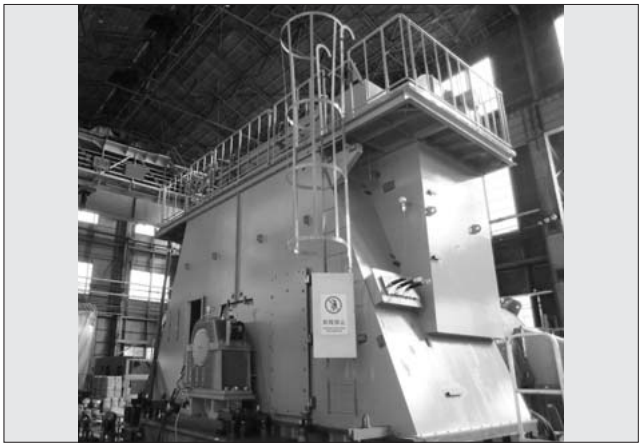
Fuji Electric has renewed a large-size synchronous motor for compressor equipment at the Mizushima Works of ASAHI KASEI CHEMICALS CORPORATION.

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.

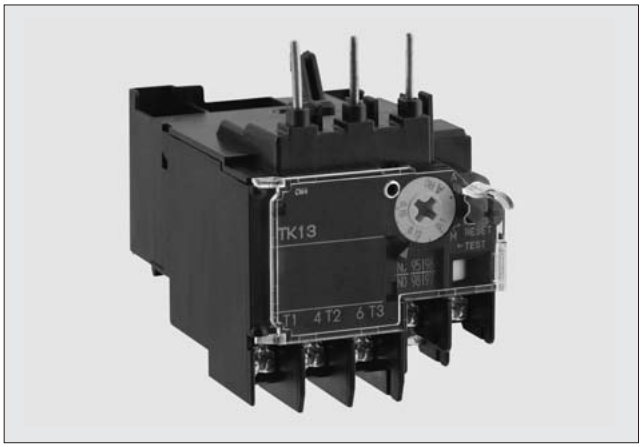
To meet these demands, Fuji Electric has developed a compact thermal overload relay that is globally compatible, being compact, economical and safe within a rated capacity of 26 A or less.

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

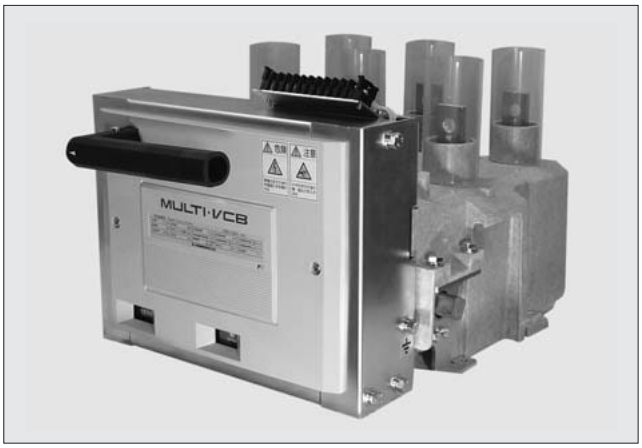
3 Fixed-Type Multi-VCB

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"

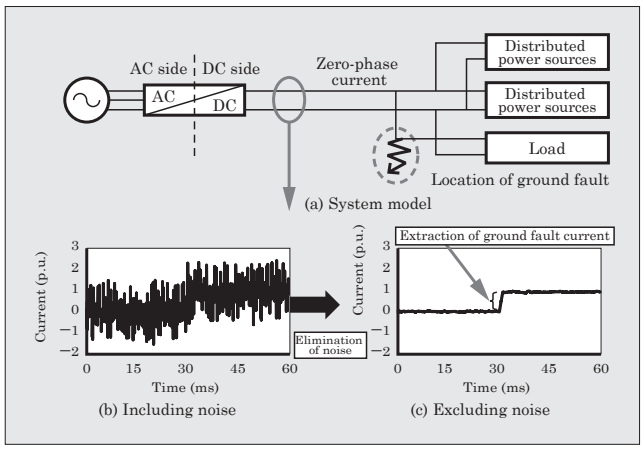
6 Grand Fault Analysis Technology for Direct-Current Distribution Systems

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.

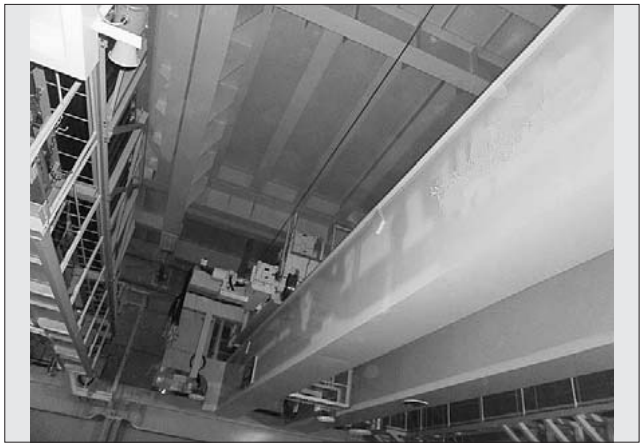
Fig.49 GECOL Benghazi combined cycle power plant

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



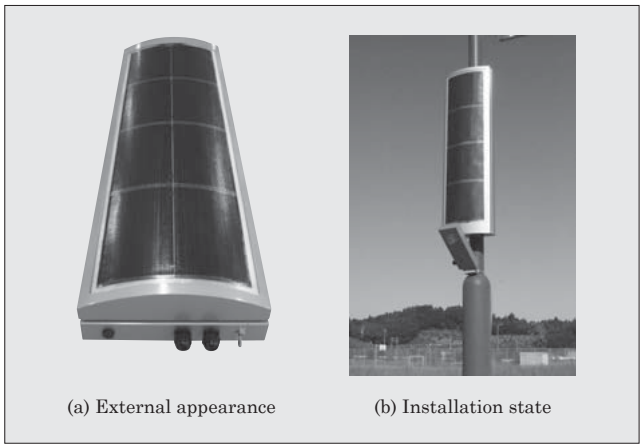
3 Low Voltage Application Products of Film Substrate Solar Cell

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