Industrial Solutions Contributing to Environmental Protection and Productivity Improvement: Current Status and Future Outlook

TOMOTAKA, Masatsugu* TETSUTANI, Hiroshi* MATSUMOTO, Yasushi*

1. Introduction

As comforts and conveniences of modern life have grown, difficult problems have been becoming to appear globally, including the spread of air pollution, tight supply-demand situation of energy, and an increase in natural disasters that is considered to be led by global warming.

Many countries and regions have been accelerating to develop and implement growth strategies to further improve productivity, economic growth, and people's livelihoods using latest technologies such as artificial intelligence (AI), the Internet of Things (IoT) and electric vehicles (EVs).

With energy and environment technology as its core technology, Fuji Electric contributes to the creation of responsible and sustainable societies through its four business segments: Power Electronics Systems, Power and New Energy, Electronic Devices, and Food and Beverage Distribution. This paper will introduce the current status and future outlook of Fuji Electric's industrial solutions mainly power electronics that contribute to environmental protection and productivity.

2. Factory Automation Field

Investment in manufacturing equipment and devices for improving productivity both domestically and abroad has been flourishing. The constant advances in factory automation technology have helped vitalize the manufacturing industry through the use of various products and systems. In the past, industrialized nations achieved remarkable growth through their industrial solutions, but in recent years, the technological divide with regions such as Southeast Asia, India and China has been shrinking, and this has created global demand for the most advanced technologies.

2.1 Drive field

In the drive field, which is represented by inverters*1 and rotating machines, we have enhanced the functionality and performance of general-purpose machines to be used for a more diverse range of applications. We have also provided specialized machines to support major applications, such as those for cranes, elevators and air conditioning systems. SiC*2 devices have been actively put into practice and inverter technology to use the devices has been almost established, allowing electrical equipment to achieve low loss and accurate control. This has created expectation for a further expansion of application (Refer to "'FRENIC-eFIT' Environmentally Resistant Inverter Designed for Harshest Installation Conditions" on page 16).

Fuji Electric is engaged in the electronic devices business, and as such, we have an advantage of being able to develop drive products characterized by even lower loss, smaller sizes and performance enhancements by consolidating technologies of our Device Department and Drive Department (see Fig. 1).

2.2 Motion control systems field

In the motion control systems field, which is represented by servo systems, controllers and human machine interface (HMI) terminals, EV and IT devices such as smartphones have continued to rapidly spread, and this has brought about increased demand for semiconductor manufacturing equip-

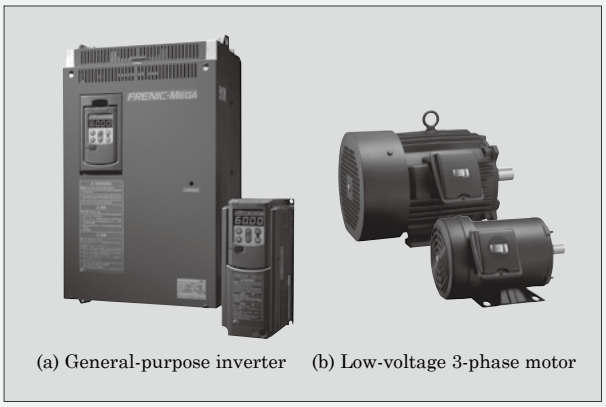
* Power Electronics Systems Business Group, Fuji Electric Co., Ltd.

***1: Inverter**

An inverter is drive equipment that freely changes the power supply frequency of 3-phase AC motors to control rotating speed.

***2: SiC**

SiC is a compound of silicon (Si) and carbon (C). It is known as a wide-gap semiconductor, having a band-gap between 2.2 and 3.3 eV, depending on its polymorphic crystal structure (3C, 4H, 6H, etc.). SiC is used for devices with high breaking voltage, low loss and high-temperature operation characteristics because it possesses physical characteristics that are advantageous as a power device, such as high dielectric breakdown voltage and high thermal conductivity.



