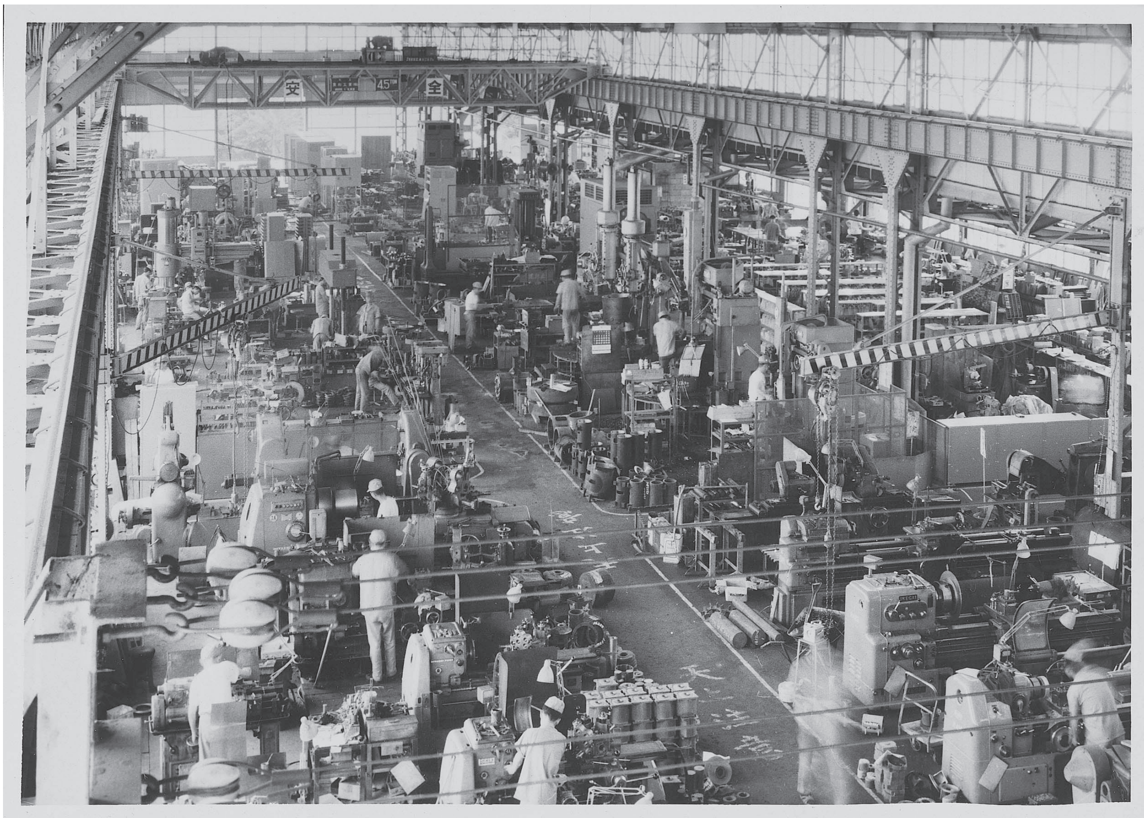
SANYO DENKI

Technical Report

Feature | SANYO DENKI's Specialty Technologies



1960
Ueda Works

48
November
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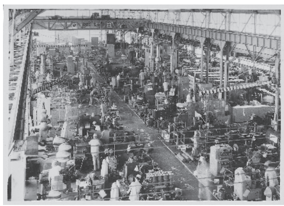

COLUMN

Cover image:

Ueda Works

1960

Before daybreak on June 4, 1960, a fire broke out at Ueda Works. Fanned by a strong wind, the fire engulfed and destroyed the wooden main factory building and production facilities. Our company lost its main factory and suddenly faced an existential crisis, but all employees, led by the president, worked together to restore their workplaces. As a result, the factory was restored in only two months.

This incident led to the replacement and expansion of our production facilities. Together with Kawaguchi Works that was completed around the same period, our production capacity was greatly increased.

Following reconstruction, large power supplies were mainly produced at Ueda Works, including AC uninterruptible power supplies, high-frequency motor generators, and constant-voltage constant-frequency power supplies. Demand for uninterruptible power supplies increased in various industries such as national rail, electric power generation, and petrochemical. Moreover, we further expanded into new markets such as for computers and broadcast stations.

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November 2019

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SANYO DENKI's Specialty Technologies

Shigejiro Miyata Operating Officer

The world's average annual temperature rose by 0.85°C over the past 100 years. In particular, the temperature rise in the Northern hemisphere was notable, especially in high-latitude locations close to the North Pole. In Japan also, the temperature rose by 1.21°C over the past century, with many of the years since 1990 being particularly hot.

I too personally feel that the climate has changed significantly, such as in the abnormal weather we have seen over the past few years.

Various gases are linked to global warming, however, carbon dioxide has the greatest impact, accounting for about 76% of greenhouse gases. Since the industrial revolution, fossil fuel use has been increasing, consequently leading to an increase in concentration of carbon dioxide in the atmosphere.

Greenhouse gas emissions have continued to increase, and are currently more than 50% higher than in 1990. Moreover, global warming is bringing about long-term changes to the entire global climate system, and if immediate action is not taken, there is a chance the situation will be irreparable. In the Paris Agreement in 2015, it was agreed that there was a need to limit global temperature rise this century to under 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5°C. There was also common recognition of the need for decarbonization.

This was indicated in Goal 13 of the 17 Sustainable Development Goals (SDGs),* which states "Take urgent action to combat climate change and its impacts." These were set at the United Nations summit as part of the 2030 Agenda for Sustainable Development, and are to be achieved in the period between 2016 and 2030.

We, SANYO DENKI Group, have set development goals at our design departments as part of our 8th Mid-term Management Plan. Two such goals are:

(1) Create products with performance that deliver new value for customers, making them happy and helping them realize their dreams.

(2) Become specialists in change. Find new value in change, turn change into value for our customers, generate change in the market through the strength of the entire group, and continuously offer new value in a changing world.

Specifically, the following product features were set as development targets: eco-efficiency, low loss, high airflow, high static pressure, low noise, water resistance, oil resistance, salt resistance, and a wide temperature range.

These targets of our design departments are consistent with Goal 13 of the Sustainable Development Goals (SDGs). The eco-efficiency and low loss features can reduce the energy consumption of our products. Features such as high airflow, high static pressure, low noise, water resistance, oil resistance, salt resistance, and a wide temperature range can simplify the structure of our customers' equipment. Also, long service life, vibration resistance, and G-force resistance can extend the maintenance cycle of our products, contributing to resource recycling and energy consumption reduction.

Moreover, as a product that can replace fossil fuels, we offer renewable energy inverters that produce energy with low environmental impact, such as photovoltaic, wind, and hydroelectric energy. These goals are consistent with Goal 7 of the 17 SDGs — Affordable and Clean Energy.

This report features our technologies used in new products and new technologies developed based on a long-term perspective as "SANYO DENKI's Specialty Technologies." Through these activities and technological developments, we will build a brand trusted by customers around the world. Through our corporate activities, we will contribute to the conservation of the global environment and prosperity of the human race.

* Sustainable Development Goals (SDGs) are the successors of the Millennium Development Goals (MDGs) set in 2001, and are global targets to be achieved in the period between 2016 and 2030 as part of the 2030 Agenda for Sustainable Development formulated at the United Nations summit in September 2015.

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Cooling Systems Specialty Technologies for Achieving High Airflow and High Static Pressure

Hiromitsu Kuribayashi

1. Introduction

Under our corporate philosophy of "Aim to help all people achieve happiness," SANYO DENKI has set three technical concepts. These are (1) technologies for protecting the global environment, (2) utilizing new energy, and (3) conserving energy. Based on these concepts, we have always developed *San Ace* cooling fans with a certain goal in mind. The goal is to realize a quiet fan with a long lifespan, minimal power consumption, and the highest airflow vs. static pressure characteristics possible.

This article will introduce our specialty technologies used in the development of *San Ace* fans to achieve high airflow and high static pressure products.

2. Background to the Demand for High Airflow and High Static Pressure

In recent years, driven by the advancement of cloud services, demand has been growing for rack mount servers (Fig. 1) used in data centers. Our fans are used in many of these servers, which are representative of ICT equipment. Generally speaking, rack mount servers are designed to be mounted in 19-inch wide racks, as standardized by the American Electronic Industries Alliance. Heights are standardized in multiples of U (44.45 mm), such as 1U, 2U, and 4U. Racks are the mainstream for server shape, and can accommodate stacks of up to forty two 1U servers so space in data centers can be used efficiently.

As with regular servers used in offices, rack mount servers have a CPU, memory, HDD, and power supply. To ensure stable operation, it is necessary to not exceed the manufacturer's guaranteed temperature for each device, and using fans for cooling is a common approach. Figure 2 depicts an example of a 1U server. There are eight 40 × 40 mm fans in the center of the device, and there is also a 40 × 40 mm fan in the power supply, as shown in Figure 3.

With the spread of the internet, the processing speed and data volume handled by servers have been rising year by year, and the heat generation of each device has increased along with these changes. Moreover, the density of components inside devices is increasing, so fans must be compact while also having high airflow and high static pressure.

Fig. 1 Example of a rack mount server
(Photo courtesy of Super Micro Computer, Inc.)

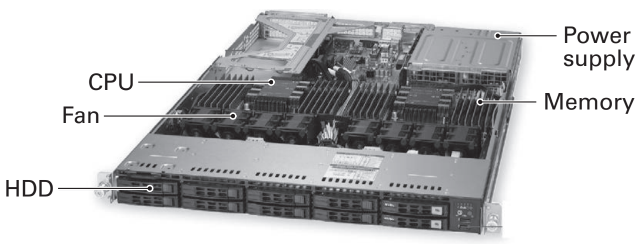

Fig. 2 Example of a 1U server
(Photo courtesy of Super Micro Computer, Inc.)

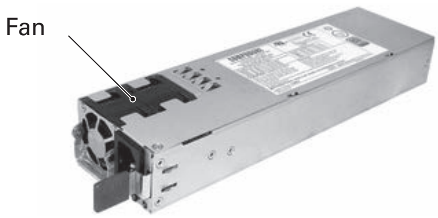

Fig. 3 Example of a 1U power supply
(Photo courtesy of Compuware Technology Inc.)

3. Specialty Technologies

3.1 Specialty technology (1): Axial fan with static blades

Let me explain the transition to high airflow and high static pressure demanded from fans used in rack mount servers. Generally speaking, to increase fan airflow, it is necessary to either increase motor speed or increase blade size. Moreover, to increase static pressure, it is necessary to either increase motor speed or alter the shape of the blades and frame to ones where static pressure can be easily secured. Meanwhile, for 1U servers, there is the aforementioned height restriction of 44.45 mm, so fan height cannot exceed 40 × 40 mm.

1U servers released in the late 1990s were equipped with our 40 × 40 × 28 mm 9P type axial fans (hereinafter 40 × 40 × 28 mm fan). Since then, whenever a new server model was developed there was a demand for higher airflow. This could be handled by increasing fan speed through minor changes such as changes to the drive circuit.

