Technology from the New Product “SANUPS K” for a Smart Grid Society

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1. Introduction

After the Tohoku Earthquake, there is a movement for advancing the establishment of smart grids for Japan’ s power supply system, which aims to develop more energy-saving solutions and a stable supply of power. Sanyo Denki Power Systems Division has been developing uninterruptible power supplies (UPS), power conditioners for photovoltaic power generation (PCS), and engine power generators (EG) as our main products. This gives Sanyo Denki an advantageous position where we can fully leverage our power electronics technologies nurtured through these products to respond to the very needs of power converters that are necessary for realizing smart grids. We consider the establishment of smart grids as a new demand in the power market, so we are now working on the development of the “SANUPS K” series products that realize effective use of power1) , 2).

This document describes the current power situation in Japan, and introduces the background of developing the “SANUPS K” series as well as its product lineup (grid management device, regenerative power compensation device, and peak cut device).

2. Power Situation in Japan

Currently, the power used by consumers within Japan’s power supply system is generated by large-scale, centralized power supplies of power companies, and supplied through the power lines and distribution lines. To balance the power’s supply and demand, the central load dispatching center monitors features such as voltages and frequencies, and it controls the supply and demand to match. Since the Tohoku Earthquake occurred on March 11, 2011, various problems have been pointed out for this type of power supply system and there have been opinions for promoting smart grids.

For example, nuclear power generation, which had been regarded as the trump card for large-scale, centralized power generation for being clean energy that does not produce CO_2 emissions, started to be considered problematic due to its hazardous nature.

Thermal power generation is the most widespread method with low cost, but power generation that uses coal, which emits large amounts of CO_2, occupies approximately 24% of the total power generated and approximately 40% of thermal power generation (FY 2010) 3). There is a tendency to shift to the latest power generation methods that emit less CO_2 such as combined cycle power generation (a highly effective power generation method with combined gas turbine and steam turbine), but still, the problem of CO_2 emission remains. Also, it was reaffirmed that with large-scale, centralized power generation, if an accident occurs, it affects a wide range and causes major confusion in the society.

To solve these problems, there is a growing expectation for clean power generation that uses renewable energy, such as photovoltaic power generation, using distributed power supplies. Furthermore, a new power infrastructure as shown in Fig. 1 has started to be investigated, where the power is supplied by clean, distributed power supplies such as photovoltaic power generation in an area closer to the consumers, and it works together with the power company’s power systems or regional power equipment while the balance of supply and demand is controlled by utilizing batteries and IT4). This type of power infrastructure that realizes local production for local consumption is one type of Japanese-style smart grid. Fig. 2 shows the overall image of the smart grid proposed by The Ministry of Economy, Trade and Industry5). In particular, an on-site type power supply system that can be operated independently from the existing power company systems is called a “micro grid” .

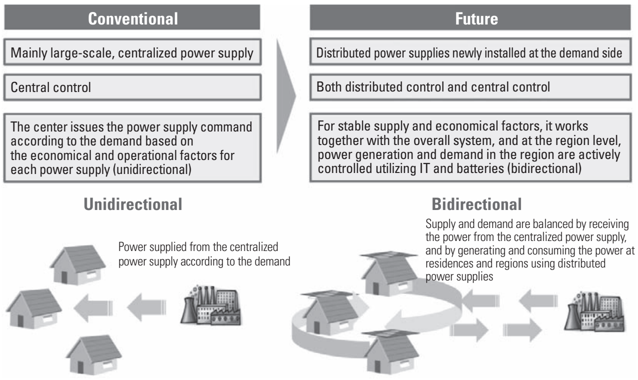


Fig. 1: Change in the power infrastructure[4)]

