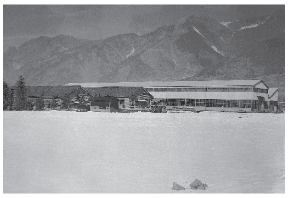
SANYO DENKI

Technical Report

Feature | Technologies Offering Value in New Fields

1944
Ueda Kita Works (Former Midorigaoka Works)

44
November
2017



COLUMN

Cover image:

Ueda Kita Works (Former Midorigaoka Works)

1944

Sanyo Shokai Special Electric Works (later Tokyo Works), established in June 1932, had continuously expanded its production capacity, eventually stretching it to the limit. This led to the decision to construct a new factory in a suburban region. Therefore, we acquired the land in the northern part of Ueda, Nagano Prefecture, and established "Ueda Kita Works" (later Midorigaoka Works) in February 1944.

However, as the war intensified, it grew increasingly difficult to acquire raw materials. Beginning with simply finding lumber, we overcame many hardships and managed to build a new factory.

Immediately after its completion, the factory started operations as an exclusive factory for the Army Aviation Headquarters. We primarily manufactured power converters for aircraft radios and engine starter generators.

At the time, we mainly produced small-sized power supplies, but after the war, shifted to larger power products including 500 VA to 5 kVA generators for ship radio power units. As those demands continued to grow, by the 1950s, our company was widely known in the radio device industry as a manufacturer with top-level technology.

Midorigaoka Works was decommissioned following the completion of Kangawa Works in 2009. However, the technologies that have supported the development of our company live on at Kangawa Works.

44 November 2017
SANYO DENKI TECHNICAL REPORT

C O N T E N T S

Toshihiko Baba
Major Operating Officer

Technologies Offering Value in New Fields

How wonderful it would be if customers around the world appreciated us and thought "I'm so happy I chose a SANYO DENKI product"!

With this feedback from our customers as our driving force, SANYO DENKI is pushing forward globalization of our businesses.

In our 8th Mid-term Management Plan, we have established the goal of "making SANYO DENKI a top brand in the world." Under that goal, we are engaged in an initiative "specialists in change" as well as the abovementioned "globalization."

Why "Specialists in Change"?

The environment that surrounds us is constantly changing. If we take action after a change has already occurred, that action will be too late and we will be swept away by the wave of change. We must seize the initiative by always anticipating and preparing for changes so we can act when necessary. In fact, it is important that we become the ones that make change rather than waiting for it.

Here, let's think about the feature theme of this report "Technologies Offering Value in New Fields."

"New fields" refers to fields expected to grow in the future. We need to be alert to the changes taking place in the world in order to identify the fields expected to grow. Moreover, by sensing the seeds of these changes, then nurturing those seeds ourselves, we become the ones that make the change happen.

Next I will introduce examples of the "new fields" SANYO DENKI is involved in by each business category.

In the Cooling Systems Division, we are expanding the sale of our products to the "multi-purpose non-cooling market."

Previously, most of the fans designed and manufactured by our Cooling Systems Division were embedded in our customers' devices and used for the purpose of cooling heat-generating areas. A typical example is a fan that cools the CPU inside a computer.

In addition to fans designed for cooling purposes, we are now targeting markets where fans are used for ventilation purposes. A recent example is the adoption of SANYO DENKI fans for household ventilation in Europe. This is the perfect example of penetrating a new field.

For the Power Systems Division, SANYO DENKI was one of the first companies to enter the PV inverter field supporting photovoltaic energy, which is gathering a lot of attention as a renewable energy source. Not stopping at this, we also expanded to PV inverter fields for wind power generation and hydroelectric power generation applications.

The Servo Systems Division has been providing the servo motors used in industrial robots since the 1980s. In recent years, robots have begun being used in fields closely related to human beings. A typical example is robots for nursing care applications. Our servo system products were some of the earliest to be adopted in robots for nursing care.

Our three brands *San Ace*, *SANUPS*, and *SANMOTION* all produce energy converting devices. Reducing the loss of each product, in other words, improving conversion efficiency, is a major theme we are constantly pursuing. We believe that the feature theme of this report "Technologies Offering Value in New Fields" should be discussed from the perspective of improving conversion efficiency.

Moreover, in addition to technologies that improve the conversion efficiency of equipment, key sub-themes of "Technologies Offering Value in New Fields" are "people-friendly equipment" and "connected equipment."

A straightforward example of "people-friendly equipment" is the aforementioned robot used in nursing care. We will continue providing the world with more equipment which users truly find easy to use.

As for "connected equipment," IoT technology is a good example, and is attracting a large amount of attention from people the world over.

SANYO DENKI wishes to equip its products with this IoT technology so we can constantly offer our customers and society at large the joy (value) of such products.

This completes my brief introduction to "Technologies Offering Value in New Fields."

SANYO DENKI is pushing forward with initiatives to work with our customers across the globe in solving their issues and helping their products become number one in the industry. Through this initiative, we will continue corporate activities that bring joy to our customers worldwide.

Cooling Systems Division Technologies Offering Value in New Fields

Satoshi Fujimaki

1. Introduction

New products sold in various fields worldwide always come equipped with many new functions with their performance greatly improved. With that in mind, to offer our customers the fans they need now and in the future, SANYO DENKI proactively listens to our customers' requests and problems, while providing technical support, so that we may develop new technologies and products which fulfill customers' needs.

While such technologies and products enjoy demand from typical applications such as ICT equipment, industrial equipment, industrial inverters, and measuring devices, they can also offer value to new applications and new fields.

This article will introduce our achievement in terms of technologies offering value in new fields, using the following recent products as examples: the Reversible Flow Fan that can blow air in both directions, the Airflow Tester to measure the operating airflow and system impedance of equipment, the PWM Controller for controlling the speed of PWM control function fans, and the G Proof Fan that can withstand high levels of G-force.

2. Reversible Flow Fan

The Reversible Flow Fan is designed mainly for use in non-cooling applications. Its unique characteristic is that it can blow air in two switchable directions with equivalent airflow and power consumption performance in both directions. As this product mainly targets the household ventilation market, the new models have circular shape with 136 mm and 92 mm diameters unlike normal square-shaped axial fans in order to match the common size of household ventilation ducts.

Technical Report No. 40 and No. 42 already introduced the first generation ø136 mm sized Reversible Flow Fan, therefore this article will focus on the technology newly adopted in the next-generation ø92 mm model.

For the ø136 mm model, equivalent performance had been achieved in airflow vs. static pressure characteristics and power consumption for both directions. However, there was a sound pressure level (SPL) difference of more than 10 dB(A), which needed to be improved. In order to improve the SPL of the newly-developed ø92 mm model, we incorporated new technology in the blade shape. A concrete explanation is provided below.

Considering its particular application, the aim of the Reversible Flow Fan is to blow air in both forward and reverse directions, therefore there is a need for the airflow vs. static pressure characteristics and SPL to be equal in both airflow directions.

The shape and mounting angle of the blades significantly change the airflow vs. static pressure characteristics as well as impact SPL and power consumption. SPL tends to increase particularly in the reverse airflow direction due to the spokes supporting the motor on the air suction side.

To minimize SPL, the surface area of the blades was increased and the shape designed to optimize pressure distribution on the blade's surface so that the necessary airflow could be obtained without increasing fan speed.

Figure 1 shows an example of pressure distribution on the surface of a blade in the Reversible Flow Fan obtained by performing fluid analysis. Figure 2 is an external view of the blade.

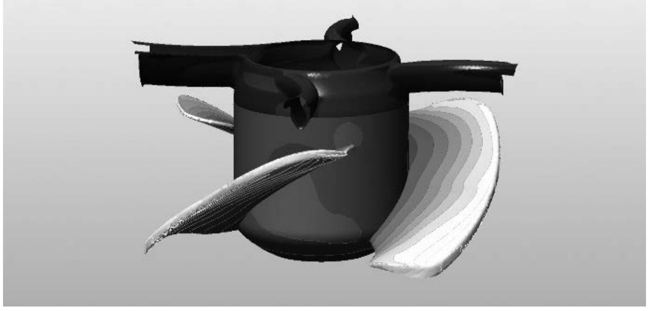


Fig. 1: Example of pressure distribution on the blade surface using fluid analysis

Fig. 2: Blades

By adopting a SANYO DENKI-original shape for the blades, we were able to achieve surface distribution with only moderate pressure change and reduce flow separation. As a result, the airflow vs. static pressure characteristics is equal for the forward and reverse directions and there is minimal difference in SPL.

This technology has reduced the SPL difference between forward and reverse directions from 11 dB(A) of the ø136 model to 4 dB(A) of the ø92 model.

Hence, this technology has proved effective for the Reversible Flow Fan.

3. Airflow Tester

One important element in thermal design is selecting the optimal fan for a device. It requires, however, to know the system impedance and operating airflow of the device. Measurement of these allow you to easily identify the fan's operating point, and select a fan with consideration to the equipment's cooling margin, fan SPL, power consumption, etc.

A measuring instrument known as a "double chamber measuring device" can accurately measure the system impedance of a device. However, they are extremely expensive, large, and require installation, making them difficult to relocate once installed.

Due to this, the majority of users opt to use anemometers and simulations rather than the double chamber measuring device for the thermal design process and select fans accordingly. However, because anemometers and simulations have poor accuracy compared to double chamber measuring devices, thermal design and verification required a great deal of time and effort.

To help solve these problems, SANYO DENKI developed the *San Ace Airflow Tester* to easily measure system impedance and operating airflow and offer value in new fields. The Airflow Tester is a portable measuring device that uses the highly accurate double chamber method.

Figure 3 is an external view of the Airflow Tester.

Fig. 3: Airflow Tester

At L600 mm × H250 mm × W250 mm and 6 kg, the Airflow Tester can be carried and used by a single person.

To make it lighter, the main body of the Airflow Tester is made of high-performance plastics for high strength. Moreover, through strength and fluid analyses, we were able to design a lightweight shape that maintains strength. Finally, by integrating the power source, control components, sensors and other necessary components to the main body of the tester, we have achieved a compact product.

Our measurement method is adapted from the highly-accurate double chamber method as per JIS-B-8330. Due to the nature of the highly accurate double chamber method, there is a need to change the size of the nozzle depending on the airflow being measured. For this reason, multiple nozzles are necessary. However, rather than fixing these nozzles directly to the Airflow Tester's main body, we have made them interchangeable to keep the tester's size to a minimum.

Because the Airflow Tester is small, light, and portable, measurements can be taken easily without moving from the location where the equipment is installed. We have also prepared a special-purpose duct which is mounted to the exhaust port to make measurements more convenient.

Figure 4 shows an example of how the Airflow Tester is connected to equipment.

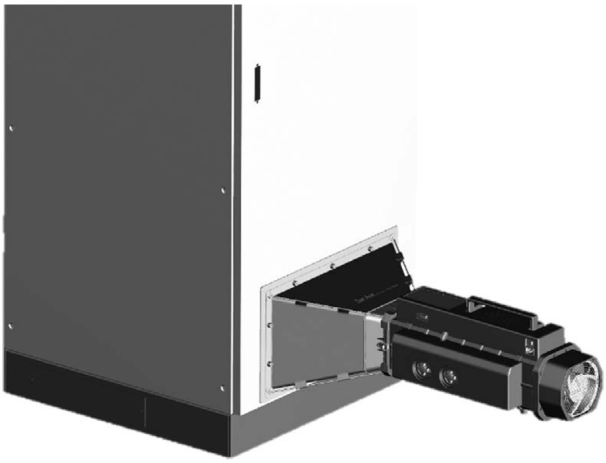


Fig. 4: Example of how an Airflow Tester is connected to equipment

Fig. 5: Box type

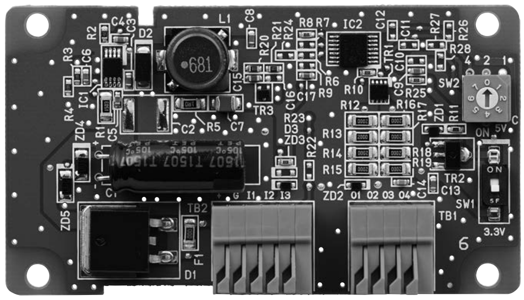


Fig. 6: PCB type

In this way, the Airflow Tester developed using new technology is having a significant impact not only in terms of equipment thermal design, but also in regard to fan selection in new fields such as ventilation.

For details on this product, please read SANYO DENKI Technical Report No. 42 (2016)

"Development of the *San Ace Airflow Tester* - A Measuring Device for System Impedance and Operating Airflow of Equipment."

4. PWM Controller

Many fans in the market use PWM control function to control a fan's airflow and rotational speed. This type of fan controls rotational speed using a PWM signal.

To do this, one must prepare a special-purpose control circuit but this requires specialist knowledge.

For this reason, SANYO DENKI developed and released the *San Ace PWM Controller* in 2016 which can be used together with the PWM controller-inclusive fan as a set.

This product is a standard controller that enables you to easily utilize PWM control function fans without special knowledge.

This product can share a DC power source with the PWM control function fans it is connected to. For this reason, we designed new control circuits and achieved a wide-operating voltage range from 7 to 60 VDC, making it compatible with all the SANYO DENKI fan's standard rated voltages 12 V, 24 V and 48 V.

This product is available in two types to suit our customers' specific application. These are the "box type", shown in Figure 5, and the "PCB type", shown in Figure 6.

For use in a variety of applications, the box type comes with functions to control the PWM signal through four types of inputs: voltage, variable resistor, thermistor, and the adjustment knob on the box. The four control functions are installed in the controller in advance, therefore by switching the control functions and input circuits with the selector switch enable it to output a PWM signal linked to each individual input. Below listed are the four types of control functions.

1) Voltage control:
   This function converts the voltage signal (0 to 5 V) from the customer to PWM output duty signal to control fan speed.
2) Variable resistor control:
   This function controls PWM output duty signal with externally-connected variable resistor.
3) Thermistor control:
   The PWM duty signal is automatically controlled by preset temperature (30 to 50°C) and the detected temperature with an external thermistor.
4) Adjustment knob control
   The PWM output duty signal is controlled by the adjustment knob on the box.

In regard to the PCB type, three models have been produced featuring one of the functions mentioned in 1) through 3) above.

The right *San Ace PWM Controller* to suit the particular application can be used, making it a user-friendly product.

SANYO DENKI is confident that this is an extremely effective solution for customers in a variety of fields that cannot easily design and fabricate controllers.

5. G Proof Fan

Inside CT scanners for medical use, the part which irradiates X-rays into the human body rotates at high speed. For this reason, the fan used to cool this portion is subjected to high levels of G-force.

CT scanners for medical use are expected to have even higher performance in the future, therefore fans that can operate in environments with even higher G-force will be needed.

In order to meet such requirements of the medical industry, SANYO DENKI has developed and commercialized *San Ace 120GP* and *San Ace 172GP* 9GP type G Proof Fans.

Figure 7 is an external view of the G Proof Fan.

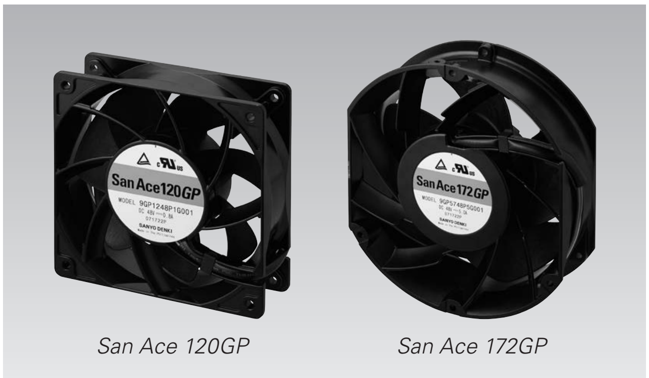


Fig. 7: G Proof Fan

By considering actual operating environment to extract problems when using a fan in environments with G-force and performing strength analysis using simulations, we have successfully produced a fan able to withstand G-force of up to 75G.

Each structures of this fan have been strengthened to withstand the target level of G-force.

An aluminum frame has been adopted. In order to improve the strength of rotating bodies (rotor, blade assembly, etc.), we have achieved a G-force tolerance of 75G by adopting a new structural design whereby each component is fixed, as well as adopted new material and shape.

For details, please read the article on this product in this Technical Report.

6. Conclusion

This article has introduced initiatives related to technologies offering value in new fields using the products developed by SANYO DENKI as examples.

We firmly believe we must continue to swiftly and accurately ascertain our customers' issues and requests, and constantly pursue fan technologies required by our customers. Then, leveraging these technologies, we will engage in the development of products offering value in new fields so that we may, together with our customers, provide products that make dreams come true.

References

(1) Toshiya Nishizawa and 3 others:
"ø136 mm × 28 mm Thick Reversible Flow Fan *San Ace 136RF* 9RF Type"
SANYO DENKI Technical Report No. 40 (2015)

(2) Katsumichi Ishihara and 4 others:
"Development of the *San Ace Airflow Tester*
– A Measuring Device for System Impedance and Operating Airflow of Equipment"
SANYO DENKI Technical Report No. 42 (2016)

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High Performance Blower *San Ace B97* 9BMC Type

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Koji Ono Hiromitsu Kuribayashi

1. Introduction

Thanks to its compact design and high static pressure, the 97 × 33 mm blower is used for air supply in printers and A/C units, as well as for cooling in servers and power sources. Its versatility allows it to be used in a wide range of markets and applications, including office equipment, industrial devices, and household appliances.

SANYO DENKI has developed and released the 97 × 33 mm blower *San Ace B97* 9BMB type (hereinafter "current model"). However, as its applications have become more compact while improving performance, blowers are also expected to increase performance.

In response, SANYO DENKI newly developed and released the 97 × 33 mm blower *San Ace B97* 9BMC type (hereinafter "new model") which achieves the highest cooling performance in the industry*.

This paper provides a detailed introduction of this new product.

2. Product Features

Figure 1 shows an external view of the new model.

Fig. 1: 97 × 33 mm
San Ace B97 9BMC type

The features of the new model are as follows:

(1) High static pressure
(2) High airflow
(3) PWM control function

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new model.

The new model has the same mounting dimensions as the current model, therefore compatibility is maintained.

3.2 Specifications

3.2.1 General specifications

Table 1 shows the general specifications.

3.2.2 Airflow vs. static pressure characteristics

Figure 3 shows the airflow vs. static pressure characteristics for the new model.

3.2.3 PWM control function

Figure 4 shows an example of the airflow vs. static pressure characteristics for different values of PWM duty cycle. The new model has a PWM control function that enables external control of fan speed.

By controlling the fan's speed to suit the device's heat generation state rather than operating it at full speed constantly, both the overall device power consumption and noise can be reduced. Therefore, the demand for fans with a PWM speed control function has increased significantly in recent years.

3.3 Expected life

The new model has a expected life of 40,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage in a free air state and at normal humidity).