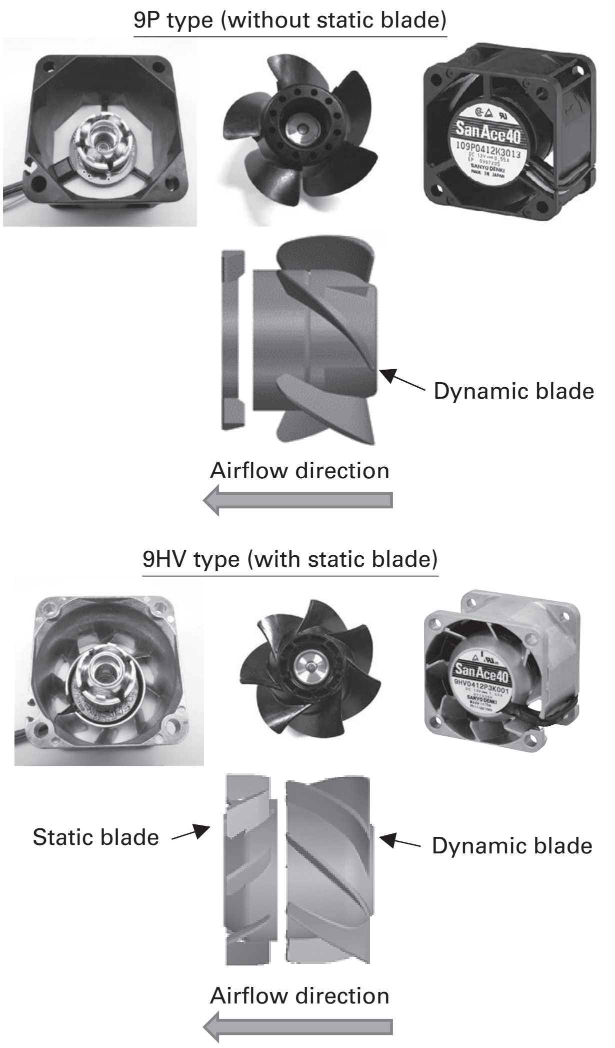

Fig. 4 Example of structures for our 40×40×28 mm fans

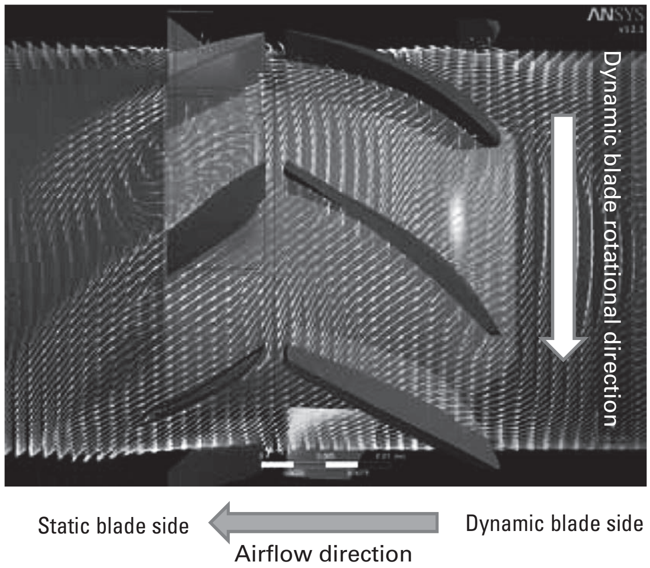

Fig. 5 A vector diagram of the air in a fan with static blades

However, by 2003, it had become difficult to effectively achieve the target airflow vs. static pressure characteristics simply through increased motor speed. We believed one of the reasons for this was that the rotating air from the dynamic blades was not contributing to axial airflow, but rather causing the flow created by the dynamic blades to lose energy.

Hence, as shown in Figures 4 and 5, we placed backward static blades in front of the dynamic blades to change the rotating air flow to the axial direction and suppress energy loss. The angle of the rotational component created by a dynamic blade varies between the area near where the blade is attached and the area near the blade tip, so we designed a static blade that match these angles. Moreover, because the overall frame thickness was 28 mm, which was insufficient to secure enough thickness of static blades in the axial direction. As such, we increased the number of static blades with the aim of increasing the rectifying effect.

Furthermore, we optimized the overall blade/frame shape, magnetic circuit, and drive circuit to minimize power consumption and noise level while maintaining the target airflow vs. static pressure characteristics.

Regarding this axial flow fan with static blades, we developed the 9GV type, 9GA type, and 9HV type for the 40 × 40 × 28 mm size in 2008, 2012, and 2015, respectively. The performance of these is shown in Table 1 and Figure 6. Compared to the 9P type (109P0412H3013) developed in 1987, the 9HV type developed in 2015 has a maximum airflow around 2.6 times greater, and a maximum static pressure around 10.7 times greater.

Table 1 Example of general specifications of our typical 40 × 40 × 28 mm fans

Model no.	Speed [min⁻¹]	Max. airflow [m³/min]	Max. static pressure [Pa]	Power consumption [W]	SPL [dB(A)]
109P0412H3013	8,700	0.32	102.9	2.34	37
109P0412K3013	15,500	0.59	340.0	6.6	50
9GV0412K301	16,500	0.76	415.0	10.08	58
9GA0412P3K01	22,000	0.81	799.0	11.04	61
9HV0412P3K001	25,000	0.83	1,100	18.3	65

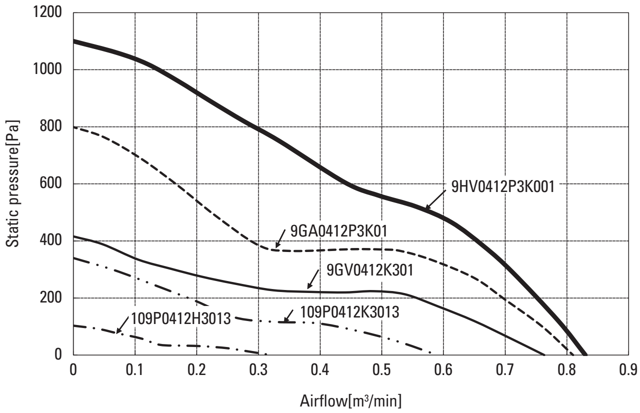

Fig. 6 Example of airflow vs. static pressure characteristics of our typical 40 × 40 × 28 mm fans

3.2 Specialty technology (2): Counter Rotating Fan

With the higher heat generation and higher component density shift in 1U servers, the cooling performance of the 40 × 40 × 28 mm fan was no longer sufficient, and cases emerged where two fans were being used in series. When two axial fans are arranged in series in the same rotational direction, similarly to the axial fans without static blades discussed in Section 3.1, rotational components remain. Hence, collision loss is caused by the flow produced by the inlet fan's dynamic blades and that of the outlet fan's dynamic blades. As a result, airflow vs. static pressure characteristics improved slightly, but it could not sufficiently satisfy the performance requirement.

In light of this, we developed the Counter Rotating Fan in 2004 as a counter rotating axial flow fan comprising an inlet fan and an outlet fan where the respective dynamic blades rotate in opposite directions. As shown in Figure 7, by installing static blades shaped to smoothly receive the flow from the inlet dynamic blades, we achieved a configuration in which the rotating flow was converted to axial flow by the outlet dynamic blades. Consequently, as Table 2 and Figure 8 show, the airflow vs. static pressure characteristics were significantly improved and we were able to solve the issue of static pressure drops in specific zones characteristic of axial flow fans.

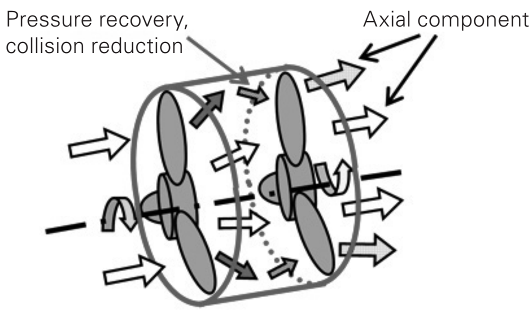

Fig. 7 Illustration of Counter Rotating Fan flow

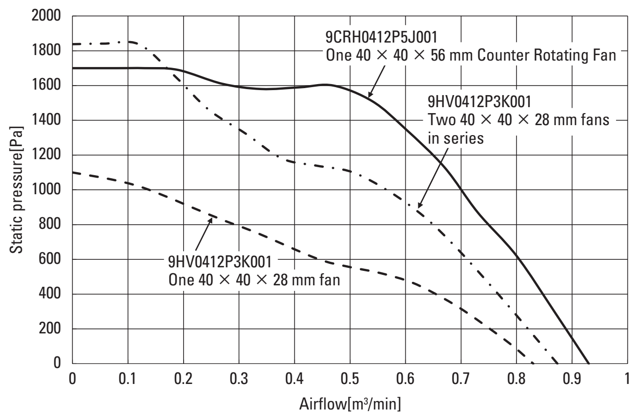

Fig. 8 Example of airflow vs. static pressure characteristics of our typical 40 × 40 mm fans

The 40 × 40 × 56 mm Counter Rotating Fan 9CRH type developed in 2017 (shown in Figure 9), has a maximum airflow 1.3 times greater and maximum static pressure 3.3 times greater than those of the 9CR type developed in 2004. Furthermore, as shown in Figure 10, flow straightness is dramatically improved compared to when an axial fan is used in isolation or in a series of two. By releasing these Counter Rotating Fans, we could offer customers unprecedented new solutions to meet their needs for higher airflow and higher static pressure.

Table 2 Example of general specifications of our typical 40 × 40 mm fans

Model no.	Speed [min^{-1}]		Max. airflow [m^3/min]	Max. static pressure [Pa]	Power consumption [W]	SPL [dB(A)]
	Inlet	Outlet				
9HV0412P3K001 One 40 × 40 × 28 mm fan	25,000		0.83	1,100	18.3	65
9HV0412P3K001 Two 40 × 40 × 28 mm fans in series	25,200	30,900	0.87	1,840	28.0	77
9CRH0412P5J001 One 40 × 40 × 56 mm Counter Rotating Fan	29,500	25,500	0.93	1,700	30.24	70