(a) General-purpose inverter (b) Low-voltage 3-phase motor

Fig.1 General-purpose inverter and low-voltage 3-phase motor

(a) Servo system

(b) Motion controller

Fig.2 "ALPHA7" servo system and "SPH3000D" motion controller

ment, machine tools and factory and production line automation technologies (see Fig. 2).

Fuji Electric has been offering its motion control systems, which are characterized by the industry's top control performance, to various industries. In particular, in the assembly and machining field, we have been supplying a data collection system to build equipment that maintains operation even when failures occur. This data collection system collects all types of data from single-cycle production activities to discover, without fail, causes of equipment abnormality and malfunction. By combining analysis and diagnosis technologies, the system helps improve productivity and safety, while also reducing loss costs (Refer to "FA Solution That Applies IoT and Motion Control Technology" on page 11).

3. Process Automation Field

In the process automation field, we have drive control technology, measurement and control technology, and industrial electric heating technology for melting furnaces and heating equipment. We use them as core technologies and offer equipment and systems that contribute to the stable operation of production equipment and the reduction of energy specific unit.

3.1 Drive control field

In the drive control field, we have been supplying high-speed drive control systems and components for metal industries and other industries.

We have delivered a drive control system and electrical equipment for rolling mills to a steel manufacturing company in Indonesia, which is expected to become the production centers for automobiles and home appliances. All engineering processes from basic planning and design to delivery are carefully implemented and reflected in our control systems to ensure the stable operation of production equipment. Some of these activities include quality improvement through expanding use of application software for control, improving localized services through adoption of overseas partner products, provision of a system that collects data and analyze production equipment conditions based on time periods and product type, as well as strengthening of local customer service responsiveness for equipment failure. Figure 3 shows the system configuration of our high-speed drive control system (Refer to "Latest Electrical Equipment and Drive Control Systems for Bar and Shape Rolling Mills Outside Japan" on page 29).

In the field of system equipment, we have newly developed the "FRENIC4400VM6" and "FRENIC4800VM6" as medium and high capacity inverters for industrial applications. Figure 4 shows the external appearance of the "FRENIC4800VM6" that was installed at a steel and non-ferrous

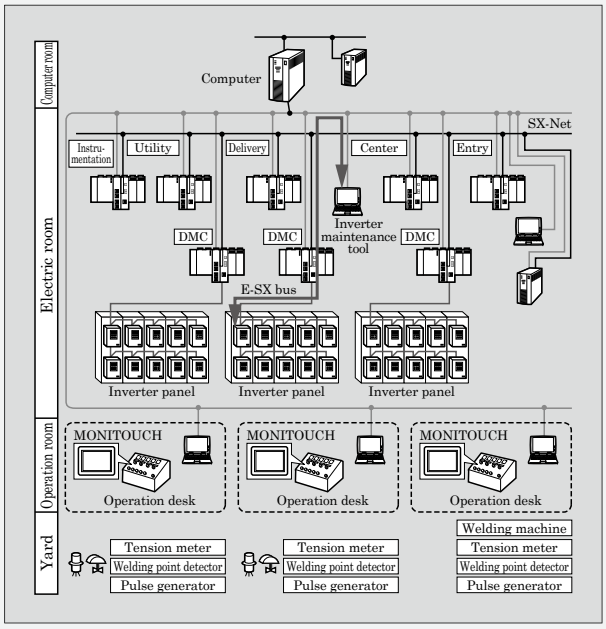


Fig.3 System configuration of high-speed drive control systems

Fig.4 "FRENIC4800VM6" medium and large capacity drive system

metal manufacturer in Japan. The units are not only characterized by basic improvements such as expanded output frequency and enhanced control functionality, but also improve ease-of-use through expanded user support functions. (Refer to "'FRENIC4800VM6' Medium-Voltage High-Capacity Inverter with Water-Cooling System Designed to Meet Various User Needs" on page 21).

3.2 Measurement and control field

In the measurement and control field, we have been developing our business by making use of our plant engineering know-how based on our advanced control technologies in the process automation field for the chemical, food and beverage, waste disposal and cement industries.

