

Drive and Power Supply Technology: Current Status and Future Outlook

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1. Introduction

At present, expectations are increasing throughout the world for drive and power supply solutions to provide energy savings and meet environmental needs. For example, with the full-scale adoption of ICT (Information and Communication Technology), by 2025 the quantity of information in Japan is expected to become about 200 times as large as the present. Accordingly, the Green IT Promotion Council estimates that by 2025 the consumption of electric power by IT devices and systems will reach approximately 5.2 times the amount consumed in 2006. Factoring in the development of the BRIC countries and the like, the consumption of electric power worldwide in 2025 will increase to 9.4 times the amount consumed in 2006, and this worldwide rate of increase exceeds that of Japan. In order to limit this sudden increase in power consumption, green ICT solutions that utilize power electronics

technology have been proposed. Moreover, regarding the battle against global warming, Japan's greenhouse

Fig.1 Drive device business concepts

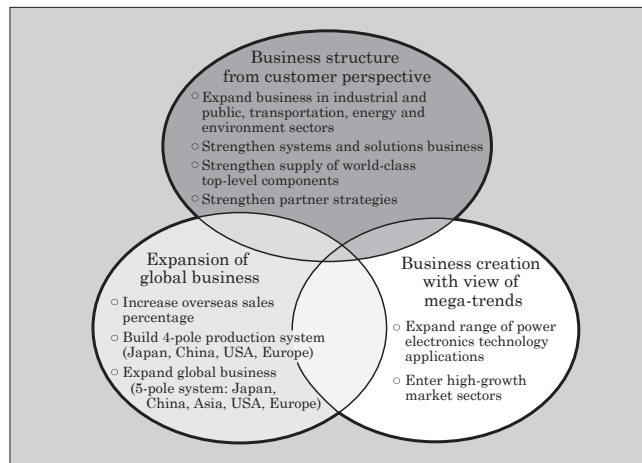


Table 1 Four sectors of the drive device business

Sub-unit	Main markets	Basic products	Solutions
Industrial systems and solutions	Domestic Japanese industrial plants Overseas steel rolling plants Overseas steel processing plants Automobile industry Petrochemistry	Inverters Servos PM motors PLCs	<ul style="list-style-type: none"> ○ Drive solutions for plants ○ Energy saving drive solutions based on PM motors ○ Global deployment
Transportation systems and solutions	Electric devices for rolling stock Merchant marine electric ship propulsion Forklift market	Electric devices for rolling stock Electric devices for special machinery in Japan Inverters	<ul style="list-style-type: none"> ○ Propulsion systems for Shinkansen trains and existing railways, door systems ○ Electric ship propulsion system having excellent environmental qualities ○ Solutions in new market sectors for rolling stock
Energy and environmental systems and solutions	IDC market Manufacturing industry New energy	Large UPSs Mini UPSs Solar PCSs	<ul style="list-style-type: none"> ○ Green data center solutions (power supply / heat/ new energy) ○ Power supplies and ultra-high efficiency power supplies for Green IDCs ○ New energy sector (photovoltaic generation system)
Components and integrated solutions	Cranes Machine tools Printing machines Testing machines Semiconductor manufacturing equipment	Inverters Servos PLCs	<ul style="list-style-type: none"> ○ Capability to provide products that satisfy market needs (faster, more affordably and with better service) ○ Expansion of integrated solution business (component and system solutions) ○ Energy saving solutions

UPS: Uninterruptible Power System
PCS: Power Converter System

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gas emissions will become apparent in 2009, the first year in the first commitment period under the Kyoto Protocol. To compensate for the divergence from the target value of emissions reduction, additional measures for energy savings and environment friendliness are likely to be requested.

On the other hand, as a result of advances in power electronics technology, products that satisfy market needs have also progressed.

