# Power Supply Technology for Energy and Environmental Solutions

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## 1. Introduction

The Kyoto Protocol, adopted in 1997 and enacted in 2005, aims to achieve a 6% reduction in greenhouse gas emissions (compared to 1990 levels) by 2012.

The emission of greenhouse gas that accompanies fossil-fuel energy consumption must be reduced significantly, and the amount of emissions worldwide must be reduced to the same level as is absorbed by nature. Thus, there is a global trend toward recognition of the importance of a sustainable lifestyle, i.e., toward a low carbon society.

As our information-intensive society has evolved, there has been an explosive increase in the amount of information that is processed. The Internet can be considered a representative example of such, and more information has been stored in the three years since 2003 than in the previous 300,000 year history of mankind. The computing resources needed to processes such vast quantities of information have lead to a rapid increase in electric power consumption.

With the enactment of the Sarbanes-Oxley Act (SOX Act) in the US and amendments to the Commercial Law in Japan, and with advances in internal control systems (prescribed partly by the Japanese version of the SOX Act, i.e., the "Financial Instruments and Exchange Law") for companies, and information security promotion, there has been an increase in the number of large companies that outsource to IDCs (Internet Data Centers). The size of the IDC market is estimated to reach 3.3 trillion yen in 2012 and to grow at an annual rate of 6%.

In the US, in the five years from 2006 to 2011, the total power consumption by IDCs is expected to double, and may require the new construction of 10 nuclear power plants. Also in Japan, by 2025, it is estimated that there will be approximately 200 times as much information circulating on the Internet as now and that the power consumption by IDCs will grow to about 2.5 times as large as now. The total power consumed by IT equipment in Japan accounted for about 5% of the total amount of Japanese power consumption in 2006, but is predicted to account for approximately 20% of the total by 2025.

To help prevent global warming, it is important that energy conservation measures be implemented in the high-growth IDC sector, and IT equipment and facility equipment are requested to provide greater energy savings and higher efficiency.

From the perspectives of energy and the environment, this paper introduces Fuji Electric's efforts, mainly in the IDC sector, for realizing energy savings, and also describes our efforts involving low-carbon energy using natural forms of energy such as solar power and efforts to realize energy savings in the industrial sector.

## 2. Fuji Electric's Efforts to Realize Energy Savings at IDCs

Of the total power consumption at IDCs, 30% is attributable to IT devices, 25% to power supply equipment, and the remaining 45% to air conditioning equipment. To advance energy savings in the IDC sector, efforts must be made to reduce the energy consumption of each device and type of equipment.

As a measure of the efficiency of power usage at an IDC, the PUE (Power Usage Effectiveness) value is used. (Refer to the Glossary on page 172.) In a typical IDC, the PUE value is approximately 2.5, but aiming for higher efficiency, a PUE value of less than 2 is desired.

In the IDC sector, Fuji Electric's approach to energy savings for air conditioning-related equipment which consumes a large amount of power is to propose not only an optimal design of the air conditioning system, but also to propose that the motor in such a system be a super high-efficiency permanent magnet synchronous motor (PM motor) so that the efficiency with an inverter and the PM motor reaches 94% and energy saving is advanced.

Moreover, to realize energy savings with power supply equipment, it is only natural that "Top Runner" super high-efficiency devices be used to increase the equipment efficiency, but Fuji Electric also seeks to increase the efficiency of the UPS itself, which is the

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source of power to the IT devices, so as approach the "Top Runner" super high-efficiency level and realize energy savings in the power supply equipment itself.

Additionally, Fuji Electric is working to realize energy saving solutions in the air conditioning equipment, power supply equipment and IT equipment in an IDC system by increasing the efficiency and reducing the consumption of power by the power circuitry inside servo equipment and other IT devices operated at an IDC.

This chapter describes Fuji Electric's approach, through leveraging its power electronics technology, to realize energy savings in the power supply and IT equipment sectors.

### 2.1 Fuji Electric's efforts in the IDC power supply sector

The conventional type of uninterruptible power system (UPS) used at an IDC has an efficiency of approximately 91%, which is much lower than that of a transformer or the like. Thus, Fuji Electric developed the UPS7000D Series, the UPS8000D Series and the UPS8100D Series of high efficiency UPSs that approach the efficiency of a transformer and are mainly intended for use at an IDC.