(1) Chemical industry

Competition in the chemical industry has intensified due to the restructuring of large overseas companies and the rise in the price of raw materials. In this regard, it has become very important to produce low-cost, high value-added products efficiently. Against this backdrop, there is a need to optimize the unit cost of energy and the use of raw materials in production, while also constructing new and intelligent infrastructure that is able to consolidate technologies.

In order to meet these needs, Fuji Electric is offering energy-saving solutions and equipment abnormality prediction solutions in addition to the control technology we always offer. In the future, we plan to provide more operation support functions such as plant simulators.

(2) Food and beverage industry

The food and beverage industry is a market characterized by more stable consumption than other industries. However, it is getting harder to make a profit in Japan due to rising material costs and deflation. Furthermore, it has become necessary to implement diversified and small-quantity production to meet the diverse needs of individuals in the midst of a shrinking population. Production sites are facing the urgent need of transferring technology to younger workers because an increasing number of skilled workers are on the verge of their retirement age. These diversified and small-quantity production and skill transfer challenges have to be handled while supporting complicated plant operations.

Fuji Electric has been providing functions that smoothly support new products and product upgrades. In the future, we plan to continue to offer IT system solutions for improving productivity, while also expanding our line-up of functions for supporting on-site know-how accumulation and operation (Refer to "Plant Operation Support System That Helps Transfer Skills and Improve Productivity" on page 25).

(3) Waste disposal industry

In the waste disposal industry, there has been an increasing need to reduce CO_2 and introduce heat recovery equipment and other advanced equipment that recover energy from the viewpoint of creating and promoting a recycling-oriented society. It is essential that waste disposal facilities operate smoothly and efficiently to continuously supply the outside of a plant with steam and electricity in addition to systematically dispose wastes. Up until now, each plant has taken care of its own operation and maintenance, but it has currently become a pressing issue to build an IoT system for optimally monitoring, analyzing and operating plants through integrated data collection and management.

As a response to these needs, Fuji Electric has been providing systems that integrate electric equipment, instrumentation and computers to easily collect data to stabilize operation. In the future, we plan to offer a comprehensive support system that mitigates abnormalities and facilitates speedy recovery from abnormalities through the analysis of large amounts of collected data.

(4) Cement industry

The cement industry has been increasing its efforts to make effective use of waste and by-products to help promote a recycling-oriented society. In addition to control functions, the industry is also seeking to reduce downtime and implement preventive maintenance through equipment operation management and equipment abnormality prediction.

Fuji Electric has supplied cement plants with raw material preparation control systems and kiln control systems. Recently, more and more companies have centrally managed manufacturing data and quality data at their headquarters using communication lines. In this respect, we offer an optimal plant operation system that remotely monitoring these data used for operation support functions to predict equipment degradation and abnormality.

3.3 Industrial electric heating field

Electric heating equipment is steadily demanded due to the energy saving and environment friendliness. Fuji Electric has been working to expand the application of induction heating, suitable for conserving the environment and improving productivity. Features also include direct heating, rapid heating, high temperature heating, localized heating, uniform heating, target temperature setting, and use of clean electric energy. We have been improving the equipment by electromagnetic field analysis and thermal analysis.

The material processing industry uses a wide variety of industrial furnaces, especially combustion furnaces. Induction heating technology is largely expected to facilitate replacing combustion furnaces that use fossil fuels with electric heating furnaces to reduce CO_2.

In steel processes such as cast forging, the energy saving of melting furnaces and heating furnaces effectively reduces costs, streamlines operations, and helps prevent global warming.

Fuji Electric has been making efforts to encourage these measures.

The wide frequency band of induction heating ranges from a commercial frequency of 50/60 Hz to high frequencies as high as 1 MHz. These types of power supplies were developed by utilizing power electronics. We have employed insulated gate bipolar transistors (IGBTs*3) for the power supply of induction furnaces, which had mainly used thyristor*4 based inverters, to achieve high efficiency. Figure 5 shows the external appearance of a high-frequency crucible induction melting furnace.