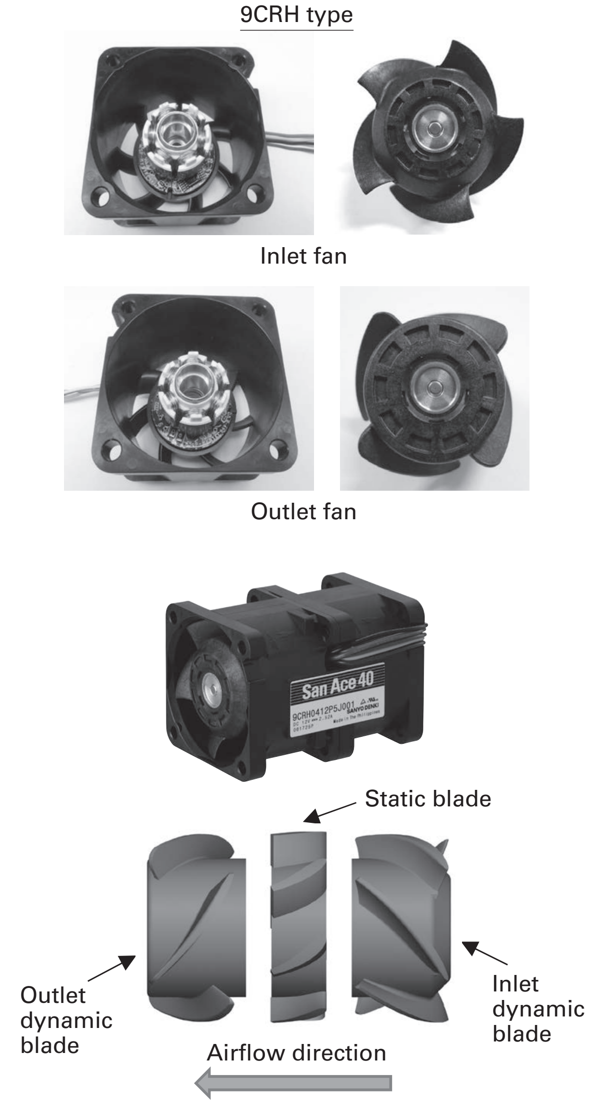

Fig. 9 Example of structure for our 40 × 40 × 56 mm Counter Rotating Fan

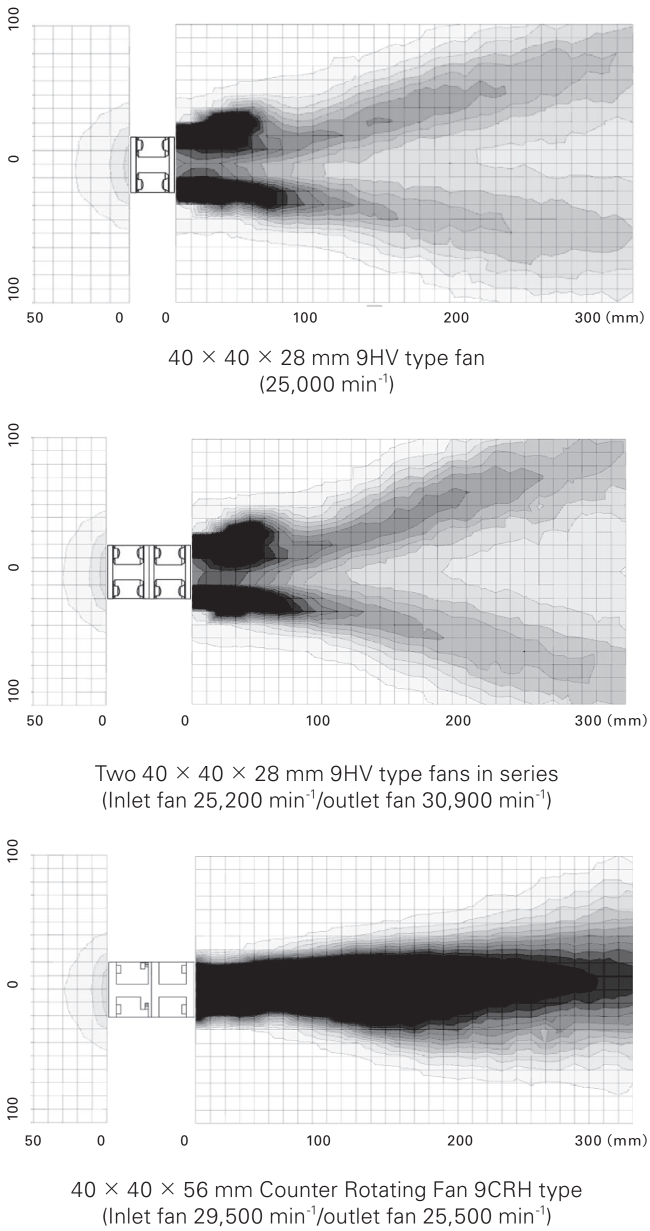

Fig. 10 Wind speed distribution (in free air and at rated voltage)

Furthermore, in addition to the 40 × 40 mm size, our current lineup has 36 × 36 mm, 60 × 60 mm, 80 × 80 mm, 92 × 92 mm, 120 × 120 mm, and ø172 mm Counter Rotating Fans. These are being actively adopted in a variety of industrial equipment, such as ICT equipment requiring compact fans with extremely high operating airflow.

4. Conclusion

This article introduced our specialty technologies for achieving high airflow and high static pressure used in the development of our *San Ace* fans, with a focus on the technologies used for fans with static blades and Counter Rotating Fans. The development of these technologies enables us to deliver optimal solutions to our customers who face cooling issues. SANYO DENKI will continue to strive toward technological development so that we can keep offering solutions matching our customers' concerns.

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Development of *San Ace Controller*, an IoT Product for Remote Fan Control and Monitoring

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Hikaru Urushimoto Masahiro Minamoto Honami Osawa

1. Introduction

In recent years, IoT (Internet of Things) has spread throughout many fields. IoT-enabled devices can be operated and monitored remotely via the internet, offering customers and users many benefits such as accumulating operating data on a cloud server to use for purposes such as preventive maintenance and product development.

Fans are a vital part of the devices in which they are used, as they enable stable operation. As such, IoT products that enable remote monitoring and preventive maintenance of fans are required.

Moreover, high energy efficiency and low SPL (sound pressure level) are always important concerns for devices. To achieve even higher energy efficiency and lower SPL, a device that can automatically control fans to operate at the proper speed for a given situation is required.

To satisfy these requirements, we developed the *San Ace Controller*, an IoT product that enables remote control and monitoring of fans with the PWM control function (hereinafter “fan”).

This article will provide an overview and introduce the features of the *San Ace Controller*, it’s dedicated sensors, and the *San Ace NET* cloud service.

Fig. 1 San Ace Controller

Fig. 2 Dedicated sensor

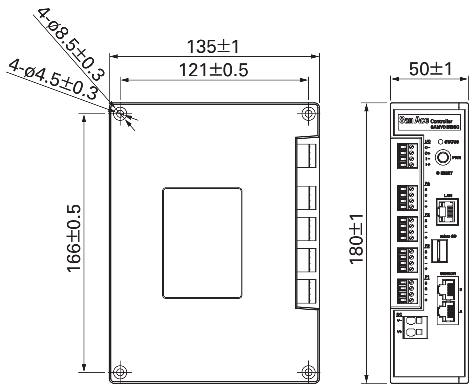

Fig. 3 San Ace Controller dimensions

2. Outline of the New Product

2.1 Appearance and Dimensions

Figures 1 and 2 show the appearances of the *San Ace Controller* and its dedicated sensor respectively, while Figures 3 and 4 provide the respective dimensions of the *San Ace Controller* and its dedicated sensor.

San Ace Controller can be installed sideways, vertically, or mounted on walls. Moreover, all connectors are positioned in the front for easy wiring.

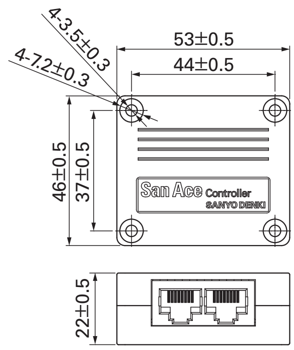

Fig. 4 Dedicated sensor dimensions

2.2 Specifications

Tables 1 and 2 show the respective specifications of *San Ace Controller* and the dedicated sensor.

It can control and monitor SANYO DENKI’s fans via a network.

Table 1 San Ace Controller specifications

Model		9CT1-001
Rated voltage [V]		12/24/48 DC
Power consumption [W]		3.1(1)
Operating voltage range [V]		7 to 60 DC
Operating temperature range [˚C]		-20 to +70
Control function		Manual/Automatic
Control signal		PWM signal High-level voltage (V_{OH}): 3.3/5 V Frequency: 25 kHz
Monitoring criteria		Fan speed, fan current, fan operation time, sensor detection value, external input
No. of connectable fans		Max. 4
Allowable fan connection terminal current		5 A (per terminal)
No. of connectable sensors		Max. 4
Supported sensors		Temperature/humidity, barometric pressure, acceleration(2)
External I/O	**Input**	Photocoupler-isolated input, ON: 15 to 28.8 VDC, OFF: 0 to 5 VDC
	Output	Photocoupler-isolated open-collector output, load voltage: 28.8 VDC or less, output current: 0.1 A or less
Communication	**Wireless**	IEEE802.11b/g/n, frequency 2.4 GHz(3)
	Wired	Ethernet 10BASE-T, 100BASE-TX
Size [mm]		50 (W) × 135 (D) × 180 (H)
Mass [g]		450
Material		Case: Plastic

(1) For use of this product alone, at 20˚C ambient temperature, (2) Dedicated sensor, (3) Supports channels 1 to 11

Table 2 Dedicated sensor specifications

Sensor type	Temperature/humidity	Barometric pressure	Accelerometer
Model	9CT1-T	9CT1-P	9CT1-A
Measurement range	Temperature: -20 to +70°C Humidity: 20 to 85% RH(1)	Barometric pressure: 800 to 1100 hPa	Acceleration: 0 to 60 m/s^2 (2)
Operating temperature range [˚C]	-20 to +70		
Operating humidity range [% RH]	20 to 85(1)		
Size [mm]	53 (W) × 46 (D) × 22 (H)		
Mass [g]	35		
Material	Case: Plastic		

(1) Non-condensing (2)Total acceleration from 3-axes

3. Product Features

3.1 Network connection function

San Ace Controller can be connected to a network either by wired or wireless connection. Figure 5 shows an example of system configuration when connected to a network.

Through its network connection function, San Ace Controller can be accessed from a device such as a computer or smartphone on a network to perform settings, control, and monitoring. Moreover, detected alarms can be received, and stored measurement data and alarm history can be downloaded. The Ethernet 10BASE-T and 100BASE-TX (wired) and IEEE802.11b/g/n (2.4 GHz) (wireless) communication standards are supported.

3.2 User interface

San Ace Controller can be operated using the regular web browser installed in devices such as computers or smartphones. The user interface is designed to be user-friendly, and a validation function prevents input and selection errors, making San Ace Controller easy to operate even for first-time users. Figure 6 shows an example of a settings screen.

3.3 Measuring and monitoring function

Regarding the connected fan and dedicated sensors, it is possible to measure and monitor the below criteria.

Fan: Speed, current value, operation time
Dedicated sensors: Temperature, humidity, barometric pressure, acceleration

The threshold of each monitoring criterion can be set arbitrarily by the user. If measurement values deviate from these thresholds, the user is alerted of an abnormality via email, a notification on a browser screen, an LED on the main unit, and an external output. Measurement data and alarm history are stored in the internal memory, and can be checked through a web browser. Moreover, measurement data and alarm history can be downloaded from a computer as a csv file, then used for preventive maintenance, new product development, and problem analysis. Figure 7 is an example of a measurement data screen.

Furthermore, an input signal from an external device enables monitoring of the external device's status, and there is a function to notify users with an alarm in the event of an abnormality.

