Power Control Technologies that Contribute to Customer Success

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1. Introduction

In recent years, various problems and demands have appeared as electric power systems are connected to different loads and power plants.

In commercial power systems and small-scale electric power systems that do not include power receiving points, when there is a load that requires great electrical power instantaneously within the installation, a voltage dip phenomenon known as voltage flicker occurs due to the peak current, which affects other equipment.

In mid-scale electric power systems that include power receiving points, there was demand for suppression of the operating voltage peak and effective use of nighttime power.

In large-scale electric power systems that include commercial power systems, customers are concerned about possible effects from the introduction of natural energy, such as solar power generation, which has unstable power generation that is influenced by the weather.

Technologies for stable electric power systems and technology for effective use of power can solve these problems and topics.

In the Sanyo Denki Power Systems Division, we have made use of power conversion technology and developed a variety of products, including a product related to stabilizing power systems and effective use of power.

This document will first explain about the power conversion technology and power suppression technology from Sanyo Denki, and then it will introduce examples of applications of the product in power regeneration device and grid management device.

2. Power Conversion Technology

Fig. 1 shows a basic circuit with two switching devices (this figure shows IGBTs) used upstream and downstream with a reactor connected in the middle. Using this configuration, the current can be converted from AC to DC, DC to AC, and DC to different voltage DC. Let us explain this principle in simple terms.
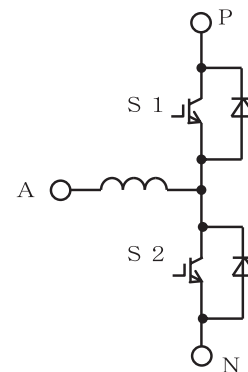

Fig. 1: Basic power conversion circuit

In Fig. 2, high-voltage DC is input into the P terminal, and by controlling the on or off status of upstream and downstream IGBTs as shown in the figure, low-voltage DC as calculated through Formula 1 is output to the A terminal. In Fig. 3, low-voltage DC is input into the A terminal, and by controlling the on or off status of upstream and downstream IGBTs as shown in the figure, high-voltage DC as calculated through Formula 2 is output to the P terminal. Figs.2 and 3 represent DC/DC converters, with Fig. 2 representing the operations of a buck chopper and Fig. 3 representing a boost chopper.
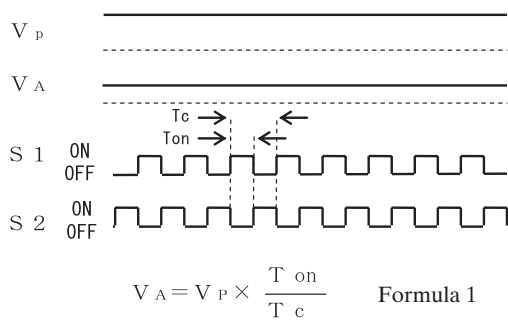
$$V_A = V_P \times \frac{T_{on}}{T_c} \qquad \text{Formula 1}$$

Fig. 2: Operations of a buck chopper

$$V_P = V_A \times \frac{T_c}{1 - T_{on}} \qquad \text{Formula 2}$$
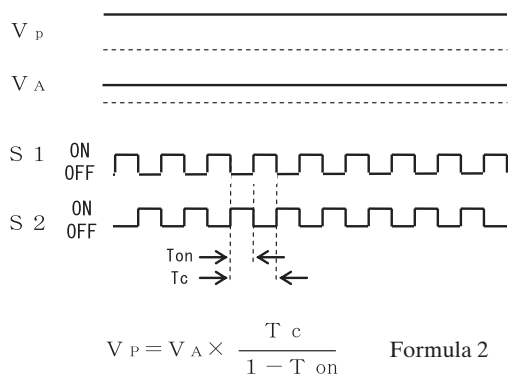
Fig. 3: Operations of a boost chopper