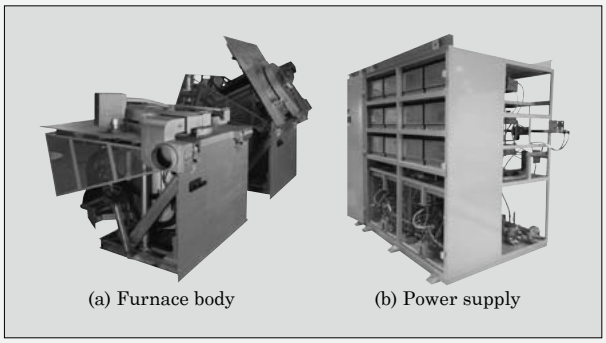


Fig.5 High-frequency crucible induction melting furnace

4. Environmental and Social Solutions Field

In the environmental and social solutions field, Fuji Electric has created innovative components based on its core technologies to develop product line-ups that contribute to various environmental fields of society. We are currently systematizing these components and offering them for use in social infrastructure and industrial infrastructure applications. We plan to apply IoT technology to the components and add a self-diagnostic function using database to them. These enhancement will encourage us to expand our businesses in further wide range of fields by offering environmental monitoring, equipment maintenance, and failure prediction.

Therefore, we are making efforts to contribute to social and industrial infrastructure in the environmental and social solutions field by offering our own unique environmental measurement solutions and environmental monitoring solutions.

4.1 Marine field

In the marine field, there are urgent needs of measures being taken on the environmental protection through exhaust gas regulations. Corresponding to this backdrop, we are offering a world's smallest "SO_X scrubber," which are compliant with the global regulations to be enforced in 2020, and an exhaust gas cleaning system (EGCS) (see Fig. 6). The compact design of the SO_X scrubber makes them easy to mount inside marine ves-

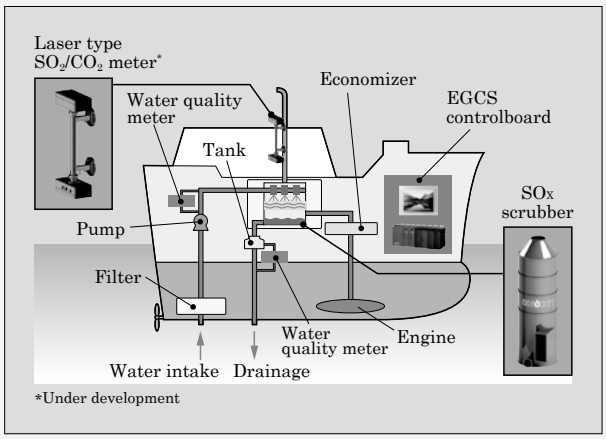


Fig.6 SO_X scrubber and exhaust gas cleaning system

***3: IGBT**

IGBT stands for insulated gate bipolar transistor. An IGBT is a voltage control-type device that has a gate insulated with an oxide insulated film, having the same structure as MOSFET. It has the strong points of both MOSFETs and bipolar transistors. Its bipolar operation allows conductivity modulation, and as a result, it achieves a high breaking voltage, low on-resistance and switching speed sufficient for use with inverters.

***4: Thyristor**

A thyristor is a semiconductor switching device for circuits that convert voltage and frequency. It consists of a 4-layer pnpn structure. Although they are characterized by a high current overload capacity, they suffer from high loss and require a large current for nonconductive states.

sels, including new, old, and retrofitted vessels. It is sure to contribute to environmental improvements not only in Japan, but throughout Asian and Europe also (Refer to "World's Smallest SO_X Removal Cyclone Scrubber for Marine Vessels" on page 34).

4.2 Road infrastructure field

In the road infrastructure field, we are offering solution systems that include tunnel ventilation systems (see Fig. 7), highway vehicle detectors and road remote monitoring control systems. In particular, our tunnel ventilation systems, which include electrostatic precipitators and jet fans for road tunnels have contributed to tunnel conditions all throughout Japan as a means of improving air quality for tunnels and surrounding areas. Fuji Electric's electrostatic precipitator uses an AC electrostatic precipitator that uses a discharge plate with discharge lines that are less susceptible to breakage, and enable to remove particles larger than nanometers highly efficiently. They preserve the downstream walls of them from dirt to contribute to improving road environment.