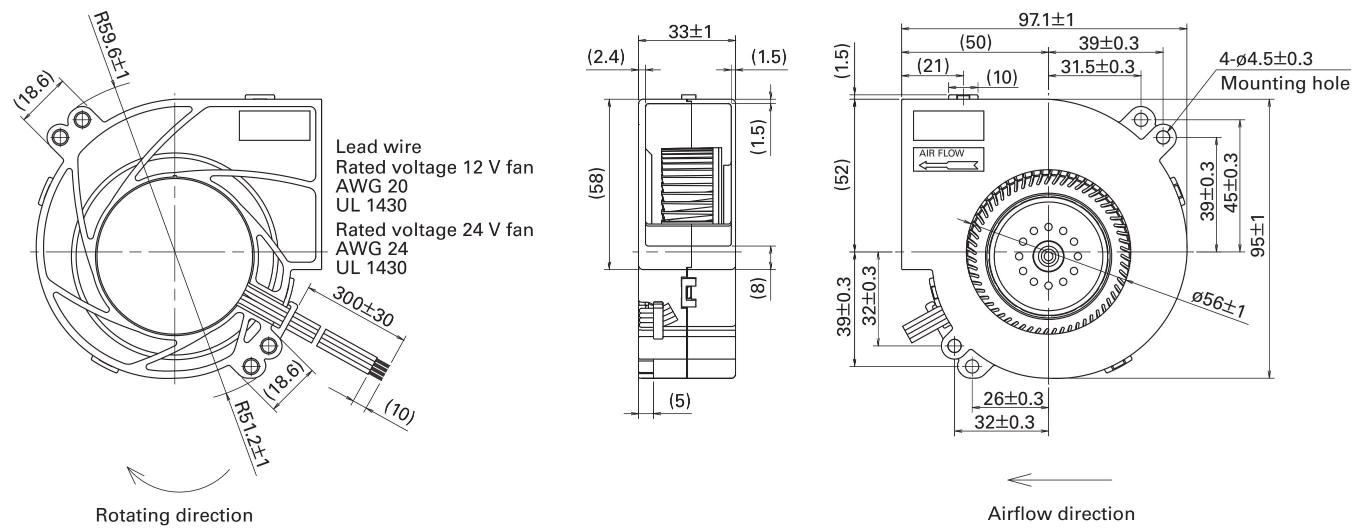


Fig. 2: Dimensions of the new model (unit: mm)

Table 1: General characteristics of the *San Ace B97* 9BMC type

Model No.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle Note 1,2 [%]	Rated current [A]	Rated Input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	SPL [dB (A)]	Operating temperature [°C]	Expected life [h]
9BMC12P2G001	12	10.8 to 13.2	100	6.2	74.4	8,200	1.85	65.3	1,950	7.83	69	-20 to +70	40,000 at 60°C (70,000 at 40°C)
			20	0.38	4.56	2,800	0.58	20.4	121.0	0.48	44		
9BMC24P2G001	24	21.6 to 26.4	100	3.1	74.4	8,200	1.85	65.3	1,950	7.83	69		
			20	0.19	4.56	2,800	0.58	20.4	121.0	0.48	44		

Note 1. Input PWM frequency: 25 kHz
Note 2. Speed is 0 min^{-1} at 0% PWM duty cycle

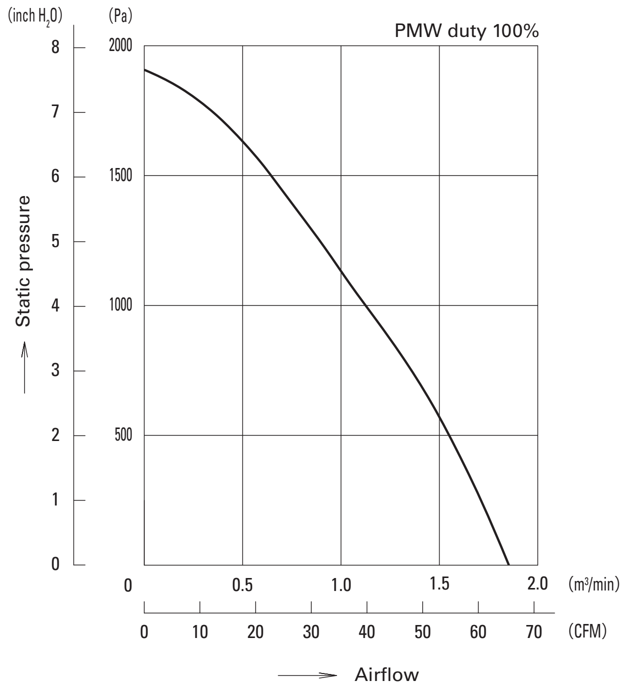


Fig. 3: Airflow vs. static pressure characteristics of new model

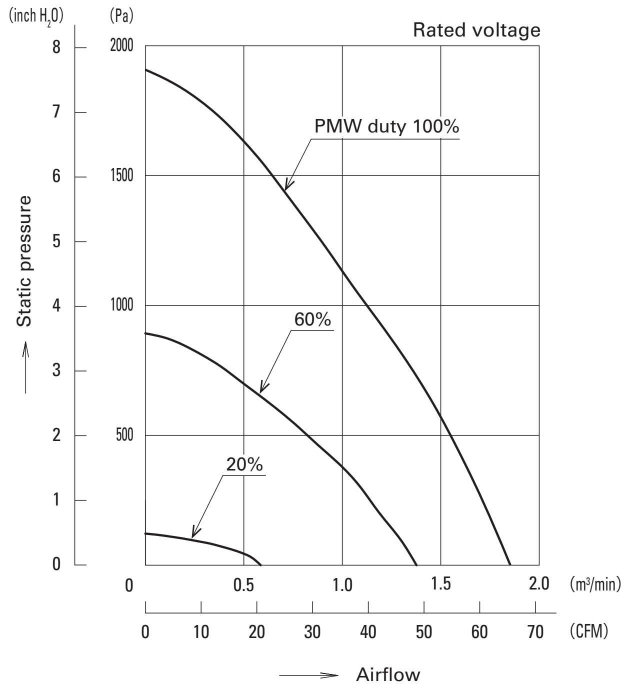


Fig. 4: Example of the airflow vs. static pressure characteristics for different values of PWM duty cycle.

4. Key Points of Development

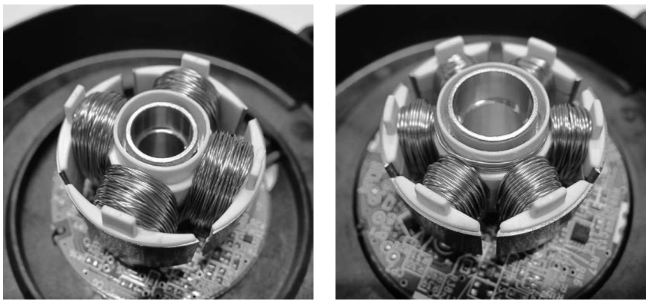
The new model achieves high static pressure and high airflow by adopting a large 3-phase motor and a newly-designed impeller, and higher rotational speed compared to the current model.

The key points of development are explained as follows.

4.1 Motor design

When rotational speed is increased, the motor generates more heat. In other words, in order to increase rotational speed, the motor must have high efficiency to minimize its heat generation. The current model adopts a 4-slot, single-phase motor; however, the new model adopts a higher-efficiency, large 6-slot, 3-phase motor to keep heat generation to a minimum and enable higher rotational speed.

Figure 5 shows the motor portion of the current model and new model.



Current model　　New model

Fig. 5: Motor of the current model and new model

4.2 Impeller design

A high static pressure can be obtained by increasing blower rotational speed. However, higher rotational speed also results in increased sound pressure level (SPL). We engineered the shape of the bottom of the impeller to facilitate smoother airflow. As a result, we achieved higher rotational speed while suppressing the increase in SPL as much as possible.

Moreover, to achieve high-speed rotation, we had to improve the rigidity of the impeller to withstand centrifugal force at high rotation. By creatively designing the shape of the guide at the top of the impeller, we have increased rigidity and made impeller diameter even wider. We used a 3D printer during design verification and repeatedly measured the model to find the optimal blade shape and achieve high static pressure and high airflow.

Figure 6 shows the shape of the impeller for both the new and current models.

Current model　　New model

Fig. 6: Impeller shape of current model and new model

5. Comparison with the Current Model

The newly designed impeller and large 3-phase motor of the new model result in higher rotational speed and significantly improved static pressure and airflow over the current model.

The following is a comparison of the characteristics of the new and current models.

5.1 Comparison of airflow vs. static pressure characteristics

Figure 7 gives a comparison of the airflow vs. static pressure characteristics for the new model 9BMC12P2G001 and 9BMB12P2K01, a current model of the same size. Both the static pressure and airflow have been significantly increased, with maximum static pressure 1.5 times greater and maximum airflow 1.15 times greater.

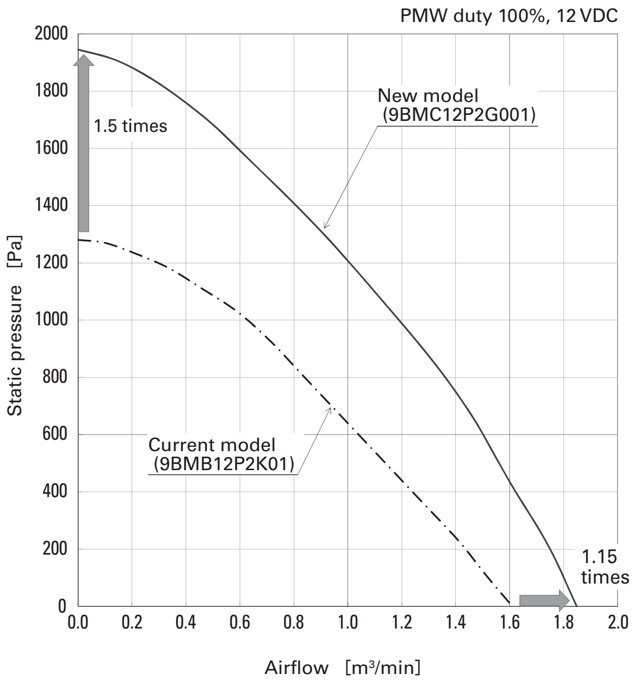


Fig. 7: Airflow vs. static pressure characteristics

5.2 Comparison at assumed system impedance

Figure 8 shows a comparison of the "airflow vs. static pressure and SPL characteristics" of the new model 9BMC12P2G001 and current model 9BMB12P2K01 as well as the assumed system impedance curve. System impedance indicates the aerodynamic load specific to a piece of equipment. Therefore, the point where the system impedance curve and airflow vs. static pressure characteristic curve intersect indicates the operating point of the blower used in the target equipment. The new model achieves higher rotational speed with high static pressure and high airflow. As such, the new model has an SPL of 69 dB(A) in a free air state which is 3 dB(A) higher than the current model's SPL of 66 dB(A).

However, the difference in SPL becomes even smaller depending on the system impedance of the equipment on which the blower is used. Figure 9 shows the airflow at the operating point of the assumed system impedance shown in Figure. 8.

At the operating point with this assumed system impedance, the SPL of the current model and the new model was the same at 66 dB(A); however, the operating airflow of the current model is 1.18 m^3/min compared to 1.45 m^3/min of the new model. The new model achieves 23% higher airflow than the current model while maintaining the same SPL.

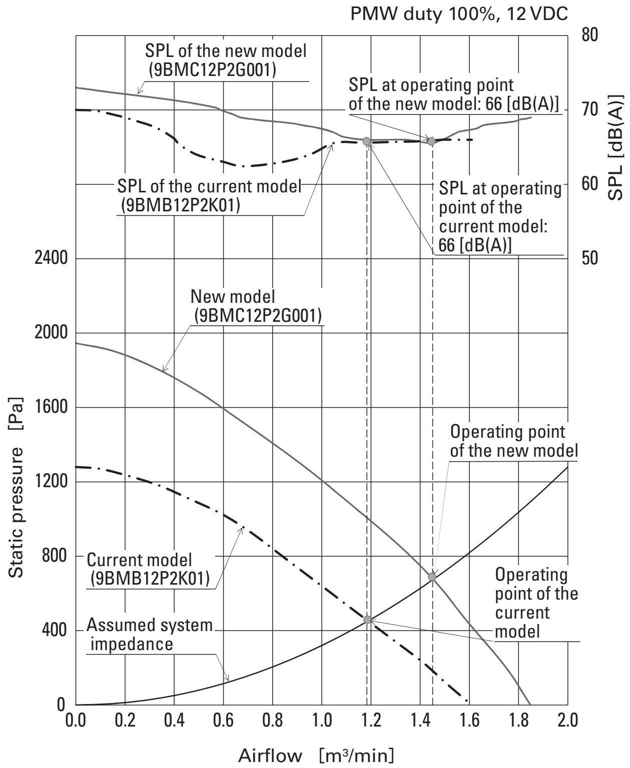


Fig. 8: Airflow vs. static pressure vs. SPL characteristics example

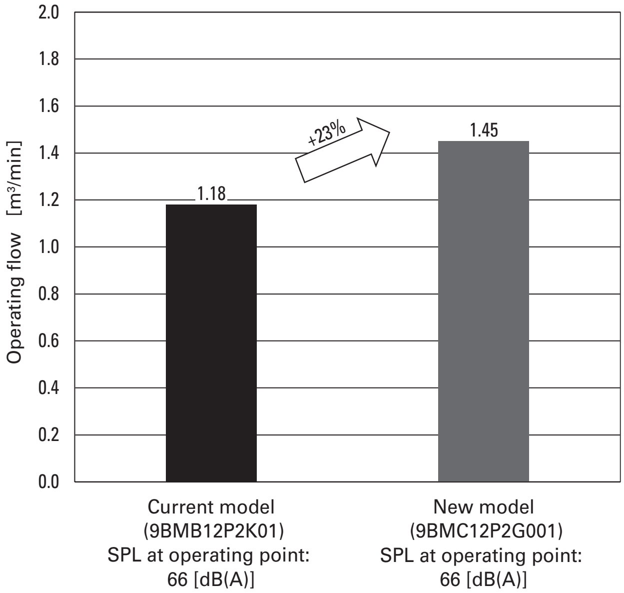


Fig. 9: Comparison of operating flow at the operating point with the assumed system impedance

6. Conclusion

This article has presented some of the features and performance of the high performance 97 × 33 mm blower *San Ace B97* 9BMC type developed by SANYO DENKI.

The new model has increased rotational speed and achieves significantly higher static pressure and higher airflow than the current model by adopting a large 3-phase motor and a newly-designed impeller.

The 97 × 33 mm blower has been used in a variety of applications thanks to its compact design and high static pressure performance, making it ideal for cooling and air supply applications in small spaces. By achieving even higher static pressure and airflow on the new model, SANYO DENKI offers new value for existing equipment, such as high performance and space efficiency. We also believe this product can offer value for equipment in new fields.

* As of May 25, 2017. Compared with blowers of equivalent size. Investigated by SANYO DENKI.

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G Proof Fans *San Ace 120GP* and *San Ace 172GP*

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1. Introduction

In recent years, there has been a growing demand for fans able to be used in environments subjected to centrifugal acceleration, commonly known as G-force. One example is the fan used for cooling the interior of medical CT scanners.

Medical CT scanners have a high-speed rotating gantry that scans the human body. For this reason, the fan that cools the gantry is subjected to high levels of G-force. It is believed that medical CT scanners will offer even higher performance and higher reliability, leading to greater demand for fans that can be used in environments with higher levels of G-force.

To meet such demands in the medical industry market, SANYO DENKI developed and produced the *San Ace 120GP* and *San Ace 172GP* 9GP type G Proof Fans (hereinafter, “new product”).

This article will introduce the features and performance of the new model.

Fig. 1: 120 × 120 × 38 mm G Proof Fan
San Ace 120GP 9GP type

Fig. 2: ø172 × 150 × 51 mm G Proof Fan
San Ace 172GP 9GP type

2. Product Features

The features of the new product are:

(1) Ability to withstand G-forces of 75 G
(2) Low power consumption
(3) PWM speed control function

Figures 1 and 2 show external views of the new product.

3. Outline of the New Product

3.1 Dimensions

Figures 3 and 4 show the dimensions of the new products.

The fan’s external dimensions and mounting hole dimensions are compatible with our existing product.

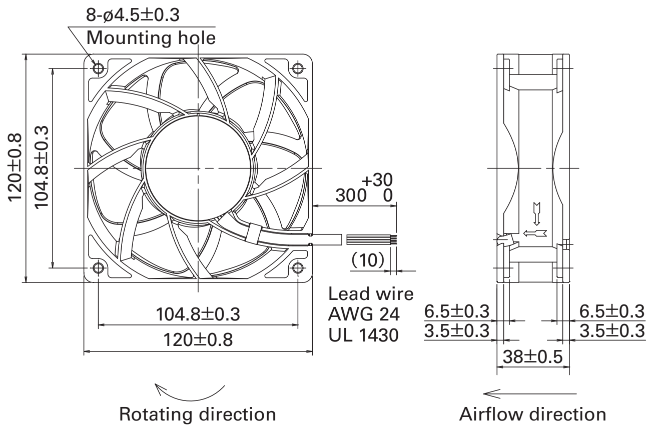


Fig. 3: Dimensions of the 120 × 120 × 38 mm *San Ace 120GP* (unit: mm)

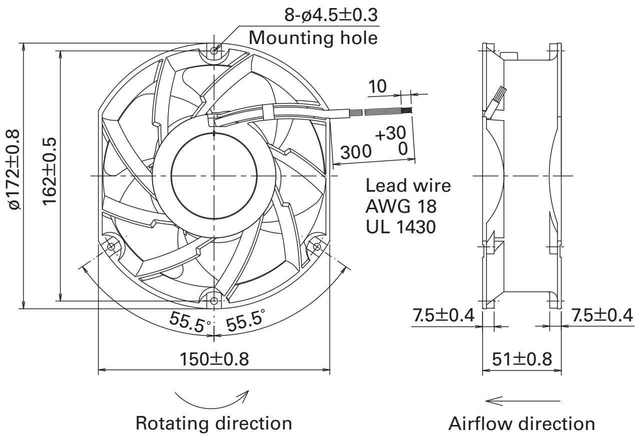


Fig. 4: Dimensions of the ø172 × 150 × 51 mm *San Ace 172GP* (unit: mm)

3.2 Specifications

3.2.1 General specifications

Tables 1 and 2 show the general specifications for the new product.

Table 1: General specifications of the 120 × 120 × 38 mm *San Ace 120GP*

Model No.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow		Max. static pressure		SPL [dB (A)]	Operating temperature range [°C]	Expected life [h]	Level of G-force tolerance [G]
							[m^3/min]	[CFM]	[Pa]	[inchH$_2$O]				
9GP1224P1G001	24	15 to 30	100	1.60	38.40	6,550	7.00	247.1	370	1.48	62	-20 to +70	40,000 at 60°C	75
			20	0.12	2.88	2,000	2.13	75.2	34.4	0.13	36			
9GP1248P1G001	48	36 to 60	100	0.80	38.40	6,550	7.00	247.1	370	1.48	62			
			20	0.08	3.84	2,000	2.13	75.2	34.4	0.13	36			

Note: Speed is 0 min^{-1} at 0% PWM duty cycle

* Input PWM frequency: 25 kHz

Table 2: General specifications of the ø172 × 150 × 51 mm *San Ace 172GP*

Model No.	Rated voltage [V]	Operating voltage [V]	PWM duty cycle [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow		Max. static pressure		SPL [dB(A)]	Operating temperature range [°C]	Expected life [h]	Level of G-force tolerance [G]
							[m^3/min]	[CFM]	[Pa]	[inchH$_2$O]				
9GP5724P5H001	24	16 to 30	100	5.0	120	8,000	12.3	434	1,000	4.02	77	-20 to +70	40,000 at 60°C	75
			20	0.5	12.0	3,000	4.6	162	175	0.70	51			
9GP5748P5G001	48	36 to 72	100	5.0	240	10,500	16.1	568	1,600	6.43	83			
			20	0.41	19.7	3,700	5.6	198	250	1.01	57			

Note: Speed is 0 min^{-1} at 0% PWM duty cycle

* Input PWM frequency: 25 kHz

3.2.2 Highly resistant to G-forces

The new product is able to withstand G-forces of up to 75 G (at normal temperature, normal humidity, continuous operation).

3.2.3 Airflow vs. static pressure characteristics

Figures 5 and 6 show the airflow vs. static pressure characteristics for the new product.

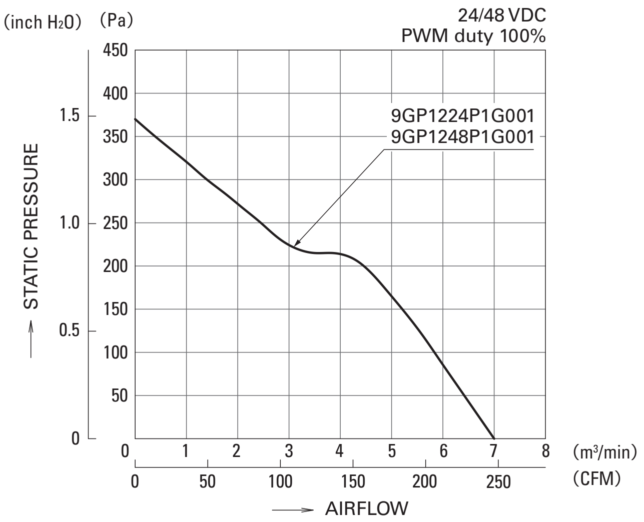


Fig. 5: Airflow vs. static pressure characteristics of the 120 × 120 × 38 mm *San Ace 120GP*

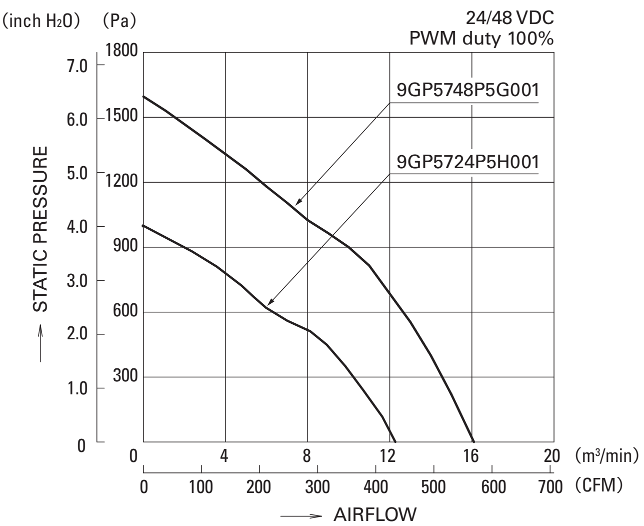


Fig. 6: Example of the ø172 × 150 × 51 mm *San Ace 172GP* airflow vs. static pressure characteristics

3.2.4 PWM control function

The new product is equipped with the PWM control function that enables external control of fan speed, contributing to lower sound pressure level (SPL) and lower power consumption.