Incorporating the strong market needs for energy savings and environmental friendliness, Fuji Electric has adopted an interim strategy of focusing on its drive business as a core business sector. In its drive business, Fuji Electric is targeting four sectors: industrial and public solutions, transportation solutions, energy and environmental solutions, and components. By rethinking the business structure from a customer's perspective, strengthening the system solutions business and providing world-class top-level components, Fuji Electric is attempting to expand its business. Business concepts are shown in Fig. 1, and products based on the markets of the four target sectors are listed in Table 1.

The chapter below describes the market trends and technology of drives, and Fuji Electric's product development strategy.

2. Market Trends

2.1 Industrial and public solutions

Variable speed driving of electric motors is used widely in energy saving applications to improve the operating efficiency of square-lowering load machines which consist mainly of fans and pumps. Consequently, general-purpose inverters and medium-voltage inverters are being used in practical applications, and motors are being replaced to permanent magnet type synchronous motors (PM motors). Furthermore, in systems that combine an inverter and an electric motor, not only is higher efficiency desired, but higher combined efficiency, including improvements in the operating method, is also requested.

At iron and steel, paper, cement, petrochemical and other industrial plants, there is healthy demand for aging renewal, to replace existing electric motors and drive equipment, and for facility renewal, to improve facility capacity and functionality. Good drive system performance and functionality contribute to efforts to increase the capacity of electric motors, increase the manufacturing capacity through higher speed operation, improve product dimensional accuracy, and to attain higher yields.

2.2 Transportation solutions

Although the size of the domestic Japanese market for rolling stock remains stable, as in the case of the N700 series Shinkansen train, development efforts for greater energy savings are actively being advanced. Overseas, mainly in emerging nations in Asia, invest-

ment in railroads is vigorously being promoted in order to improve the transportation infrastructure. Also in the shipping sector, environmental friendliness is being advanced through the use of electrical propulsion ships. Future market growth is expected for electric propulsion systems used in merchant vessels.

2.3 Energy and environmental solutions

Driven by needs for stronger internal controls and improved work efficiency, the trends toward a concentration of larger-scale IT devices and management outsourcing are increasing, and the IDC (Internet Data Center) market is growing. Reducing the consumption of energy in the information sector is an urgent task.

With the rapid expansion of new energy sources, such as solar power generation and wind power generation, the power conditioners, system coordination and electric power stabilization technology used in connecting generated electric power to a power distribution system have become crucial.

2.4 Components

In the industrial sector, electric motors, inverters and servo drive system components are requested to provide energy savings, reduced CO₂ emissions, improved safety of machinery and equipment, an expanded range of carriage applications and capacities, and so on.

To realize energy savings, higher device efficiency is requested of the general-purpose inverters and electric motors that operate fans and pumps at optimal output levels. Also, in addition to providing the previous level of high speed and high accuracy operation, the servo drive systems installed in machinery and equipment are also requested to have a simple system configuration, be easy to use, have a short setup time and a low price.

2.5 Services

After the abovementioned solutions and components have been delivered to customers, the provision of operational support for these solutions and components throughout their lifecycle, up to and including renewal and disposal, is highly expected.

Especially for components such as general-purpose inverters which have been delivered widely in Japan and overseas, greater readiness is requested worldwide for supplying the spare parts and finished spare parts needed for emergency maintenance, and for the related repair work and technical support.

Moreover, to improve planned facility maintenance, a data acquisition function for acquiring the data necessary to ascertain the operating condition, and also the enhancement and higher accuracy of predictive maintenance technology to avoid unexpected facility shutdowns and realize more stable operation, are indispensable.

Responding to the above-described expectations

and requests, Fuji Electric is actively strengthening its worldwide network and developing predictive maintenance technology to enrich its lifecycle maintenance support (service) which is a critical element of operational support.