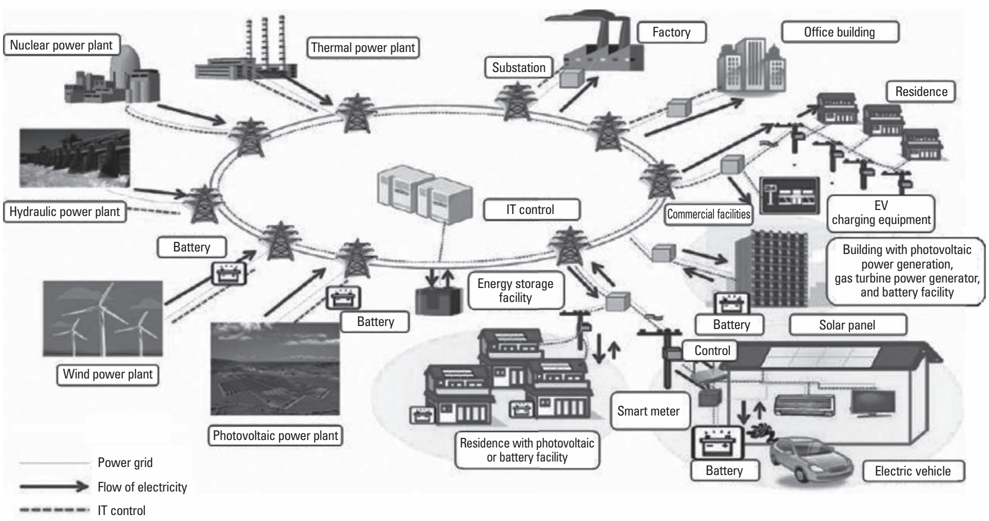


Fig. 2: Conceptual diagram of a Japanese-style smart grid[5)]

3. Study of Micro Grid and Verification Examples

3.1 Study of micro grid

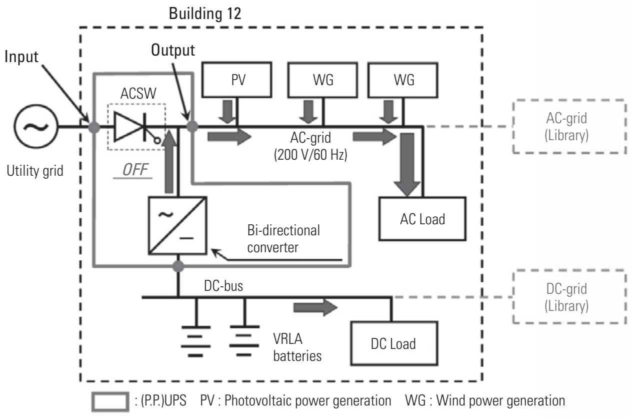
As mentioned in Section 2, there is an ongoing plan to turn the power supply system into a smart grid, and on-site type power supply system such as micro grid that locally produces and consumes power has also started to be considered. What is necessary for such on-site type power supply systems is power electronics technology that is applied to batteries and power converters used to balance the supply and demand of the power. Sanyo Denki has a long history of developing UPS and PCS products, which allowed us to have the power electronics technology required for new power supply system. Although there are various potential methods for the power supply system, Sanyo Denki participated in a joint research on micro grid with Aichi Institute of Technology and NTT Facilities between 2006 and 2010, and this system serves as the base of a new power supply system that Sanyo Denki proposes. Fig. 3 shows the configuration of the micro grid system designed through the joint research, and its operation mode diagram[6)]. The power is supplied directly to consumption devices (AC load) from distributed power supplies such as photovoltaic power generation (PV) and wind power generation (WG). The fluctuation in power generation of the distributed power supplies and the fluctuation in consumption on the consumer side are controlled by batteries via bidirectional power converters. The interconnection point with the utility grid can be separated by the ACSW, which allows this micro grid system to operate independently on-site. The ACSW and the bidirectional power converter are integrated, and a parallel processing UPS (P.P.UPS) with the same configuration serves as a base model[6)].

As shown in Fig.3 (c), in the basic operation mode, the ACSW is normally turned off and the system operates in isolated mode separate from the utility grid. If the generated power exceeds consumption, it charges the batteries via bidirectional power converters, and once fully charged, the distributed power supply is stopped. Also, if the generated power is less than consumption, the power is supplied from the batteries, and when the batteries reach the lowest voltage, the utility-connected mode is established with no interruption. If power outage occurs during the utility-connected mode, the backup mode (the same state as isolated mode) is established with no interruption, which is just like the characteristics of P.P.UPS[7].

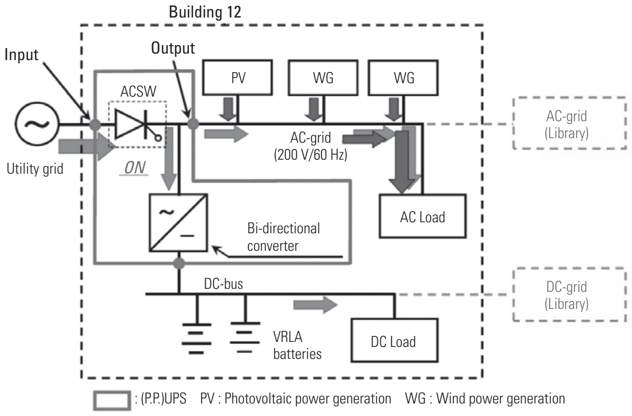
In this manner, the ACSW and the bidirectional converter control the AC power grid for power generation and consumption, so Sanyo Denki calls this device, which is an integration of the ACSW and the bidirectional converter, a “grid management device.”