3.3 Expected life

The new product has an expected life of 40,000 hours at 60°C (survival rate of 90%, when run continuously at rated voltage in free air and at normal humidity).

4. Key Points of Development

In order to develop a product never before seen on the market, we needed to consider how it is actually used. As such, we identified the issues that occur when a fan is used in an environment with high G-force. We also conducted strength analysis using simulation and investigated a new structure. By adopting this new structure based on the analysis results, we successfully produced a fan able to withstand G-forces of up to 75 G.

The key points of development are explained below.

4.1 CT scanner application example

Medical CT scanners create cross-sectional images of the body using an X-ray source and detectors that rotate around the patient. Multiple fans are used to cool the detectors.

Currently, there is a demand to shorten the scan time of CT scanners, therefore efforts are being made to increase rotational speed. As such, a fan able to withstand the high levels of G-force that accompany high-speed rotation is required.

Figure 7 illustrates how the new product can be used in a medical CT scanner.

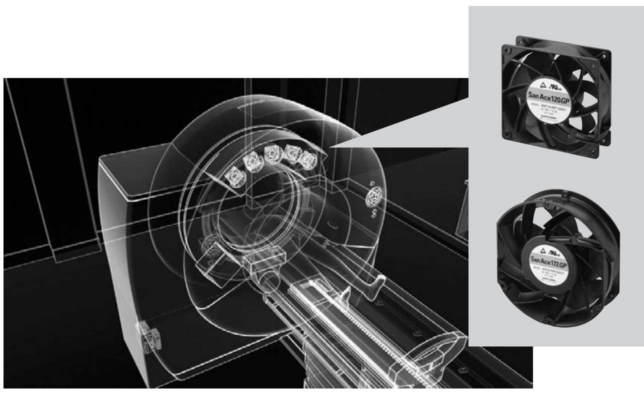


Fig. 7: Example of a fan being used in a medical CT scanner

4.2 Ability to withstand G-forces

The ideal product is one that could be used in multiple mounting directions to suit various operating environments. For this reason, we developed a fan that can operate normally even when subjected to G-forces of 75 G from the X, Y or Z axial directions.

Figure 8 shows the directions of G-force able to be withstood by the fan.

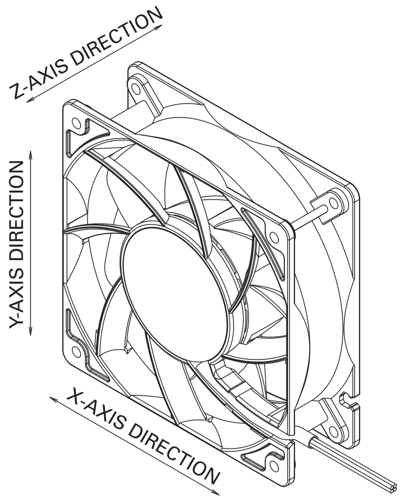


Fig. 8: Withstandable G-force directions

4.3 Impeller design

To develop a fan able to tolerate G-forces as high as 75 G, we had to create an impeller structure that could withstand a high load. As such, we employed a structure that integrated the blades and rotor cover. By increasing joint strength, the impeller can withstand a high load.

Figure 9 shows an external view of the new product's impeller.

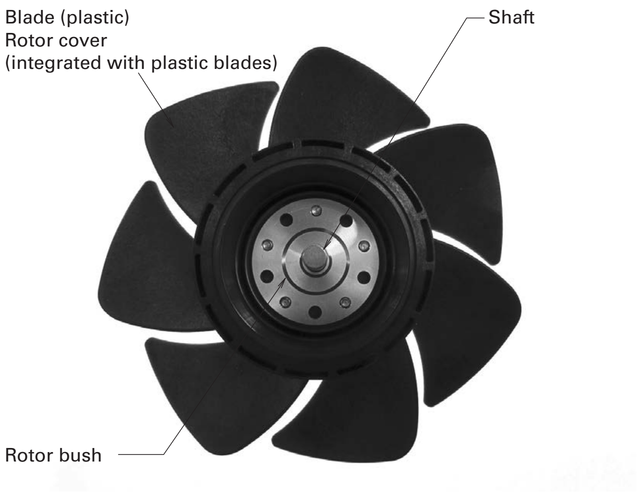


Fig. 9: Impeller of the new product

4.4 Frame design

The frame must have high rigidity, so we used an aluminum frame. Moreover, using simulation, we identified where strength needed to be improved and increased strength without sacrificing fan performance, thus ensuring the fan's ability to withstand stress when under a load.

4.5. Structural design

For structural design, first we identified the problems that arise in environments subjected to G-force, then conducted simulation analysis to pinpoint where strength needed to be improved. Through this, we improved rigidity by selectively increasing strength.

Below is an overview of the points that have been significantly improved compared with the existing structure.

(1) Improved rotor bushing rigidity

A rotor bushing is used to join the rotor cover and shaft. To increase rigidity and increase strength, we reviewed the rotor bushing material and fixing method.

(2) Bearing retention

Fans use bearings to secure rotating parts such as the rotor and impeller.

When a fan is subjected to G-force, its rotating parts are constantly subjected to an opposing force. In order to withstand this force, we designed a structure that secures the bearings to withstand a greater external force than the structure of the existing model.

5. Conclusion

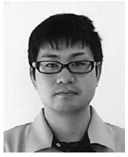
This article has presented some of the features and performance of the 120 × 120 × 38 mm *San Ace 120GP* and ø172 × 150 × 51 mm *San Ace 172GP* 9GP type G Proof Fans developed by SANYO DENKI.

Through adopting a new design with higher rigidity, the new product is capable of withstanding G-forces of up to 75 G and is the industry's first* product able to withstand G-forces.

We believe this product will not only contribute to cooling of medical devices such as CT scanners, which are increasing in performance and subjecting fans to G-force, but also contribute to the development of new markets.

SANYO DENKI wishes to continue developing products for all kinds of environments and markets, as well as products that contribute to the creation of new value, so that we may provide products that make dreams come true together with our customers.

* Based on our own research as of August 25, 2017, among equally sized axial DC cooling fans on the market.



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Power Source-Related Technologies Offering Value in New Fields

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1. Introduction

The Paris Agreement was adopted at COP21 in 2015 as a groundbreaking initiative seeking efforts to reduce greenhouse gases by all major greenhouse gas-producing nations including the U.S. and China, and to establish their own targets, and conduct mutual reviews on a global level.

Japan established the target of reducing greenhouse gas emissions by the year 2030 by 26% compared to the 2013 level. This was verified to be an extremely high target from the global comparison indicator of cost required for such reduction by individual countries announced afterwards.

Meanwhile, following the Great East Japan Earthquake, Japan's energy self-sufficiency rate fell from 20% to 6%, its dependence on fossil fuels climbed from 62% to 88% and electricity prices rose by around 20% for households and around 30% for industrial. The increasing cost of energy procurement is a major issue impacting the ability of the manufacturing industry to maintain its competitiveness. To advance energy conservation while raising the economic growth rate, we must engage in fresh initiatives for overall energy management using AI, IoT (Internet of Things), and related new services and products as well as developing technological innovations for next-generation power semiconductors, hydrogen utilization, and storage batteries. SANYO DENKI must promote product development with these new fields in mind.

This article introduces initiatives by the Power Systems Division relating to UPS and renewable energy products that can offer value in new fields.

2. Development of *SANUPS N11B-Li*: Power Supply Technology for Fields Seeking Environmental Durability

Until recently, small-capacity UPSs (uninterruptible power supply) with an output capacity of 5 kVA or less were primarily used in indoor equipment such as backup for servers and ICT devices or for embedding in industrial devices. In recent years, due to the recent spread of mobile devices and lessons learned from natural disasters, use as backup power for outdoor equipment has emerged as a new field for small-capacity UPSs, such as cellular base stations, parking meters, outdoor surveillance cameras, traffic lights, and emergency equipment.

UPSs used for these outdoor equipment must have a wider operating temperature range due to environmental requirements. Moreover, since regular inspections and replacement cannot be easily carried out for UPSs of this use, UPSs for outdoor use must be maintenance-free. Furthermore, social infrastructure equipment such as traffic lights and equipment used during disasters such as emergency wireless systems are required to have longer power failure backup time due to lessons learned from previous natural disasters.

Also, because UPSs used outdoor often have only limited installation space available, they must be compact as well as provide prolonged backup. Conventional lead-acid batteries can provide a relatively short backup time per battery volume and mass, so a large installation space is necessary to achieve prolonged backup. Moreover, deterioration of lead-acid batteries is severe at high and low temperatures, therefore the battery must be replaced after only short periods of outdoor use.

To solve these issues, we developed the *SANUPS N11B-Li* series that uses a Li-ion battery (hereinafter "LIB") with superior energy density and service life. This UPS also has a power conversion unit that generates minimal heat, and a housing for outdoor use.

Compared to conventional lead-acid batteries, LIB offers the benefits of prolonged backup in smaller installation space and eliminated battery replacement reduces maintenance work. Moreover, by creatively mounting UPS components, improving the performance of its cooling system, and by adopting LIB with high temperature resistance, the *SANUPS N11B-Li* series has achieved a wide operating range between -20 and +50°C. Also, thanks to its stainless steel IP65 housing, it can be used outdoors even in harsh environments.

As a power backup technology, the *SANUPS N11B-Li* series is anticipated to be used in high-growth sectors such as outdoor ICT equipment, traffic lights, and disaster-prevention equipment.

Fig. 1: *SANUPS N11B-Li*

3. Development of *SANUPS P73L*: Power Supply Technology for Fields which Effectively Utilize Renewable Energy

Power storage systems are anticipated to contribute to the realization of a low-carbon society and are a core technology of the smart grid. In recent years, competition has intensified due to market participation by Chinese and Korean manufacturers and venture companies mainly from the U.S., leading to a wide-range of storage battery types and applications. Also, the importance of storage batteries is growing in terms of both industry and everyday living. Amidst this, LIB is gathering a lot of attention for achieving high energy density and long service life, as well as being small and light compared with conventional lead-acid batteries.

Moreover, there is an increasing demand from local governments and private businesses considering installing backup power sources in preparation of prolonged power outages during disasters. Of the available systems, power generation systems combining PV panels and LIB are attracting interest due to their numerous advantages, such as the ability to generate renewable energy at point of use, act as an independent power source during disasters, and minimize power consumption during peak times.

By incorporating an LIB, SANYO DENKI responded to these market needs with the development of the *SANUPS P73L* PV inverter. Below is an overview of the product and its features.

The *SANUPS P73L* comprises of a 10 kW PV inverter unit, 10 kW charging unit, and I/O box. It is scalable up to six 10 kW PV inverters.

This product comes in the “grid-connected isolated charging type” and “grid-connected isolated type,” with output capacities ranging from 10 to 60 kW. This section will describe the “grid-connected isolated charging type” as a model that can be used as a storage battery system.

This model features a peak cut function wherein the power from the PV panels and storage batteries can be supplied to a general load. Also, it can supply AC power to a specific load even during power outages through isolated operation. Moreover, during isolated operation, the storage battery can absorb the power difference between the electricity supplied to the load and the power generated by the PV panel while the inverter unit performing tracking control to maximize the output of PV generation for effectively utilizing the PV-generated power.

In addition to these functions, the *SANUPS P73L* has achieved parallelization of isolated output, batch PV panel input, and automatic switchover to isolated operation, and can therefore be proposed as a flexible system to meet customer needs.

We expect that the technologies evolved during the development of *SANUPS P73L* will contribute to the effective utilization of renewable energy.

Fig. 2: *SANUPS P73L*

4. Development of Generation System Status Monitoring Service *SANUPS NET*: Information Transmission Technology for the IoT Field

In recent years, there has been an extremely high level of interest in IoT, or Internet of Things. SANYO DENKI's power management products adopted network communication technology over twenty years ago and have offered technologies to manage and monitor via a network. With the expanded utilization of networks, we have constantly continued to develop new communication methods and accumulated network communication technologies that serve as the foundation of IoT.

We have offered power monitoring products for use with backup products such as UPS, but they primarily assumed use in in-house LANs. The monitoring of these products aimed at power supply devices within the same in-house LAN.

Meanwhile, PV systems are installed outdoors, therefore many cases exist in which installation of a dedicated line as part of an in-house LAN is difficult. However, it has been demanded from generation system operators, who introduce PV systems for selling electricity, to centrally manage the data from multiple systems and monitor the operating status of PV systems from remote locations.

In order to satisfy this kind of demand, SANYO DENKI developed *SANUPS NET* as a PV system status monitoring service.

Figure 3 shows an example of system configuration for this service.

This service collects information on the PV inverter by using the *SANUPS PV Monitor* (hereinafter "PV Monitor"). The collected information is transmitted to an online cloud server, then customers can check this information using a smartphone or other Internet-connected devices, thus enabling remote monitoring of the PV system's status.

The cloud server uses SMTP, a standard email transmission protocol, to request various information from the PV Monitor (① in Fig. 3).

The PV Monitor uses POP3 protocol to verify request emails from the cloud server (② in Fig. 3) and, if there are any requests, uses SMTP to send the requested data to the cloud server (③ in Fig. 3).

The cloud server uses POP3 protocol to check if any emails containing information have been received from the PV Monitor and, if any, saves the information contained (④ in Fig. 3).

This communication method is secure as all the information transmission within the customer's network environment is conducted with the PV Monitor as the base point, meaning there is no direct access to the customer's network from outside. Moreover, security is assured also in that spam is blocked through SMTP authentication when sending emails.

By using this service, customers can safely monitor the power generation status and operating status of a PV system via a web browser from a remote location with a computer or smartphone as long as there is an Internet connection without the need to install any special software.

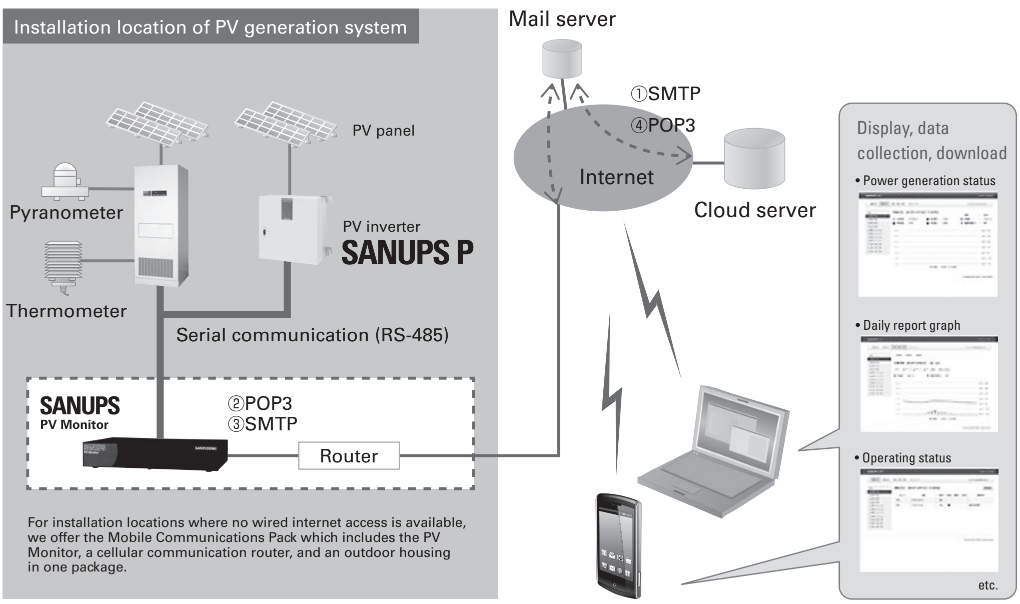

Fig. 3: System configuration

SANYO DENKI wishes to broaden the applicable scope of this service so that it can monitor not only PV systems, but all kinds of systems and provide a technology for the utilization of products for IoT.

5. Conclusion

This article has introduced the initiatives of the Power Systems Division which offer value in new fields of the power supply market.

SANYO DENKI will continue to seize upon new opportunities born from future market changes and exert every effort in developing technologies that offer new value.

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Developing Web Applications for Power Management Products

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1. Introduction

Power management products such as our *LAN Interface Card* have adopted technology for displaying settings via web browser by using “Java applet” technology. Java applets once had the benefit of being able to provide rich display features independent of the differences between browser specifications.

However, due to security reasons, the current trend is move away from Java applet and other such web application technologies. In response, as of August 2017, the only web browser that still employs Java applets is Internet Explorer.

Moreover, Java applet has been depreciated in version 9 of “Java” (hereinafter Java 9), released in September 2017, there is no longer a recommendation to use Java Applet.

It is against this backdrop that SANYO DENKI developed web applications for power management products using Java Web Start, a replacement technology of Java applet. This article will provide an overview of this new solution.

2. Overview of Power Management Products

Power management products is the collective term for optional products used in combination with our uninterruptible power supplies (hereinafter “UPS”) and PV inverters.

For example, by combining a UPS with a *LAN Interface Card*, it is possible to monitor the UPS status and automatically shut down computers during prolonged power outages. Moreover, a PV inverter combined with *SANUPS PV Monitor* lets users see and calculate the generated power volume and monitor the operational status of the PV inverter.

Configuring and checking the operational history of these products is done through a browser-based Web management tool. Also, the *LAN Interface Card* features a function for graphically displaying the operational status of a UPS on a web browser (hereinafter Web display tool).

Figure 1 is an external view of the *LAN Interface Card*, Fig. 2 shows the Web management tool screen, and Fig. 3 shows the Web display tool screen.

Fig. 1: *LAN Interface Card*

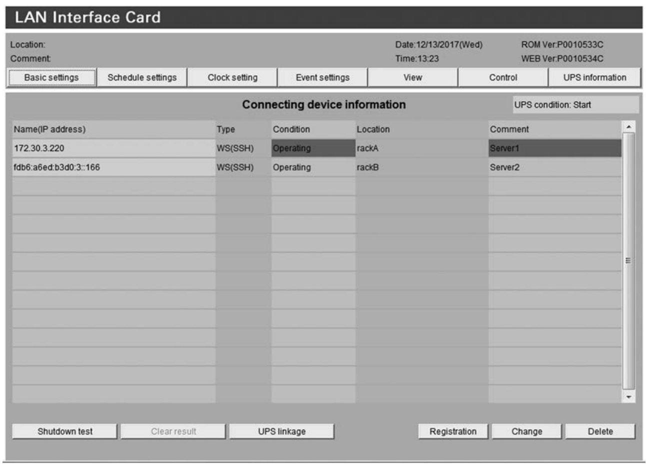


Fig. 2: Web management tool

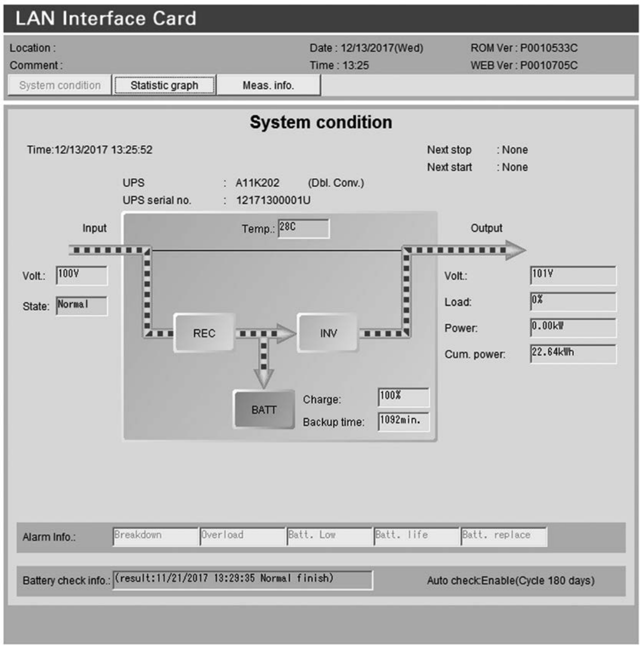


Fig. 3: Web display tool

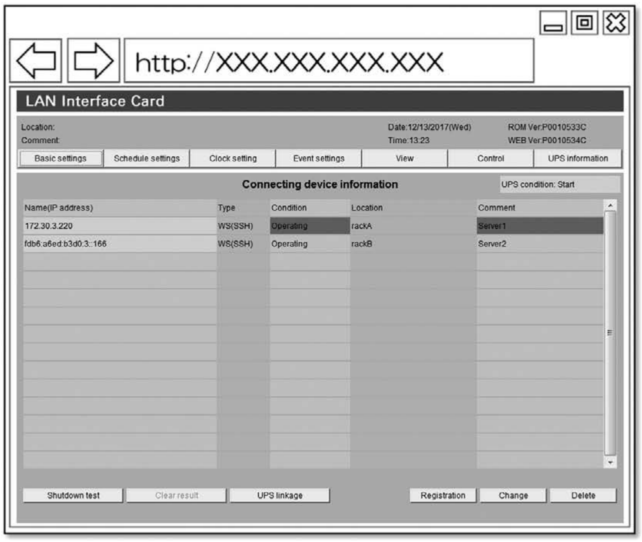
3. Overview of Java Web Start

As mentioned at the outset, it is becoming difficult to use applications that operate on web browsers.