3. Trends of Fuji Electric's Drive and Power Supply Technology

3.1 Market trends

Energy and the environment are recent megatrends of the market, and based on the keywords of "low-loss" and "new energy", drives and power supplies are pursuing lower power consumption and higher efficiency through the use of low-loss devices and circuit technology, and machinery is beginning to transition to electric propulsion. Meanwhile, for the electric power generated by solar power, wind power and other types of new energy, conversion by a power conditioner, storage by an electric storage device, and stabilization by a bidirectional converter have become necessary. Moreover, products and technologies for the optimal usage of electric power with a smart grid have appeared in the marketplace. Thus, in today's market which emphasizes energy and the environment, the technology for drives and power supplies is extremely critical.

3.2 Direction of technical development

Fuji Electric's vision of its drive business is "to become the number-one provider of products, systems and services that maximally utilize power electronics technology and contribute to environmental friendliness." Thus, the basic objectives of technical development in the four target sectors are as follows.

In the energy and environment sector, Fuji Electric's power supply business has achieved the number one rank in Japan, and in the transportation sector, Fuji is expanding its business through partnership strategies. In both of these sectors, Fuji Electric is making significant inroads to overseas markets. In the industrial/public sector, Fuji Electric is focused on expanding its energy savings business consisting mainly of medium-voltage inverters and PM motors. In the component sector, Fuji Electric aims to change from a component business to an integrated solution business, and to expand its business that uses standard modules suitable for customization. For each of these four sectors, the development of technology and hit products that help expand Fuji Electric's solution business are key measures, and basic technology that is common to both drives and power supplies is strengthened for this purpose.

3.3 Features of technical development

Power electronics technology is a technical field that combines devices, circuits and control elements, and these closely correlated technologies can be combined to create competitive products. Power electron-

ics technology is a strength of the Fuji Electric Group, which possesses synergy for the technology of these three elements. By leveraging this group synergy and pursuing higher efficiency, Fuji Electric creates overwhelmingly distinctive products that consume low amounts of power.

Fuji plans to introduce powerful products in the energy savings sector for power supply systems, variable speed control systems and electric propulsion systems for ships and rolling stock, and in the energy generation sector for solar power conditioners, wind power generation bidirectional converters, power supply stabilizers and electrical power storage. Specifically, Fuji Electric plans to combine the development of green power electronics, which uses new devices, with common basic technology for which development has traditionally been prioritized, and apply this combination to green IDC, solar power generation, power storage, global vehicle electric propulsion, ship propulsion and variable speed drive products.

3.4 Common basic technology

(1) Power electronics platform

In order to more efficiently utilize development resources through the design and restructuring of basic technologies common among power electronics, Fuji Electric is pushing to strengthen common technologies and establish a power electronics platform. Main tools for this platform are listed below.

- (a) Magnetic component design tool for minimizing materials and downsizing components through optimized design and critical design of reactors and transformers, also for reducing product development time by enabling highly accurate performance measurements during the design phase
- (b) Automatic design tool for built-in type switching power supplies capable of quickly supporting different customer specifications and realizing mistake-free designs, also for reducing the time needed for design changes and re-evaluation
- (c) Cooling design tool capable of estimating with high accuracy, and within a short amount of time, the airflow distribution in a large power electronics panel and the distribution of temperature due to chip-level heat generated by a semiconductor module

(2) Power conversion technology

Drive technology is basically power device and power conversion circuit technology, and the control technology for these under optimal conditions. Fully utilizing its advantage of having an internal device department, Fuji Electric has traditionally applied thyristors, transistors, MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors), IGBTs (Insulated Gate Bipolar Transistors) and other conversion devices to various power electronics products. These power electronics products range from a several tens-of-

Watts-class switching power supply for IT equipment, to a ten to several hundred kVA-class general-purpose inverter, a several MVA-class inverter for rolling mills, and a several hundred MVA-class rectifier for aluminum electrolytic capacitors. Distinctive conversion circuit technology is applied to these products according to their application.