(1) UPS7000D Series features

The elimination of the insulated transformer in this series results in higher efficiency than in a conventional UPS. The 500 kVA model of this series achieves a high efficiency of 95% and 45% lower loss than the conventional type.

The footprint of the 400 V model, the device capacity used most commonly at an IDC, is approximately 70% that of a conventional model, and thereby enables a more efficient use of space. Supporting the parallel redundancy systems and the recently popular standby redundancy systems that are used at IDCs, separate input and separate battery systems are employed.

On the other hand, since the insulated transformer has been eliminated, the front and rear of the UPS are not insulated and earth leakage must be considered. Moreover, in the case where the bypass input and AC input are different, the operation will switch between different ground systems, and this switching will be implemented via the UPS battery power source.

(2) UPS8000D Series/UPS8100D Series features

The loss is large in a conventional UPS since the AC input is first converted to a DC voltage, and then that DC voltage is reconverted to an AC voltage and output. Moreover, even if the insulated transformer is eliminated, the lost efficiency of the portion involved in the conversion cannot be ignored.

In order to avoid the decrease in efficiency resulting from the conversion of the power supply voltage, Fuji Electric employs a method wherein a input power source is controlled directly so as to supply power according to the needs of the load device, thereby realizing a high efficiency of 98% (500 kVA model, ECO mode operation) and loss that is reduced by 78% compared to a conventional UPS.

In normal operation, AVR (automatic voltage regulation) compensation and active filter compensation are implemented so that a stable supply of power is provided to the load (Fig. 1). If a power outage or momentary voltage drop occurs in the commercial power supply, the power feed is switched to battery power so that a stable supply of power can be provided without interruption.

As shown in Fig. 2, the transient voltage characteristics of the UPS8000D Series at the time of switching satisfy the class 1 requirements, which are the strictest requirements specified by JEC-2433, and characteristics equivalent to those of a normal inverter feeding system are maintained.

The relevant series are the UPS8000D Series of 100 kVA or larger capacity UPSs, and the AVR function-constrained UPS8100D Series of 75 kVA or smaller capacity UPSs.

The power feed is usually from a commercial power source, and therefore at the time of a UPS failure or the like, the standard operation was to switch the power feed to the same commercial power source. This did not pose a problem with a parallel redundancy sys-