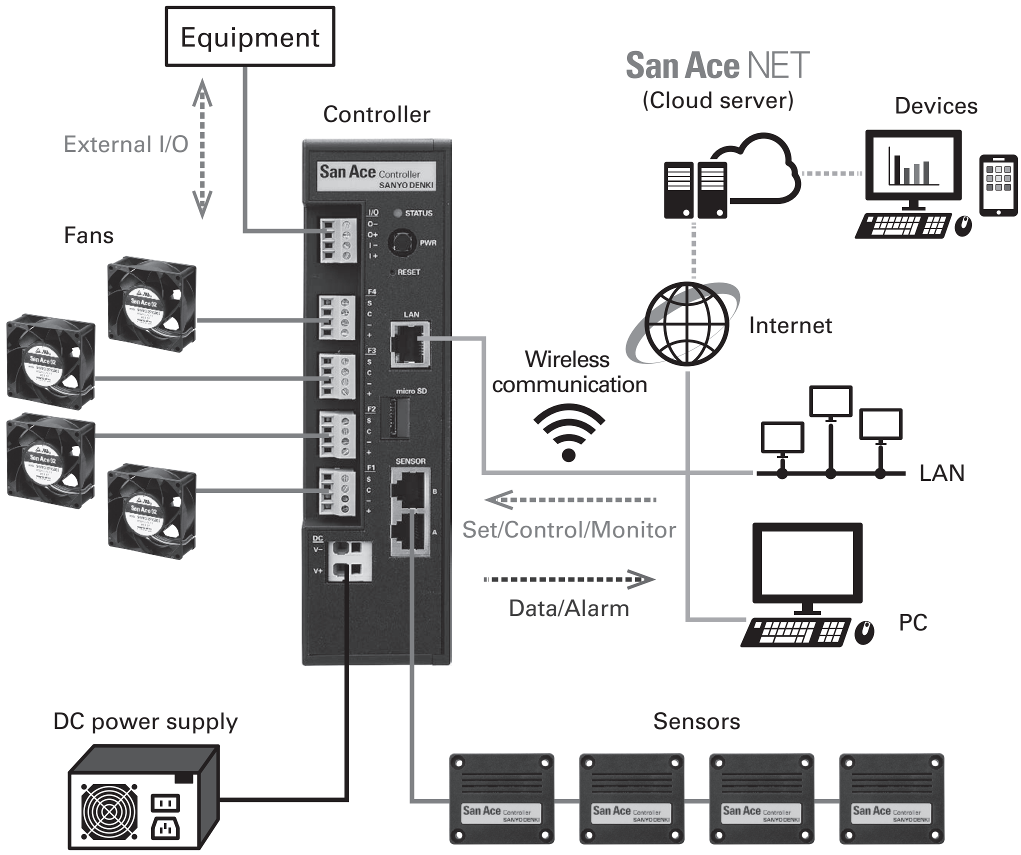

Fig. 5 Example of system configuration

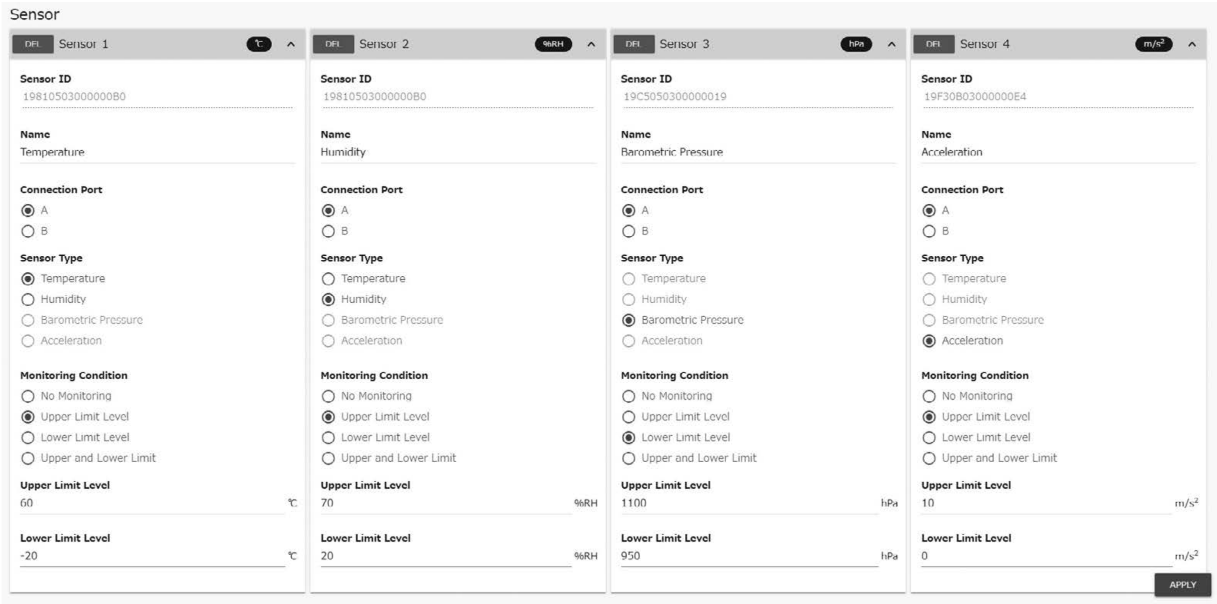

Fig. 6 Example of a settings screen

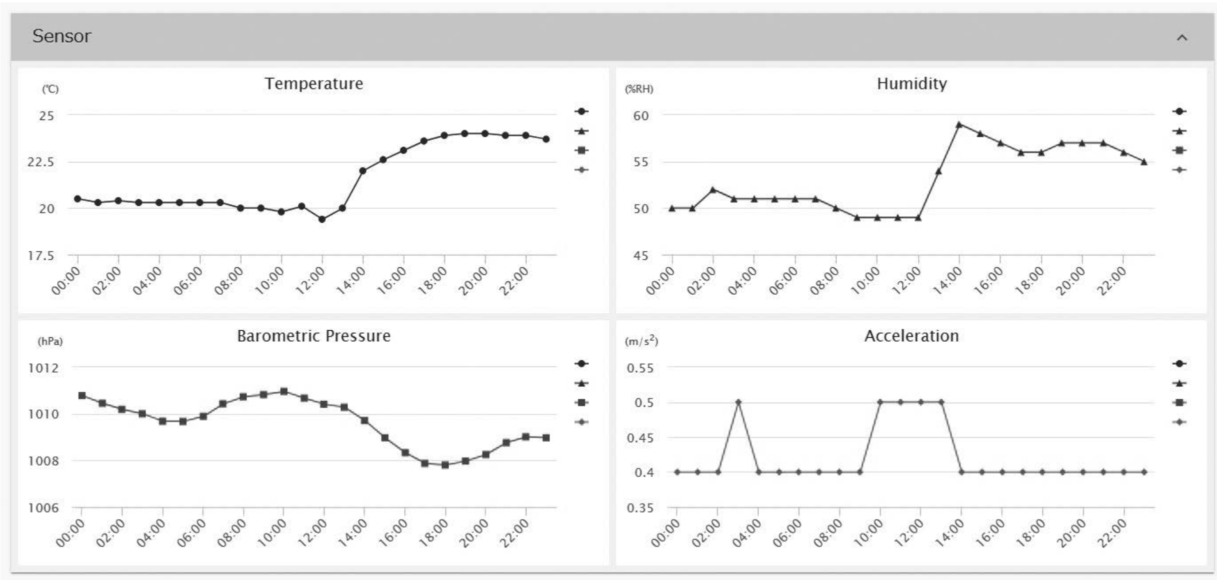

Fig. 7 Example of a measurement data screen

3.4 Fan control function

San Ace Controller can control up to four fans. Both manual control and automatic control methods are options.

3.4.1 Manual control

Manual control is a function to control fan speed by inputting an arbitrary PWM signal duty value into the connected fan. PWM signal duty can be set in increments of 1%, so users can adjust to their desired fan speed.

3.4.2 Automatic control

Automatic control is a function to automatically adjust fan speed in line with the measurement values of the connected sensor. Automatic control is achieved using either a dedicated temperature/humidity sensor or barometer. Figure 8 shows connection and operation examples of automatic fan control using temperature/humidity sensors. In this example, fans 1 and 2 are automatically controlled in accordance with the measurement values of temperature/humidity sensor A, while fans 3 and 4 are automatically controlled in accordance with the measurement values of temperature/humidity sensor B. The speeds of the fans are automatically adjusted so that the measurement values of temperature/humidity sensors A and B reach the preset target values. Because automatic control enables users to operate fans at the optimal speed, it is possible to suppress SPL and power consumption caused by excessive fan speed.

Figure 8 is an example of using two sensors for the automatic control of four fans, but it is also possible to automatically control four fans with their own individual sensor at a different target value. It is also possible to automatically control our Counter Rotating Fan and Reversible Flow Fan.

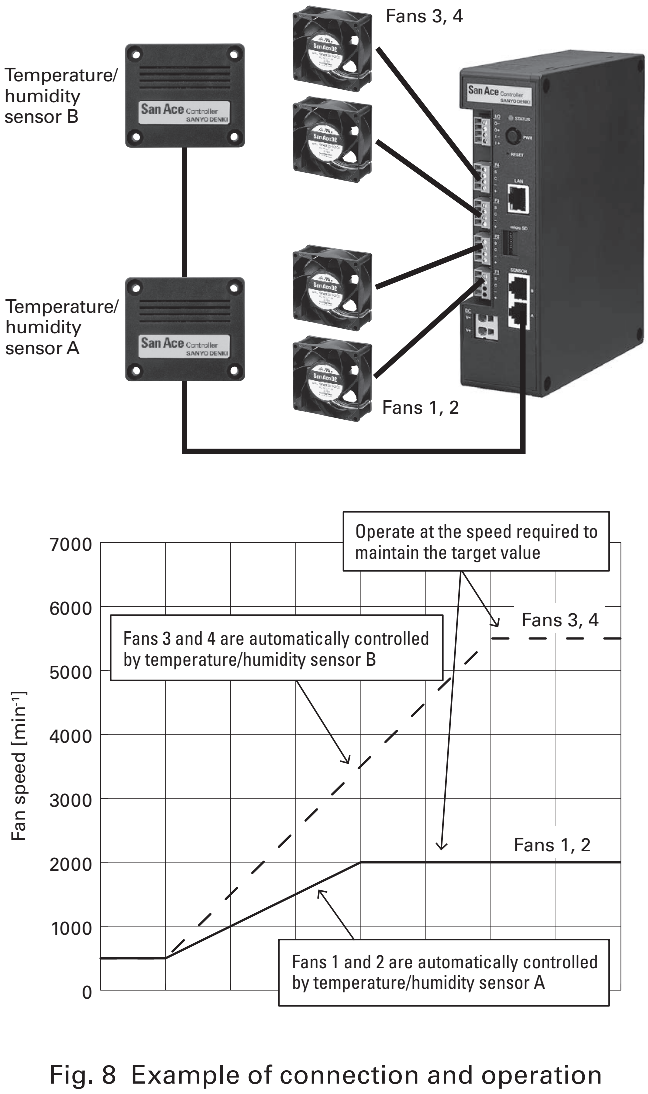

Fig. 8 Example of connection and operation of automatic control

3.5 *San Ace NET* cloud service

By using the *San Ace NET* dedicated cloud service, San Ace Controller can be set, controlled, and monitored on a computer, smartphone, or other device from a remote location as long as there is an internet connection available. Furthermore, San Ace Controller's measurement data is automatically transferred and saved to San Ace NET, meaning it can be used for data backup.

4. Conclusion

This article has given an overview and introduced the features of our *San Ace Controller*.

This is the industry's first(1) IoT product realizing remote control and monitoring of fans. It enables remote monitoring of the fan's operational status and sensor measurement values, and stores the monitoring data in the product or in *San Ace NET*. This enables such data to be used for purposes such as preventive maintenance, new product development, and problem analysis.

Moreover, with the fan automatic control function, excessive increase of fan speed can be prevented, thus significantly contributing to the realization of high energy efficiency and low SPL in our customers' equipment.

We wish to continue engaging in the development of new products to meet new requests of our customers that occur with technological advancements.

(1) Based on our own research as of August 20, 2019.

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Splash Proof Blower *San Ace 97W* 9W1B Type

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1. Introduction

Devices today, including battery packs, ventilation systems, commercial kitchen equipment, and digital signage, are becoming denser. Cooling of such equipment is performed at a high static pressure range which cannot be covered using axial flow fans, so demand for blowers has grown. Moreover, these types of equipment are often used outdoors, exposed to water, or close to people, so are also required to have high waterproof performance and low sound pressure level (hereinafter "SPL").

To meet these requirements, SANYO DENKI has developed and launched the Splash Proof Blower *San Ace 97W* 9W1B type, which has high cooling performance in the high static pressure range (hereinafter "new model").

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

2. Product Features

Figure 1 shows the appearance of the new model.

The new model is our first blower with IP68-rated dust- and waterproof performance.

Furthermore, it has high static pressure performance compared to an axial flow fan of equivalent size.

The features of the new model are:

(1) High static pressure
(2) Low power consumption and low SPL
(3) IP68[1] dust- and waterproof performance.

(1)Protection rating
The degree of protection (IP code) is defined by IEC (International Electrotechnical Commission) 60529 "DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP Code)." (IEC 60529:2001)

Fig. 1 *San Ace 97W* 9W1B Type

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new model.

To maintain compatibility with existing products, the new model has the same width and height dimensions as current models.

3.2 Specifications

Tables 1 shows the general specifications for the new model.

There are two rated voltages to choose from 12 V, 24 V, and each of these are available with speeds of 4,800 min^{-1} (H speed), or 4,100 min^{-1} (M speed). Figure 3 shows the airflow vs. static pressure characteristics of H speed, while Figure 4 shows the airflow vs. static pressure characteristics of M speed. The airflow vs. static pressure characteristics differ for the two speeds, and they can be selected to suit the heat generation situation of equipment. Moreover, because the product is equipped with a PWM control function to control fan speed to suit the situation, equipment power consumption and noise levels can be decreased.