As an example of large-capacity converter technology, a 7.5 MVA industrial-use inverter (Fig. 2) with multi-level control has been commercialized by connecting 3.3 kV IGBT devices in series, and application to large-capacity frequency converters and flicker compensators is being considered. For uninterruptible power supplies (UPS), power units that are common among UPS model product series and realize increased capacity.

To realize high power density in the switching power supplies for IT equipment with small-capacity converters, technology for configuring the windings of an insulated transformer using the wiring pattern of a multilayer printed circuit board and technology for discharging the heat generated by a semiconductor switching device and the like using the printed pattern of a printed circuit board are put into practical use.

(3) Control technology

Magnetic pole location sensor-less control technology capable of driving a PM motor stably even at low speeds is applied to applications for rolling stock and the like. A magnetic flux observer control method capable of accurately estimating the location of magnetic poles without being limited by noise or motor type is applied to the above control technology.

Also, anti-sway control for the conveyor and machine tool sectors is realized by applying a multi-rate observer consisting of a high-rate sampling observer and a low-rate sampling observer. The use of this technology helps reduce the tact time involved in the automation of crane equipment.

(4) Motor technology

A PM motor is a product that has a permanent magnet positioned in its rotor, and the significant re-

duction in loss within a rotor enables the motor to realize higher efficiency and smaller size and to meet the needs for energy savings and environmental friendliness. Energy saving systems comprised of a PM motor and an inverter are core products of Fuji Electric's drive business, and Fuji Electric is advancing their technical development. A PM motor design platform has been constructed, and this key items enables the optimal design and performance estimation of a motor, minimization of the amount of magnetic material used, and design of the demagnetization withstand ability of a magnet to be implemented within a short time. This design platform is presently being used by Fuji Electric's design department.

(5) Service related technology

(a) Remote monitoring technology

Fuji Electric began to develop a remote monitoring function in 1975 in order to supervise the operation of a control computer from remote overseas locations, and has expanded the applicable range of this technology to include DCS (Distribution Control Systems), UPS (Uninterrupted Power Systems), electric power generators, and some inverters and fuel cells.

Fuji Electric has newly developed a remote monitoring module that functions as a common foundation when providing plant devices with a remote monitoring function, and is promoting the use of this module with all products supplied by Fuji Electric. As the result, "plant (equipment) status ascertainment" function is added to the conventional "product status ascertainment" function, enabling acquisition of the operating data necessary for ascertaining the operating state. These functions enable improvement in the preventative maintenance for equipment, and contribute to more efficient delivery tests and post-delivery startup tests, after equipment has been shut down for maintenance. Figure 3 shows an overview of a remote monitoring module for inverters.

(b) Predictive maintenance technology

Predictive maintenance technology is status monitoring maintenance technology for predictive maintenance, and consists of degradation diagnostic

Fig.2 3.3 kV IGBT series-connected inverters

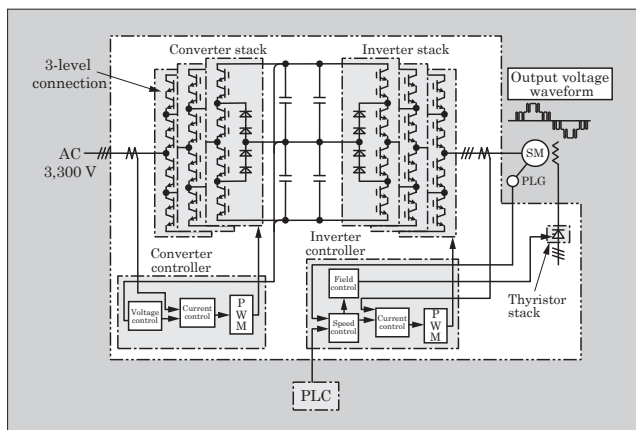
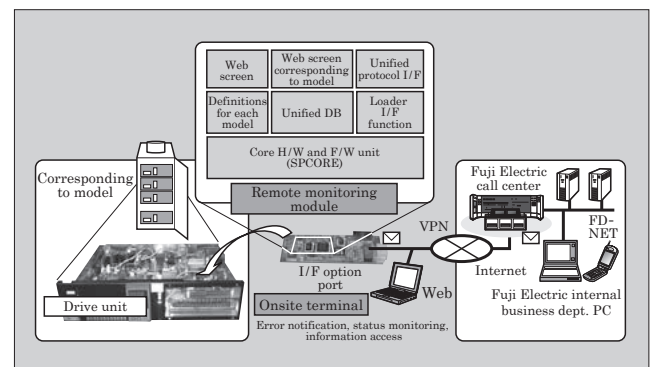


