Development of the Grid Management Device “SANUPS K23A (M Type)”

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1. Introduction

After the Tohoku Earthquake, in order to achieve even more energy conservation and reliable power supply, Japan’s power supply systems have been considering new power infrastructures, such as smart grids. However, there are extremely few power conversion devices that can meet those needs.

Using power electronics technologies gained over the years, Sanyo Denki developed the grid management device “SANUPS K23A (M Type)” , which uses batteries to efficiently balance and control the power between distributed power supplies from renewable energy, such as photovoltaic power generation, and commercial power systems.

This document explains these features.

2. Background of the Development[1)]

Currently, in Japan’s power system, power companies manage and supply power generated from large scale centralized power supplies to consumer terminal devices. By monitoring the voltage, frequency, and amount of power in the load dispatching center, the operating ratio in the power plant is controlled to match the supply and demand balance for power. Ever since the Tohoku Earthquake on March 11, 2011, the following issues have been pointed out for this type of power supply system. We were reminded that if an accident occurs in a large scale centralized power supply, the effects are widely felt and society can be thrown into chaos. Furthermore, the risks of nuclear power generation were seen as a problem, while the CO_2 emissions from thermal power generation also caused concerns. As a result, the expectations started to grow for clean energy from distributed power supplies using renewable energy. In this situation, power supply systems using distributed power supplies and located locally to consumers, as shown in Fig. 1, have received great attention.

However, when a large number of distributed power supplies using renewable energy are installed into an electrical system, concerns rise that they may have an adverse effect on commercial power. Renewable energy is greatly influenced by the natural environment, making it possibly difficult to maintain electrical quality due to output fluctuations caused by weather or accidents such as simultaneous loss of distributed power supplies.

To address these concerns, the need for “smart grids” has risen as they are efficient, non-wasteful systems that use batteries and IT to control the balance of supply and demand while consolidating the commercial power company and local area power supply systems[2), 3)].

With this in mind, Sanyo Denki proceeded with development of this smart grid management device based on the parallel processing UPS (P.P.UPS) “SANUPS E23A” [4)].

The new model manages generation and consumption of AC power networks (grids) in a local area, which is why Sanyo Denki refers to the new model as a “grid management device” .

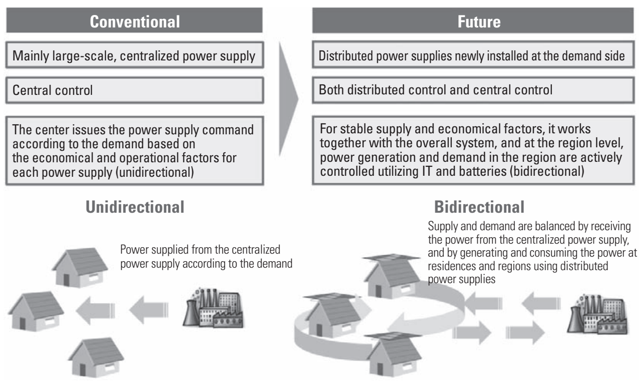

Fig. 1: Changes in the power infrastructure[2)]

3. Basic Architecture and Operation Concept

Fig. 2 shows the basic circuit architecture of the grid management device. The new model is composed of the ACSW, which is connected in series between the generating lines between the commercial power system and the power-consuming equipment; the battery through the bi-directional inverter connected in parallel to the commercial power system; and the distributed power supply connected to the output of the device. The grid management device can control the distributed power supply and the supply of power to local area power consumption, including buildings and factories.

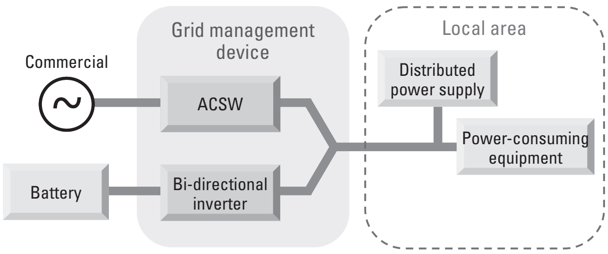

Fig 2: Basic circuit architecture of grid management device

The grid management device primarily operates in one of two operating modes: utility connected system mode or standalone mode. When there is an abnormality in the commercial utilities, the local area and commercial utilities are disconnected without momentary power breaks, and the device will run in backup mode supplying power to the power-consuming equipment.