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

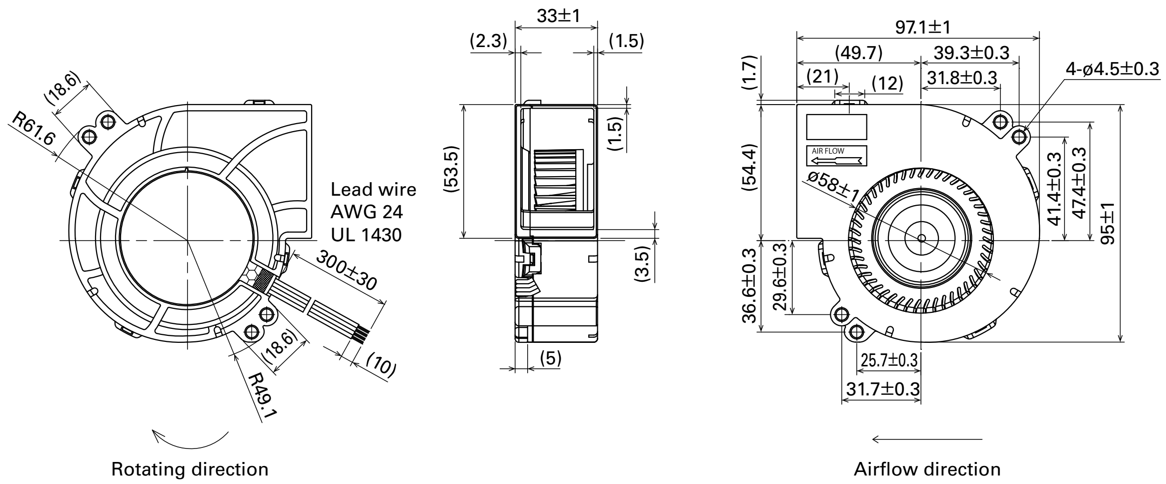

Fig. 2 Dimensions of the new model (unit: mm)

Table 1 General specifications for the new model

Model	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min⁻¹]	Max. airflow [m³/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH2O]	SPL [dB(A)]	Operating temperature range [°C]	Expected life [h]
9W1BM12P2H001	12	10.2 to 13.8	100	1.30	15.6	4,800	1.09	38.5	540	2.17	58	-20 to+70	40,000 at 60°C (70,000 at 40°C)
			20	0.14	1.68	1,500	0.32	11.3	51	0.20	30		
9W1BM12P2M001			100	0.90	10.8	4,100	0.93	32.8	380	1.53	55		
			20	0.14	1.68	1,500	0.32	11.3	51	0.20	30		
9W1BM24P2H001	24	20.4 to 27.6	100	0.65	15.6	4,800	1.09	38.5	540	2.17	58		
			20	0.07	1.68	1,500	0.32	11.3	51	0.20	30		
9W1BM24P2M001			100	0.45	10.8	4,100	0.93	32.8	380	1.53	55		
			20	0.07	1.68	1,500	0.32	11.3	51	0.20	30		

* Input PWM frequency: 25 kHz. speed is 0 min⁻¹ at 0% PWM duty cycle.

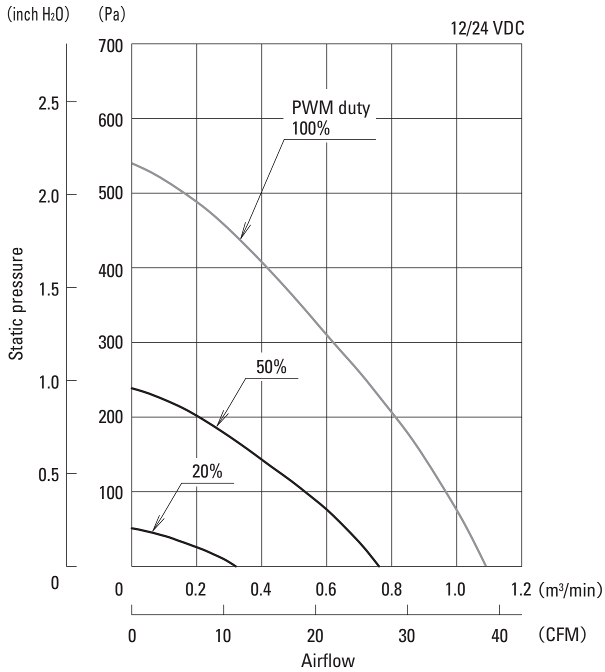

Fig. 3 Example of airflow vs. static pressure characteristics of the new model (H speed)

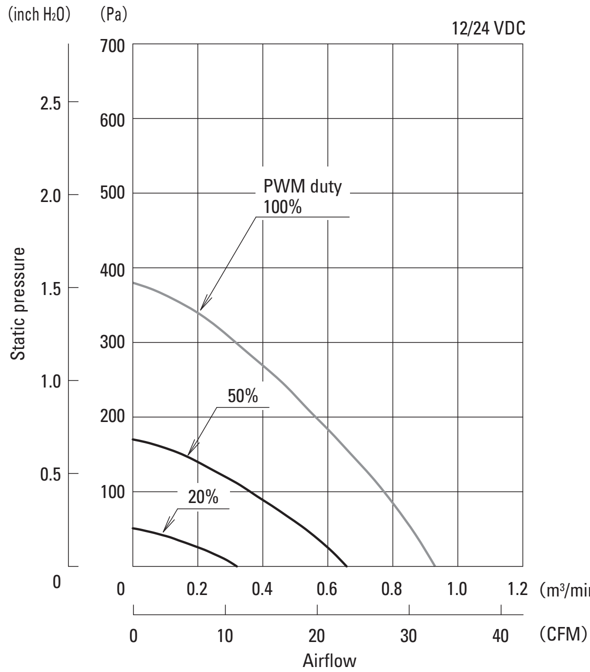

Fig. 4 Example of airflow vs. static pressure characteristics of the new model (M speed)

4. Key Points of Development

The new model is waterproof and supports high static pressure. Below is a brief introduction of design points.

4.1 Waterproof design

As Figure 5 shows, to prevent breakdown due to water penetration, live parts (motor, control circuit) are coated with resin to achieve IP68-rated dustproof and waterproof performance. Also, the following techniques were adopted so the product can be used for prolonged periods in environments exposed to water.

(1) Magnet with excellent waterproof performance used
(2) Coated aluminum die cast frame

Fig. 5 Appearance of the live parts of the new model

4.2 Frame design

The blower is made of a case consisting of a frame and cover that encloses the impeller. It was assumed that water would accumulate inside the case depending on the mounting direction of the blower and the necessary characteristics could not be achieved. For this reason, we added water drain holes to drain water from inside the case as shown in Figure 6. By taking an innovative approach to the hole shape and position, we successfully achieved both reliability and high static pressure.

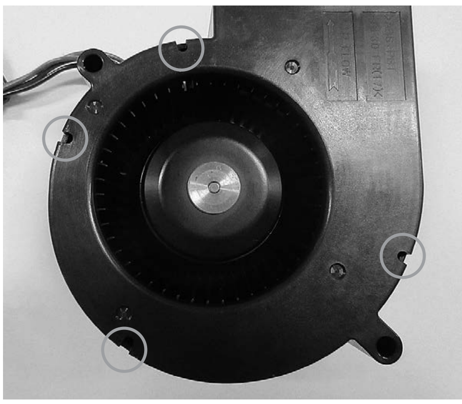

Fig. 6 Appearance of the live parts of the case

4.3 Impeller design

During operation, we assumed that water splashing on the impeller would cause overload, so there was a need to improve impeller strength. Based on previously accumulated reliability data, we used pressure simulation technology and increased the number and thickness of the impeller blades. We also used fluid simulation technology as shown in Figure 7 to optimize blade length and angle, and reach target performance.

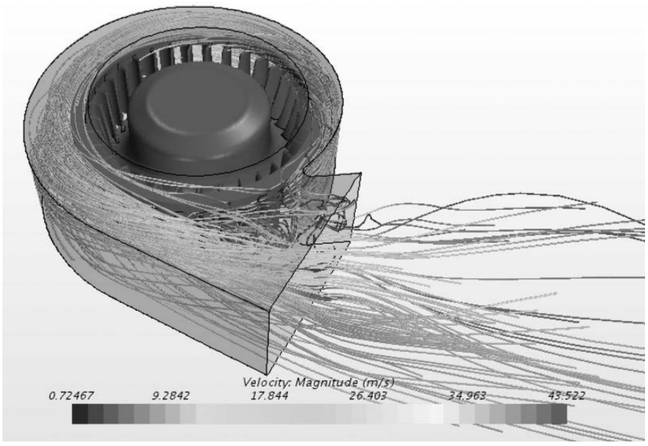

Fig. 7 Visualization of air flow

4.4 Circuit design

In addition to the configuration-based protection described in 4.2 and 4.3, this product is equipped with a dual protection function that suppresses motor drive current when overload is detected in the circuit.

5. Comparison with Splash Proof Axial Flow Fan

5.1 Comparison of airflow vs. static pressure characteristics

Figure 8 is a comparison of the airflow vs. static pressure characteristics for the new model 9W1BM24P2H001, and a conventional similar size model, 92 × 92 × 38 mm Splash Proof axial flow fan 9WV0924P1H001 (hereinafter "current model"). Compared to axial flow fans, blowers have higher static pressure, and the maximum static pressure of the new model is 40% higher than the current model. As such, this model can support equipment with high impedance.

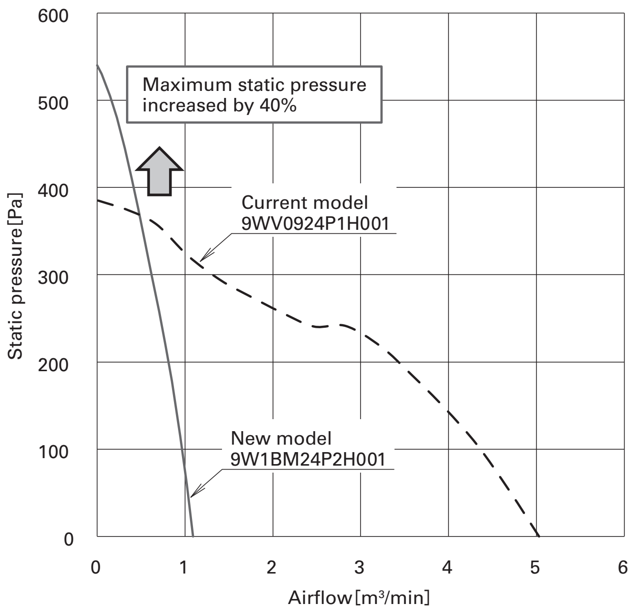

Fig. 8 Comparison of airflow vs. static pressure characteristics

5.2 Comparison at estimated operating point

In devices with the estimated system impedance stated in Figure 9, we compared the new and current models at the operating point where an equivalent cooling performance can be obtained. Power consumption is reduced by 74%.

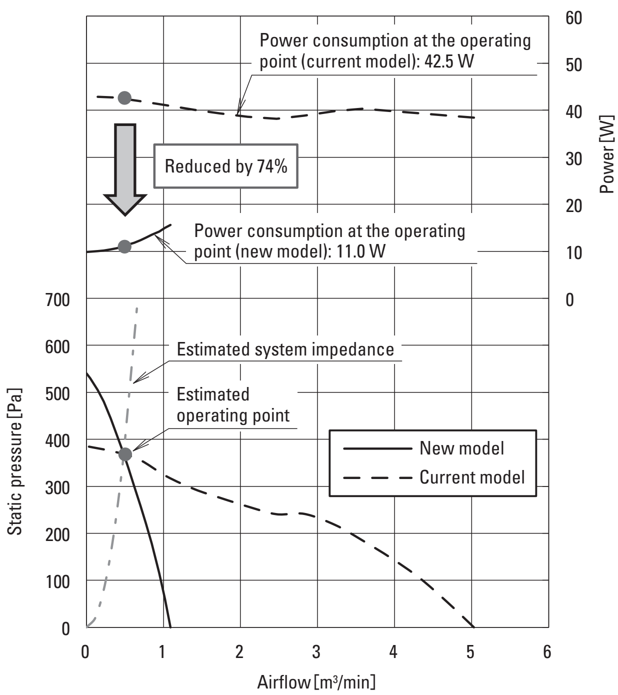

Fig. 9 Comparison of power consumption at operating point

Also, as shown in Figure 10, SPL is reduced by 13 dB(A). As described above, compared to the axial flow fan, the blower has lower power consumption and SPL in an operating range with high system impedance.