Fig.3 Remote monitoring module



technology and remaining life assessment technology. Fuji Electric has been performing degradation diagnoses and remaining life assessments for oil-filled transformers since 1980 and for electric motors since 2000. Recently, in addition to increasing the accuracy of remaining life assessment for oil-filled transformers, and systematizing the degradation diagnosis and remaining life assessment technology for molded transformers and inverters, Fuji Electric has developed a wireless vibration diagnostic system that uses RFID (Radio Frequency Identification) technology for diagnosing the vibration of rotary machines (electric motors and their load machines).

4. Direction of Product Development

4.1 Industrial and public solutions

Fuji Electric is engaged in the following development efforts in order to provide system and service solutions that combine strong components with an abundance of plant engineering know-how.

As an example of new product development linked to a power electronics platform, Fuji Electric is developing products to broaden its lineup of overseas production models of medium-voltage inverters, which have a successful track record in the energy savings sector, and to maintain and improve their competitive strength in Japan. Also, as an example of technical development of large drive devices, Fuji Electric has commercialized an IGBT module series-connected inverter.

On the other hand, to expand the existing equipment renewal business, Fuji Electric is pushing to expand the menu offerings of the FRENIC4000/4400 series of inverters for iron and steel, paper, petrochemical and other industrial plants, to enhance the thyristor Leonard control functions, and to achieve better reliability through theoretical explanations of the voltage surges and roller bearing electrolytic corrosion in an inverter drive motor system.

To further expand product menu offerings to the automobile and construction equipment sectors, Fuji Electric has developed a test equipment drive system and a large-capacity servo system.

4.2 Transportation solutions

As product development for the rolling stock sector, Fuji Electric is engaged in efforts to develop a propulsion system for Shinkansen trains, electrical equipment for electric multiple units (EMU) and diesel multiple units (DMU), and the next generation of linear door systems.

As a propulsion system for Shinkansen trains, a PM motor magnetic pole sensor-less drive system is under development. As electrical equipment for electric multiple units (EMU) and diesel multiple units (DMU), Fuji Electric is developing higher performance and higher functionality auxiliary power supplies hav-

ing IGBT multi-serial connection technology at their core in order to advance the development of multifunctional auxiliary power supplies for overseas railroads. For door systems, the linear motor method has been highly evaluated.

In the shipping sector, to meet future market needs, technical development is advancing to develop a system structure that combines an electric propulsion system and an auxiliary power system.

4.3 Energy and environmental solutions

Fuji Electric is involved in the following development efforts in order to satisfy the strong needs of the market for energy savings, to move into the new energy market, and to improve power supply stability.

For medium and large capacity UPSs, Fuji Electric is expanding support of the parallel redundancy function of the UPS7000D Series of high efficiency UPS models for use at IDCs, advancing support of the standby redundancy function of the UPS8000D Series of UPS models, and will continue with development efforts in pursuit of lower loss so as to realize greater power supply stability and energy savings in the IDC sector.

For small-size power supplies, Fuji Electric is developing products to meet efficiency standards such as the international Energy Star program (Refer to the Glossary on page 172) and the CSCI (Climate Savers Computing Initiative) (Refer to the Glossary on page 172), and is also working to digitize control circuitry and apply new silicon carbide (SiC) MOSFET devices to power supplies.