Utility connected system mode is the mode in which the grid management device operates with the commercial utilities connected as shown in Fig.3. Power generation fluctuations in the distributed power supply and consumption fluctuations in the power-consuming equipment may occur in the local area, and supply and demand fluctuates as a result.

In this mode, by connecting with commercial utilities, the supply and demand fluctuations in the local area are suppressed by the commercial power supply and the battery. Furthermore, by using the commercial power supply, the amount of charge and discharge of the battery can be controlled and the battery can be made smaller. In this way, two types of power supplies—commercial utilities and batteries—allow the supply and demand balance in the local area and between the commercial utilities and the local area to be controlled.

Isolated operation mode is the mode in which the local area and commercial supply are disconnected as shown in Fig.4, and the grid management device performs isolated operation in the local area. This mode balances supply and demand in the local area only with the battery, so a larger battery is needed compared to utility connected system mode. However, by making the battery larger, the local area can maintain operations independent from the commercial power system for a longer period of time, making it effective for emergencies such as natural disasters.

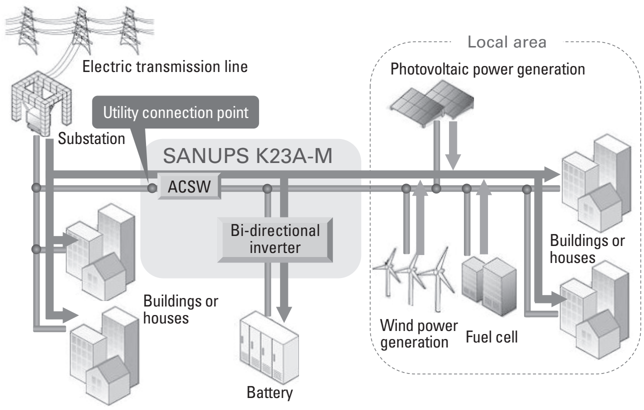

Fig. 3: Utility connected system mode

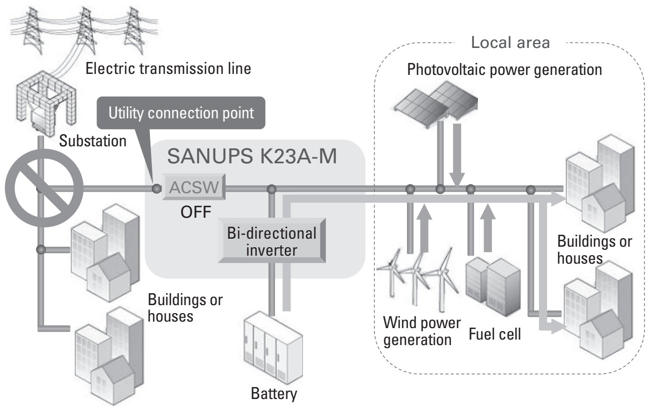

Fig. 4: Isolated operation mode

4. Basic Operating Mode

Fig. 5 shows the transitions between operating modes.

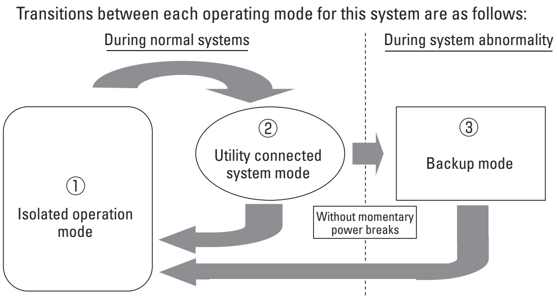

Fig. 5: Transition of operating modes

The following are the details about the device operating modes.

4.1 Utility connected system mode

In utility connected system mode, maximum received power from the commercial utilities is set and then the grid management device operates within the received electric power setting. This setting can suppress peaks of received electric power from the commercial utilities, and it is therefore called the peak cut setting.

The peak cut setting can be set by time. By setting the peak cut value to correspond with electrical consumption time frames outside of the local area, the received electric power from outside the local area can be scheduled, which can contribute to load leveling on the entire commercial utility system. Furthermore, since the peak cut value can be set by time frame, there is no need to set excessive peak cut values, which reduces the load on the batteries.

The following indicates the operating patterns for utility connected system mode.

4.1.1 Power generated from distributed power supplies is less than power consumption

When the power generated from the distributed power supply is less than the power consumption in the local area, one of the following three patterns occur.