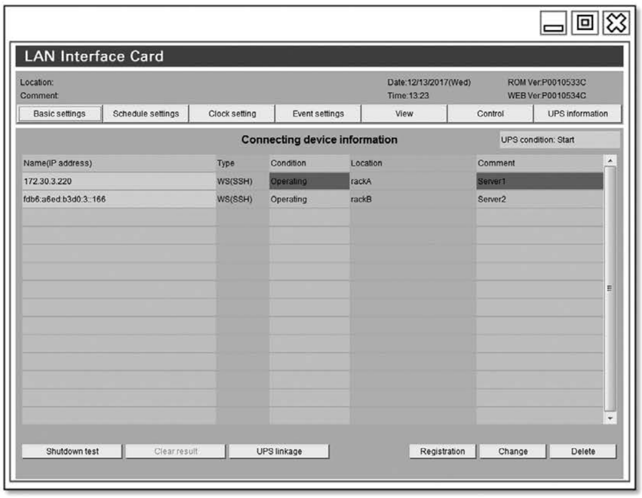
Java Web Start deals with this issue by running programs as application, whereas Java applet runs programs on a web browser. With this, it is possible to use the same Web management tool and Web display tool as with Java applet while maintaining cross-browser usability.

Moreover, as the screen layout has not changed, existing customers already familiar with SANYO DENKI's power management products and the tools can use Java Web Start applications with ease.

Figure 4 shows one image depicting the Web management tool via Java applet and another image via Java Web Start.



Java Applet
Screen is displayed on a web browser



Java Web Start
Web management or display tool is opened as one application

Fig. 4: The display images of Java Applet and Java Web Start

4. Features of Java Web Start

4.1 How to use the Web management tool and Web display tool

Below is the procedure for displaying the Web management tool of power management products equipped with Java Web Start. Figure 5 provides a diagram to accompany the procedure.

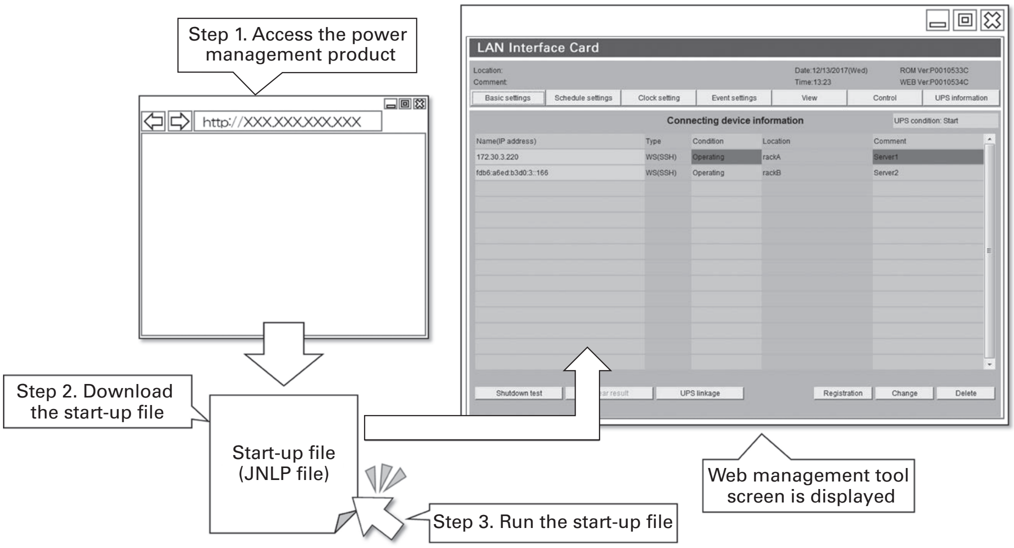


Fig. 5: Steps for displaying the Web management tool using Java Web Start

Step 1:	Access the power management product from a web browser
Step 2:	Download the Web management tool's start-up file (JNLP file)
Step 3:	Run the start-up file to launch the Web management tool

In Step 1, the user downloads a start-up file via web browser to launch the Web management tool in Java Web Start. Because no applications are executed in a web browser, it is also possible to launch the Web management tool on web browsers other than Internet Explorer (Google Chrome, Firefox, Microsoft Edge, etc.).

Save startup file downloaded in Step 2, then simply double-click the file to launch the Web management tool. There is no need to first open a web browser. Thanks to this feature, power management products can be used with greater simplicity, as there is no need to run a web browser to open the Web management tool.

These steps and features are the same for the Web display tool.

4.2 Continued support of Java applet

Just as before, the Web management tool and Web display tool can be launched via Java applet even for Java Web Start equipped products. This feature means customers who must use Java applet for operational purposes are also supported.

5. Products Targeted by This Development

Table 1 lists the power management products equipped with Java Web Start as a result of this development.

Table 1: List of power management products equipped with Java Web Start

Product name	Model number
LAN Interface Card (IPv6-compatible)	PRLANIF011, PRLANIF012, PRLANIF013, PRLANIF014, PRLANADP011, PRLANADP012, PRLANBOX011, PRLANBOX012
LAN Interface Card (not IPv6 compatible)	PRLANIF003, PRLANIF004, PRLANIF005, PRLANIF006, PRLANADP001, PRLANADP002, PRLANBOX001, PRLANBOX002
LAN Interface Card (100BASE-TX/10BASE-T-compatible)	PRLANIF001, PRLANIF002, PRE11A01, etc.
LAN Interface Card (10BASE-T only)	PRASC04C, PRASD01, PRASE03, etc.
SANUPS SOFTWARE Ver.3	PMS50B00, PMS51B00, etc.
SANUPS SOFTWARE Ver.2	PMS40H00, PMS41H00, etc.
SANUPS T11A/T11B	T11A152A001R, T11A202A002R, T11B152A001R, T11B402A002R, etc.
SANUPS MT15A/ MT15B	MT15AW03, MT15BW03, etc.
SANUPS IT Monitor	EV01W02
SANUPS PV Monitor Type C	PVMBC21
SANUPS PV Monitor E Model	PVMB011
SANUPS PV Monitor	PVMB001B
SANUPS Monitor K	SMON-K-001

As mentioned above, Java applet is no longer recommended for use as of Java 9. For this reason, we extended this development even to the products no longer available for sale so that our customers currently using our power management products can continue using them with confidence after Java 9's release.

If existing customers update their power management product's program, they will be able to use Java Web Start, and can continue using their product even after Java 9's release.

6. Specifications

Table 2 shows the software required to use Java Web Start for displaying the Web management tool and Web display tool.

Table 2: Required software

Software	Description
Java	Required to use Java Web Start. Version 7 or later.
Web browser	Required to download the start-up file. Compatible with web browsers such as Internet Explorer, Google Chrome, Firefox and Microsoft Edge. If Internet Explorer, must be Version 8 or later.

7. Conclusion

This article has provided an overview of SANY DENKI's development of web applications for power management products. As a result of this development, it is now possible to use Java Web Start on power management products, allowing our customers to use such products even after the release of Java 9.

Web technology is evolving daily. SANYO DENKI will continue moving forward with product development by quickly identifying changes and applying advanced technologies in our products.

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Development of the Small-Capacity UPS *SANUPS A11K-Li* and *SANUPS N11B-Li* Series

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1. Introduction

Conventionally, SANYO DENKI had offered small-capacity UPSs for indoor use as backup for servers and ICT equipment or in combination with industrial devices. In recent years, there has been an increased demand for the backup power for outdoor applications such as base stations, traffic lights, planned power outages, coin-operated parking lots, and surveillance cameras.

Assuming outdoor usage will involve exposure to harsh environments, requirements include a wide operating temperature range, securing installation space, extended backup, and low maintenance.

To date, small-capacity UPSs have used lead batteries; however, these have a limited operating temperature range, short runtime towards the end of their life cycle, and require replacing. Moreover, to achieve extended backup, more batteries are needed, which in turn requires more installation space.

By adopting Lithium-ion batteries (hereinafter "LIB"), UPSs can be used in a wider operating temperature range compared to conventional lead storage batteries. Other benefits include extended backup, space-saving, and no need for battery replacement, making the UPS low maintenance.

This article will provide an overview of our new UPS series *SANUPS A11K-Li* and *SANUPS N11B-Li* which are embedded with an LIB and correlated interface functions, and effectively utilize the large-capacity charging function of the current *SANUPS A11K* UPSs.

2. Product Overview

The *SANUPS A11K-Li* is an online UPS while the *SANUPS N11B-Li* is a standby UPS. Just as the current model, the *SANUPS A11K-Li* can be used as an indoor backup for servers and the like while the *SANUPS N11B-Li* can be used as backup for equipment installed outdoors.

2.1 The *SANUPS A11K-Li*

The *SANUPS A11K-Li* lineup includes models with output capacities of 1.5, 3, and 5 kVA.

Figure 1 shows the appearance of the *SANUPS A11K-Li* series.

Fig. 1: The *SANUPS A11K-Li* series

2.2 The *SANUPS N11B-Li*

The *SANUPS N11B-Li* lineup includes models with output capacities of 1 kVA and 1.5 kVA.

Figure 2 shows the appearance of the *SANUPS N11B-Li* series.

3. Features

3.1 Common features of the *SANUPS A11K-Li* and *SANUPS N11B-Li*

3.1.1 Wide operating temperature range

Due to the adoption of an LIB, both the *SANUPS A11K-Li* and *SANUPS N11B-Li* have wide operating temperature ranges (-20 to +55°C for the former and -20 to +55°C for the latter). This means these products can be used with confidence in extremely hot or cold environments.

3.1.2 Low maintenance

The current model required battery replacement approximately every five years, but by adopting LIB, the new model can be used for up to ten years without the need for battery replacement. This reduction in maintenance work means battery replacement cost can also be reduced.

3.1.3 Improved maintainability

Tasks such as battery replacement have been made easy through the modularization of the inverter. Figure 3 shows an image of the *SANUPS N11B-Li* equipped with an inverter module and battery modules.

All series models have a maintenance bypass circuit, therefore modules can be replaced without the need to interrupt power supply from a commercial power source.

3.1.4 Enhanced functionality

An LCD panel is used on the operation panel to improve user-friendliness and visibility.

Fig. 2: *SANUPS N11B-Li* series

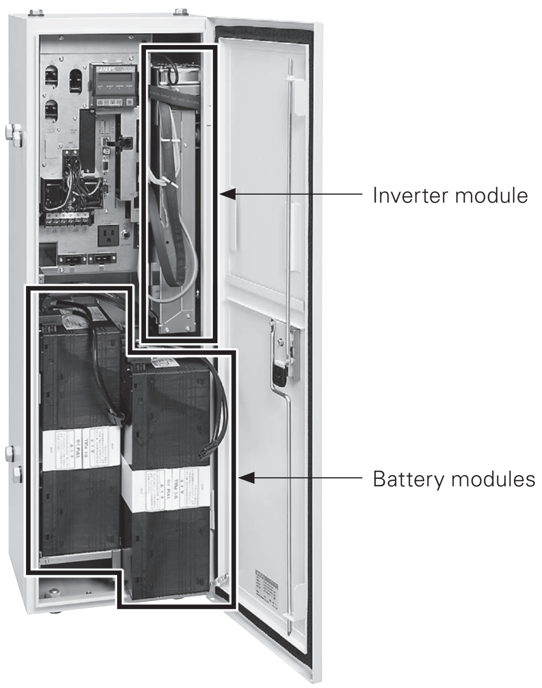

Fig. 3: Inverter module and battery modules
(the *SANUPS N11B-Li*, 1 kVA)

3.2. Features of the *SANUPS A11K-Li*

3.2.1 Space-saving

Compared to the current model, which uses a lead battery, the *SANUPS A11K-Li* can be installed in approximately half the space.

Note: If the initial backup time is equivalent

3.2.2 Wide input range

Just as the current model, the allowable input voltage range is wide: -20 to +20% at a load level above 70%, and -40 to +20% at a 70% load level or below.

This wide input range makes it possible to reduce the frequency of operation switchover to battery-feed operation even when the power source is unstable, as well as minimize battery wear and deterioration.

3.2.3 High power factor

As with the current model, the *SANUPS A11K-Li* has a load power factor of 0.8, therefore can also supply electricity to high power factor equipment such as servers.

3.3. Features of the *SANUPS N11B-Li*

3.3.1 Eco-efficient

With the passive standby topology, the *SANUPS N11B-Li* suppresses power consumption and achieves a conversion efficiency of 95%. This reduces running costs and contributes to energy-saving.

3.3.2 Outdoor installation

The *SANUPS N11B-Li* uses sealed housing. As such, it can be used as outdoor power backup for base stations, traffic lights, coin-operated parking lots, and so on.

3.3.3 Water resistance and protection against solid foreign objects

This device adopts a sealed structure, therefore has excellent water resistance and protection against solid foreign objects including small insects and animals. This means it can be used outdoors with peace of mind.

The *SANUPS N11B-Li* achieves a protection rating of IP65* in protection performance tests.

* Classifications defined in "JIS C 0920: Degrees of Protection Provided by Enclosures (IP Code)"
IP65: No ingress of dust. Devices operate stably even when directly exposed to water from many directions.

4. Circuit Configuration

Figure 4 shows the circuit diagram for the *SANUPS A11K-Li*.

Figure 5 shows the circuit diagram for the *SANUPS N11B-Li*.

The *SANUPS A11K-Li* comprises a "power source unit" consisting of a main circuit, control circuit, communication interface circuit, etc., and a "battery unit" consisting of a battery module, battery management unit (hereinafter BMU), and other components.

The *SANUPS N11B-Li* integrates an "inverter module" consisting of a main circuit and a control circuit, and an "I/O portion" consisting of a communication interface circuit, input/output circuit, and BMU, etc., and a battery module.

4.1 LIB monitoring circuit configuration

Equipped with a BMU, this product features a data interface between the UPS and LIB. By monitoring detailed LIB data, and having the UPS and LIB perform mutual protection operations and fault detections, the LIB can be used safely.

(1) UPS error detection

When an UPS error occurs, notification is sent from the UPS to the BMU via CAN communication. Once the BMU receives notification, it trips the battery breaker.

(2) LIB error detection

When an LIB error occurs, notification is sent from the BMU to the UPS via CAN communication. In response, the UPS stops the charger's output. Moreover, as soon as the BMU detects an LIB error, it trips the battery breaker.

(3) Monitoring LIB cell voltage and cell temperature

Cell voltage and temperature are measured in the battery module and the BMU is notified of the measurement values through CAN communication. If the cell becomes over-charged, over-discharged, or reaches an abnormal temperature, the BMU determines that an LIB error has occurred and, as mentioned in section (2) above, trips the battery breaker and separates the UPS from the LIB.

Users can check the measured values for cell voltage, cell temperature, and state of charge on the LCD panel.