4.3 Radiation monitoring equipment and system field

In the radiation monitoring equipment and system field, Fuji Electric has provided radiation control systems that contribute to environmental monitoring activities related to radiation dose and radioactivity at nuclear power facilities, controlled areas and surrounding areas. We have the longest history and track record in Japan as a manufacturer of radiation measurement equipment and systems. These products and systems are being used in a wide variety of fields, including nuclear power facilities, laboratories, hospitals and universities.

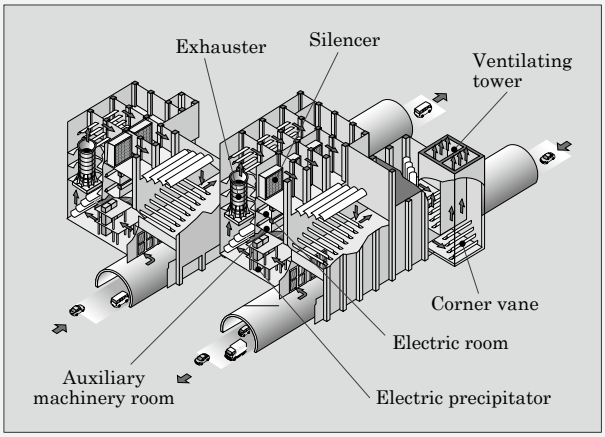


Fig.7 Fuji Electric's tunnel ventilation system

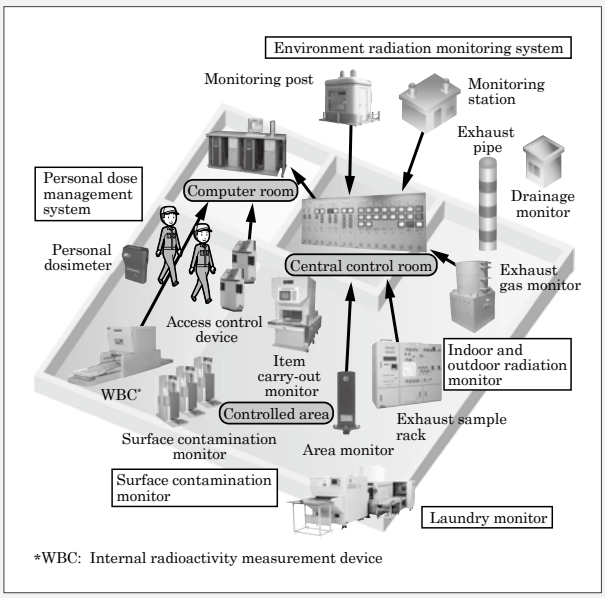


Fig.8 Fuji Electric's radiation control system

Figure 8 shows a radiation control system. Some typical examples of our systems include personal exposure management systems that measure and manage external and internal exposure for workers in radiation controlled areas, environmental radiation monitoring systems that measure and monitor γ-ray dose rates and dust concentrations in the air inside and outside of power plant sites, as well as radiation equipment, radiation management systems and survey meters for power companies, hospitals and universities. In addition, based on our environmental measurement experiences gained through reconstruction activities after earthquake disaster, we have newly developed several products including environment monitoring services with IoT environmental monitors, industry-leading high-resolution compact and lightweight spectrum survey meters that utilize strontium iodide as a scintillator*5 material, atmospheric monitors that continuously monitor radioactivity concentrations in floating dust particles, monitoring equipment used in incineration facilities for earthquake disaster reconstruction to monitor radioactive material concentration in emission gas, and radioactive soil sorting equipment. Our radiation equipment systems accurately measure radiations in real time to help ensure safety for people and the environment through radiation management (Refer to "Radiation Management Solutions Contributing to Environmental Protection" on page 39).

***5: Scintillator**

A scintillator is a material characterized by its ability to emit luminescence when excited by radiation. It is used as an element for detecting radiation. A scintillation detector is combined a scintillator with a photodetector such as a photomultiplier tube. It converts luminescence generated by radiation into electric signals to output current pulses. Typical scintillators include a NaI (Tl) scintillator and CsI (Tl) scintillator.