In Fig. 4, DC voltage is input into the P terminal, and by controlling the on or off status of upstream and downstream IGBTs with Formula 3, AC voltage is output to the A terminal. Furthermore, in Fig. 5, AC voltage is input into the A terminal, and by controlling the on or off status of upstream and downstream IGBTs with Formula 4, DC voltage is output to the P terminal. Fig. 4 represents a DC/AC converter (INV), while Fig. 5 represents an AC/DC converter (CONV).
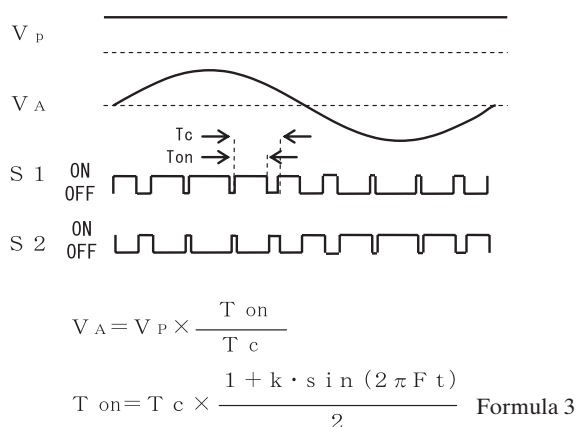

$$V_A = V_P \times \frac{T_{on}}{T_c}$$

$$T_{on} = T_c \times \frac{1 + k \cdot \sin(2\pi F t)}{2} \qquad \text{Formula 3}$$

Fig. 4: Operations of a DC/AC converter (INV)

$$V_P = V_A \times \frac{T_c}{T_{on}}$$

$$T_{on} = T_c \times \frac{1 + k \cdot \sin(2\pi F t)}{2} \qquad \text{Formula 4}$$
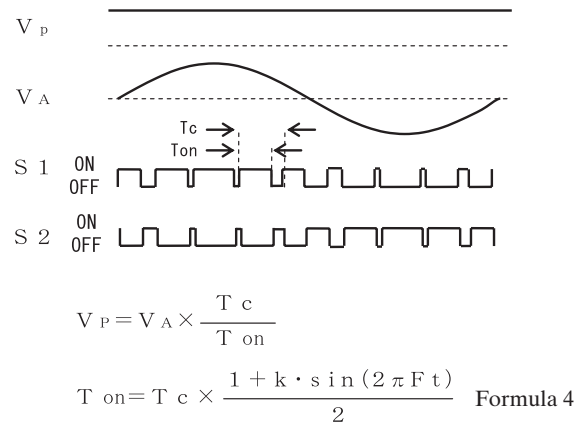
Fig. 5: Operations of an AC/DC converter (CONV)

As explained here, simply by controlling whether the IGBTs are turned on or off, the circuit can convert DC into different voltage DC, DC into AC, or AC into DC.

Furthermore, this basic circuit (Fig. 1) can use either the A or P terminals as the input or output terminals. This means that power can pass through the terminals from A to P, from P to A, or in both directions.

Through combinations of this basic circuit, various power conversion equipment can be realized. The UPS circuit in Fig.6 uses two basic circuits as an AC/DC converter (CONV) and as a DC/AC converter (INV). By connecting a storage battery to the DC line, an on-line UPS can be realized. The UPS circuit in Fig.7 uses one basic circuit to switch between an AC/DC converter (CONV) and a DC/AC converter. By connecting a high-speed switch to the AC line and a storage battery to the DC line, a parallel processing type UPS [1][2] can be realized. The power conditioner circuit in Fig.8 uses two basic circuits as a DC/DC converter (CHOP) and a DC/AC converter (INV). By connecting photovoltaic cells to the DC input, a power conditioner for photovoltaic power generation [3] can be realized. Finally, Fig. 9 uses two basic circuits, one which has the functions of both an AC/DC converter (CONV) and a DC/AC converter (INV), and one which has the step-up and step-down functions as a DC/DC converter (CHOP). By creating a structure of an energy storage device, as shown in the figure, a power control device can be realized. The next section explains about this.
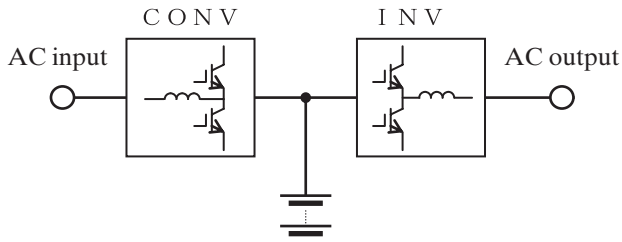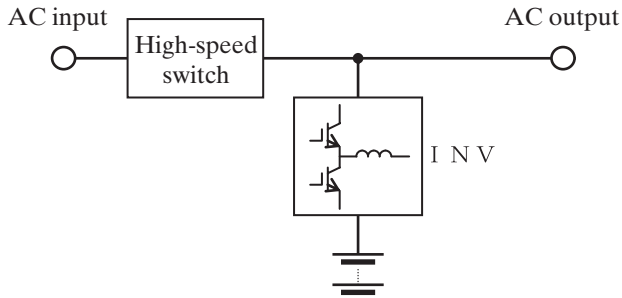
Fig. 6: On-line UPS