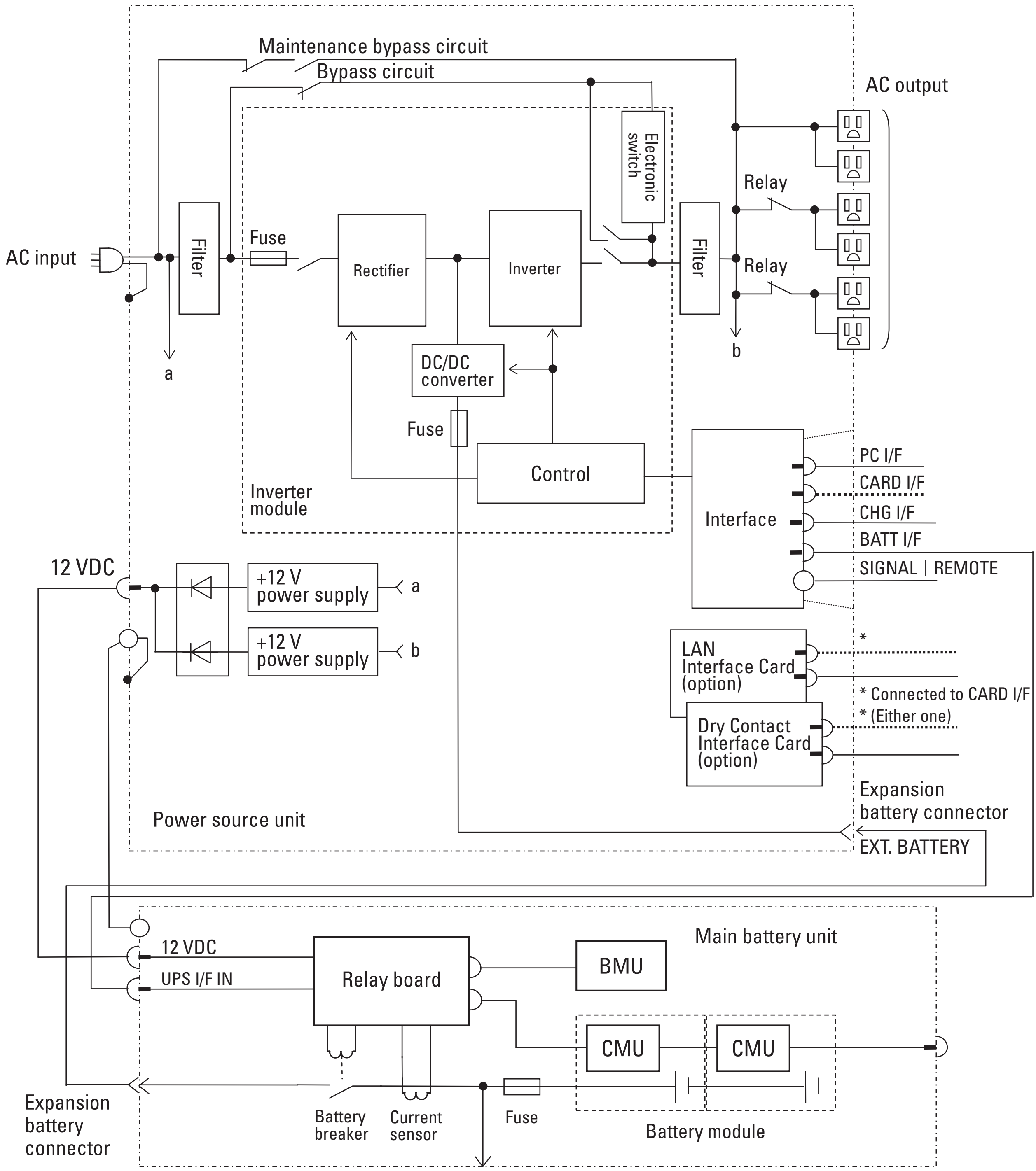

Fig. 4: Circuit diagram for the *SANUPS A11K-Li*

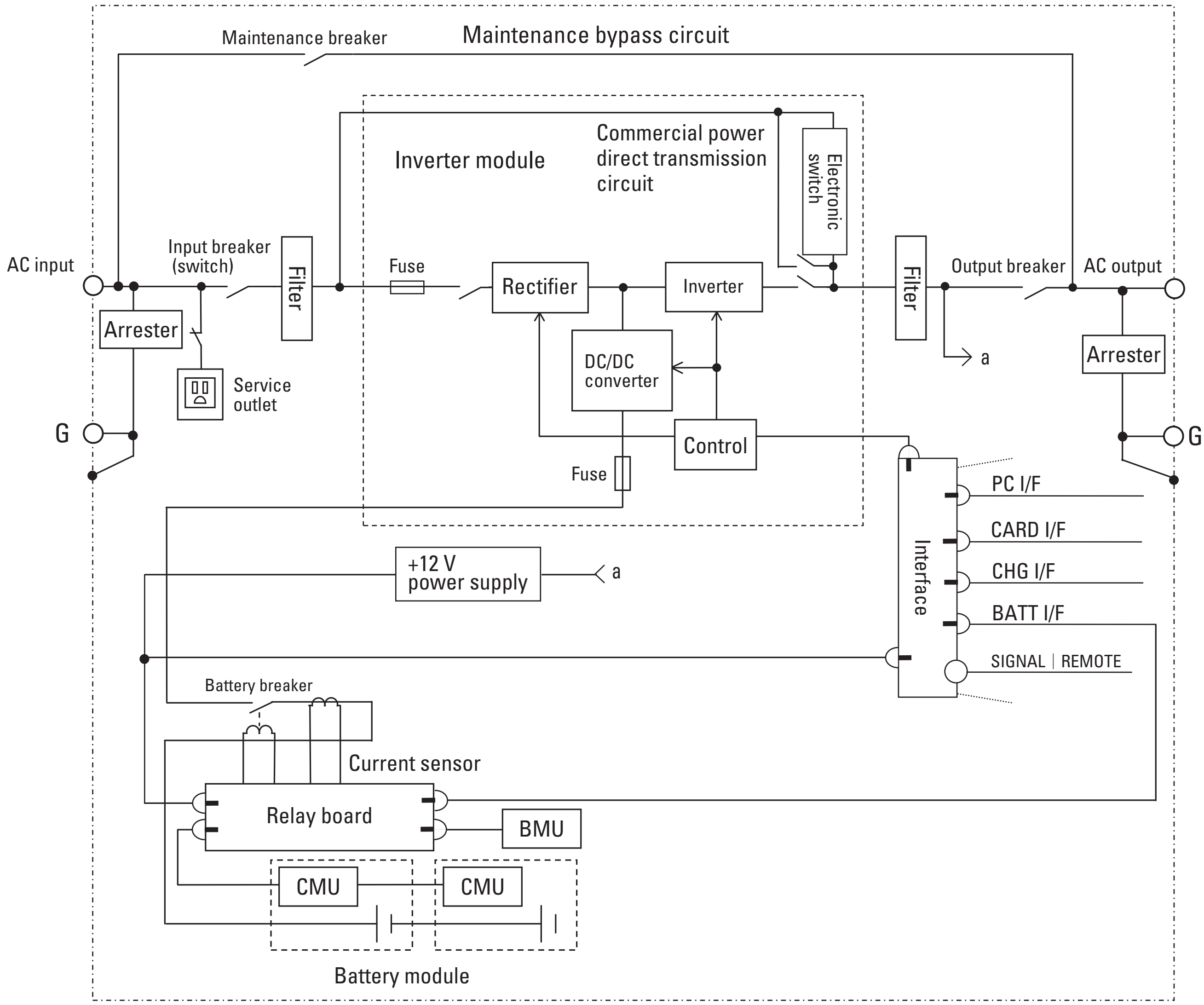

Fig. 5: Circuit diagram for the *SANUPS N11B-Li*

5. Specifications

Table 1 and Table 2 show the standard specifications of the *SANUPS A11K-Li* and *SANUPS N11B-Li*, respectively.

Table 1: The *SANUPS A11K-Li* series specifications

Item			Unit	Ratings and characteristics			Remarks
Model			—	A11KL152	A11KL302	A11KL502	
Rated output capacity			kVA/kW	1.5/1.2	3/2.4	5/4	(Apparent power/active power)
Type	UPS topology		—	Double conversion online			
	Cooling system		—	Forced air cooling			
	Inverter system		—	High-frequency PWM			Commercial synchronous online double conversion
AC input	No. of phases/wires		—	Single-phase 2-wire			
	Rated voltage		V	100, 110, 120			Same as output voltage
	Voltage range		%	Within ±20 of rated voltage			At a 70% load level or greater
				Within -40 to +20 of rated voltage			At a load level less than 70% Recovery voltage is -20% of rated voltage or more
	Rated frequency		Hz	50 or 60			Frequency is automatically detected(1)
	Frequency range		%	Within ±1, 3, 5, or 7 of rated frequency			(The fluctuation range is the same as the selected output frequency accuracy)
	Required capacity		kVA	1.5 or less	3.0 or less	5.3 or less	Max. capacity during battery recovery charging
	Power factor		—	0.95 or greater	0.97 or greater		When input voltage harmonic distortion < 1%
AC output	No. of phases/wires		—	Single-phase 2-wire			
	Rated voltage		V	100, 110, 120			Voltage waveform: Sine wave
	Voltage accuracy		%	Within ±2 of rated voltage			At rated output
	Rated frequency		Hz	50 or 60			Same as the input frequency
	Frequency accuracy		%	Within ±1, 3, 5, or 7 of rated frequency (Default value: ±3)			Frequency accuracy setting can be changed (±1, 3, 5, or 7%) Within ±0.5% during battery operation (1)
	Voltage harmonic distortion		%	3 or less/7 or less			Linear load/rectifier load, at rated output
	Transient voltage fluctuation	Rapid load change	%	Within ±5 of rated voltage			0⇔100% at transient or output switch
		During power outage, recovery	%				At rated output
		Input voltage during rapid change	%				±10% variation
		Response time	Or less	5 cycles			
	Power factor		—	0.8 (lag)			Variation range 0.7 (lag) to 1.0
	Overcurrent protection		%	105 or more			Auto switching to bypass circuit (1)
	Overload capability	Inverter	%	105 or more			200 ms
		Bypass		200/800			30-second period / 2 cycles
Battery	Type		—	Lithium-ion battery (LIB)			
	Backup time		Minute	100/200/ 300/400	50/100/ 150/200	30/60/ 90/120	Ambient temperature 25˚C, at rated output Default value
Acoustic noise			dB	45 or less	46 or less	46 or less	1 m from front of device, A-weighting (Where the ambient temperature is 40˚C or lower)
				51 or less	55 or less	55 or less (2)	1 m from front of device, A-weighting (Where the ambient temperature exceeds 40˚C)
Operating environment	Ambient temperature		˚C	-20 to +55			(3)
	Relative humidity		%	10 to 90			Non-condensing
Storage environment			˚C	-20 to +55			(4)

(1) The inverter synchronizes operation with AC input and allows switchover without interruption through a bypass circuit provided that the AC input frequency is within a range of the rated frequency ±3% (able to be switched between 1, 3, 5 and 7%), and the AC input voltage is within the rated voltage ±20% (if the load level is less than 70%: between -40% and +20%). Note that operation changes to battery operation when the AC input frequency exceeds the setting range.
(2) 60 dB or less when battery voltage drops.
(3) Battery charging stops when battery temperature exceeds 55˚C.
(4) To prolong battery life, avoid use or storage for extended periods of time in environments exceeding +30˚C. If the UPS is stored without being operated for a long period, the batteries may require recharging once a year.

Table 2: The *SANUPS N11B-Li* series specifications

<table>
<tr><th colspan="3">Item</th><th>Unit</th><th colspan="2">Ratings and characteristics</th><th>Remarks</th></tr>
<tr><td colspan="3">Model</td><td>–</td><td>N11BL102</td><td>N11BL152</td><td></td></tr>
<tr><td colspan="3">Rated output capacity</td><td>kVA/kW</td><td>1/0.8</td><td>1.5/1.2</td><td>Apparent power/active power</td></tr>
<tr><td rowspan="3">Type</td><td colspan="2">UPS topology</td><td>–</td><td colspan="2">Passive standby</td><td></td></tr>
<tr><td colspan="2">Cooling system</td><td>–</td><td colspan="2">Passive
Forced air cooling during battery operation and high temperatures</td><td></td></tr>
<tr><td colspan="2">Inverter system</td><td>–</td><td colspan="2">High-frequency PWM method (during battery operation)</td><td>Commercial synchronous online double conversion</td></tr>
<tr><td rowspan="6">AC input</td><td colspan="2">No. of phases/wires</td><td>–</td><td colspan="2">Single-phase 2-wire</td><td></td></tr>
<tr><td colspan="2">Rated voltage</td><td>V</td><td colspan="2">100, 110, 120</td><td>Same as output voltage</td></tr>
<tr><td colspan="2">Voltage range</td><td>%</td><td colspan="2">Within ±10 of rated voltage</td><td></td></tr>
<tr><td colspan="2">Rated frequency</td><td>Hz</td><td colspan="2">50 or 60</td><td>Frequency is automatically detected</td></tr>
<tr><td colspan="2">Frequency range</td><td>%</td><td colspan="2">Within ±1, 3, 5, or 7 of rated frequency</td><td>(The fluctuation range is the same as the selected output frequency accuracy)</td></tr>
<tr><td colspan="2">Required capacity</td><td>kVA</td><td>1.4 or less</td><td>2.1 or less</td><td>Max. capacity during battery recovery charging</td></tr>
<tr><td rowspan="14">AC output</td><td colspan="2">No. of phases/wires</td><td>–</td><td colspan="2">Single-phase 2-wire</td><td></td></tr>
<tr><td colspan="2">Rated voltage</td><td>V</td><td colspan="2">100, 110, 120</td><td>Voltage waveform during battery operation: Sine wave</td></tr>
<tr><td colspan="2" rowspan="2">Voltage accuracy</td><td rowspan="2">%</td><td colspan="2">During commercial operation: Same as input power source</td><td></td></tr>
<tr><td colspan="2">During battery operation: Within ±2 of rated voltage</td><td>At rated output</td></tr>
<tr><td colspan="2">Rated frequency</td><td>Hz</td><td colspan="2">50/60</td><td>Same as the input frequency</td></tr>
<tr><td colspan="2" rowspan="2">Frequency accuracy</td><td rowspan="2">%</td><td colspan="2">During commercial operation: Same as input power source</td><td></td></tr>
<tr><td colspan="2">During battery operation: Within ±0.5 of rated frequency</td><td>At rated output</td></tr>
<tr><td colspan="2">Voltage harmonic distortion</td><td>%</td><td colspan="2">3 or less/7 or less</td><td>During battery operation, at rated output</td></tr>
<tr><td rowspan="2">Transient voltage fluctuation</td><td>Rapid load change</td><td>%</td><td colspan="2">Within ±7 of rated voltage</td><td>During battery operation, for 0⇔100% load step changes /
output switch</td></tr>
<tr><td>During power outage, recovery</td><td>%</td><td colspan="2">Within ±5 of rated voltage</td><td>During battery operation, at rated output</td></tr>
<tr><td colspan="2">Power factor</td><td>–</td><td colspan="2">0.8 (lag)</td><td>Variation range 0.7 (lag) to 1.0</td></tr>
<tr><td colspan="2">Overcurrent protection</td><td>%</td><td colspan="2">Output breaker trip</td><td></td></tr>
<tr><td rowspan="2">Overload capability</td><td>Inverter</td><td rowspan="2">%</td><td colspan="2">105 or more</td><td>200 ms</td></tr>
<tr><td>Bypass</td><td colspan="2">200/800</td><td>30 s / 2 cycles</td></tr>
<tr><td rowspan="2">Battery</td><td colspan="2">Type</td><td>–</td><td colspan="2">Lithium-ion battery (LIB)</td><td></td></tr>
<tr><td colspan="2">Backup time</td><td>Minute</td><td colspan="2">150</td><td>Ambient temperature 25˚C, at rated output, default value</td></tr>
<tr><td colspan="3">Acoustic noise</td><td>dB</td><td>40 or less</td><td>43 or less</td><td>1 m from front of device, A-weighting</td></tr>
<tr><td colspan="3">IP rating</td><td>–</td><td colspan="2">IP65</td><td></td></tr>
<tr><td rowspan="2">Operating environment</td><td colspan="2">Ambient temperature</td><td>˚C</td><td colspan="2">-20 to +50</td><td>(1)</td></tr>
<tr><td colspan="2">Relative humidity</td><td>%</td><td colspan="2">10 to 90</td><td>Non-condensing</td></tr>
<tr><td colspan="3">Storage environment</td><td>˚C</td><td colspan="2">-20 to +55</td><td>(2)</td></tr>
</table>

(1) Battery charging stops when battery temperature exceeds 55˚C.
(2) To prolong battery life, avoid use or storage for extended periods of time in environments exceeding +30˚C. If the UPS is stored without being operated for a long period, the batteries may require recharging once a year.

6. Advantage for Customers

Below is a list of customer advantages gained by adopting this device.

(1) Common to the *SANUPS A11K-Li* and *SANUPS N11B-Li*

1) Broader selection of applications and installation environments due to a wider operating temperature range
2) Reduced maintenance costs thanks to low-maintenance batteries
3) In the unlikely event of a problem, maintenance work can be performed without interrupting power supply to the load equipment.

(2) The *SANUPS A11K-Li*

1) More freedom of installation environment due to less required installation space.
2) Can perform backup safely even when power source is unstable thanks to its wide input voltage range.

(3) The *SANUPS N11B-Li*

1) Backs up power for outdoor equipment.
2) Sealed structure enables use in environments exposed to dust and rain.

7. Conclusion

Moving forward, information and communication technologies will undergo even further sophistication and play an even more important role in society. Moreover, with increased applications in a variety of environments, it is likely that the requirements for UPS will diversify.

We will continue to quickly develop products to meet these market demands and provide devices that fulfill our customers' needs.

We wish to express our deep appreciation to the many people who cooperated and offered advice in the development and production of these UPSs.

References

Kazuya Yanagihara and Others: " Development of the Small-Capacity UPS SANUPS A11K Series ", SANYO DENKI Technical Report No.40 (2015)

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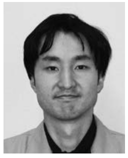

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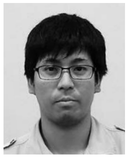

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Development of the *SANUPS P73L* PV Inverter with a Peak Cut Function

Tetsuya Fujimaki Takeshi Hama Yuzo Kubota Takashi Kobayashi

Makoto Ishida Masahiro Inukai Masahiro Uchibori

1. Introduction

Since the Great East Japan Earthquake, there is an increasing demand for local governments and private businesses to install backup power sources in preparation for prolonged power outages during disasters. Of the available systems, power generation systems combining PV panels and Li-ion storage batteries are attracting interest due to their numerous advantages, such as the ability to be used as a "local-production, local-consumption" decentralized power source during disasters to minimize power consumption during peak times.

SANYO DENKI already offers the *SANUPS P73K* as a PV inverter with a peak cut function supporting Li-ion storage batteries. However, now we have developed the *SANUPS P73L*, which maintains the functions and performance of the *SANUPS P73K* while gaining functions that further meets market demands. This article will introduce the features of this new product.

2. Overview and Features of the *SANUPS P73L*

2.1 System configuration from 10 to 60 kW

The *SANUPS P73L* is comprised of a 10 kW PV inverter unit, 10 kW charging unit and I/O box, with the ability to add up to six 10 kW PV inverters as a scalable system. This product comes in the "grid-connected, isolated, charging type" and "grid-connected, isolated type," with output capacities ranging from 10 to 60 kW.

2.2 Circuit configuration and basic operations

Figure 1 shows the appearance of the *SANUPS P73L* grid-connected, isolated, charging type and grid-connected, isolated type. Figures 2 and 3 show the block diagrams for the grid-connected, isolated, charging type and the grid-connected, isolated type respectively.

The grid-connected, isolated, charging type is comprised of a PV inverter unit, charging unit and I/O box. The grid-connected, isolated type is comprised of a PV inverter unit and I/O box. The PV inverter unit is common with that of the grid-connected, isolated, charging type.

The grid-connected, isolated, charging type supports peak power cut by supplying the power of its PV panel and storage battery to a general load via the isolated converter circuit and inverter circuit equipped in the PV inverter unit. Moreover, it can supply AC power to the isolated operation output during power outages on the grid. The charging unit controls the charging and discharging of the storage battery through a bi-directional converter circuit. The I/O box has an isolated operation output bypass breaker and can switch between power circuits. It automatically starts and stops peak cut through the input of a power transducer signal that measures the power grid.

The grid-connected, isolated type supplies the power of its PV panel to a general load and the power grid via the isolated converter circuit and inverter circuit in the PV inverter unit. Moreover, it can supply AC power to the isolated operation output during power outages on the grid. The I/O box has an isolated operation output bypass breaker and can switch between power circuits.

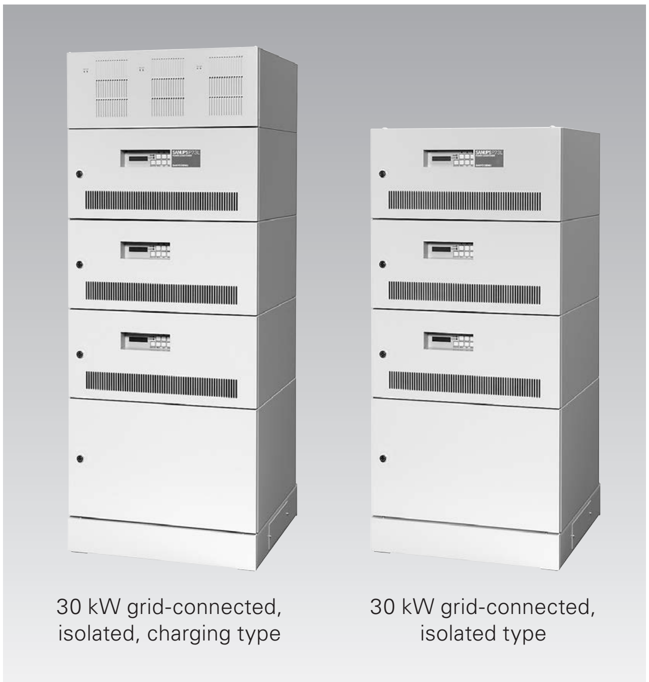

Fig. 1: The *SANUPS P73L*

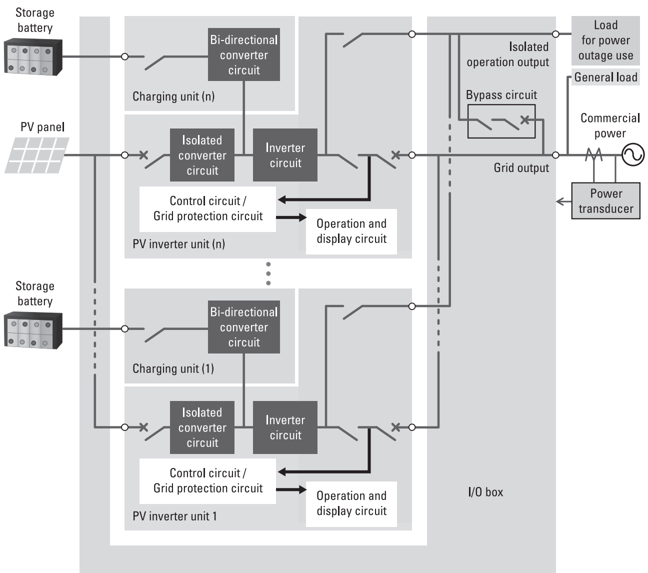

Fig. 2: Block diagram for the grid-connected, isolated, charging type

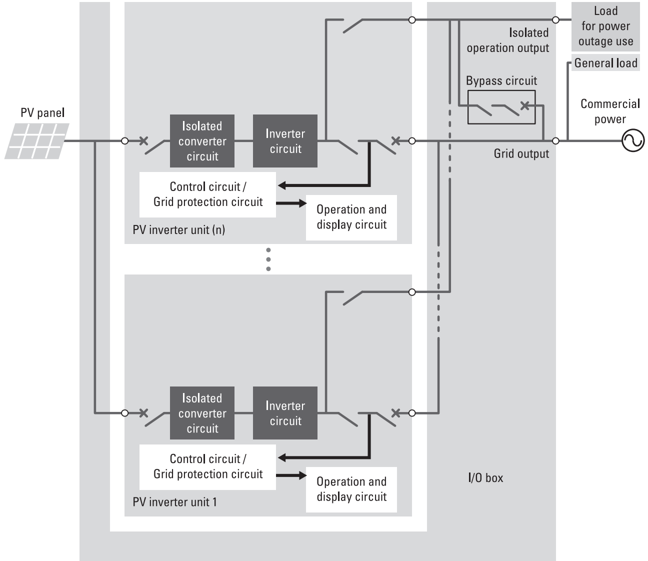

Fig. 3: Block diagram for the grid-connected, isolated type

2.3 Parallelization of isolated operation output

The existing model, the *SANUPS P73K*, has an isolated operation output capacity of up to 10 kVA. However, in the new model, the *SANUPS P73L*, the circuit configuration of the isolated operation output has been revised and by enabling parallel operation capacities to the isolated operation output, it has become possible to supply power up to 60 kVA. With the *SANUPS P73L*, it is possible to offer more flexible proposals meeting needs for systems requiring isolated operation output capacities exceeding 10 kVA.