Fig.1 Operating principle of the UPS8000D Series

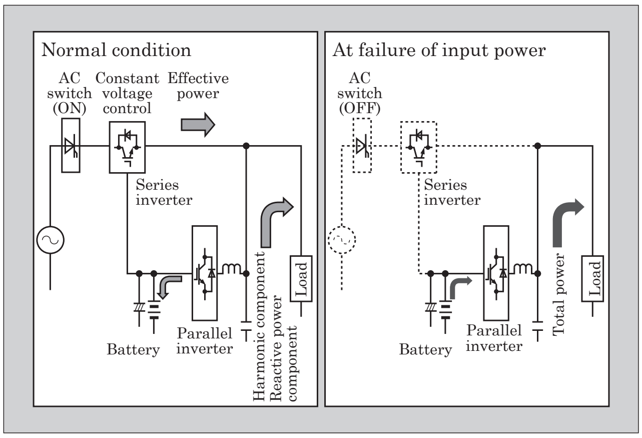



Fig.2 Switching characteristics of the UPS8000D Series

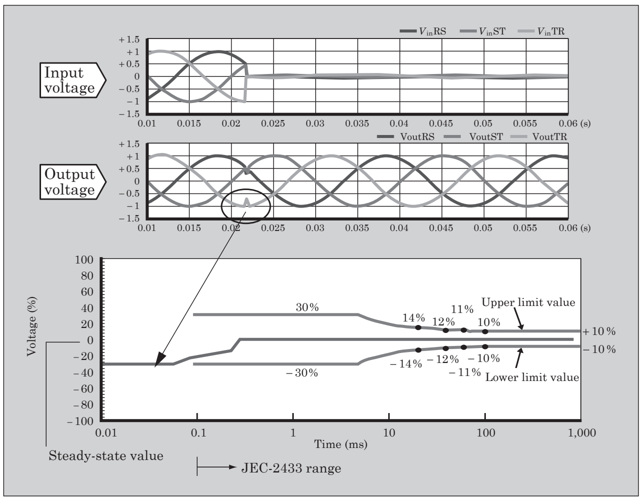
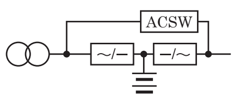
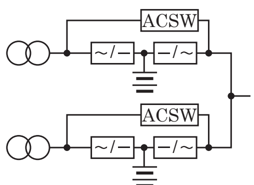
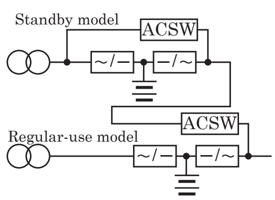


Table 1 Functional comparison of each UPS Series

| (See Note 1) | UPS6000D Series (previous model) | UPS7000D Series | UPS8000D Series |
|---|---|---|---|
| Efficiency | 91% | 95% | 98% (during Eco mode) |
| Setting area (see Note 2) | 100 | 70 | 60 (see note 2) |
| No. of phases and wires | 3-phase, 3-wire | 3-phase, 3-wire | 3-phase, 3-wire |
| Output voltage | 415 V | 415 V | 415 V |
| Voltage tolerance (steady state) | ± 1.0% or less | ± 1.0% or less | During AVR mode: ± 2% or less<br>During ECO mode:<br>According to set value (± 1 to ± 5%) |
| Output frequency | 50 Hz ± 1%<br>During battery-powered operation: ± 0.01% | 50 Hz ± 1% or ± 2%<br>During battery-powered operation: ± 0.01% | Same frequency as input<br>During battery-powered operation: ± 0.01% |
| Load power factor | 0.7 (delay) to 1.0<br>Rated 0.8 or 0.9 (delay) | 0.7 (delay) to 1.0<br>Rated 0.9 (delay) | 0.7 (delay) to 1.0<br>Rated 1.0 |
| Transient voltage regulation (see Note 4) | ± 5% or less | ± 5% or less | ± 5% or less |
| Voltage waveform distortion | 2.5%<br>(RMS value of total harmonics at 100% linear load)<br>5% or less<br>(RMS value of total harmonics at 100% rectifier load) | 2.5%<br>(RMS value of total harmonics at 100% linear load)<br>5% or less<br>(RMS value of total harmonics at 100% rectifier load) | 5% or less |
| Overload capability | 125%: 10 min<br>150%: 1 min | 125%: 10 min<br>150%: 1 min<br>200%: 2 s | 125%: 10 min<br>200%: 1 min<br>800%: 1 cycle (at failure of input power)<br>150%: 10 s |
| DC circuit rated voltage | 360 V | 528 V | 384 V |
| Switching time at failure of input power | JEC-2433 class 1 compliant | JEC-2433 class 1 compliant | JEC-2433 class 1 compliant |

Note 1: 500 kVA, 415 V, 50 Hz models are compared
Note 2: In the case where the 6000 Series is 100
Note 3: Comparison includes protection device. When standby redundancy is supported, it will be same as 7000 Series without protection device.
Note 4: In the case where the load changes from 0 to 100%

Table 2 Comparison of system compatibility of each USP series

| Item (conceptual diagram) (See Note 1) | | UPS6000D Series (previous model) | UPS7000D Series | UPS8000D Series |
|---|---|---|---|---|
| Single |  | ○ | ○ | ○ |
| Parallel redundant |  | ○ | ○ | ○ |
| Standby redundant |  | ○ | ○ | ○ (See Note 2) |

Note 1: 500 kVA, 415 V, 50 Hz models are compared
Note 2: To be compatible as of FY2009

tem, but was incompatible with a standby redundancy system or a system in which the input and the bypass power supply were different. In 2009, the expansion of this function to ensure compatibility with standby redundancy systems, which are becoming the mainstream systems in the IDC sector, is expected to lead to a broader range of applications.