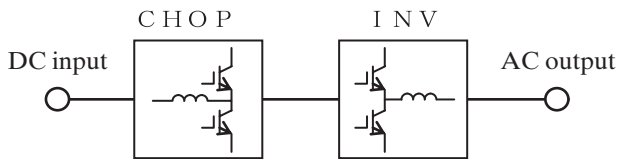Fig. 7: Parallel processing type UPS

Fig. 8: Power conditioner for
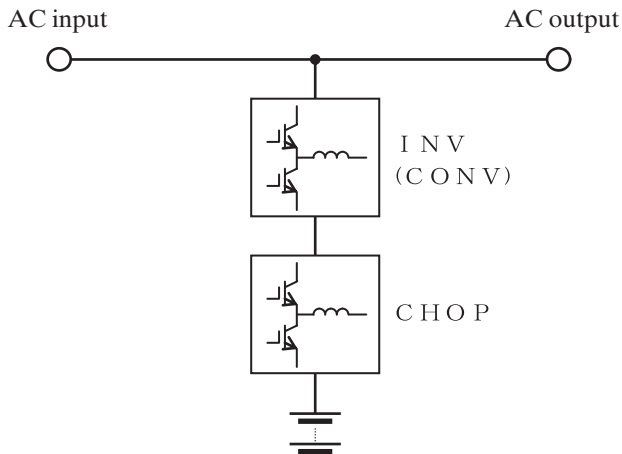photovoltaic power generation

Fig. 9: Power control device

3. Power Control Technology

Section 2 explained that there is one basic circuit as the main circuit for power conversion, and simply by changing the controls, the circuit can convert from AC to DC, DC to AC, or DC to different voltage DC, thus allowing the flow of power to be used freely. Using this conversion technology, the flow of power in the power control device shown in Fig. 9 can be managed and controlled, allowing Sanyo Denki to propose systems that can help the customer.

This section explains the types of management controls for power. Fig. 10 shows the flow of power. The regenerative power is indicated as negative power.
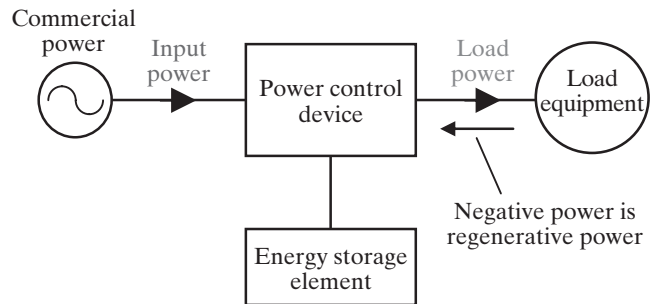

Fig. 10: Flow of power

First, the following are used as power controls over short periods of time: instantaneous power peak-cut controls, instantaneous regenerative power peak-cut controls (Fig. 11), instantaneous power base assistance controls, and instantaneous regenerative power base assistance controls (Fig. 12).
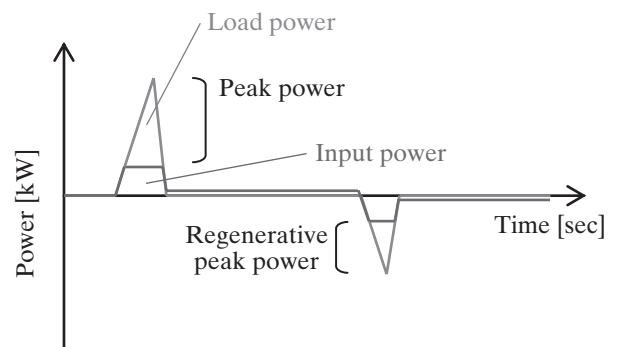

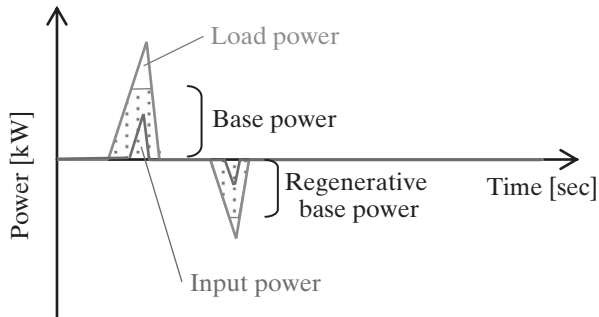Fig. 11: Instantaneous power peak-cut controls