2.4 Single circuit connection of the PV panel input

The PV panel input for the existing model *SANUPS P73K* require an input circuit for every 10 kW, and thus wiring for multiple circuits in total. Multi-circuit wiring has the disadvantages of an increased number of wires and complicated installation due to the need to wire PV panel inputs to the I/O box terminal blocks individually for each 10 kW. However, the new *SANUPS P73L* enriches the lineup with the added specification of single circuit connection for the PV panel input, thus making wiring work easy.

2.5 Benefits of a bi-directional converter

Just as the *SANUPS P73K*, the *SANUPS P73L* grid-connected, isolated, charging type is equipped with a bi-directional converter in its storage battery input. The bi-directional converter eliminates the need to make the PV panel and storage battery voltages equal, thus reducing overall system cost.

Furthermore, for PV inverters with a circuit type based on direct connection between the PV panel and storage battery, the PV panel's operating point is the terminal voltage of the storage battery, therefore MPPT control is not possible. However, with the newly-developed control method adopted on the *SANUPS P73L*, it is possible to maximize the PV panel output through maximum output tracking control even during charging/discharging of the storage battery or isolated operation. As such, the power generation amount is expected to increase significantly.

2.6 Function to switch to isolated operation mode

In regards to switching to isolated operation mode, the *SANUPS P73L* has been equipped with switchover functions that can be activated manually, automatically, and remotely.

This makes it possible to propose more flexible systems.

3. The *SANUPS P73L* Operation Modes

The *SANUPS P73L* has the following four operation modes: grid-connected operation mode, peak cut operation mode, charging operation mode and isolated operation mode. Below is a description of each operation mode.

3.1 Grid-connected operation mode

Figure 4 shows the flow of power during grid-connected operation mode. Grid-connected operation mode is activated when all of the following conditions are met.

- Schedule settings start grid-connected operation mode
- The PV panel power exceeds a set value
- The power grid is normal

During grid-connected operation mode, the *SANUPS P73L* converts the PV panel-generated DC power into AC power, adjusts voltage, and synchronizes frequency to connect with the grid, enabling the AC power to be supplied to the grid. Moreover, the PV inverter performs MPPT control and supplies AC power to the power grid depending on the amount of the PV-generated power. In such case, if the PV-generated power is larger than the general load power consumption, this product sends the surplus power to the grid.

Also, commercial power is supplied to the load for power outage use via a bypass circuit.

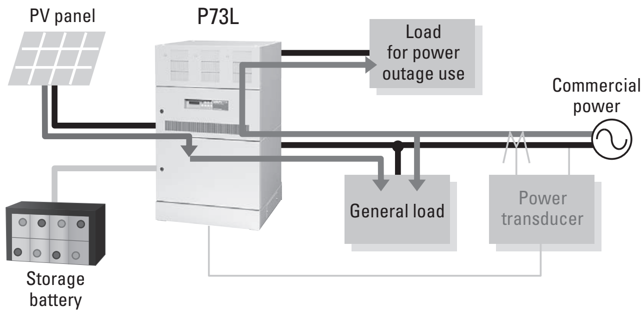

Fig. 4: Grid-connected operation mode

3.2 Peak cut operation mode

Figure 5 shows the flow of power during peak cut operation mode. Peak cut operation mode is activated when all of the following conditions are met.

- Schedule settings start peak cut operation mode
- The power grid is normal
- The power being received from the power grid exceeds a pre-set value
- The remaining capacity of the storage battery is above a set value

During peak cut operation mode, the *SANUPS P73L* converts DC power generated by PV panels and storage batteries into AC power, adjusts voltage, and synchronizes frequency to connect with the grid, enabling AC power to be supplied to a general load. This suppresses the increase in the received power.

Also, commercial power is supplied to the load for power outage use via a bypass circuit.

In such case, if the received power being received from the power grid is below the pre-set value, the PV inverter will stop discharging the storage battery.

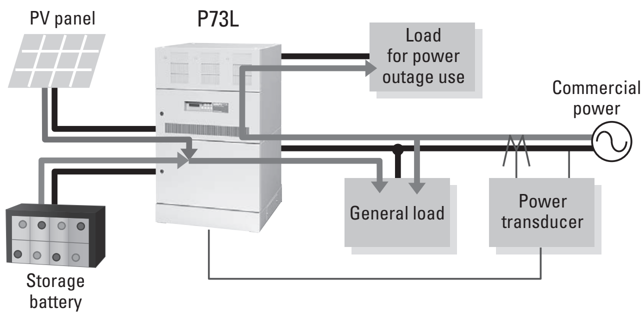

Fig. 5: Peak cut operation mode

3.3 Charging operation mode

Figure 6 shows the flow of power during charging operation mode. Charging operation mode is activated when all of the following conditions are met.

- Schedule settings start charging operation mode
- The power grid is normal

During charging operation mode, the *SANUPS P73L* converts commercial AC power into DC power and charges the storage battery with the power specified using the schedule function. Power from the PV panels supplement the charging commercial power, and if PV panel power is larger than the charging power, it will be supplied to the grid.

Also, commercial power is supplied to the load for power outage use via a bypass circuit.

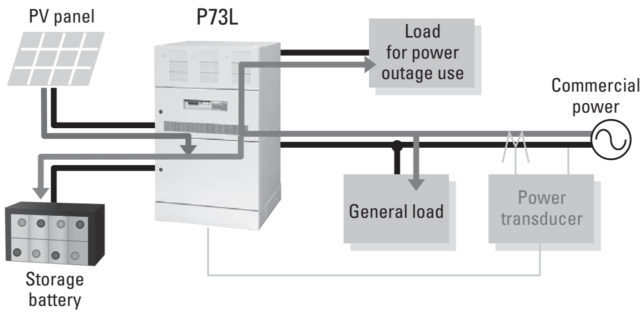

Fig. 6: Charging operation mode

3.4 Isolated operation mode

Figure 7 shows the flow of power during isolated operation mode. Isolated operation mode is activated when all of the following conditions are met.

- Isolated operation mode is enabled via manual switchover, automatic switchover, or remote switchover.
- The remaining capacity of the storage battery is above a set value

During isolated operation mode, the DC power of the PV panel and storage battery is converted to AC power while voltage adjustment and waveform conditioning are performed, and AC power of a constant-frequency, constant-voltage sine wave is supplied to the load for power outage use. In such case, the power of the storage battery is supplied to the load for power outage use even when there is no sunlight. Meanwhile, if the power generated by the PV panel is larger than the power supplied to the load for power outage use, the surplus power will be used to charge the storage battery.

Also, in cases of ongoing isolated operation due to prolonged power outages, if the DC voltage falls below a set value due to a decrease in storage battery power, the PV inverter will stop isolated operation in order to protect the storage battery.

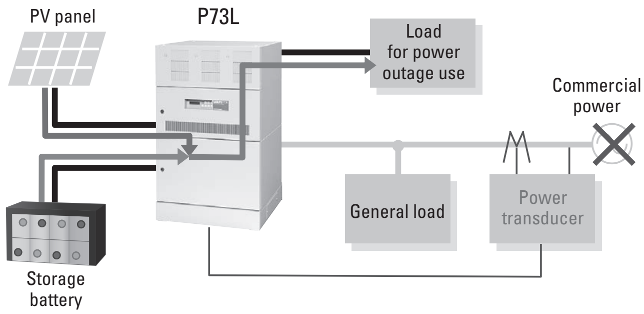

Fig. 7: Isolated operation mode

3.5 Switching to each operation mode

Figure 8 shows the switchover to each of the operation modes: grid-connected operation mode, peak cut operation mode, charging operation mode, and isolated operation mode.

Through schedule settings, automatic switchover to grid-connected operation mode, peak cut operation mode, or charging operation mode can be performed.

The automatic switchover function for isolated operation mode automatically switches to isolated operation mode when a power grid outage is detected. The remote switchover function for isolated operation mode switches the operation mode to isolated operation mode with an isolated operation command inputted from an external contact.

Both the manual and automatic switchover functions can be selected with PV inverter unit settings. The remote switchover function is valid when manual switchover is set.

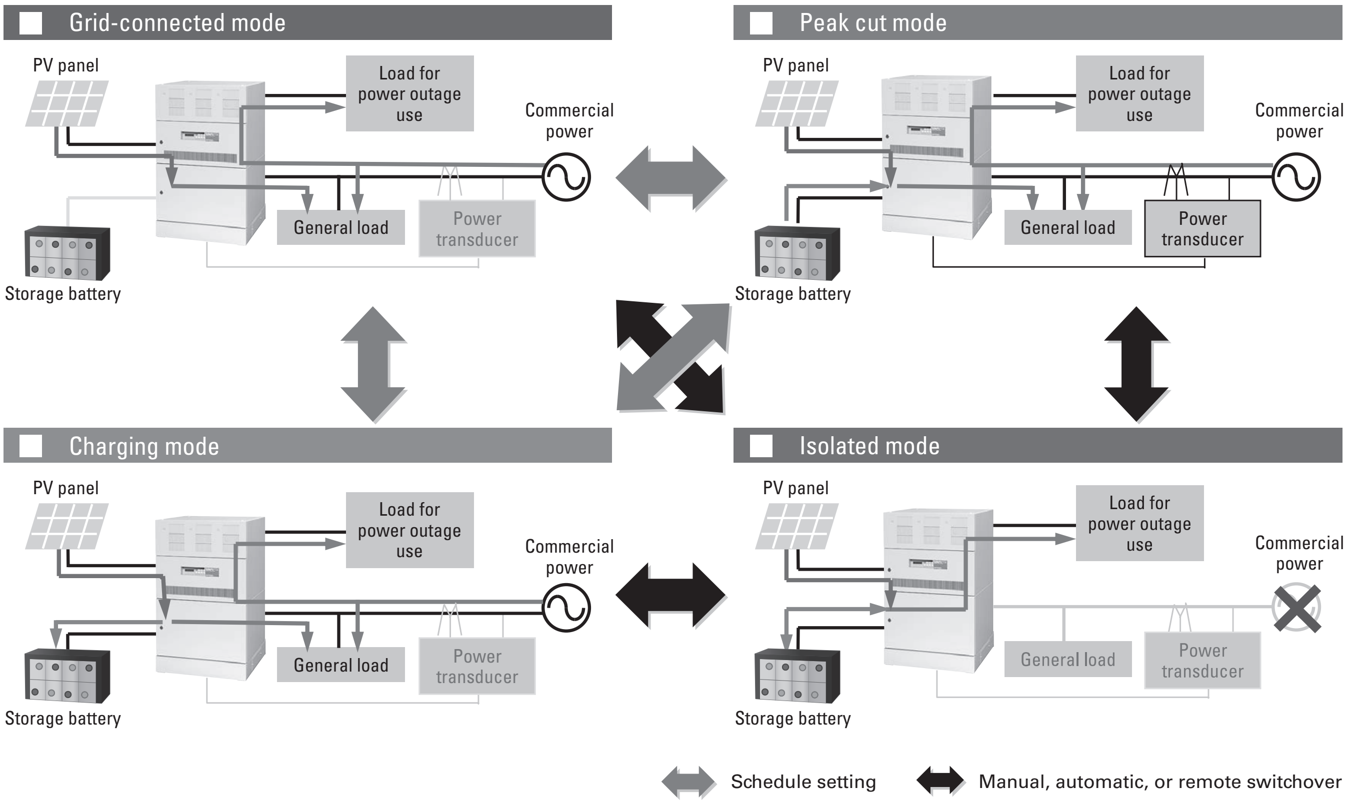

Fig. 8: Switching to each operation mode

4. Specifications

Table 1 shows the electrical specifications of the *SANUPS P73L* PV inverter with peak cut function (grid-connected, isolated, charging type), while Figure 9 shows its external dimensions.

Table 2 shows the electrical specifications of the *SANUPS P73L* PV inverter with peak cut function (grid-connected, isolated type), while Figure 10 shows its external dimensions.

Table 1: Electrical specifications of the *SANUPS P73L* grid-connected, isolated, charging type

Item	Model	P73L103P	P73L203P	P73L303P	P73L403P	P73L503P	P73L603P
Rated output capacity		10 kW	20 kW	30 kW	40 kW	50 kW	60 kW
Main circuit type		Self-commutated voltage type					
Switching method		High-frequency PWM					
Isolation method	PV input	High-frequency isolation type					
	Battery input	Non-isolation type					
Cooling method		Forced air cooling					
PV input	Rated voltage	400 VDC					
	Maximum allowable input voltage	570 VDC					
	Input operating voltage range	150 to 570 VDC (rated output range: 250 to 540 VDC)					
	Maximum power point tracking range	190 to 540 VDC					
Battery input/output	Fluctuation range	200 to 400 VDC					
	Max. charge/ discharge power*	10 kW x 1 circuit	10 kW x 2 circuits	10 kW x 3 circuits	10 kW x 4 circuits	10 kW x 5 circuits	10 kW x 6 circuits
	Charging voltage	Factory settings: 296 VDC, Adjustment range: 200 to 400 VDC (1 V increments) (rated range: 250 to 400 VDC)					
Grid output	Rated voltage	202 VAC					
	Rated output current	28.6 AAC	57.2 AAC	85.7 AAC	114.3 AAC	142.9 AAC	171.5 AAC
	Rated frequency	50/60 Hz					
	No. of phases/wires	3-phase 3-wire					
	Output current harmonic distortion	Total current: 5% or less, individual harmonic order: 3% or less					
	Output power factor	0.95 or greater (at rated output, power factor 1.0 setting), power factor setting range: 0.8 to 1.0 (0.01 increments)					
Isolated operation output	Rated output	10 kVA (at 1.0 p.f.)	20 kVA (at 1.0 p.f.)	30 kVA (at 1.0 p.f.)	40 kVA (at 1.0 p.f.)	50 kVA (at 1.0 p.f.)	60 kVA (at 1.0 p.f.)
	No. of phases/wires	3-phase 3-wire (possible to convert to single-phase output using the optional Scott-connected transformer)					
	Rated voltage	202 VAC					
	Voltage accuracy	Within ±8% of rated voltage					
	Rated frequency	50/60 Hz					
	Frequency accuracy	Within ±0.1 Hz of rated frequency					
	Output voltage harmonic distortion	Linear load: 5% or less					
	Overload capability	100% continuous					
Efficiency		93% (at grid-connected operation mode, with efficiency measurement method in accordance with JIS C 8961)					
Grid protection		Overvoltage (OVR), undervoltage (UVR), overfrequency (OFR), underfrequency (UFR)					
Islanding detection	Passive method	Voltage phase jump detection					
	Active method	Reactive power variation method					
Communication		RS-485					
Operating environment	Ambient temperature	-10 to +40˚C					
	Relative humidity	30 to 90% max. (No condensation)					
	Altitude	1000 m or lower					
Paint color		Munsell 5Y7/1 (semi-gloss)					
Heat dissipation		1100 W	2200 W	3300 W	4400 W	5500 W	6600 W
Received-power measurement function		Yes, 4 to 20 mA					
Mass		190 kg	290 kg	390 kg	580 kg	705 kg	780 kg

* Maximum current 40 ADC

Table 2: Electrical specifications of the *SANUPS P73L* grid-connected, isolated type

Item / Model		P73L103S	P73L203S	P73L303S	P73L403S	P73L503S	P73L603S
Rated output capacity		10 kW	20 kW	30 kW	40 kW	50 kW	60 kW
Main circuit type		Self-commutated voltage type					
Switching method		High-frequency PWM					
Isolation method	PV input	High-frequency isolation type					
Cooling method		Forced air cooling					
PV input	Rated voltage	400 VDC					
	Maximum allowable input voltage	570 VDC					
	Input operating voltage range	150 to 570 VDC (rated output range: 250 to 540 VDC)					
	Maximum power point tracking range	190 to 540 VDC					
Grid output	Rated voltage	202 VAC					
	Rated output current	28.6 AAC	57.2 AAC	85.7 AAC	114.3 AAC	142.9 AAC	171.5 AAC
	Rated frequency	50/60 Hz					
	No. of phases/wires	3-phase 3-wire					
	Output current harmonic distortion	Total current: 5% or less, individual harmonic order: 3% or less					
	Output power factor	0.95 or greater (at rated output, power factor 1.0 setting) power factor setting range: 0.8 to 1.0 (0.01 increments)					
Isolated operation output	Rated output	10 kVA (at 1.0 p.f.)	20 kVA (at 1.0 p.f.)*	30 kVA (at 1.0 p.f.)*	40 kVA (at 1.0 p.f.)*	50 kVA (at 1.0 p.f.)*	60 kVA (at 1.0 p.f.)*
	No. of phases/wires	3-phase 3-wire (possible to convert to single-phase output using the optional Scott-connected transformer)					
	Rated voltage	202 VAC					
	Voltage accuracy	Within ±8% of rated voltage					
	Rated frequency	50/60 Hz					
	Frequency accuracy	Within ±0.1 Hz of rated frequency					
	Output voltage harmonic distortion	Linear load: 5% or less					
	Overload capability	100% continuous					
Efficiency		93% (at grid-connected operation mode, with efficiency measurement method in accordance with JIS C 8961)					
Grid protection		Overvoltage (OVR), undervoltage (UVR), overfrequency (OFR), underfrequency (UFR)					
Islanding detection	Passive method	Voltage phase jump detection					
	Active method	Reactive power variation method					
Communication		RS-485					
Operating environment	Ambient temperature	-25 to +60˚C (Operates with derated output above 40˚C)					
	Relative humidity	30 to 90% (No condensation)					
	Altitude	2000 m or lower					
Paint color		Munsell 5Y7/1 (semi-gloss)					
Heat dissipation		760 W	1520 W	2280 W	3040 W	3800 W	4560 W
Received-power measurement function		None					
Mass		145 kg	220 kg	295 kg	440 kg	540 kg	590 kg

* Model with 10 kVA isolated operation output is also available.

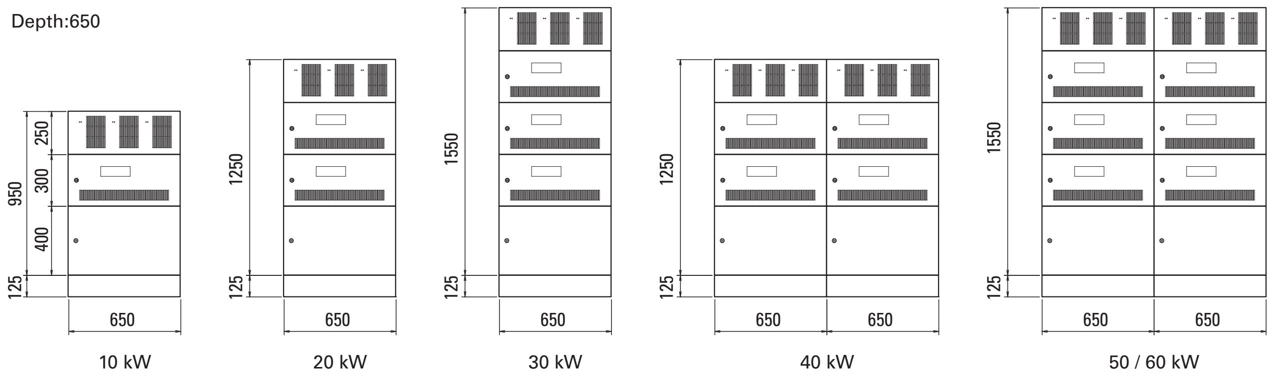

Fig. 9: External dimensions of the *SANUPS P73L* grid-connected, isolated, charging type

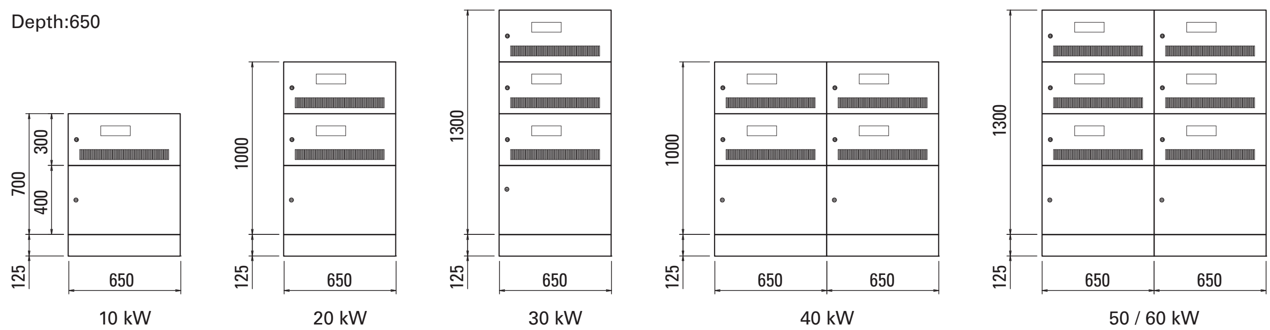

Fig. 10: External dimensions of the *SANUPS P73L* grid-connected, isolated type

5. Conclusion

This article has briefly introduced the overview and features of the *SANUPS P73L* PV inverter with peak cut function.