Table 1 compares the functions of the previous UPS6000D Series with the new UPS7000D and UPS8000D Series introduced above, and Table 2 shows that the system compatibility is the same as that of the previous series.

### 2.2 Fuji Electric's efforts in the IT equipment sector

In computers, servers and other hardware, commercial power of AC100 V or AC200 V is first converted to DC power and then supplied to the CPU, memory and the like.

As is shown in Fig. 3, when the operating voltage of the CPU, memory and the like was 3.3 V or 5 V, a centralized power system was employed and the power supply and the device mother board were connected by wiring.

Recently, operating voltages have dropped to within the 1-to-2 V range, and wiring inductance between

Fig.3 Conventional centralized power system

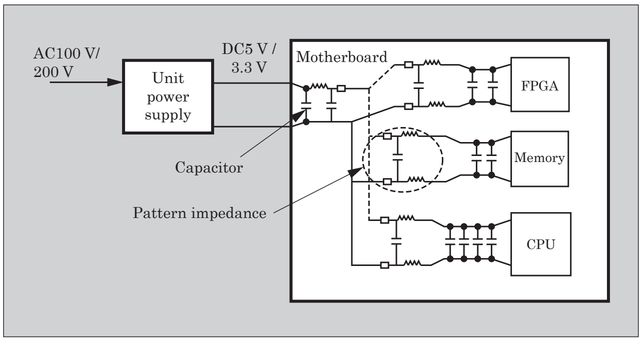
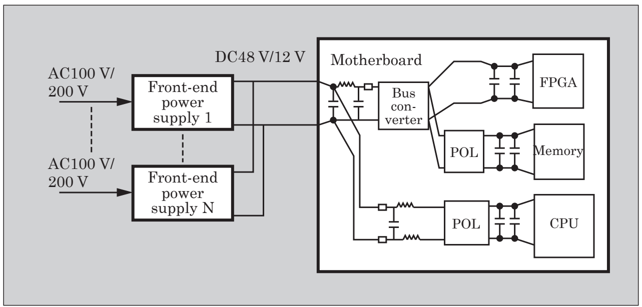



Fig.4 Example of distributed power system




the power supply and mother board and pattern inductance in the motherboard adversely affect the operation of the load. To inhibit such adverse affects, by providing, as shown in Fig. 4, a front-end power supply that converts the AC input to 12 V or 48 V DC and also positioning, in a later stage, a DC/DC converter as close as possible to the load, a distributed power system that reduces the abovementioned inductance effect can be realized.

Compared to a centralized power system, a distributed power system uses more converters arranged in series, and therefore has poorer conversion efficiency, which is disadvantageous for energy saving. Our customers, however, request power supply efficiency equal to or greater than that of a centralized power system, and therefore, as a benchmark, the capability to satisfy efficiency regulations such as Energy Star (Refer to the Glossary on page 172), CSCI (Climate Savers Computing Initiative) (Refer to the Glossary on page 172) and the like is necessary.

In order to satisfy these regulations, Fuji Electric is engaged in product development by applying leading-edge technology to the conversion circuit, switching element, wiring structure and the like. Examples of a front-end power supply and a bus converter are described below.

(1) Front-end power supply

Figure 5 shows a 12 V and 2 kW output front-end power supply product.

This power supply satisfies the requested 92% efficiency at a load factor of 50%, which is the strictest efficiency regulation of Energy Star and CSCI. The external dimensions of this power supply are 100 (W) × 375 (D) × 41 (H) (mm).