Fig. 4 shows the operation example during the normal operation. In the daytime, even if there are fluctuations in photovoltaic power generation or load, the balance is maintained by the batteries without depending on the utility grid. In the nighttime, since photovoltaic power generation is unavailable, the discharge from the batteries increases and it automatically switches to the utility-connected mode.

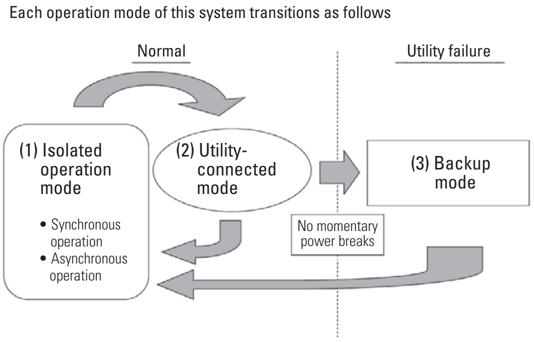
To operate on the complete micro grid without depending on the utility grid, it is necessary to use larger batteries. However, batteries are still expensive, so we think there are more needs for operations that use the utility grid than completely independent operation micro grids. Thus, as another example from operation example 1 shown in Fig. 4, we present Fig. 5 showing an operation example where batteries are used at a necessary minimum (optimized) while using the utility grid as well. This assumes that the operation is done in the utility-connected mode and the power from the utility grid (input power of the grid management device) is preset beforehand according to time slot, or an EMS (Energy Management System) controller is configured above the grid management device and the operation is done based on its command values. If the power to be supplied from the utility grid is planned beforehand, the load to the batteries is reduced, and so the installation capacity of the batteries can be optimized. In addition, in terms of the utility grid as a whole, the demand can be well planned, which allows the overall load to be equalized. Also, in terms of the interface of the utility grid, since the fluctuation in the power generation and consumption within the micro grid does not affect the utility grid, this operation does not adversely affect the power quality such as the system frequency, which is concerned due to the power fluctuation caused by massive installation of photovoltaic power generation.



(a) Isolated mode (Normal)



(b) Utility-connected mode (Normal)



(c) Operation mode

Fig. 3: Configuration of micro grid and operation mode diagram

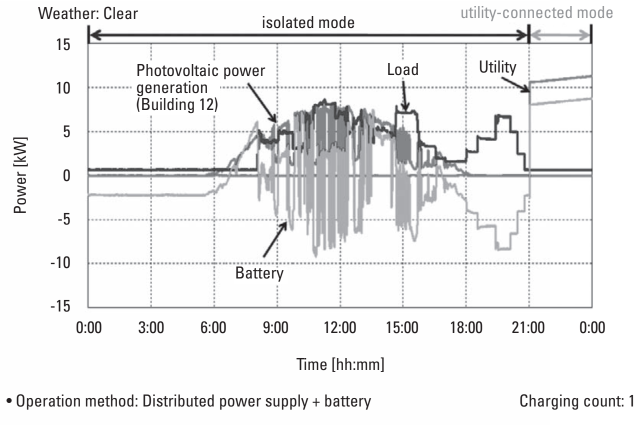


Fig. 4: Operation example 1

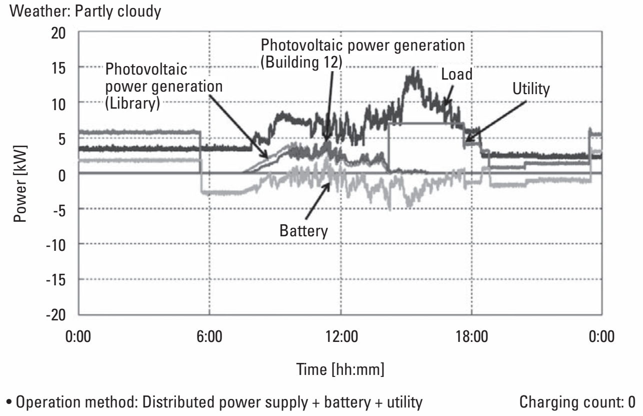


Fig. 5: Operation example 2

3.2 Verification example

This section introduces an example of verification using actual facilities. The application used is a charging system for electric vehicles (EV).

Although EVs emit no CO_2 while driving, if they are charged with a utility power that includes thermal power generation, a genuine zero-emission automotive society cannot be achieved. Thus, the verification was carried out by applying a grid management device to a zero emission charging system where EVs are charged using the power generated mainly by photovoltaic power generation. Fig. 6 shows the configuration diagram of the verification. It is configured with photovoltaic power generation (40 kW), 3 rapid chargers (50 kW), 14 normal chargers (3.3 kW), a grid management device (200 kW), and 4 batteries (96 kWh, batteries mounted on EV LEAF). A zero emission charging system was achieved by operating the grid management device by controlling the input power to always be zero as shown in operation example 2 of Fig. 5. This system has been operated since July 2011, and it continues running without any problem.