In addition to improving operating rate of power equipment by reducing peak demand, this product is expected to contribute to fields such as environmental conservation through effective utilization of natural energy and emergency power source during disasters. Moreover, as a PV inverter with even richer functions than existing products, this new product is expected to enable the building of optimal systems and be introduced to a wider market. SANYO DENKI will continue swift product development responding to these fields to provide products which win customer satisfaction and contribute to the realization of a low-carbon society.

We wish to express our appreciation to all those who cooperated and offered advice in the development and production of this product.

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Servo Systems Products Offering Value in New Fields

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1. Introduction

Research and development of "service robots" is being promoted to tackle the problem of Japan's shrinking workforce and increased social insurance costs caused by a declining birthrate and aging population. Service robots are expected to advance into various applications including medical, security, nursing, welfare, and customer service. Servo Systems products used in these fields must not only be compact, lightweight, and wire-saving, but also reduce power supply voltage and power consumption while enabling multi-axis systems. Moreover, there is also a need to support a fieldbus capable of high-speed, real-time control of multiple axes, and controllers for their batch control.

This article will introduce products and systems that can be used in such fields.

2. Servo Systems Products for Service Robots

2.1 48 VDC compact 20 mm sq. AC servo motor

For the configuration of compact, lightweight, and high-output servo motors, the design must either be small-diameter, long, thin cylinder or a flat, thin disc. The compact cylindrical type is structured the same way as general servo motors, therefore the basic design is simple. However, the core, winding, and magnet must be arranged in a limited space, so some creative maneuvering was necessary to increase output and reduce loss. Meanwhile, the flat type can be designed with a large torque area, therefore high output is easily achieved; however, the motor's magnetic circuit is complicated, so we creatively arranged the core, bearings, and other components. Both types have their pros and cons but this article will introduce the *SANMOTION R* series 20 mm sq. AC servo motor as a compact cylindrical servo motor achieving high output, low loss, and weight reduction.

Figure 1 shows an external view of the compact 20 mm sq. AC servo motor, while Table 1 shows its main specifications. To increase output and minimize loss and weight, we employed coupled analysis of optimization support tools and electromagnetic field simulation to solve the conflicts between improving motor characteristics and reducing weight.

(1) High output

Through optimization of the core profile and magnet, this product has 17% higher peak torque compared to our existing product. This contributes to the size reduction and high-load drive of equipment.

(2) Low loss

By applying high-space factor winding technology in which the magnet wire is mechanically bent then inserted into the core, copper loss is significantly reduced to achieve low loss. Loss has been decreased by 34% compared to our current model. Loss reduction helps minimize temperature rise in motors, decreasing device heat emissions.

(3) Lightweight

We reduced weight by using a frame with a round cross-section and eliminating the corners of the frame which did not contribute to the magnetic path. The result was 8.5% less weight compared to the current model. A lighter motor contributes to lighter equipment.

This product can also be used in mobile service robots thanks to its 48 VDC support, and its compact, lightweight, high output, low heat generating, and power saving design.

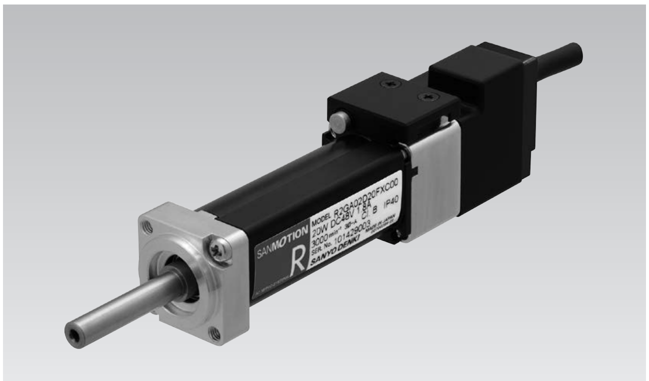

Fig. 1: Compact 20 mm sq. AC servo motor

Table 1: Main specifications
of the compact 20 mm sq. AC servo motor

Model number	R2GA02D20F	R2GA02D30F
Flange size	20 mm sq.	20 mm sq.
Input power	48 VDC	48 VDC
Rated output	20 W	30 W
Rated speed	3,000 min^{-1}	3,000 min^{-1}
Maximum rotational speed	6,000 min^{-1}	6,000 min^{-1}
Rated torque	0.064 N·m	0.095 N·m
Continuous stall torque	0.064 N·m	0.095 N·m
Peak stall torque	0.23 N·m	0.38 N·m
Motor mass	0.14 kg	0.18 kg
Encoder (standard)	MA018	MA018
Encoder resolution	13 bit	13 bit
Servo amplifier model number	Pulse input, single-axis RF2G21A0A00 EtherCAT, single-axis RS2K04A2HL5 / RS2K04A2HA5 EtherCAT, multi-axis RF2J24A0HL5 / RF2K24A0HL5	

2.2 24/48 VDC, 4-axis integrated servo amplifier with EtherCAT interface

This section will introduce the 4-axis integrated servo amplifier equipped with an EtherCAT interface.

Figure 2 shows the appearance of the 4-axis integrated amplifier while Table 2 shows its main specifications. This amplifier has an input power of 24 or 48 VDC to enable battery-powered drive, therefore it can be used in mobile service robots. Also, by sharing a common power circuit, regenerative power of a motor can be used to power other motors, contributing to energy savings.

With its multi-axis design, this product has achieved 40% volume reduction and 60% weight reduction compared with four single-axis servo amplifiers. Furthermore, through common use of the power circuit and general-purpose I/O circuit, and the built-in daisy chain connection circuit for host communication, we have significantly reduced the number of power cables and cables used for I/O and communication, thus contributing to a smaller footprint. Moreover, by minimizing heat generation with built-in heat radiator fins and a cooling fan (RF2K24A only), the new product improves the device's thermal management.

From a safety perspective, Safe Torque Off (STO) function has been standardly equipped with this product. All four axes can be controlled via safety circuit. As a result, this product has been certified with a high safety level (SIL3 for IEC 61508, PL=e for ISO 13849-1) with the same 2-input/1-output design as a single axis amplifier, meaning it can be used in fields such as medical and nursing where high safety performance is required.

The fieldbus between the controller and servo amplifier is EtherCAT, which SANYO DENKI has used for some time. With a communication speed of 100 Mbps and minimum communication cycle of 125 μs, this product achieves excellent real-time performance and high-accuracy synchronization. Moreover, the position assist function can compensate the position feedback of two axes to further improve synchronization accuracy.

Fig. 2: Appearance
of the 4-axis integrated servo amplifier

Table 2: Main specifications of the 4-axis integrated servo amplifier

Model number			RF2J24A	RF2K24A
Basic specifications	Mass		0.75 kg	0.8 kg
	Dimensions		200 H x 50 W x 130 D mm	
	Input power	Control power	24 VDC ±10%	
		Main circuit power	48 VDC ±10% or 24 VDC ±10%	
	Compatible motor		20 mm sq. 40 mm sq. (20 to 30 W)	20 mm sq. 40 mm sq. 60 mm sq. (20 to 200 W)
	Output limit per axis		30 W or less	200 W or less
	Total output of 4 axes		120 W or less	300 W or less
Function	Host interface		EtherCAT Minimum communication cycle: 125 μs	
	Assist function		Position assist, torque assist	
	General-purpose I/O		Inputs: 8 (common to 4 axes) Outputs: 8 (2 outputs per axis)	
	Safety functions Safety performance level		Safe Torque Off (STO) IEC 61508: SIL3 IEC 62061: SILCL3 ISO 13849-1: PL=e	

2.3 24/48 VDC, 4-axis integrated closed-loop stepping driver with EtherCAT interface

This section introduces the 4-axis integrated closed-loop stepping system equipped with an EtherCAT interface.

Our *SANMOTION Model No.PB* series closed-loop stepping system does not step-out. This system does not require complicated adjustments, therefore it is suitable for such peripherals as a robot's auxiliary axes.

Figure 3 shows the appearance of a closed-loop stepping motor and 4-axis integrated PB driver, and Table 3 provides the main specifications of the driver. The advantages of a compact and wire-saving design resulting from the 4-axis integrated structure are as stated in the servo amplifier section. In addition, as with the 4-axis integrated servo amplifier, the input power is either 24 or 48 VDC to enable the battery-powered drive. Moreover, the power supply connector and the pin arrangement are common with the servo amplifier, therefore the same harness can be used.

Previously, encoders were mounted to a stepping motor to monitor step-out, therefore the emphasis was on low cost rather than high resolution. Nowadays, however, a 16,000 P/R high-resolution incremental encoder comes as standard to achieve smooth control. Furthermore, this product supports the battery-less absolute encoder, *Model No.HA035(HA035)*. *HA035* does not require a battery for retaining multi-turn data so it reduces maintenance while being environmentally friendly. If *HA035* is used, there is no need to wire in a limit sensors or homing sensor. Homing sequence is also unnecessary, delivering new value through short system boot times.

Customers can choose from two control types: closed-loop control and low-deviation closed-loop control. The former offers energy-saving and smooth operation, producing minimal torque, noise, and heat, making it suitable for applications that require human interaction such as medical and nursing fields. Moreover, closed-loop control systems can push at a constant force, thereby replacing a pneumatic actuator to offer further simplification of systems. Meanwhile, the low-deviation closed-loop control is suitable for applications requiring minimal position command delay, trajectory control with multiple axes and synchronized operations. By refreshing position commands with a 250 μs minimum communication cycle, and maximizing the performance of synchronous stepping motors, high-speed and accurate motion can be obtained.

Fig. 3: Appearance of a stepping motor and 4-axis integrated closed-loop stepping driver

Table 3: Main specifications of the 4-axis-in-one type PB driver

Model number			PB4D003E440
Basic specifications	Mass		0.7 kg
	Dimensions		160 H x 60 W x 95 D mm
	Input power	Control power	24 VDC ±10%
		Main circuit power	48 VDC ±10% or 24 VDC ±10%
	Compatible motor		28 mm sq. 42 mm sq. 60 mm sq.
	Compatible encoder		16000 P/R incremental encoder or absolute encoder (28 mm sq. only supports 2000 P/R incremental encoders)
Function	Host interface		EtherCAT Minimum communication cycle time: 250 μs
	Control method		Closed-loop control, Low-deviation closed-loop control
	General-purpose I/O		Inputs: 16 (4 inputs per axis) Outputs: 12 (3 outputs per axis)

2.4 The 24 VDC high-speed processing controller *SANMOTION C*

The *SANMOTION C* is a motion controller for servo-driven industrial machinery. It can control a servo amplifier and closed-loop stepping driver through a network for motion control, thereby controlling the position, speed, and torque of a servo motor and stepping motor. Furthermore, the *SANMOTION C* is equipped with a robot control function and kinematics to support various robot mechanisms, allowing customers to easily build robots themselves.

To improve the drive quality of equipment, we increased the command refresh cycle speed of servo amplifiers for smoother control. Our lineup of products enable complex operation of multiple robots by increasing the number of controllable motor axes. Moreover, with a 24 VDC input, the controller can be battery-driven, making it appropriate for mobile service robots. Additionally, we use an open network EtherCAT as the motion network therefore a different drive units can be combined and used, such as EtherCAT-compatible servo amplifiers and stepping drivers, making it possible to select and use the optimal servo system.

Figure 4 is the appearance of the *SANMOTION C* and the below section introduces its features.

Fig. 4: Appearance of high-speed processing controller *SANMOTION C*

(1) Control function

The *SANMOTION C* is equipped with PLC control, motion control, and robot control functions. The control and programming methods differ between motion control and robot control so the *SANMOTION C* supports both by having various runtime firmware and integrated development tool software to choose from depending on user's application.

(2) Motion control

By using the various standardized MFB (motion function block), anyone can write a motion control program with ease. Table 4 provides details of the motion control function.

Table 4: Motion control function

No. of controlled axes	Max. 64
Communication cycle time	1 to 8 ms
Control method	Position control (PTP), speed control, torque control
Acceleration/ deceleration method	Automatic trapezoidal acceleration/ deceleration, S-shaped acceleration/ deceleration
Unit for positioning control	Arbitrary (pulse, mm, inch, degree)
Max. command value	-2147483648 to 2147483647 (32-bit signed)
Programming language	Complies with IEC 61131-3 (IL, ST, LD, FBD, SFC, CFC)
Motion function block	Homing, incremental mode, absolute mode, constant speed mode, electronic cam, electronic gear

(3) Robot control

By supporting kinematics for various mechanisms and by using original robot language, robot orientation and TCP (tool center point) position can be controlled. Table 5 provides details of the robot control function

Table 5: Robot control function

No. of controlled axes (for each robot)	Max. 9 (6-axis articulated robot＋additional 3 axes)
Communication cycle time	2 to 8 ms
Control method	PTP, 3D linear, 3D circular
Teaching method	Remote teaching, numeric input
Unit for positioning control	Arbitrary (pulse, mm, inch, degree)
Programming language	Original robot language
Supported robot	Cartesian coordinate robot, horizontal articulated robot, vertical articulated robot, parallel link robot, etc.

(4) Processing performance

The high-speed, high-accuracy control of multiple peripheral control devices such as control machinery and multi-axis robots is possible with just one controller unit, making equipment smaller and faster motion. Moreover, finer and smoother motion of equipment is achieved thanks to high trajectory accuracy during positional control and synchronization control of the cam, etc. As a concrete example of high-speed processing performance, Table 6 shows the control performance when combined with one of our servo amplifier equipped with an EtherCAT interface is connected.

- Basic command processing time:
  The shortest processing time for basic commands (floating point arithmetic commands) is 11 ns.
- Maximum no. of controlled axes:
  Up to 64 axes can be controlled.
- Multiple robot control:
  Capable of driving up to two 6-axis articulated robots.

Table 6: Control performance when combined with our servo amplifier equipped with an EtherCAT interface

Control performance	Communication cycle time	Product model	
		SMC263X	**SMC265X**
Basic command processing time	—	18 ns	11 ns
Max. no. of controllable axes	**4 ms**	64	64
	2 ms	32	64
	1 ms	16	32
No. of controlled robots (6-axis articulated robots)	**8 ms**	2 units	2 units
	4 ms	1 unit	2 units
	2 ms	—	1 unit

3. Conclusion

This article has introduced the 48 VDC compact 20 mm sq. AC servo motor, 24/48 VDC EtherCAT interface-equipped 4-axis integrated servo amplifier, 4-axis integrated PB driver, and the 24 VDC high-speed processing controller *SANMOTION C* as Servo Systems products offering value to the “service robot” field, where advancements have been made in R&D.

These products are suitable for “service robots” thanks to their compact, lightweight, wire-saving, and power-saving design, their support of multi-axis systems, and their standardized power supply voltage allowing everything from the servo motor to the controller to be battery-driven. SANYO DENKI believes that Servo Systems products with a common concept can create new value for our customers’ equipment and system development as well as contribute to the development of high-quality products.

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Development of the *SANMOTION R 3E Model* EtherCAT Servo Amplifier

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1. Introduction

In recent years, industries such as semiconductor manufacturing equipment, machine tools, industrial robots, and general industrial machinery have seen a rapid adoption of Ethernet for industrial applications and its market share is expanding. Propelled along by factors such as Industry 4.0 and the shift towards IoT, industrial Ethernet is predicted to expand on a global scale.

In 2009, SANYO DENKI released the EtherCAT-equipped *SANMOTION R ADVANCED MODEL* AC servo amplifier which is currently being used by a variety of customers. In 2014, we released the new series *SANMOTION R 3E Model* AC servo amplifier with improved usability and evolved performance. In 2017, we developed *SANMOTION R 3E Model* as an EtherCAT servo amplifier with further improved usability and scalability.

This article briefly introduces the performance and functions of this newly developed EtherCAT servo amplifier added to the *SANMOTION R 3E Model* series.

2. Product Overview

2.1 The new model and our product lineup

Figure 1 shows the history of SANYO DENKI's EtherCAT servo amplifier to date. Since developing the *SANMOTION R ADVANCED MODEL* EtherCAT servo amplifier in 2009, we have expanded the lineup and improved performance by releasing a high-speed communication type in 2012 that has a minimum communication cycle of 125 μs, and a low-voltage input multi-axis type in 2014. The new model has improved its basic performance for communication and servo control as a product of the *SANMOTION R 3E Model* series.

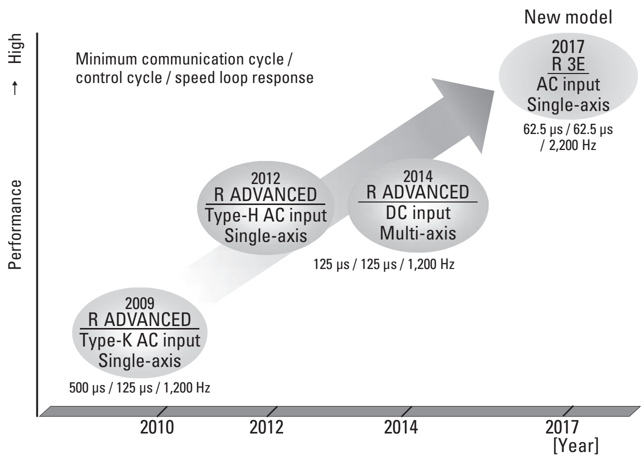

Fig. 1: History of the EtherCAT servo amplifier and positioning of the new model

2.2 Appearance and dimensions

Figure 2 shows an external view of the 200 VAC, 10 A models as typical examples. The standard model is shown on the left, and the safety function-equipped model (Safety) is shown on the right. Figure 3 gives a dimensional drawing of the 200 VAC, 10 A standard model as a typical example. All the new amplifiers have the same dimensions as the *SANMOTION R 3E Model* analog/pulse input amplifiers corresponding in terms of the input power and amplifier capacity.

Standard model Safety function-equipped model (Safety)

Fig. 2: Appearance of the new model (200 VAC/10 A)

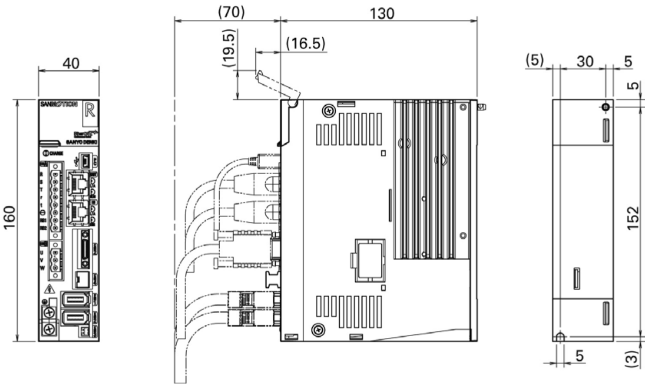

Fig. 3: Dimensions (200 VAC, 10 A model)

2.3 Main specifications

Table 1 shows the main specifications of the newly developed *SANMOTION R 3E Model* EtherCAT servo amplifiers.

Regarding input power and amplifier capacity, the new models added to the lineup include nine 200 VAC models, three 100 VAC models, and three 400 VAC models with amplifier capacity variations.

These amplifiers can drive various servo motors: the *SANMOTION R* series rotary servo motors, linear motors, and direct drive motors.

These are compatible with our battery-less and battery-backup absolute encoders and wire-saving pulse encoders. Also, for use in linear systems or fully-closed loop control systems, encoders supporting EnDat2.2 (manufactured by HEIDENHAIN) can be combined.

Table 2 shows the functions and communication specifications. While basic EtherCAT functions remain compatible with existing products, the communication performance has been improved with the shortened minimum communication cycle and expanded amount of data transfer for data processing. Moreover, the new models are equipped with a scaling function enabling command input not only in the conventional encoder pulse unit but also in linear and rotational units. In addition, the new models have passed the latest conformance test, “EtherCAT Conformance Test Tool Version 2.0” which is the standard for interoperability of EtherCAT communication.