Fig. 12: Instantaneous power
base assistance controls

The peak-cut controls and regenerative power peak-cut controls are used to suppress peak power in the input by supplying or absorbing power with the energy storage device when the absolute value of the input power exceeds the set value. Furthermore, the peak-cut energy is used to charge or discharge the energy storage device by the next load fluctuation. The charged and discharged power can be set smaller when the load power fluctuates for a long time.

The base assistance controls and regenerative power base assistance controls are used to supply power from the energy storage device without supplying power from the input until the load power starts to rise and reaches the set value. The remaining power is supplied from the input power source when the load power exceeds the set value. The goal of these controls is to suppress the peaks in the input power. Through these controls, the electrical charge from the energy storage device can be covered with regenerative power. The controls are effective when the difference between the antegrade load power and the regenerative power is great and the fluctuations in load come in short intervals. Furthermore, this is the method in which regenerative power from loads can be used effectively.

For both, charging and discharging of power are performed in a short period of time, and therefore the capacity for the energy storage devices can be set smaller. From this, electric double layer capacitors (hereafter referred to as EDLC) are suitable as the energy storage devices.

Next, the following are used as power controls over long periods of time: average power peak-cut controls (Fig. 13), base assistance controls (Fig. 14), and power equalization controls (Fig. 15). These controls are used to control average power over 30 minutes, cutting the peaks of this average power or assisting the base.

Peak-cut, aimed at lowering the customers' contract demand, is effective for a low frequency of peak power where the peak power is great compared to the average

power for one day, and the energy storage device does not become relatively large.

Base assistance supplements base power during the time range when using daytime power as shown in the figure, The supplemental power is stored in the energy storage device during nighttime, resulting in constant power output during daytime. This is similar to the normal methods of power storage.
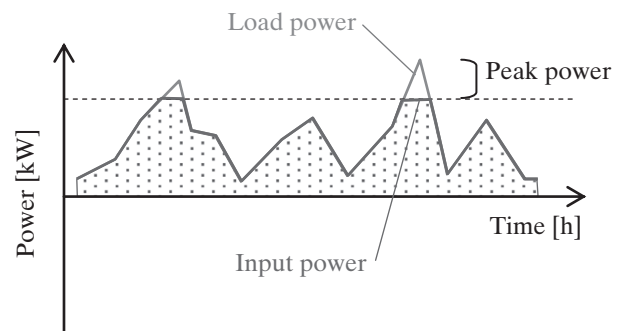

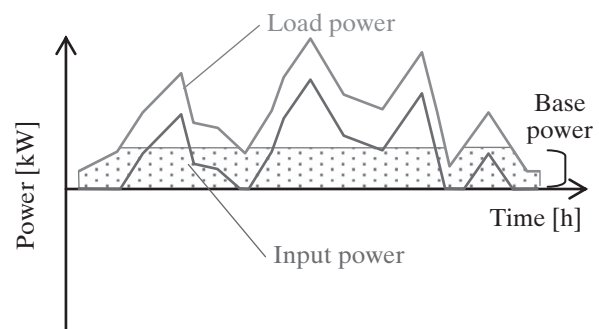Fig. 13: Average power peak-cut controls

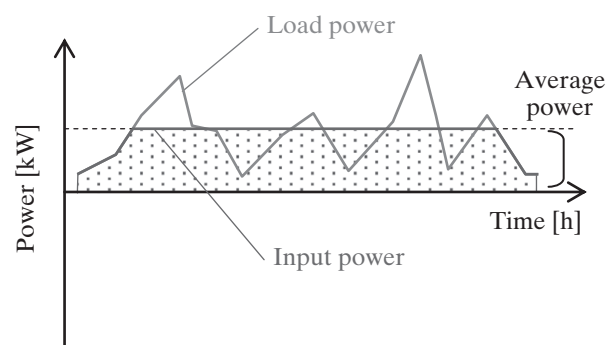Fig. 14: Average power base assistance controls