In the new energy sector, Fuji Electric is advancing the development and commercialization of power conditioners for photovoltaic generation and power conditioners for power storage systems.

4.4 Components

Fuji Electric is engaged in development to provide world-class top-level components.

So that new products can be developed efficiently and speedily, the following items of basic technical development are being advanced as a part of our efforts to strengthen the power electronics platform.

- (a) Improved simulation technology as a result of the creation of thermal analysis, transmission noise and strength analysis models for the inverter unit
- (b) Advanced functional safety technology
- (c) High-speed communications interface (Ethernet*¹ application technology)
- (d) Improved vibrational resistance and research of evaluation technology for PM motors
- (e) Commonalization of the PM motor and servo motor technology (critical design technology for loss and cooling)

*1: Ethernet is a registered trademark of Fuji Xerox Corp.

- (f) Establishment of development process for next-generation general-purpose inverters

On the basis of these basic technical development works, we are working to develop such new components as next-generation inverters, custom inverters, servo drive systems, PM motors and custom controllers. To strengthen integrated solutions that feature combinations of components, we are also developing various types of software packages for controllers.

4.5 Services

Fuji Electric is strengthening a lifecycle maintenance support (service) function that provides maintenance support for solutions and components that have been delivered to customers.

Development for expanding call center functions to improve responsiveness to emergency maintenance requests, and for expanding the parts supply management system and remote monitoring system is being advanced from a global perspective.

Moreover, with the goal of improving planned facility maintenance, we are promoting expanded use of the remote monitoring module with other products. Additionally, to avoid unexpected facility shutdowns, we are working to establish new predictive maintenance technology and to increase the accuracy of existing predictive maintenance technology.

5. Inverter and Power Supply Product Series

As an example of our drive products, Fuji Electric's inverter product series is shown in Fig. 4. This product lineup supports a wide range of market needs, from low voltage and small capacity to medium voltage and large capacity models, and applications ranging from multipurpose to high precision and sophisticated plant applications.