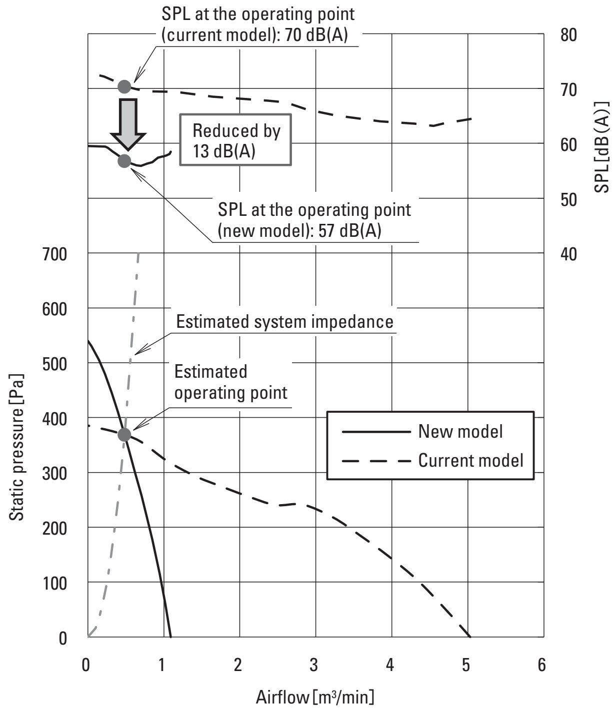

Fig. 10 Comparison of SPL at operating point

6. Conclusion

This article has introduced some of the features and performance of the 97 × 33 mm Splash Proof Blower *San Ace 97W* 9W1B type.

It is SANYO DENKI's first blower with high static pressure performance with an IP68 rating. As such, the new model is expected to perform well in equipment with high system impedance used in environments exposed to water and dust.

By staying ahead of the diversifying market and developing products that meet new demands, we will continue to offer products which contribute to the creation of new value for our customers to help make their dreams come true.

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Specialty Technologies in *SANUPS* Power Systems Products

Takeshi Hama

1. Introduction

Stable electric power supply is essential for comfortable use of networked electronic devices such as the smartphones and tablets upon which modern-day society depends.

Our *SANUPS* Power Systems products, including uninterruptible power supplies (UPS) and renewable energy inverters, not only provide customers with the high basic performance and functionality required in normal situations, but also supply high-quality and stable power to customers' equipment in the event of unexpected power outages caused by natural disasters such as heavy rain and earthquakes. They can also be used for emergency management and BCP (business continuity planning) purposes.

This article will introduce our specialty technologies supporting the high functionality, performance, and quality of *SANUPS* Power Systems products.

2. High Efficiency Technology

High efficiency is required of UPSs and renewable energy inverters. Therefore, in addition to using high-efficiency circuit systems such as a resonance circuit, 2-phase modulation system, and 3-level inverter system, we design products using next-generation semiconductors and low-loss components. In addition, we optimize the circuit in our own unique way.

In this article, we will introduce our technologies used for achieving higher efficiency using basic UPS circuit configurations, as shown in Figure 1, as an example.

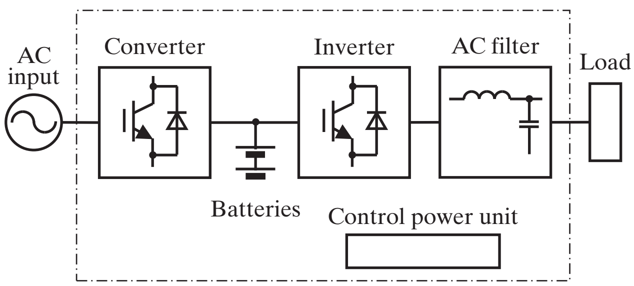

Fig. 1 Example of basic UPS circuit configuration

2.1 Achieving higher efficiency in the converter, inverter, and control power unit

2.1.1 Use of low-loss circuits

We use low-loss circuits in circuits with switching elements, such as the UPS's converter, inverter, and control power unit.

Below are examples of these circuit systems.

(1) Soft-switching system (resonance type)

Using LC resonance enables zero-voltage and zero-current switching that reduces switching loss.

(2) 3-level inverter system

Compared with typical 2-level inverter systems, 3-level inverter systems have a greater steady-state loss, but have a 1/2 switching loss, which is significantly lower.

Moreover, the switching ripple current amplitude is small, leading to a smaller iron loss of the reactor comprising the AC filter and a reduced overall loss.

(3) 2-phase modulation

This method reduces the switching loss in the 3-phase output inverter; two of the three phases perform switching with the remaining phase stopped, thus reducing switching loss by one-third.

2.1.2 Circuit optimization

In addition to using the aforementioned circuit systems, we achieve the greatest efficiency improvement by optimizing peripheral circuit configurations including gate drive circuit and gate power supply circuit, the number of used components, circuit voltage, and switching frequency.

Moreover, in the *SANUPS E11A* shown in Figure 2, by creatively reducing the number of switching elements, we successfully omitted their peripheral circuits such as a drive circuit and isolated power circuit required to activate switching elements.

This improved efficiency by the amount of the reduced circuit loss.

Fig. 2 *SANUPS E11B*

2.1.3 Use of a next-generation semiconductor

In recent years, wide-bandgap semiconductors such as SiC (Silicon Carbide) and GaN (Gallium Nitride) are attracting attention as next-generation semiconductors. We use SiC devices which can be expected to provide high-pressure resistance and low loss.

For example, the *SANUPS A22A* shown in Figure 3 uses a 3-level inverter system with a circuit configuration effective for improving efficiency. In addition, an efficiency of 94.5% was achieved by using SiC devices in peripheral circuits, which is considerably high for a double conversion online UPS.

Fig. 3 *SANUPS A22A*

2.2 Higher efficiency in the AC filter

This section will explain how we achieved higher efficiency in the AC filter.

We select the windings used in the reactor of the AC filter considering the skin effect due to harmonic current. Also, we use a core made of low-loss magnetic materials.

Furthermore, early in the design phase, we perform calculations using specification ratings and perform circuit simulation to determine which components to use. However, sometimes we cannot obtain the expected efficiency on the actual circuit due to unforeseen factors.

On such occasions, we prototype several dozen reactors using various windings and cores, and compare them in use to select the one with the highest efficiency.

2.3. Miscellaneous

High efficiency can be achieved not only by using the above-mentioned circuit systems and high-efficiency devices, but also by improving the system efficiency.

For example, our power conditioner (renewable energy inverter) for wind power and hydro power generation systems, *SANUPS W73A*, has a function to enable the DC input voltage vs. DC input power characteristics to be freely set to suit the output characteristics of the wind/hydro power generator that the power conditioner is connected to, thereby increasing efficiency of the overall system.

3. Uninterrupted Output Technology

In recent years, a wider range of increasingly complex and advanced production systems can be affected by instantaneous voltage dips; today's UPSs not only require high efficiency, but also must provide uninterrupted transfer. We offer UPSs which provide zero transfer time, such as the *SANUPS E23A* and *SANUPS E33A* shown in Figure 4.

Fig. 4 *SANUPS E23A* / *SANUPS E33A*

The *SANUPS E23A* and *SANUPS E33A* use a parallel processing topology which normally feeds grid power to the load while a bi-directional inverter connected in parallel cancels out the harmonic current generated from load equipment to make the input current sinusoidal and improve UPS input power factor.

Moreover, with this circuit system and our unique transfer technology, these UPSs can supply uninterrupted pure sine waves even during power outages, instantaneous voltage dips, and momentary outages.

Figure 5 illustrates the parallel processing topology.

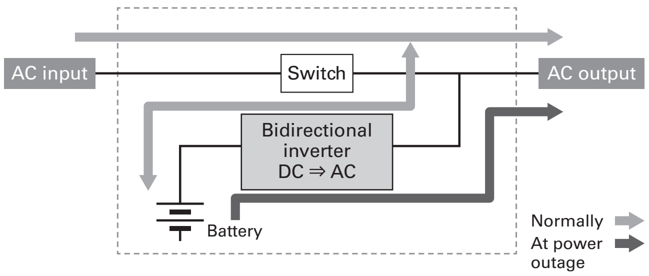

Fig. 5 Parallel processing topology

4. Technology for Improving Power Supply Reliability

Reliability is an important feature of a UPS. Our UPSs including *SANUPS A11M* and *SANUPS A22A* achieve improved reliability by using a parallel redundant configuration and our unique technology.

4.1 Use of a parallel redundant operation system

These ensure a highly reliable power supply by using a parallel redundant operation system that can continue to supply power even if one of a number of parallel-connected identical UPS units happens to fail.

Figure 6 illustrates the parallel redundant operation system.

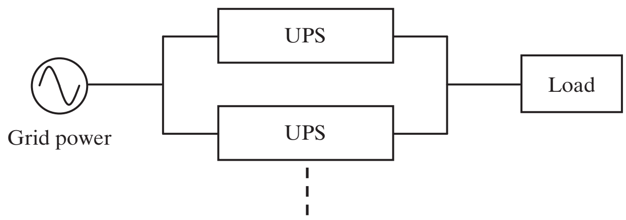

Fig. 6 Parallel redundant operation system diagram

4.2 Use of a fully autonomous control method

In general, with parallel UPS units that output AC power, it is necessary to synchronize the voltage amplitude, phase, and frequency to prevent potentially excessive high currents (known as "cross currents") from damaging the UPS.

However, if a central control unit is used to prevent this cross current, the failure of this unit may lead to the shutdown of the entire UPS system. Even with highly reliable UPS units, if the reliability of the central control unit was low, the reliability of the whole system would be low.

Therefore, we used a fully autonomous control method with a control unit on each UPS unit instead of a central control unit for parallel operation.

We successfully improved the reliability of the system by achieving parallel operation with each UPS unit independently suppressing cross current.

Figure 7 illustrates the fully autonomous control method.

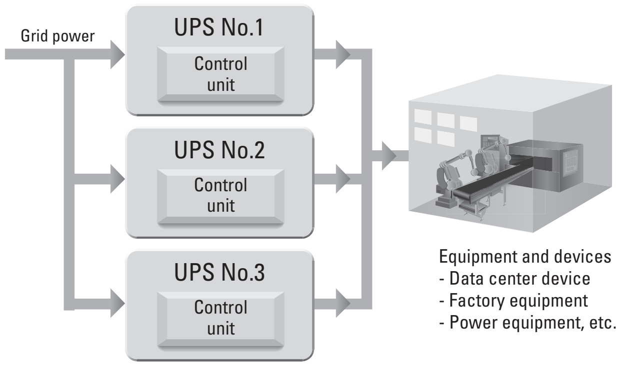

Fig. 7 Fully autonomous control method

5. Conclusion

This article has introduced our technologies to achieve higher efficiency, uninterrupted output, and improved reliability that support the high functionality, performance, and quality of *SANUPS* Power Systems products.

Moving forward, SANYO DENKI will stay committed to technological development so we can offer our customers UPSs and renewable energy inverters that can supply safe, stable power.

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Development of the Small-Capacity UPS *SANUPS A11M* Series

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Yuhei Shoyama　Takuya Ozawa　Hiroyuki Saito

1. Introduction

In addition to the advancement of ICT technology in recent years, the evolution of electronic equipment such as smartphones and tablets, which are high-performance information devices, has made global network systems essential in our daily lives for over a decade now. Such systems cannot afford even a split second of downtime, therefore uninterruptible power supplies (UPS) are used. When an abnormality such as a power outage occurs in the AC voltage supply, a UPS supplies power without interruptions to electronic equipment by converting the built-in battery power to AC power. As such, UPSs must be highly reliable.

SANUPS A11M, the newly developed small-capacity UPS series, is optimal for such applications requiring high reliability. This article will provide an overview of this product.

2. Development Background

From the late half of the 1990s, computers have been getting smaller, and requiring lower power consumption. Moreover, to minimize the risk of data loss the mainstream method was to connect a UPS to each piece of equipment. At that time, all high-reliability UPSs had high capacities of 100 kVA or higher and used either the working/spare switching system or the parallel redundant system. There were no high-reliability UPS in the small-capacity 1 kVA class.

In 2003, we developed the *SANUPS ASE-H* enabling the configuration of high-reliability redundant systems for the small-capacity UPS market. The *SANUPS ASE-H* has been used in situations requiring higher reliability for 10 kVA or less, such as backup operation of railway and expressway management systems.