Fig. 15: Power equalization controls

Power equalization combines both peak-cut controls and base assistance controls. If the power increases greater than previously defined power level, then power is supplied from the energy storage device to maintain a constant level of input power. If the power falls below the previously defined power level, then the power charges

the energy storage device to maintain a constant level of input power. In this way, the input power is kept constant during the day and power fluctuations on the load do not appear in the commercial power source, thus making it load equipment that even stabilizes the commercial power source. Furthermore, by establishing a power plant on the load such as a photovoltaic power generation plant, the input power can approach 0W as shown in Fig. 16.
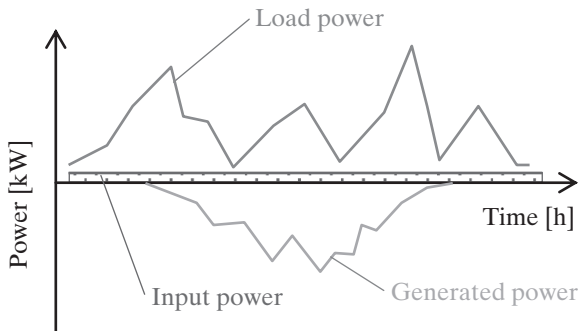

Fig. 16: Power equalization controls when input power is 0W

The amount of power handled here is great, and therefore a rechargeable battery is suitable for the energy storage device. In recent years, rechargeable batteries such as lithium ion batteries have been developed with very high energy densities for the volume and mass, allowing customers to construct easy-to-use systems.

4. Customer Examples

This section introduces examples of how products using power control technology have been proposed and used by customers, and how these technologies have helped contribute to customer success.

Example 1:
Power regenerative device for parking elevators (K23AA-R)

In parking elevators, the motor applies the break while the elevator is being lowered, and therefore, the lowering energy can be gathered from the motor as regenerative power. In conventional systems, this regenerative power was consumed as resistance. Furthermore, when the elevator rises, a large amount of power is consumed instantaneously.

This time, the regeneration power charges the EDLC, and when the next elevator rises, that power is produced from the power regeneration device supplied from the EDLC. Fig. 17 shows the system configuration diagram. When consuming power, the peak power, shown as the positive power in Fig. 11, is discharged from the EDLC. When regeneration power comes, the base power, shown as the negative power in Fig. 12, charges the EDLC. The regeneration power that was consumed by load in conventional systems is stored in the EDLC and reused
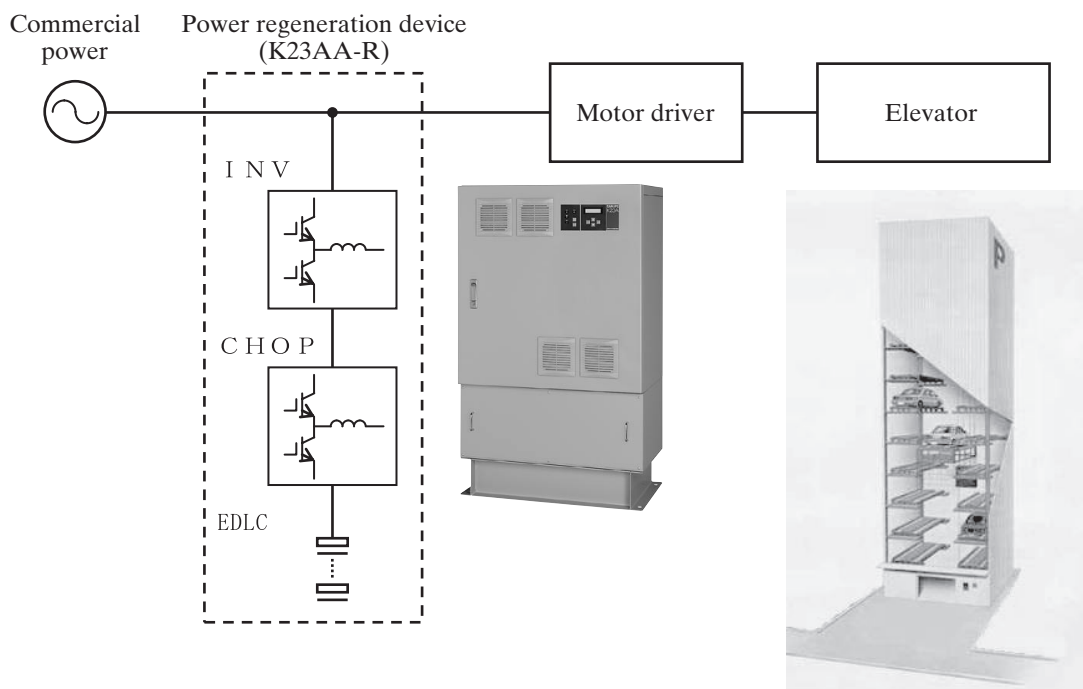