4.4 Transport solutions field

Global urbanization is expected to continue, so that by 2050, the world will be two-thirds urban (66%), roughly reverse of the global rural-urban population ratio in the mid-twentieth century.[1] In particular, developing countries are facing the problem of environmental destruction due to CO_2 and NO_X emission through excess traffic congestion in urban areas.

Under these circumstances, railroads are attracting attention as an environmentally friendly transportation system against the transfer of personnel and distribution of goods through air pollution control. Comparing energy consumption per unit of transportation volume (passenger-km), a railroad only consumes about one-sixth of private car and about one-fourth of aircraft.

Fuji Electric is the only manufacturer in Japan that can integrally supply drive systems running rolling stock, auxiliary power supplies for supplying stable electricity to rolling stock, and electrical door open-close systems for providing safety and security to passengers. It has greatly contributed to the safe, stable, and comfortable daily operation of environmentally friendly railroad systems.

Fuji Electric's equipment for rolling stock has received a high evaluation from railroad business operators on account of its reliability to ensure safe, stable, and comfortable daily operation, while it has contributed also maintaining and improving the convenience and quality of life in society. Moreover, it has a rich track record of usage in all types of environments, ranging from high-temperature high-humidity equatorial areas and deserts to subpolar climate regions.

(1) Drive systems

Drive systems for high-speed rail are indispensable to operate railroad vehicles. Their major components include traction transformers that step down high-voltage power supplied from overhead lines, traction converters that convert the stepped down power into suitable AC power according to speed and operation commands, and traction motors that generate driving force from the converted AC power.

Fuji Electric has developed traction converters for Shinkansen (Bullet) trains in collaboration with the customer, Central Japan Railway Company. The developed traction converter uses power semiconductor modules that utilize silicon carbide (SiC) component chips (see Fig. 9). Compared with conventional Si-IGBT power semiconductor modules, SiC helps reduce the size of the power unit by approximately 20% while also reducing its weight by about 8%. Figure 10 shows the external appearance of a traction converter. Downsizing and weight saving traction converters facilitate the reduction of the weight of rolling stock, helping to reduce the effects on the environment throughout all life cycle stages from production to disposal. The increased regenerative power (during braking operation) using SiC devices contributes to the protection of the environment by reducing the total driving power of rolling stock. The traction converters achieved a high evaluation with no malfunctions after two years running test on commercial lines from 2015. This was the world's first running test on commercial lines for high-speed rail drive systems that utilize SiC modules.