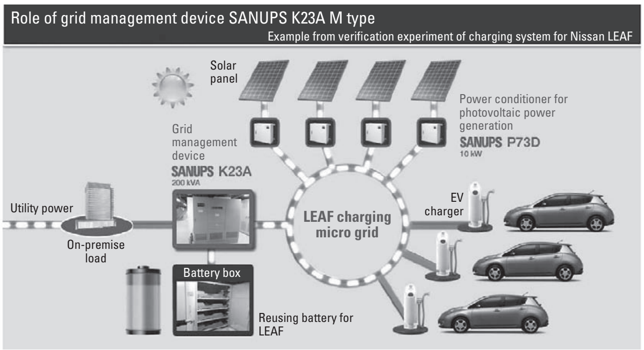


Fig. 6: Verification example

4. Lineup of the “SANUPS K” Series

Based on the research results and verification in Section 3, good insight was gained regarding the effectiveness of the grid management device. The technologies gained through this research can be applied not only to the power system but also to the motor drive system. This means that the regenerative power in the motor drive system can be used effectively by replacing the excessive power during power generation with the “regenerative power,” and the power during shortage with the “Running power.” Even for the motor drive system that is considered to occupy approximately 57% of the power currently used in Japan[8), it is now possible to propose new energy-saving products.

In this context, Sanyo Denki developed the following lineup of products as the “SANUPS K” series, which realizes the effective use of power using storage devices. Fig. 7 through Fig. 9 show the picture of each product.

(1) Grid management device “SANUPS K M type”
(2) Regenerative power compensation device “SANUPS K R type”
(3) Peak cut device “SANUPS K P type”

As storage devices, lithium ion batteries are used in the grid management device, and electric double layer capacitors (EDLC) are used in the motor drive system, which does not need as much energy as the power system.

Fig. 7: Grid management device

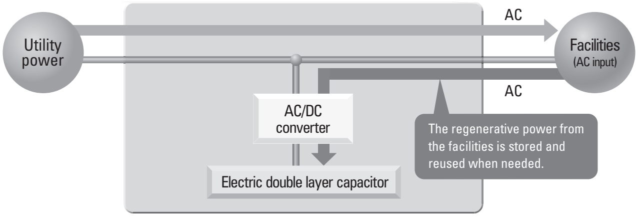
Fig. 8: Regenerative power compensation device

Fig. 9: Peak cut device

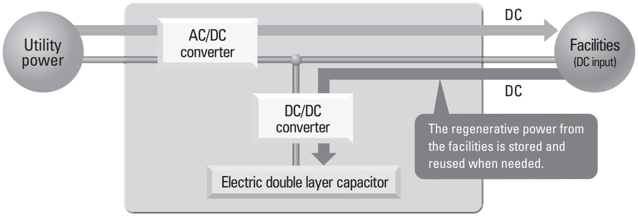
The grid management device is a product made for the aforementioned power system, while the regenerative power compensation device and peak cut device are those developed for the motor drive system.

The regenerative power compensation device reduces the peak reception power as well as power consumption (energy saving) by temporarily charging the EDLC with the regenerative power generated from the motor drive system and discharging the stored power from the EDLC for the next powering. As one of its main applications, it is introduced to the motor drive systems for multi-story parking structures. This device not only has the AC output type shown in Fig. 10 (a), but also the DC output type as shown in Fig. 10 (b), so that the power can be supplied directly to the inverter for motor drive. For details, refer to Documentation 1) and 9).

When a large amount of power is required for motor drive powering, an instantaneous drop phenomenon called voltage flicker may occur in the system voltage, which causes problems such as flickering light. The peak cut device mainly aims for suppressing voltage flicker by reducing the system power using the power stored by regeneration during powering at which the peak power occurs. This device has a DC output type as shown in Fig. 10 (b). As one of its main applications, it is introduced to the power supply for servo presses. For details, refer to Documentation 2) and 9).



(a) AC output type



(b) DC output type

Fig. 10: Configuration of “SANUPS K” for the motor drive system

5. Conclusion

This document introduced the background of developing the new “SANUPS K” series products, which realize effective use of power, and the technology behind it. Each one of the products is expected to contribute to a smart grid society and energy-saving society, and we expect to take them into new markets.

Documentation

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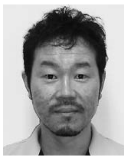

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