Fig. 17: System configuration diagram using a power regenerative device for parking elevators (K23AA-R)

the next time power is consumed, helping the customers' equipment become energy saving and suppress the peak power, thus allowing the receiving power distribution system to be smaller. In this way, the energy-saving multi-story parking structure that customers have been hoping for was realized.

Example 2:
Grid management device (K23AA-M)

Sanyo Denki proposed a parallel processing type power supply management device [4] suitable for power feeding systems for power grids.

This time, a smart grid using photovoltaic power generation and a lithium ion battery was implemented in the charging system for electric cars, so a grid management device (K23AA-M) using the parallel processing method was adopted for use.

We want power from the photovoltaic power generation to charge the power for fast chargers and use the power from commercial power sources as little as possible.

The power for fast chargers gets extremely large for a short period of time, so to supply it with only photovoltaic generated power, a large capacity photovoltaic power generator is required. However, the utilization rate for chargers is low and the average power is small, so we want the photovoltaic power generation to be equivalent to this power. This system was used in order to respond to these concerns from customers.

Fig. 18 shows a system configuration diagram for a smart grid using a grid management device. For the large capacity fast charger, there is one 10kW photovoltaic power generator. The photovoltaic generated power charges a lithium ion battery, and when a fast charger operates, power is supplied from the lithium ion battery. This equalizes the power from the commercial power source to the power in the grid as shown in Fig. 16 in Section 3, thus keeping the power from the commercial power source as small as possible. We achieved a power supply system aimed towards realizing a zero emissions society through EV.

Example 3:
Peak-cut device (K33AD-P)

When driving the motors built into large pressing machines, a large amount of power is required momentarily. This causes a momentary voltage fluctuation in the input voltage and causes abnormal operations in the devices connected to the power source. In order to eliminate this problem, power receiving equipment and power distribution equipment have to be strengthened, which results in a large cost. The Sanyo Denki peak-cut device (K33AD-P) can suppress the power peaks from the commercial power by discharging power stored in the EDLC to be used as the large power required for large pressing machines. Furthermore, the regeneration power previously lost through heat from the generation resistors can be stored in the EDLC and it can be reused when next powering the motor, thus realizing power saving.
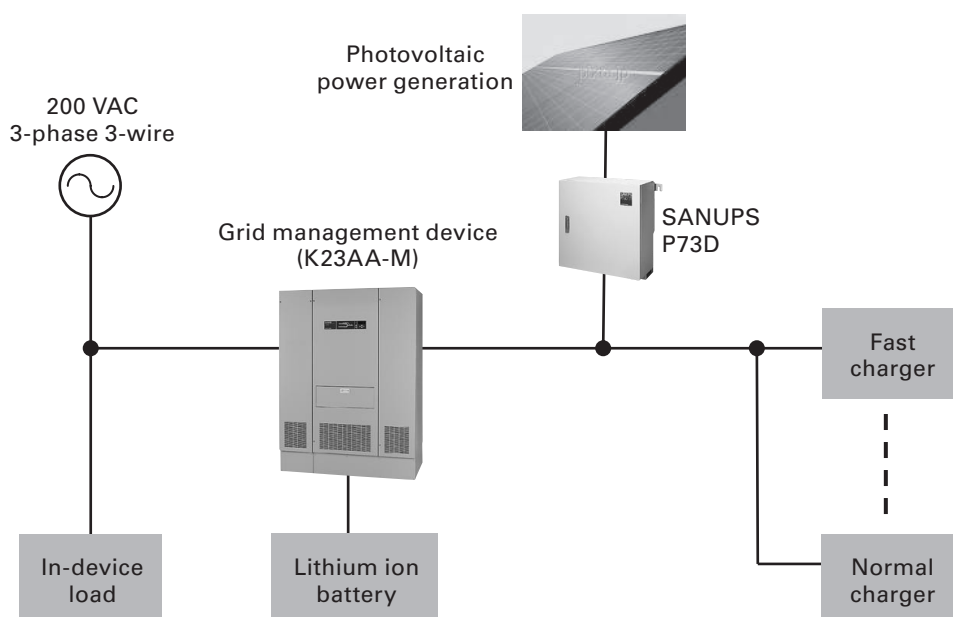
Fig. 18: System configuration diagram of a smart grid management device (K23AA-M)