(1) Insufficient local area power is less than or equal to the peak-cut setting

Fig. 6 shows the power supply status of the grid management device when the insufficient power in the local area (calculated as the power consumption minus the power generated from the distributed power supply) is less than or equal to the peak-cut setting value. In this state, the insufficient power in the local area is supplied from the commercial utilities and power is supplied to the power-consuming equipment from the distributed power supply and the commercial utilities. At this time, the battery does not discharge.

(2) Insufficient local area power is greater than the peak-cut setting

Fig. 7 shows the power supply status of the grid management device when the insufficient power in the local area is greater than the peak-cut setting value. In this state, power is supplied to the power-consuming equipment from the distributed power supply, commercial utilities, and battery. Part of the insufficient power in the local area is supplied from the commercial utilities, but the amount of power received from the commercial utilites is determined by the peak-cut setting that is set depending on the local usage status, such as power consumption and power-generating patterns of the distributed power supply. At this time, the remaining insufficient power in the local area is supplied by discharging the battery. When the battery reaches the minimum usage voltage, one of the following two patterns can be chosen: the grid management device automatically recharges the battery until it reaches battery capacity, or stops the inverter and does not charge the battery until charge is performed with the distributed power supply. When the battery reaches the minimum usage voltage, one of these two patterns will run depending on the use and application.

(3) Charging the battery

By setting the charge start time beforehand, the battery can be charged automatically at the set time. Fig. 8 shows the power supply status at this time.

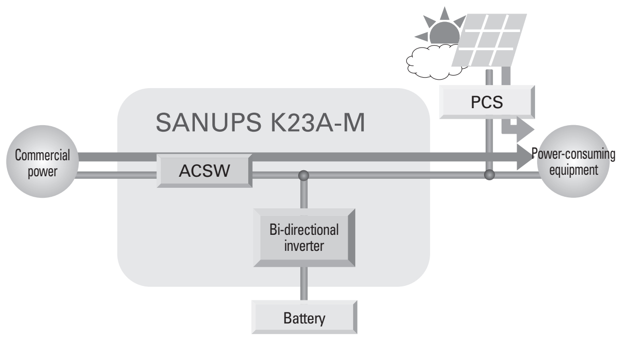

Fig. 6: Insufficient local area power is less than or equal to the peak-cut setting

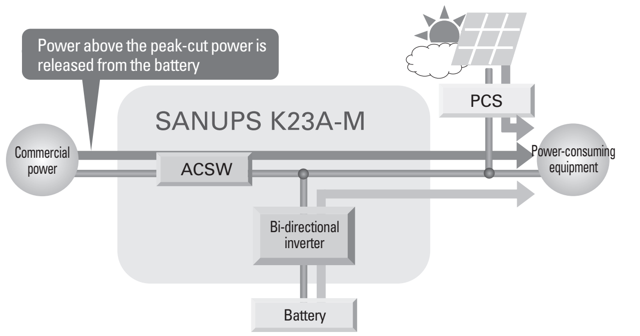

Fig. 7: Insufficient local area power is greater than the peak-cut setting

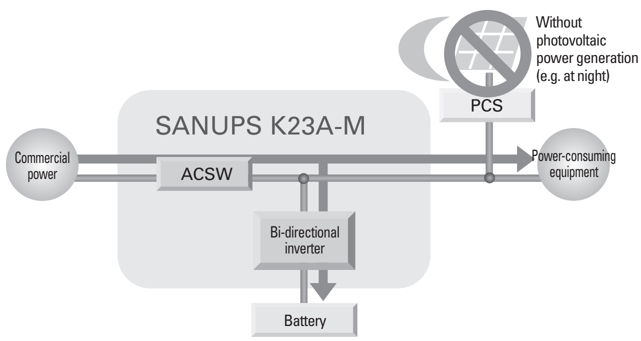

Fig. 8: Charging with commercial utilities

4.1.2 Power generated from distributed power supplies is greater than power consumption

Fig. 9 shows the power supply status of the grid management device when the amount of power generated from the distributed power supply is greater than the power consumption in the local area.

In this state, the power to the power-consuming equipment is supplied from the distributed power supply and the excess power not consumed by the power-consuming equipment is used to charge the battery. When the battery reaches the maximum usage voltage, one of the following two patterns can be chosen: the grid management device stops the inverter and feeds the excess power to the utility through a reverse power flow, or stops the distributed power supply. When the battery reaches the maximum usage voltage, one of these two patterns will run depending on the use and application.