As the successor of the *SANUPS ASE-H* (hereinafter "current product"), the *SANUPS A11M* (hereinafter "new product"), inherits the concept of supporting easy high-reliability and scalable capacity through parallel operation of multiple 1 kVA units, while increasing the number of units connectable in parallel from 5 to 8. Also, with SANYO DENKI's original parallel operation control technology, stable operation, including backup operation in the event of a power outage, is possible even if communication lines are cut. Moreover, with a wider operating temperature range and input voltage/frequency range than the current product, the new product can minimize battery wear and enable stable operation by reducing the frequency of switching to battery operation, even in regions with unstable power sources.

3. Features

As mentioned above, the new product can connect a maximum of 8 units in parallel while the current product can connect up to 5 units. Figure 1 shows the appearance of the new product with 8 units mounted on a rack.

Fig. 1　*SANUPS A11M* (8 kVA rack mount type)

3.1 High reliability with autonomous method of parallel control

As the inverter output is AC voltage, when connecting inverter units in parallel, the voltage amplitude, frequency, phase, etc. of all units must be exactly the same or an electrical current called a “cross-current” occurs between units, and it is no longer possible to maintain current balance.

Examples of control methods of connecting inverters in parallel include the central control method and the master/slave method. These methods have many parts in common, such as control circuits and control/communication lines, so they are suitable for capacity expansion. However, they are not considered highly reliable.

In contrast, the new product does not have a central control unit, but rather features independent control circuits for each unit. This enables parallel operation of the inverters through individual control.

This control method detects input and output voltages, then calculates the momentary frequency and momentary phase and make adjustments.

The new product has communication lines between units for starting/stopping them and sharing measurement data. However, synchronization between units is performed at each unit without relying on inter-unit communication, so even if inter-unit communication is cut, parallel operation can be maintained not only during AC operation, but also during backup operation.

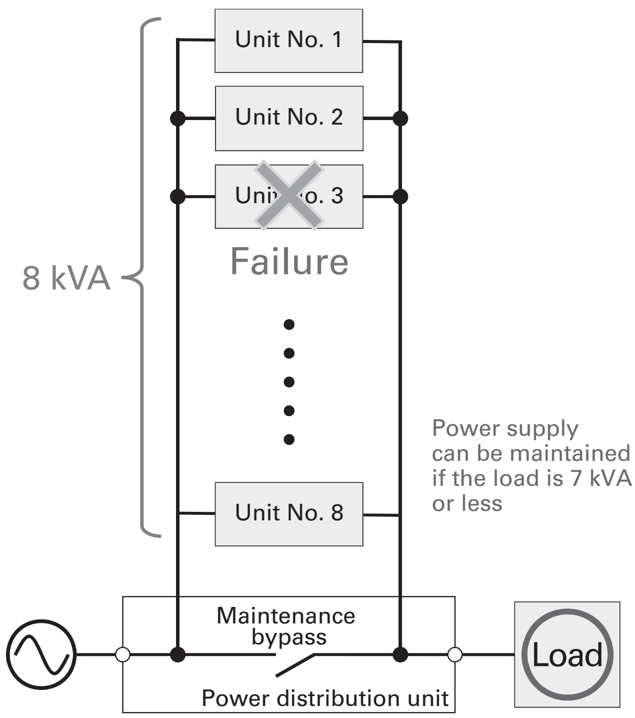

Fig. 2 Parallel redundant operation

When 8 units are run in parallel as shown in Figure 2, for example, they can handle a load of up to 8 kVA. For a load capacity of 7 kVA or less, having one unit worth or excess capacity means there will be redundancy to maintain operation even if one unit fails. In this way, the new product achieves highly reliable redundancy through parallel operation control with a minimum of common parts.

3.2 Wider input voltage range

Some regions of the world have underdeveloped infrastructure and unstable power systems. Using conventional UPSs in such regions may lead to accelerated battery wear from frequent battery operation caused by voltage and frequency fluctuations.

We solved this issue by designing the new product to have wide input voltage and frequency ranges; the voltage range is 55 to 150 V for the 100 V model and 110 to 300 V for the 200 V model, and the frequency range is 40 to 120 Hz. This can reduce the number of transfers to battery operation even in regions where grid power is unstable and voltage and frequency fluctuate greatly. This means that stable power can be supplied to a load while battery wear is kept minimal.

3.3 Wider operating temperature range

Conventionally, UPSs were primarily used for backup of ICT equipment and servers, and often used in temperature-controlled environments. In contrast, recently an increasing number of UPSs are used in environments with little temperature control, such as factories, offices, and stores. Against this backdrop, we developed the new product to have an operating temperature range of -10 to 55°C. Battery charging stops at 40°C or above, however, the new product can be used at a higher ambient temperature than the current product as long as the battery lasts.

3.4 Support of high load power factors

Current electronic devices can provide power factor correction and have a high input power factor. Considering this, we designed the new product to have an increased rated output power factor of 0.8, while that of the current product is 0.7.

This led to the new product’s increased active power of 4.0 kW, while that of the current product is 3.5 kW, when compared in a 5-unit parallel operation.

3.5 Battery management function

The new product has a function to automatically perform regular battery tests to ensure batteries are problem-free. Furthermore, the new product ensures increased reliability by offering battery management functions the current product does not. Such functions include a battery service life warning, total battery run time, battery state of charge, and estimated backup time.

3.6 Easy maintainability and serviceability

As Figure 3 shows, in the new product, batteries are built into a plastic tray for easy removal. This makes battery replacement easy.

Fig. 3 Front panel and battery

3.7 Reduced size and weight

With a volume of 15.19 liters, the new product is around 1% smaller than the current product, which has a volume of 15.34 liters. Moreover, by using high-capacity batteries, the number of batteries used has been reduced from 3 to 2. Also, by simplifying the internal structure, a significant weight reduction (from 19 kg to 15 kg) has been achieved.

3.8 Network functions

For simple UPS management, UPS management software *SANUPS SOFTWARE STANDALONE* can be downloaded free of charge. A serial cable for computer connection comes included as a standard accessory. Connection is also possible via a commercially-available USB cable. (USB and serial communications are mutually exclusive)

Moreover, we have an optional LAN Interface Card and *SANUPS SOFTWARE* available for advanced UPS management in a network. These can help users build a flexible, integrated network environment.

3.9 High performance interface

The new product comes with the following interfaces:

(a) Dry contact interface

Just as for the current product, combining with an optional Dry Contact Interface Card will enable dry contact output. Moreover, mounting compatibility is maintained, and the new product can replace the current product in customers' systems.

(b) Remote switch connector

In addition to having a contact input with an on/off function just as the current product, the new product can also use the functions shown in Table 1 with settings.

Table 1 Remote switch functions

Setting value	Function
ON/OFF Both are used	ON/OFF is operated using the respective switches. When both ON and OFF signals are input, OFF is given priority.
ON only (Positive logic) (OFF is disabled)	Turn ON/OFF with an ON-side switch. When the ON signal is input, the UPS starts up.
OFF only (Negative logic) (OFF is disabled)	Turn ON/OFF only with the ON-side switch. When the ON signal is input, the UPS shuts down.

(c) EPO (Emergency Power Off) connector

Connecting a switch to this connector and turning it on will enable the emergency stop of the UPS.

4. Circuit Configuration

Figure 4 shows the circuit configuration and system diagram for the new product UPS unit.

4.1 Main circuit configuration

The new product UPS unit is composed of a high input power factor converter, inverter, charger, battery boost circuit, output transfer switch, bypass circuit, filter, and control circuit.

With a power distribution unit, up to 8 UPS units can be connected in parallel.

For the high input power factor converter, we adopted a single-switch boost chopper. This chopper is composed of a bi-directional semiconductor switch and boosts AC voltage into DC voltage. At the same time, there is a function to condition input current waveform into a sine wave.

The inverter is of the half-bridge type and has a reduced number of elements, enabling us to eliminate the drive circuit and other peripheral circuits.

We have improved the efficiency of the battery charger by supplying the input power directly.

4.2 Control circuit

Through digitization of the control circuit, the new product achieves input and output waveform rectification, UPS operation sequence, and parallel operation control with a single CPU. Moreover, it has CAN for communicating information from each UPS unit. This makes high-speed data transfer possible, and unit-specific information such as measurement results and failure information can be shared. The number of connected units are managed automatically, and an alarm sounds when any of the UPS units stop.

4.3 Electrical characteristics

Table 2 provides the standard specifications of the new product (per UPS unit).

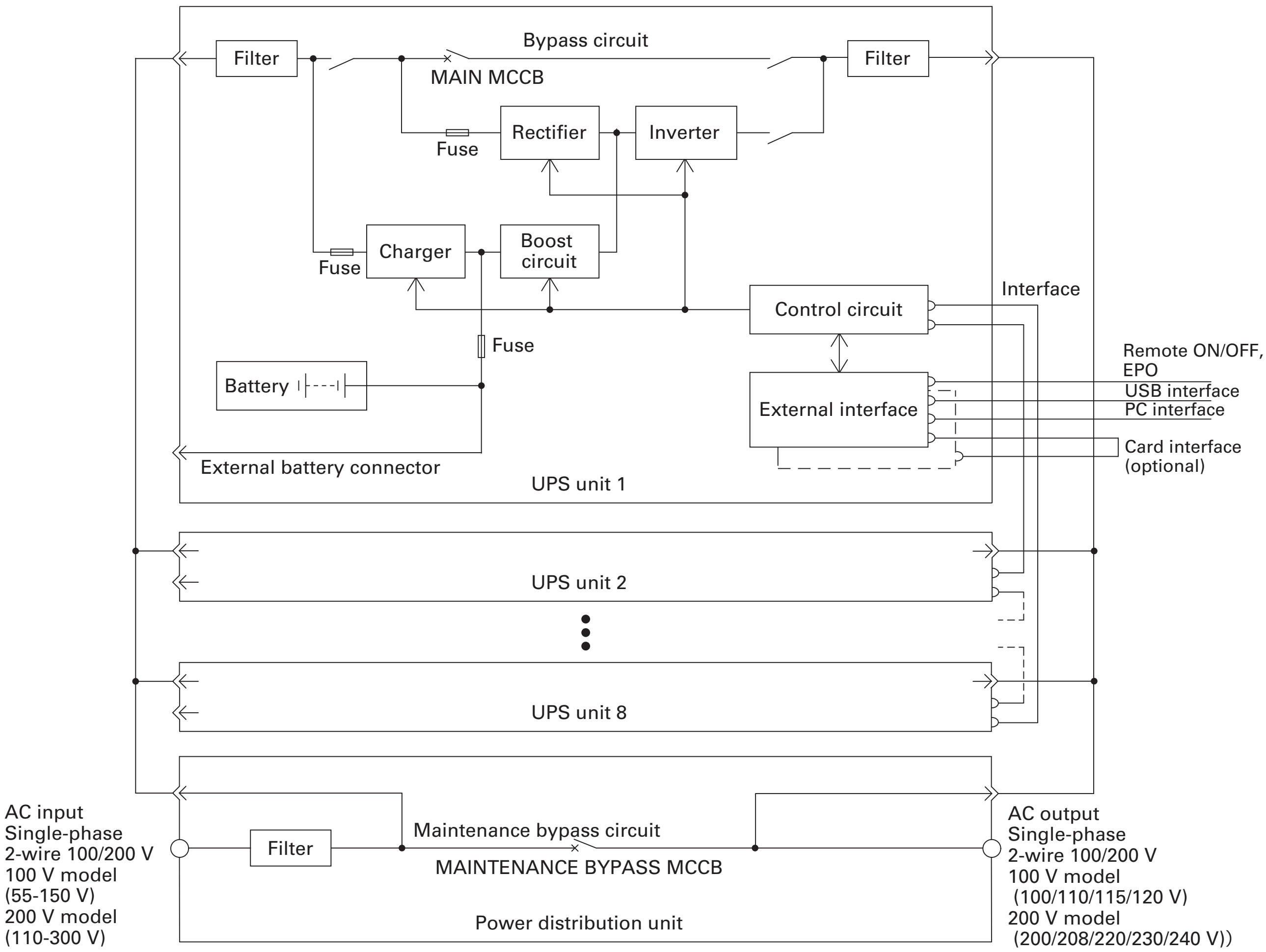

Fig. 4 System diagram

Table 2 Specifications

Items		Specifications
Output capacity		1 kVA / 0.8 kW
System	**Topology**	Double conversion online
	Rectifier	High input power factor converter
	Cooling method	Forced air cooling
	Inverter	High-frequency PWM
AC input	**No. of phases/wires**	Single-phase 2-wire
	Input voltage range	55 to 150 V (100 V model) 110 to 300 V (200 V model)
	Input frequency range	40 to 120 Hz
	Required capacity	1.1 kVA
	Power factor	0.95 or greater (at rated output)
AC output	**No. of phases/wires**	Single-phase 2-wire
	Rated voltage	100/110/115/120 V (100 V model) 200/208/220/230/240 V (200 V model)
	Voltage regulation	Within ±5% of rated voltage
	Rated frequency	50/60 Hz
	Frequency regulation	±1, 3, 5% of rated frequency (Factory setting: ±3%)
	Voltage harmonic distortion	3% or less (With a linear load) 8% or less (With a rectifier load)
	Rated load power factor	0.8 (lagging)
	Transient voltage fluctuation	Within ±10% (For abrupt load change) Within ±10% (Loss or return of input power) Within ±10% (For abrupt input change)
	Overcurrent protection	Uninterrupted transfer to bypass
	Overload capability	105% (Inverter)
Battery type		Small-sized valve-regulated lead-acid (VRLA) battery
Backup time		5 min (When the power factor is 0.7)
Acoustic noise (at 1 m from the front of unit)		45 dB or less
Operating environment		Ambient temperature: -10 to 50˚C Relative humidity: 10 to 90% (non-condensing)