Table 1: Main specifications

Power supply voltage range	**200 VAC**	200 to 240 VAC
	100 VAC	100 to 120 VAC
	400 VAC	380 to 480 VAC
Amplifier output capacity	**200 VAC**	10, 20, 30, 50, 75, 100, 150, 300, 600 A
	100 VAC	10, 20, 30 A
	400 VAC	25, 50, 100 A
Compatible motor		SANMOTION R series motors
Compatible encoder		• Absolute encoder (Battery backup, Battery-less) • Wire-saving pulse encoder • EnDat2.2 encoder*
Safety function	**Amplifier**	STO (Safe Torque Off)
	Safety module	STO, SS1, SS2, SLS, SOS, SSM, SBC
Function	**Control function**	• Dual position feedback control • Tandem operation control
	Mechanical vibration/ resonance suppression	• FF vibration control (2 levels) • Vibration control for track control • Adaptive notch filter
	Servo tuning	• Auto tuning response 40 levels • Servo tuning support function
	Start-up, monitoring, diagnosis	• Virtual motor operation • Encoder/amplifier temperature monitoring • Power consumption monitoring • Drive recorder
Safety standards	**UL/cUL**	UL 61800-5-1
	Low-voltage directive	EN 61800-5-1
	EMC directive	EN 61800-3, EN 61326-3-1
	Functional safety	ISO 13849-1: PL=e EN 61508: SIL3, EN 62061: SILCL3
	KC mark	KN 61000-6-2, KN 61000-6-4

* Not compatible with the safety function-equipped model (Safety)

Table 2: Communication specifications and functions

Interface	EtherCAT	
Device profile	CoE: CANopen over EtherCAT	
	FoE: Fileaccess over EtherCAT	
Synchronization mode	DC sync (Sync0, Sync1)	
	SM2 event synchronization	
Communication cycle	Minimum communication cycle: Position control: 125 μs Velocity/torque control: 62.5 μs (1/2 of current model but with PDO mapping limitations)	
Communication parameter	SDO: Service Data Object	
	PDO: Process Data Object	
Amount of data transfer	Maximum mapping number Transmitting PDO: 31 objects Receiving PDO: 31 objects	
Authentication test version	Conformance test (CTT) Ver 2.0	
Operation mode	PP	Profile Position mode
	PV	Profile Velocity mode
	TQ	Torque Profile mode
	IP	Interpolated Position mode
	HM	Homing mode
	CSP	Cyclic Sync. Position mode
	CSV	Cyclic Sync. Velocity mode
	CST	Cyclic Sync. Torque mode
Function	FT	Touch Probe function
	Scaling function (Pulse, mm, degree)	

3. Performance and Main Functions

3.1 Servo performance and functions

The basic servo performance and functions are the same as the regular *SANMOTION R 3E Model* series amplifiers. The main features are as follows.

3.1.1 High-response position speed control

Feedback response can be improved with a function to improve the phase delay within position control and speed control systems, as well as a function to increase integral gain. Moreover, with both speed and torque feed-forward compensation, an improvement in command responsiveness can be expected as well.

3.1.2 Power consumption monitoring function

The new models feature a power consumption monitoring function which estimates the power consumption of the servo motor and amplifier based on the speed and current of the motor. This makes it possible to easily monitor a device's power consumption.

3.1.3 Virtual motor operation function

As a user assist function aimed at enhancing usability, the new model is equipped with a virtual motor operation function which simulates operations of the servo motor and servo amplifier based on commands from a host device, without actually operating the motor. This function makes it possible to start up a device safely and swiftly.

3.1.4 Drive recorder function

To improve troubleshooting, the new model features a drive recorder function to record the operational data of the servo motor and amplifier for a set period of time. Such data recorded during fault occurrences includes motor rotational speed, torque, and main circuit DC line voltage. As a result, troubleshooting is made easy as fault cause can be identified and appropriate countermeasures can be performed swiftly. This helps to improve the reliability of the system.

3.2 EtherCAT-related functions

The new and current models share the same main communication functions and parameters, making it easier for customers to upgrade to a new model. The following functions were expanded to better leverage the advantages of EtherCAT communication.

3.2.1 Shortening minimum communication cycle

By leveraging the strengths of high-speed communication, we have maximized servo performance and enabled smooth motion, thus shortening minimum communication cycle from 125 μs on the current models to 62.5 μs on the new models. (During speed control and torque control mode)

3.2.2 Expanding the maximum amount of data transfer

As Figure 4 shows, the maximum amount of data transfer in one communication cycle has increased from 20 objects on current models to 31 objects on the new models, which is an increase of around 1.6 times. This has made it possible to monitor the customer's device data managed by the servo amplifier with greater speed and in more detail, thus contributing to the IoT trend by providing predictive maintenance diagnostics of the device and servo equipment.

■ R ADVANCED MODEL Type-H

PDO Mapping Object	
Sub-Index	Data
0x00	20
0x01	PDO Object 1
0x02	PDO Object 2
0x03	PDO Object 3
0x04	PDO Object 4
0x05	PDO Object 5
0x06	PDO Object 6
0x07	PDO Object 7
0x08	PDO Object 8
0x09	PDO Object 9
0x0A	PDO Object 10
0x0B	PDO Object 11
0x0C	PDO Object 12
0x0D	PDO Object 13
0x0E	PDO Object 14
0x0F	PDO Object 15
0x10	PDO Object 16
0x11	PDO Object 17
0x12	PDO Object 18
0x13	PDO Object 19
0x14	PDO Object 20

x 1.6

■ R 3E Model

PDO Mapping Object	
Sub-Index	Data
0x00	31
0x01	PDO Object 1
0x02	PDO Object 2
0x03	PDO Object 3
0x04	PDO Object 4
0x05	PDO Object 5
0x06	PDO Object 6
0x07	PDO Object 7
0x08	PDO Object 8
0x09	PDO Object 9
0x0A	PDO Object 10
0x0B	PDO Object 11
0x0C	PDO Object 12
0x0D	PDO Object 13
0x0E	PDO Object 14
0x0F	PDO Object 15
0x10	PDO Object 16
0x11	PDO Object 17
0x12	PDO Object 18
0x13	PDO Object 19
0x14	PDO Object 20
0x15	PDO Object 21
0x16	PDO Object 22
0x17	PDO Object 23
0x18	PDO Object 24
0x19	PDO Object 25
0x1A	PDO Object 26
0x1B	PDO Object 27
0x1C	PDO Object 28
0x1D	PDO Object 29
0x1E	PDO Object 30
0x1F	PDO Object 31

Fig. 4: Comparison
of maximum PDO mapping number

3.2.3 Scaling function

The new models feature a scaling function enabling users to select the unit of measurement used for commands and feedback data to suit the particular piece of equipment. Figure 5 illustrates the concept of the scaling function. Conventionally, host controller would operate by first converting position commands to encoder pulse units. However, thanks to the scaling function, it is possible to give position commands for linear motion in mm and for rotational motion in degrees, thus alleviating the burden on the controller and improving convenience.

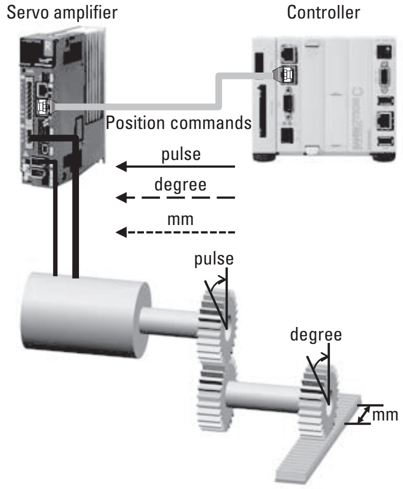

Fig. 5: Concept of scaling function

4. Conclusion

This article has presented an overview of the performance, functions, and features of the EtherCAT servo amplifier that has been newly added to the AC servo amplifier *SANMOTION R 3E Model* series lineup.

The new models add a high-speed network type to the high-performance, highly-functional *SANMOTION R 3E Model* series which pursues safety and usability. We believe it will greatly contribute to further improving the reliability and safety of our customers' devices and help shift towards IoT.

Moving forward, we plan to enhance functions to further promote the IoT transition. Moreover, SANYO DENKI intends to enhance our lineups for DC input, multi-axis specifications and other network products in order to propose products which better satisfy customer needs and contribute to our customers' value creation.

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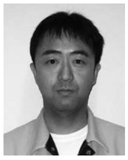

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Development of the *SANMOTION R 3E Model Safety* Servo Amplifier

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Yuuki Nakamura Yasuhiro Wakui Mitsuhiro Nishimura Naoki Kubo Yoshiki Okada

1. Introduction

In recent years, Europe in particular has established international safety standards for a variety of industries and equipment, including machine tools, industrial robots, and medical devices. Such standards place a greater emphasis on "functional safety," whereby hazards and risks are reduced to a tolerable level by implementing safety functions using electrical, electronic, and programmable electronic control systems. Even in Japan, there is an increasing demand from the market to support this functional safety standard primarily in the machine tool and industrial robot industries and this has led to initiatives for even higher safety functions.

Components such as servo amplifiers adopted in equipment which are required to have high safety must be equipped with the various safety functions defined in international standards and obtain safety standard certification.

SANYO DENKI already offers the widely-used *SANMOTION R ADVANCED MODEL* and *SANMOTION R 3E Model* which are equipped with STO (Safe Torque Off) as a basic safety function. However, in response to the aforementioned demands, we have expanded our lineup with the addition of the *SANMOTION R 3E Model Safety* servo amplifier which supports a variety of safety functions. This article describes the specifications and features of the new model.

2. Product Overview

2.1 Appearance

Figure 1 shows the 200 VAC input, analog/pulse train interface model (left) and the EtherCAT interface model (right).

Fig. 1: Appearance (10 A)

2.2 General specifications

Table 1 provides the general specifications of the 200 VAC input model, while Figure 2 is a structural drawing. The new safety functioned servo amplifier (hereinafter "new model"), the *SANMOTION R 3E Model Safety*, can be configured by attaching a special-purpose board (hereinafter "safety module") on the side of the existing *SANMOTION R 3E Model* analog/pulse train interface or EtherCAT interface servo amplifier. Moreover, the safety module and side cover are standardized, so all amplifier capacities of each input power specification are compatible with the expansion.

Table 1: General specifications

Input power specifications	100, 200, 400 VAC
Amplifier capacity	All capacities
Compatible motor	*SANMOTION R* series motors
Compatible encoder	Absolute encoder (for incremental systems, battery-backup, battery-less) Wire saving pulse encoder
User interface	Analog/pulse train interface EtherCAT interface

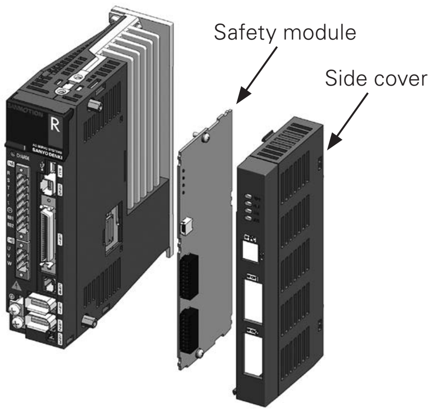


Fig. 2: Structural drawing (10 A model)

The new model is compatible with our standard encoders, and can be used with the *SANMOTION R* servo motors. This means that safety functions can be added by simply replacing the existing servo amplifier with this new, safety function-equipped model, eliminating the need to make changes to the servo motor or equipment itself.

3. Functions and Features

Table 2 shows the safety specifications of the new model. The new model uses software to monitor motor speed and position to deliver a variety of complex safety functions. Furthermore, it also supports a safety output function whereby the circuit has a self-diagnosis function.

Table 2: Functional safety specifications

Item			Safety performance	
Safety function	IEC/EN 61800-5-2		EN 61508 IEC/EN 62061	ISO 13849-1: 2015 EN ISO13849-1: 2015
	Safe Torque Off (STO)		SIL3 SILCL3	PL=e Category 3
	Safe Stop 1 (SS1)			
	Safe Stop 2 (SS2)			
	Safe Operating Stop (SOS)			
	Safely-Limited Speed (SLS)			
Safety output function	Safe Brake Control (SBC)			
	Safe Speed Monitor (SSM)			
Safety I/O	Configuration		Redundant configuration (SF-CN1, SF-CN2)	
	Input device	No. of inputs	5 points x 2 systems (sink/source)	
		Mismatch detection time	10 s	
		Diagnosis cycle	10 min	
		Off-shot pulse width	Less than 1 ms	
	Output device	No. of outputs:	3 points x 2 systems (source)	
		Diagnosis cycle	10 min	

3.1 Safety functions

Table 3 describes the safety functions. The new model is equipped with five safety inputs to execute each of these five functions. Moreover, parameters can be used to determine which safety function is executed by each safety input.

Table 3: Safety function overview

Safety function	Description
STO	Safely shuts off power supply to the motor.
SS1	Safely reduces motor speed until the motor stops, then shuts off power supply.
SS2	Safely reduces motor speed until the motor stops, then monitors stop position.
SOS	Monitors the motor stop position, and if the safe stop range is exceeded, shuts off power supply to the motor.
SLS	Monitors motor speed, and if the safe speed range is exceeded, shuts off power supply to the motor.

Table 4 lists the safety inputs and corresponding selectable safety functions. Safety inputs SFIA and SFIB support all safety functions and the appropriate function can be selected to suit the purpose.

SFIC through SFIE function as inputs for Safely-Limited Speed (SLS). Seven stages of safe speed range (speed limited levels) can be selected through ON/OFF combinations of the three inputs. Moreover, for fine-tuned control, SFIA and SFIB can be used to expand the safe speed range up to a maximum of 31 stages.

With multiple safety inputs and the freedom to select which safety function to execute, the safety functions can be used flexibly to match the device operating conditions. It is also possible to execute multiple safety functions simultaneously.

Table 4: Safety inputs and selectable safety functions

Safety input	Safety function				
	STO	SS1	SS2	SOS	SLS (SSM)
SFIA	○	○	○	○	○
SFIB	○	○	○	○	○
SFIC	–	–	–	–	○
SFID	–	–	–	–	○
SFIE	–	–	–	–	○

○: Selectable

3.2 Safety output functions

Table 5 provides descriptions of the safety output functions and monitor output functions. The new model supports two types of safety outputs and three types of monitor outputs, which are selectable using parameters.

Table 5: Descriptions of the safety output function and monitor output function

Output function		Description
Safety output function	SBC	Outputs a signal to control the motor's holding brake.
	SSM	Outputs a signal to ensure the motor is within a safe speed range.
Monitor output function	INM	Outputs a signal to notify the safety input status.
	STA	Outputs a signal to notify the safety-function execution status.
	STO	Outputs a signal to notify the motor power shut off status.

Table 6 lists safety outputs and the corresponding selectable safety output functions/monitor output functions.

Table 6: Safety outputs and corresponding selectable safety output functions/monitor output functions

Safety output	Safety output function		Monitor output function		
	SSM	SBC	INM	STA	STO
SFOA	–	○	○	○	○
SFOB	–	○	○	○	○
SFOC	○	○	○	○	○

○: Selectable

Safe Speed Monitor (SSM) can be outputted from SFOC and, in the same way as Safely-Limited Speed, a maximum of 31 stages of safe speed ranges can be selected through different combinations of the safety inputs.

Safe Brake Control (SBC) is a signal for the motor's holding brake control and can be outputted from all safety outputs.

The Safety Input Status Monitor (INM) outputs the statuses of safety inputs SFIA and SFIB to SFOA and SFOB, and the combined statuses of SFIC through SFIE to SFOC. This output function enables equipment failures to be monitored in the path from the safety inputs to the safety outputs of the servo amplifier circuit.

Moreover, by utilizing the Safety Function Operating Monitor (STA) and Safe Torque Off (STO) status monitor, the new model can monitor consistency between the safety inputs and servo amplifier internal status, as well as assess the amplifier's status.

4. Achieving Required Safety Levels

4.1 Basic structure of safety functions

As Figure 3 shows, the safety module for the new model duplicates the "input devices," "logic," and "output devices" and uses a Cat. 3 (ISO 13849-1) configuration which has a mutual monitoring function.

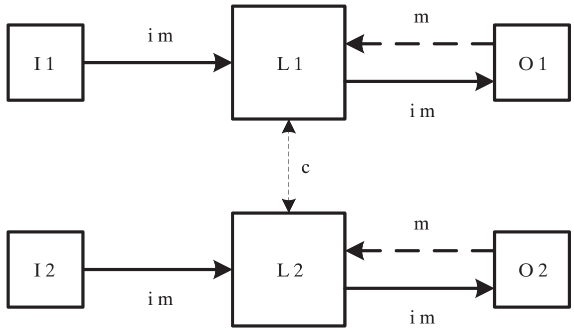
The safety input/output circuit has two I/O connectors (SF-CN1, SF-CN2) and all safety I/O signals have been organized into two systems. As such, when the user executes a safety function, there is a need to simultaneously control both safety input signal systems and this new model can detect a failure if there is a logic mismatch between the two systems. Moreover, the safety I/O circuit has a self-diagnosis function and regularly monitors circuit failures.

The safety module has duplicated voltage generating circuit and it is equipped with a self-diagnosis function. Hazardous movements of equipment are avoided by regularly monitoring mutual voltage faults (excessive voltage, low-voltage), shutting off the power supply to a system if a fault has been detected and transferring into a safe state (in the case of SANYO DENKI, a Safe Torque Off state).

The major components that make up the logic unit have also been duplicated and equipped with a self-diagnosis function. The main diagnosis functions are shown below.

- Processor diagnosis
- Memory diagnosis
- Clock diagnosis
- Program mutual monitoring, etc.

As shown above, by duplicating all circuits and equipping them with a self-diagnosis feature, the safety function is not lost and safety can be maintained when a failure occurs on single system.



i m	Internal connection
c	Mutual monitoring
I 1, I 2	Input unit
L 1, L 2	Logic
m	Monitoring
O 1, O 2	Output unit

Fig. 3: Basic configuration

4.2 Encoder diagnosis

With a Cat. 3 configuration, the encoder is also included as an input device. As such, the encoders should have been made redundant and able to detect encoder failures from the positional information of these encoders. Or, the encoder adopted should have obtained functional safety certification and be able to detect failures from the encoder's self-diagnosis. However, these methods would require significant changes to the equipment configuration, thus increase the customer's burden.

As such, SANYO DENKI has newly developed and embedded a diagnosis function in the safety module for the new model that regularly detects encoder failures. As a result, a high-level safety function has been achieved simply with our standard encoder, which has not obtained any functional safety certification.

4.3 Parameter settings

The safety module has parameters specifically for safety functions (hereinafter "safety parameters") separate from the servo amplifier. Just as servo parameters, safety parameters can be edited using our setup program, the *SANMOTION MOTOR SETUP* tool. The following special-purpose functions have been added for safety parameters.

- Requires a password to authorize parameter changing.
- Displays final confirmation notification at parameter updating.
- Displays "power re-boot" notification after parameter changes.
- Records history of additional information such as when parameters were changed and which tool versions were used.
- Prohibits input of values if parameter changing has not been authorized.

The above special-purpose functions prevent unintended parameter changes and secure parameter safety.

4.4 Safety level

By adopting the above-described redundant configuration with self-diagnosis and mutual monitoring in addition to a diagnosis function for the encoder, the new model achieves SIL3 for EN 61508, SILCL3 for IEC 62061, and PL=e for ISO 13849-1 which is the highest level of safety in the industry (as of April 2017 according to SANYO DENKI's investigation) even when combined with a standard encoder.

5. Conclusion

This article has presented an overview and features of the *SANMOTION R 3E Model Safety* servo amplifier that has been newly added to the AC servo amplifier *SANMOTION R 3E Model* lineup.

(1) Features five safety functions to suit the specific application of equipment, including "decelerating and stopping the motor safely then shutting off motor power" and "monitoring the motor to ensure rotation at a safe speed."

(2) Enables selection of up to 31 stages by using a maximum of five safety inputs for Safely-Limited Speed and Safe Speed Monitor.

(3) Equipped not only with the safety output functions of Safe Brake Control and Safe Speed Monitor, but also three types of status monitoring output functions so that the equipment can monitor the servo amplifier to ensure operation of safety functions.

(4) By developing a new encoder failure diagnosis function, we have realized safety functions with one of the industry's highest safety levels, and by combining the new model with our standard *SANMOTION R* series servo motors and encoders.

We believe this new model will greatly contribute to enhancing equipment safety and obtaining functional safety certification.

Moving forward, SANYO DENKI wishes to continue development of products that can contribute to the creation of safety systems by our customers with our focus on obtaining both communication and safety certification and enhancing safety levels.

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