Fig.5 FH2000U1

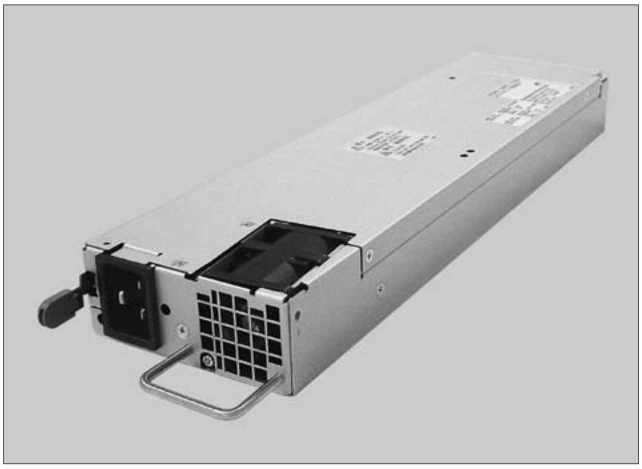
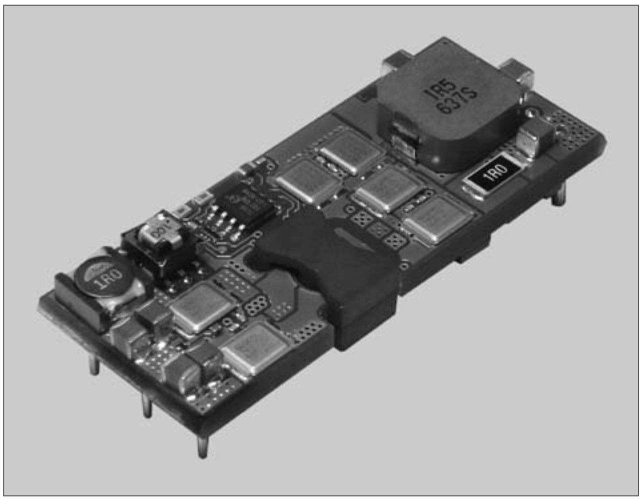


Fig.6 200W bus converter



(2) Bus converter

Figure 6 shows a DC48 V input, 12 V and 200 W output bus converter.

This high-efficiency and high-density power supply has the industry-standard 1/8 brick size (22.8 (W) × 57.8 (D) × 8.8 (H) (mm)), an efficiency of 92.5%, and output power per unit volume of 16 W/cc.

Fuji Electric is presently working to digitize the control circuit. Development is being advanced not only to improve the control performance, but also to reduce the man-hours required for delivery inspection, and to enable hardware to be deployed horizontally across many different models. Moreover, in cooperation with the Device Technology Dept. of the Fuji Electric Group, we also plan to focus on the application of a new device [silicon carbide (SiC) MOSFET] to power supplies.

## 3. Fuji Electric's Efforts to Realize Energy Savings in the Industrial Sector

A composite power supply for use in the elevator industry is an example of Fuji Electric's efforts to realize energy savings in the industrial sector. In the elevator industry, the system configuration of a product and the required devices and functions differ for each customer. Product proposals must be presented as a product plan that incorporates the needs of the customer and maximizes the value provided to the customer.

There is a high degree of awareness of safety in the elevator industry, and approximately 70% of new construction is for the installation of automatic landing devices that operate during power outages.

In the conventional method, separate batteries were installed in the inverter unit, control unit and brake control to configure individual backup systems. Consequently, many power supply units existed, the circuitry was complex and maintenance was difficult to implement. Moreover, the regenerated energy created when the elevator slowed or stopped was dissipated as heat by resistors.

Fuji Electric comprehensively reassessed and consolidated the design of emergency power supplies for elevator-use. A new simplified and high-efficiency power supply system, shown in Fig. 7 and Table 3, that meets customer needs has been built and is being offered by Fuji Electric. Adopting a backup method in which the backup system abuts the AC power supply, the new system provides a backup power supply for each control unit.

In this method, the power supply unit is shared so as to simplify the circuitry and to configure an optimal evacuation system that is linked to the control units. Fuji Electric is also working to realize energy savings such as by absorbing the regenerative energy created when an elevator ascends or descends.

This system is compatible with conventional elevator equipment design and uses high-density mounting technology so that it can be installed in the control panel of an elevator building.