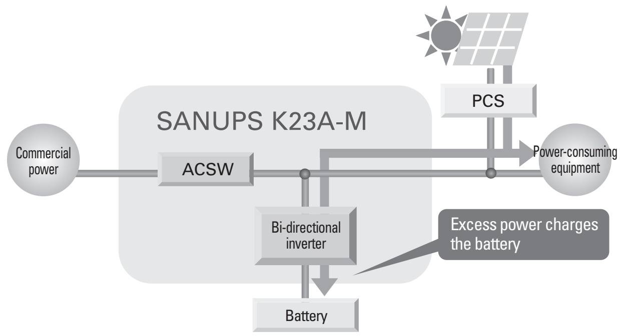

Fig. 9: Charging with a distributed power supply

4.2 Isolated operation mode

When a command to turn off the ACSW is received from an external input during utility connected system mode, the ACSW is turned off without momentary power breaks, the commercial utilities and local area are disconnected, and the device runs in isolated operation mode. In this mode, the grid management device is completely independent from the commercial utilities, so the device can operate without depending on the commercial utilities and power can be maintained in the local area even if there is a disaster affecting the commercial utilities. Therefore, this mode is also an effective operation mode for business continuity plans.

Fig. 10 shows the power supply status in isolated operation mode.

4.2.1 Power generated from distributed power supplies is less than power consumption

When the power generated from the distributed power supply is less than the power consumption in the local area, power is supplied to the power-consuming equipment from the distributed power supply and the battery.

During a long power outage, such as during a disaster, if the battery reaches minimum usage voltage in a situation where power generation from the distributed power supply cannot be anticipated, the grid management device stops the inverter and enters standby to minimize power loss.

In this state, if power generation from the distributed power supply becomes predictable again, an external signal causes the grid management device to restart the inverter and, using the power from the distributed power supply, the battery is charged and power is supplied to the power-consuming equipment.

4.2.2 Power generated from distributed power supplies is greater than power consumption

When the power generated from the distributed power supply is greater than the power consumption in the local area, power is supplied from the distributed power supply to the power-consuming equipment directly and the excess power not consumed by the power-consuming equipment is used to charge the battery. When the battery reaches the maximum usage voltage, the grid management device stops the distributed power supply.

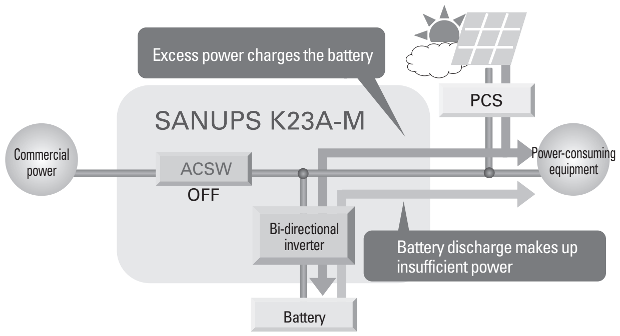

Fig. 10: Isolated operation mode

4.3 Backup mode

If an abnormality in the commercial utility occurs during utility connected system mode, then as described in Section 4.2, the ACSW is turned off without momentary power breaks, the commercial utilities and local area are disconnected, and the device switches to isolated operation mode.

5. Features and operation example

The following summarizes features of the device with an operation example.

5.1 Features

5.1.1 Peak power suppression

By setting peak-cut values for different time periods in a day, the received power peaks from the commercial utilities can be suppressed. Furthermore, by charging the battery using excess power from the distributed power supply or nighttime power from the commercial utilities and discharging the battery during periods with high power consumption, the received power can be equalized throughout a day.

5.1.2 Scheduled charging

This function is primarily used to set a time period to charge the battery using power from the commercial utilities. The batteries are automatically charged during the set time.

5.1.3 Peak shift

By charging the battery during periods of low power consumption using the scheduled charging function described in 5.1.2, and by discharging the battery during periods of high power consumption as described in 5.1.1, the peak power from the commercial utilities is suppressed to enable power peak shifting.

5.1.4 Maintaining power quality for commercial utilities

Power generation fluctuations in the distributed power supply and consumption fluctuations in the power-consuming equipment can be balanced by charging and discharging the battery, so the commercial utilities are not affected. Therefore, concerns about commercial power instabilities caused by bringing in large amounts of renewable energy can be eliminated.