Fig.4 Fuji Electric's inverter product series

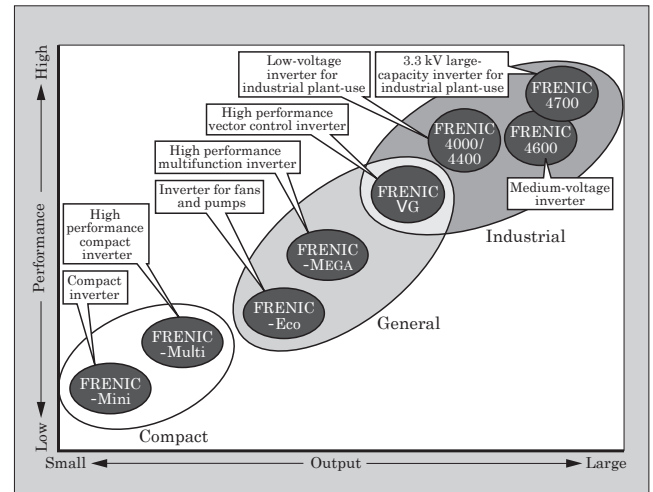


Fig.5 Fuji Electric's uninterruptible power supply product series

Model	Series name (product name)	Capacity of the series (kVA)										Main applications				
		0.1	0.5	1	5	10	50	100	500	1,000	5,000					
Switching power supply for IT equipment	DC/DC converter	0.1 to 0.2												Installed on motherboard, etc.		
	High density front-end power supply	1 to 3													Used on primary-side of motherboard, etc.	
Mini UPS	NetpowerProtect (100 V)	0.5 to 3													Single-phase load for PC NetpowerProtect: Standby type UPS GX series: Dual-conversion method	
	Global mini UPS GX200 series (200 V) GX100 series (100 V)	0.7		10												
		1		10												
	Intelligent UP RX series	7		21												Single-phase load for computer etc. (added internal units can increase capacity up to 21 kVA) Dual-conversion method
Large UPS	UPS6000D-1 series	20		100												Single-phase medium-capacity load for computer etc. (3-phase input), isolated type
	UPS6100D series	10		100												Three-phase medium-capacity load for computer etc., isolated type
	UPS6000D-3 series	100		1,500												Three-phase load for large capacity computer system and manufacturing facilities, isolated type
	High-efficiency UPS7000D series	500												High-efficiency (95%) large capacity system such as IDC, non-isolated type		
	UPS7700 series	100		600												Overseas spec product (3-phase, 4-line) high-efficiency (94%), non-isolated type
	Dual processing type UPS8000D series	100		2,000												Super-high efficiency (98%) large capacity system for IDC and manufacturing facilities, non-isolated type, dual processing type
	Parallel processing type UPS8100D series	15		75												Super-high efficiency (98%) system for medium capacity manufacturing facilities, non-isolated type, parallel processing type

An energy-saving drive system that combines a high efficiency PM motor and a FRENIC-MEGA general-purpose inverter is able to realize the IE4 efficiency level stipulated by IEC 60034-30. Moreover, the medium-voltage inverter FRENIC4600 Series, suitable for realizing energy savings in large fans and pumps that are driven by 3.3 to 10 kV electric motors, has a successful track record as a product matched to the needs of the market. The platform technology for these inverters is also used with inverters for rolling stock.

Fuji Electric's product lineup of power supplies, the key devices for uninterruptible power system solutions such as green IT, is shown in Fig. 5. The lineup includes an uninterruptible power supply for each type of application.

During the development and planning phases, products are formed according to a roadmap. In the energy and environmental solution sector, we aim to achieve a comprehensive optimization of heat and electric energy in order to realize a green IDC, and in the transportation sector, we are concentrating on systems that support our solution business in the global market for rolling stock.

As examples of product development, Fig. 6 shows the roadmap for the component and solution/service sectors. For applications to machines tools, Fuji Electric has commercialized a popular-type servo drive system and increased our competitiveness against foreign manufacturers, and for high-performance vector control inverters which have a successful record of production, Fuji is working to realize compatibility with safety standards that are requested mainly from overseas markets. Energy saving applications with factory ventilation equipment are highly anticipated for large overseas markets, and special-purpose machinery that improves the environmental resistance of low-voltage inverters is commercialized. For energy-savings applications such as plant fans and pumps, with which significant energy savings can be realized,

Fig.6 Roadmap of main products

Market sector	Strategic model	Main market sectors	2009	2010	2011
Components	Future generation popular-type servo drive system	Machine tools (China), Metal processing (Europe)	200 V, to 22 kW	400 V, to 55 kW	Customization for overseas use
			Functional safety	Stack type	
Solutions/ Services	High-performance vector inverters (safety standard-compliant inverters)	Cranes	30 to 630 kW, to 22 kW	Improved function	
			Inverters for overseas HVAC-use	Factory ventilation	Eco IP54-compliant
	Medium-voltage inverters	Energy-saving, environmental protection measures	10 kV	For Asia and Europe	For USA
			China 6.0 kV		
	Large-capacity inverters for plant-use	Iron and steel, Nonferrous metals, Petrochemistry	Air-cooling 5 MVA	Water-cooling 10 MVA	
			Large-capacity low-speed machines	Large-capacity high-speed machines	Large-capacity general-purpose machines

medium-voltage inverters having the highest level of performance in Japan have been commercialized successively for overseas use.

6. Postscript

The present status and future direction of Fuji Electric's drive and power supply technology and products have been presented in part. In particular, "energy" and "environment" have become technical keywords for the 21st Century, and expectations for the evolution of power electronics technology are surely increasing. To meet these expectations, Fuji Electric intends to continue to increase its level of technology and to contribute positively to society by providing products that satisfy needs for energy savings and environmental friendliness.



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