Fig.7 Example of emergency-use power supply for elevator

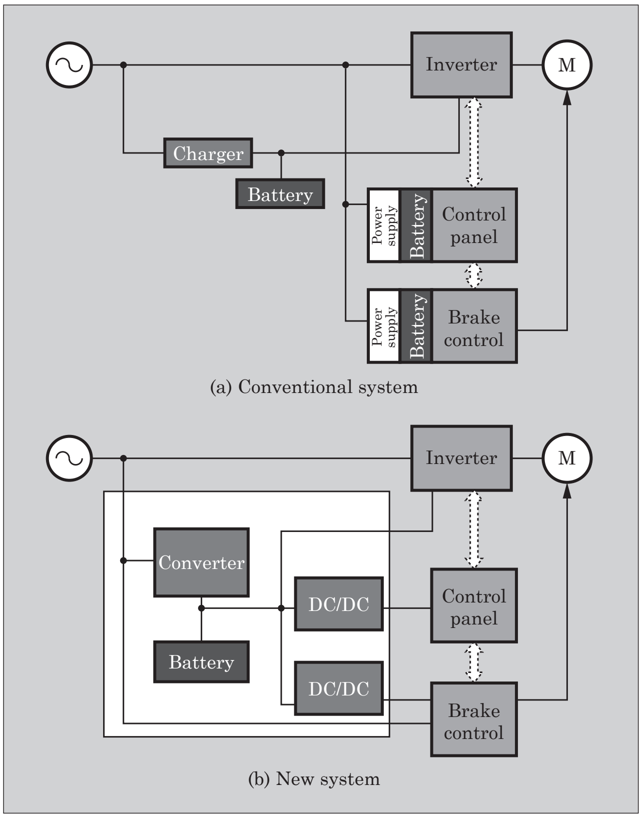



Table 3 Comparison of elevator emergency power supplies

| Item | Conventional system | Fuji Electric's proposed new system |
|---|---|---|
| Battery power supply | Must be provided at each unit (elevator main unit, control unit, brake control unit) | Centralized at one location in emergency-use power supply unit |
| Regenerative energy at time of power outage | Heat dissipated by resistors and the like | Used for charging the battery |

## 4. Fuji Electric's Efforts in the Natural Energy Sector

Power conditioners that use natural energy such as photovoltaic power and wind power are representative products of the new energy sector.

In Japan, as can be seen in Fig. 8, photovoltaic power generation is commonly used in homes and the home-use market is expected to increase significantly in the future.

Power companies are announcing plans one-after-another for large-scale photovoltaic power generation, "mega solar" plants. In September 2008, The Federation of Electric Power Companies of Japan announced plans by 10 power companies to build "mega solar" power generation plants with a total capacity of approximately 140,000 kW at about 30 sites by 2020.

In this manner, efforts to address global warming and to reduce $CO_2$ emissions are spreading from small-scale home-use photovoltaic power generation equipment to large-scale "mega solar" power genera-

Fig.8 Domestic Japanese market for photovoltaic power generation by usage

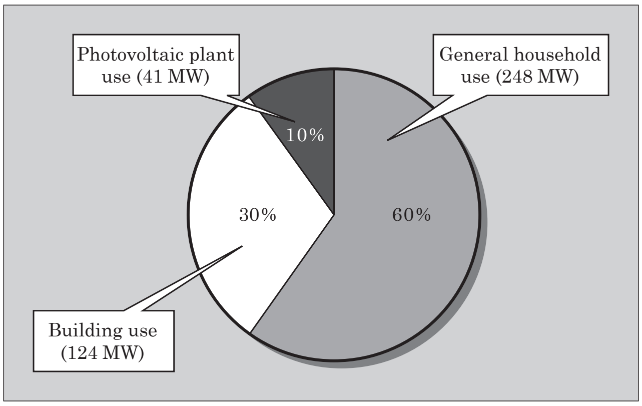
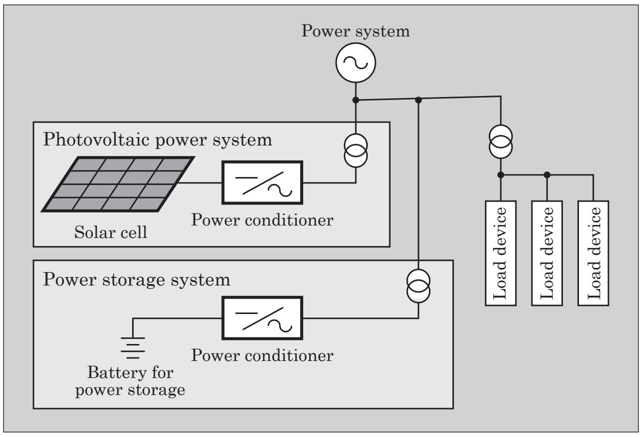


Fig.9 Example configuration of photovoltaic system




tion plants.