In this case, as the power supply for an 1800kW large pressing machine, power discharged from the EDLC is used in the peak-cut device K33AD-P as 300kW so the input capacity can be reduced from 1800kW to 1500kW, so a large pressing machine can be installed without needing to reinforce the existing power equipment. Fig. 19 shows the system configuration diagram.
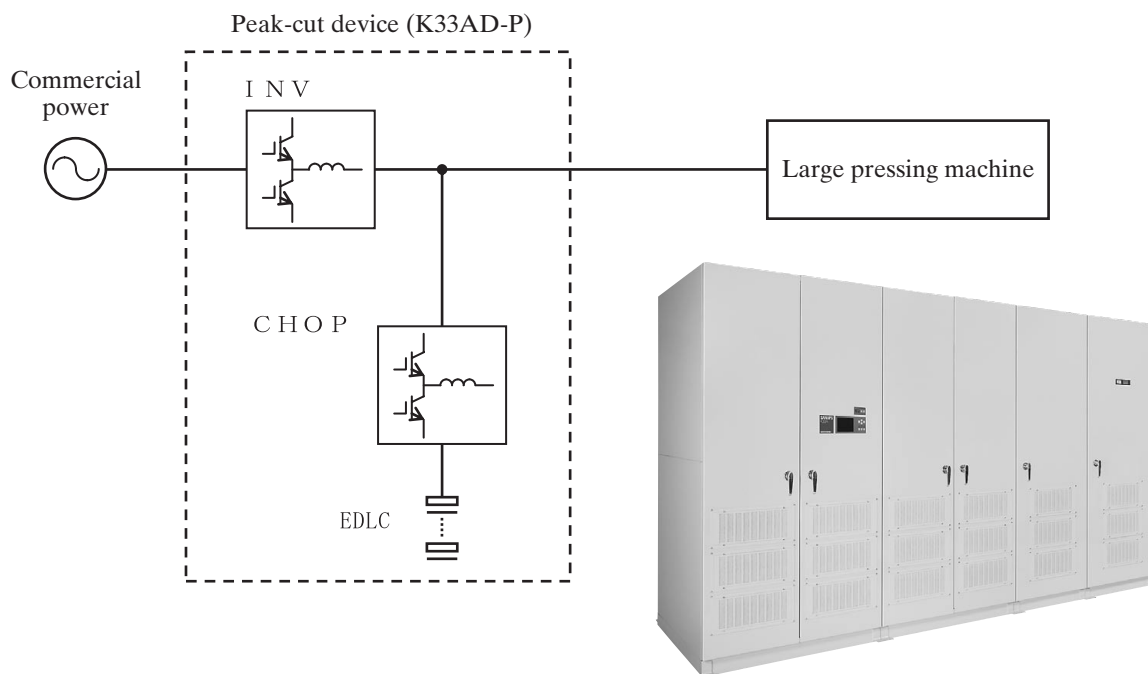

Fig. 19: System configuration diagram for a large pressing machine and peak cut device (K33AD-P)

5. Conclusion

This document described our power control technology and examples of stabilizing power systems and effective use of power by using the products with this technology. The examples introduced here are but a few examples of market needs, and this product is viewed as one that can be suitable for any customer's needs. In the future, we plan to propose products that meet customers' needs and contribute to customer success.

Documentation

[1] Minoru Yanagisawa: "Power System Technology That Changes The Conventional Trend" SANYO DENKI Technical Report Issue 16, pages 7-10 (2003).

[2] Hiroshi Hirata and Others: "Development of the medium capacity UPS 'SANUPS E'" SANYO DENKI Technical Report Issue 14, pages 24-27 (2002).

[3] Norio Tazawa and Others: "Development of Power Conditioner for Photovoltaic Power Generation, 'SANUPS' P73D103" SANYO DENKI Technical Report Issue 17, pages 15-19 (2004).

[4] Yoshiaki Okui and Others: "Development of Power Supply System with Distributed Generators using Parallel Processing Method" Journal of Institute of Electrical Engineers B (Electric/Energy Department Journal) Vol. 129, No. 11, pages 1349-1356, 2009.

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