5.1.5 Isolated operation function

The ACSW can be turned off at any time with an external signal, so the commercial utilities and local area are disconnected and isolated operations can be performed. During isolated operations, the device can continuously operate using only the distributed power supply and battery, making it extremely effective as a disaster prevention power supply during disasters.

5.1.6 Emergency startup

During a long power outage, such as during a disaster, if the battery reaches minimum usage voltage in a situation where power generation from the distributed power supply is low, the grid management device stops the inverter and enters standby to minimize power loss. In this state, if power generation from the distributed power supply becomes predictable again, an external signal causes the grid management device to restart the inverter and, using the power from the distributed power supply, the battery is charged and power is supplied to the power-consuming equipment.

5.1.7 No-break transfer

When there is an abnormality in the commercial utilities, by turning off the ACSW without momentary power breaks, the commercial utilities and local area are disconnected, and power can continue being supplied to the power-consuming equipment. Furthermore, after the commercial utilities recover from the abnormality, the device automatically transitions to utility connected system mode.

5.2 Operation example

Fig. 11 shows an example of device operations and the power changes during one day when the peak received power is suppressed during the day.

During the night, when there is low power consumption, the battery is charged using the scheduled charging function. By setting the peak-cut value and limiting received power from the commercial utilities during operations, the peak power can be suppressed during the day and the power used during one day can be equalized. Furthermore, contract power costs can be reduced.

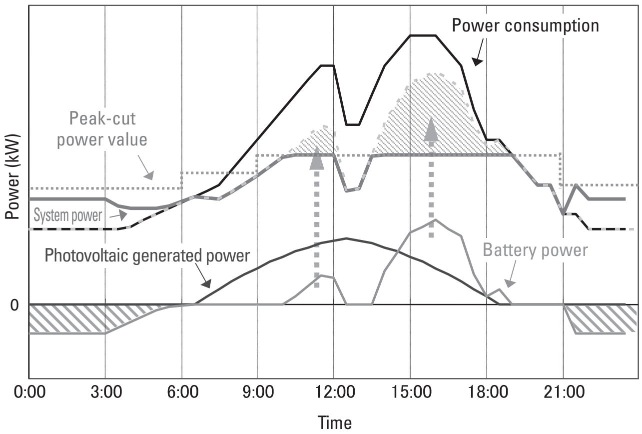

Fig. 11: Operation example

6. Overview of Specifications

Table 1 shows the standard specifications. Furthermore, Fig. 12 shows the appearance of the developed "SANUPS K23A (M Type)" with a rated output capacity of 20 kW.

The lineup includes 20 kW, 50 kW, and 100 kW models, and the target is building and energy management systems. Furthermore, there is an optional I/O board with a built-in power meter that can be used to observe information such as input, output, and power used by the battery.

A lithium ion battery comes standard to realize high-current charge and discharge and long-term use.

Table 1: Standard specifications

Item	Model	K23A203M	K23A503M	K23A104M
Rated output capacity		20 kW	50 kW	100 kW
AC input	**No. of phases/wires**	Three phase, three wire		
	Rated voltage	200 V AC		
	Rated frequency	50/60 Hz		
AC output	**No. of phases/wires**	Three phase, three wire		
	Rated voltage	200 V AC		
	Voltage precision	Within ±2% (during battery operations)		
	Rated frequency	50/60 Hz		
	Frequency precision	Within ±0.1% (during battery operations)		
	Load power factor	1.0 Fluctuation range: 0.7 to 1.0 (lag)		
Equipment dimensions/mass (W x D x H)		500×700×1400 240 kg	500×700×1650 350 kg	750×800×1825 600 kg

Fig. 12: Appearance of
"SANUPS K23A (M Type)" 20 kW

7. Conclusion

This document introduced the product overview of the "SANUPS K23A (M Type)" , a device that can balance, control, and effectively use renewable energy through a distributed power supply and power from commercial utilities.

We expect that this model will contribute to a smart grid society and we think that it will open up a new power infrastructure market.

The grid management device was based on collaborative research about microgrids between Aichi Institute of Technology and NTT Facilities during 2006 to 2010. We sincerely thank the many people involved for their advice and support.

Documentation

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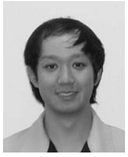

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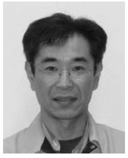

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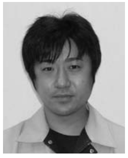

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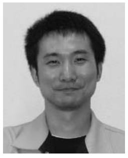

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