As shown in Fig. 9, in a photovoltaic power generation system, a power conditioner that converts the DC power generated by a solar cell into AC power is a key device that enables the DC power generated by a solar cell to be fed into the power system.

A power conditioner not only has an inverter function to convert the DC power generated by a photovoltaic cell into AC power, but also has a function for adjusting the load impedance seen from the photovoltaic cell and a maximum power tracking control function for extracting the maximum power. Moreover, so as not to adversely affect the AC power of the system, a power conditioner is also provided with a system protection function and an independent operation prevention function, both of which enable the power conditioner to be shut down safely in the case of system power outage.

Fuji Electric's power conditioner product lineup ranges from the medium-capacity to large-capacity devices listed in Table 4. These power conditioner products form the nucleus of a photovoltaic power generation system together with the "FWAVE", a film-type amorphous photovoltaic cell, and Fuji Electric plans to expand sales of these product both in Japan and internationally through direct marketing and OEM sales.

Particularly in the case of a "mega solar" system, unlike photovoltaic power generation equipment for home-use and the like, the power system will be affected significantly. When using natural energy in which the generated power fluctuates dramatically, power smoothing technology linked to a power storage system is absolutely essential. Even with a large power storage system such as a NAS battery, a power conditioner for converting AC power and DC power is a critical device.

Fuji Electric will continue to leverage its power electronics technology to develop its line of power conditioner products, and to leverage its power system linkage technology, to continue to propose new solar power systems.

Table 4 Fuji Electric's power conditioner product line up

| | Specification | | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|
| Output apparent power (kW) | 50 | 100 | 200 | 300 | 400 | 500 | 600 | |
| Rated output voltage | AC 380 V/400 V/415 V | | | | | | | |
| Rated frequency | 50/60 Hz | | | | | | | |
| No. of phases and wires | 3-phase 3-wire, or 3-phase 4-wire system | | | | | | | |
| Insulation method | Commercial frequency insulated transformer | | | | | | | |
| Output load power factor | 0.95 or greater | | | | | | | At rated operation |
| Output current harmonic distortion | 5% or less (total), 3% or less (each phase) | | | | | | | At rated operation |
| Rated input voltage | DC500 V | | | | | | | |
| Input voltage range | DC0 to 700 V | | | | | | | |
| Input voltage (operating range) | DC250 to 600 V | | | | | | | |
| Input voltage (MPPT range) | DC250 to 600 V | | | | | | | |
| Installation | Indoor, free-standing | | | | | | | |
| Cable feed | Top-fed | | | | | | | Bottom-fed is available as an option |
| Cooling method | Forced cooling | | | | | | | |
| Panel width (mm) | 500 | | 1,000 | 1,500 | 2,000 | 2,500 | 3,000 | Not including transformer |
| Panel height (mm) | 1,950 | | | | | | | |
| Panel depth (mm) | 800 | | | | | | | |
| Mass (kg) | 400 | | 800 | 1,200 | 1,600 | 2,000 | 2,400 | Not including transformer |
| Ambient temperature | Indoor: – 5 to + 40 °C | | | | | | | |
| Relative humidity | 30 to 90% | | | | | | | No freezing or condensation |
| Elevation | 1,000 m or less | | | | | | | |

## 5. Postscript

This paper has discussed UPSs, power supplies for IT devices, and energy saving measures using power conditioners as examples of Fuji Electric's efforts to realize energy savings in the energy and environmental sectors using Fuji Electric's expertise in power electronics technology.

In the future, Fuji Electric intends to continue to work to realize energy savings in each of the air-conditioning systems, power supplies and IT devices used at IDCs, and to strive to establish system-wide energy saving solutions for the entire IDC sector.

### References


(1) Solarbuzz. http://www.solarbuzz.com/