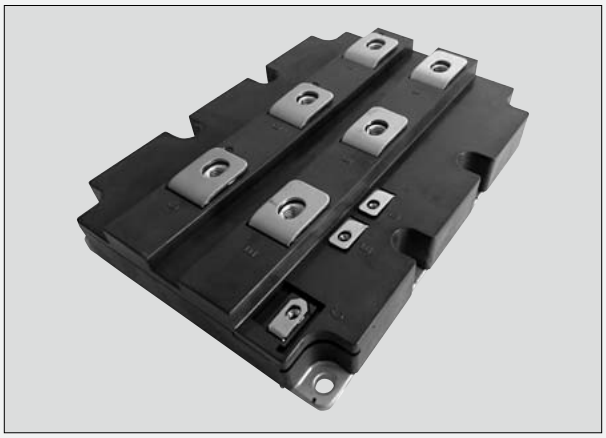


Fig.9 SiC power semiconductor module

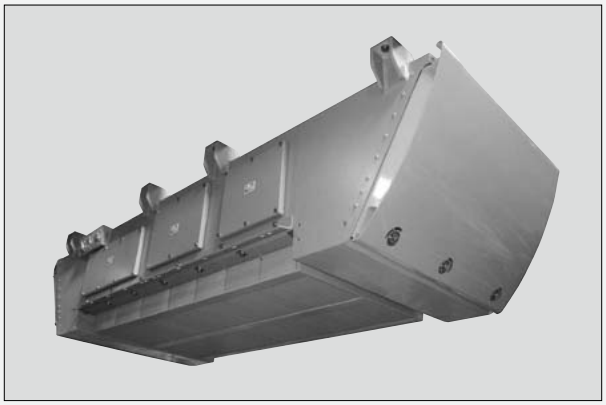


Fig.10 Traction converter

Currently, based on the results of the evaluation test, we have started developing traction transformers, traction converters and traction motors for the next-generation Shinkansen (Bullet) trains in pre-mass production trial as shown in Fig. 11. In 2018, we plan to implement another field running test on commercial lines with the pre-mass production rolling stock to obtain final confirmation for the commercial operation. In the future, we intend to release the products for commercial operation.

(2) Auxiliary power supplies

Auxiliary power supplies supply power to several control devices and electric air compressors used for brakes to ensure the safe, stable and comfortable daily operation of electrical rolling stock.

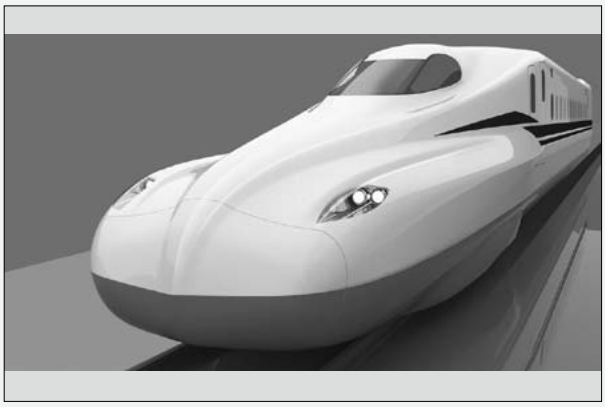


Fig.11 Next-generation Shinkansen (Bullet) train

They also supply power to passenger information displays and air conditioning systems to create a comfortable in-car stay for passengers.

Fuji Electric offers a large line-up of products compatible with a wide range of applications: large-capacity auxiliary power supplies for DC rolling stock operating mainly in metropolitan areas, standby redundant systems with improved reliability, high-frequency linkage devices for the small-scale rolling stock operated in new transportation systems, and AC rolling stock and diesel multiple-unit equipment.

Furthermore, we select environmentally friendly components. For example, we have changed filter capacitors for smoothing electric power from conventional oil capacitors to dry film capacitors.

(3) Door systems

A door system protects the safety of passengers with opening and closing the door in rolling stock. We improve safety operation of door systems to open and close operation of the passenger doors with several sensing systems to ensure smooth boarding and alighting even during rush hours at commuter trains and subways in urban areas. These enhancements contribute to maintaining the punctual schedule operation of commercial trains.

Fuji Electric door systems achieve safety door opening and closing operations without declining in function even in a failure, providing standby redundant and power supply redundant door systems. The door system's fault detection functions and self-diagnosis functions enable quick detection of system abnormality or failure, thereby minimizing the impact and facilitating repair and the investigation of the causes. Inspection functions provides customer with equipment information to perform preventive maintenance through checking the safety and health of other functions. Door obstruction functions decrease the departure delay of trains through separating the door operation of obstruction doors from that of non-obstruction doors with maintaining passenger's safety.

On May 22, 2017, E235 Series' Yamanote Line trains of East Japan Railway Company started the scheduled commercial operation, which is equipped with the door systems that employ latest electronic devices and obstruction sensing technology. We plan to spread out this Yamanote Line products into rolling stock such as for subway systems and new transportation systems in Japan and abroad (Refer to "Passenger Door System for Series E235 Train of East Japan Railway Company (Yamanote Line) Designed to Improve Transportation Quality" on page 44).

5. Postscript

In this paper, we introduced the current status and future outlook of some of our main initiatives that are contributing to environmental protection and productivity enhancement.

Fuji Electric, as responsible corporate citizens in local communities, will continue to seek harmony with the environment and strengthen our trust with communities, customers and partners.

References

(1) "IoT Acceleration Consortium". IoT Acceleration Consortium. http://www.iotac.jp/en/, (accessed 2017-12-14).

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