5. Conclusion

This article has introduced the *SANUPS A11M* UPS capable of parallel operation of up to 8 kVA by combining 1 kVA UPS units (a maximum of 7 kVA in redundancy). This product supports high-reliability and scalable capacity, adopts SANYO DENKI's original parallel operation control technology, and features an expanded operating temperature range and input voltage/frequency range.

Worldwide, there are not many UPSs in the small-capacity few kVA class capable of performing parallel redundant operation. As such, we are confident this product can contribute to customers requiring small capacity and high reliability.

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Development of the *SANUPS W73A* Grid-Connected Isolated Type

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1. Introduction

An outcome of the 21st yearly session of the Conference of the Parties "United Nations Climate Change Conference" (COP21) held in late 2015, was the adoption of the Paris Agreement, whereby member states declared their commitment to suppressing temperature increase to less than 2°C above pre-industrial levels and ongoing efforts to limit the temperature increase to 1.5°C.

In Japan, the Strategic Energy Plan was revised in 2018 and the 5th Strategic Energy Plan was established.(1) This plan aims to make renewable energy "an economically self-supporting, decarbonized main source of electricity" by 2050. Moving forward, it is expected that introduction of renewable energy will be promoted further.

Against such a backdrop, wind power and hydroelectric power generation are expected to grow more than others; wind power generation is more popular than photovoltaic power generation in terms of the capacity that has been applied for connection request to power companies, and hydroelectric power generation has a relatively high purchase price in the renewable energy feed-in tariff (FIT).

As such, we have newly developed the *SANUPS W73A* grid-connected isolated type as a power conditioner for wind power and hydro power generation systems that can be used as an emergency power supply. This article will provide an overview of the new model and its features.

2. Development Background

In 2017, we released the *SANUPS W73A*, a 9.9 kW grid-connected type power conditioner (renewable energy inverter) for wind power and hydro power generation systems.

However, grid-connected type power conditioners cannot provide power in the event of a power outage in the grid.

As represented by the Hokkaido Eastern Iburi Earthquake and the 2018 Japan floods, large-scale power outages due to natural disasters have occurred across Japan in recent years, and in each case it took several days to restore power. As such, there is an increasing number of customers considering the installation of power conditioners with an isolated operation function to secure a power supply for emergency situations.

There is also a demand for independent power supplies in non-electrified areas such as remote islands. As such, we developed the *SANUPS W73A* grid-connected isolated type, by adding an isolated operation capability to the existing *SANUPS W73A* grid-connected type.

3. Specifications of the *SANUPS W73A*

Figure 1 shows the appearance of the *SANUPS W73A*, Figure 2 shows its basic circuit configuration, and Table 1 provides its main specifications.

We designed the new *SANUPS W73A* grid-connected isolated type to feature an isolated operation capability by adding parts to, changing the parts layout of, and changing the control program of the existing *SANUPS W73A* grid-connected type without changing the dimensions.

Fig. 1 *SANUPS W73A*

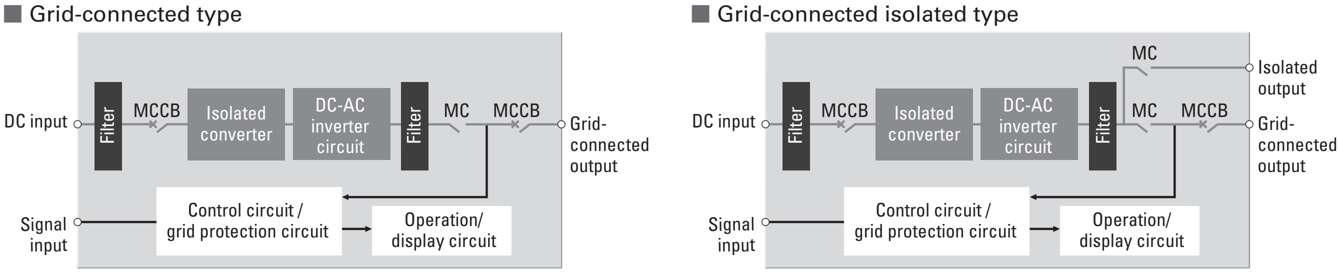

Fig. 2 Basic circuit configuration

Table 1 Main specifications

Item		Grid-connected type W73A992R	Grid-connected isolated type W73A992S	Remarks
Output capacity		9.9 kW		
Main circuit type		Self-commutated voltage type		
Switching method		High-frequency PWM		
Isolation method		High-frequency isolation		
Cooling method		Forced air cooling		
DC 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
	No. of input circuits	1 circuit		
Grid-connected output	**No. of phases/wires**	3-phase 3-wire		
	Rated voltage	202 VAC		
	Rated frequency	50/60 Hz		
	Rated output current	28.3 AAC		
	Current harmonic distortion	Total current: 5% or less, individual harmonic order: 3% or less		Percentage of rated output current
	Output power factor	0.95 or greater		At the rated output and a power factor of 1.0 Power factor setting range: 0.8 to 1.0 (in increments of 0.01)
	Efficiency	93%		Efficiency measurement method in accordance with JIS C 8961 With a power factor setting of 1.0
Isolated output	**Rated output**	—	9.9 kVA	
	No. of phases/wires	—	3-phase 3-wire	
	Rated voltage	—	202 VAC	
	Voltage regulation	—	Within ±8% of rated voltage	
	Rated frequency	—	50/60 Hz	
	Frequency regulation	—	Within ±0.1 Hz of rated frequency	
	Voltage harmonic distortion	—	Linear load: 5% or less	
	Overload capability	—	100% continuous	
	Efficiency	—	93%	Efficiency measurement method in accordance with JIS C 8961
Operation mode (grid-connected operation/ isolated operation) switchover setting		—	Automatic or manual (Factory setting: Manual)	
Grid protection		Overvoltage (OVR), undervoltage (UVR), overfrequency (OFR), and underfrequency (UFR)		An overvoltage ground relay (OVGR) shall be externally connected to the factory-configured normally-closed dry contact input.
Islanding detection	**Passive method**	Voltage phase jump detection		
	Active method	Frequency feedback method with step injection		
Communication		RS-485		
Acoustic noise		50 dB or less		A-weighting, 1 m from front of unit
Operating environment	**Ambient temperature**	-25 to +60°C		Operates at derated output above 40°C during grid-connected operation
	Relative humidity	90% or less (non-condensing)		
	Altitude	2000 m max.		
Paint color		Munsell 5Y7/1 (semi gloss)		
Heat dissipation		745 W		
Mass		64 kg		

4. Features

4.1 Isolated operation function

The *SANUPS W73A* grid-connected isolated type can perform isolated operation when in isolated operation mode.

Isolated operation is an operation mode used during grid power outages. Power generated by a wind power generator or hydroelectric power generator is rectified to DC power, then converted to AC power with a constant frequency, constant voltage, and sinusoidal waveform, before being supplied to emergency equipment.

The new model delivers 9.9 kW, 3-phase 3-wire 202 VAC output power during isolated operation, supplying power to emergency equipment even in the event of a power outage. Moreover, it can supply power as an off-grid power supply in non-electrified areas such as remote islands.

Figure 3 illustrates the isolated operation of the *SANUPS W73A* grid-connected isolated type.

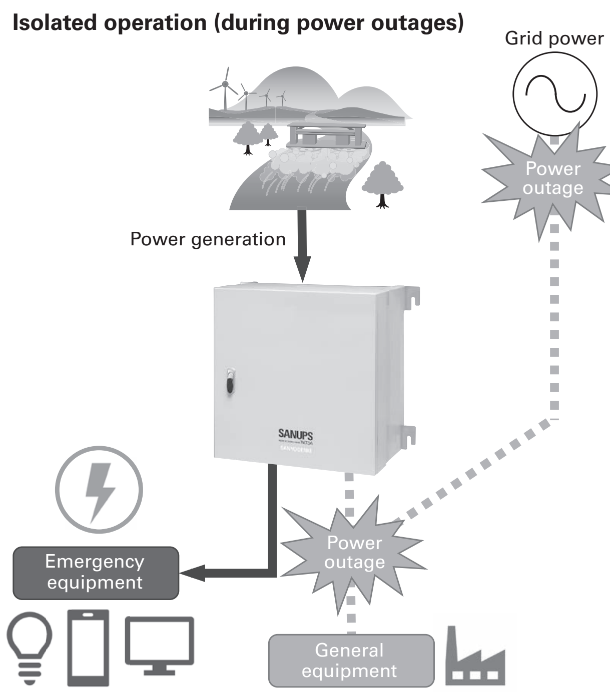

Fig. 3 Illustration of isolated operation

4.2 Switchover to isolated operation

The *SANUPS W73A* grid-connected isolated type can be set to either manually or automatically switch between operation modes as follows: from grid-connected operation to isolated operation when an outage occurs in the grid, or from isolated operation to grid-connected operation when grid power is restored after an outage.

Moreover, manual switchover between grid-connected and isolated operation modes has been simplified and can be done by merely turning the grid output circuit breaker on or off, rather than the conventional method of selecting operation modes.

This enables customers to switch over to isolated operation without having to perform difficult operations.

4.3 Soft start method

When connecting transformers and pumps to the isolated output of a power conditioner, the following issues arise. First, to excite the transformer, an excitation inrush current approximately ten times the regular current flows. Also, a large starting current occurs when starting the motor that drives the pump. This might activate the protection function of the power conditioner (overcurrent detection), often leaving the isolated operation not activated.

Against such a load, the transformer's excitation inrush current can be suppressed by starting up the power conditioner's isolated output from a low voltage (0 V) and rising gradually to the rated voltage. This type of soft start is referred to as a VVCF (variable voltage, constant frequency) soft start.

Furthermore, it is possible to suppress the pump's starting current by raising it to the rated value with the ratio of start voltage and frequency fixed to a constant. This type of soft start is known as VVVF (variable voltage, variable frequency).

The *SANUPS W73A* offers both the VVCF and VVVF soft start methods, and customers can also choose from the four startup time options of 2, 5, 10, and 20 seconds. This allows the power conditioner to perform isolated operation with the starting current suppressed regardless of the load connected.

4.4 DC input voltage - DC input power characteristics settings

For the *SANUPS W73A*, customers can freely select a minimum of 2 to a maximum of 32 DC input voltage - DC input power characteristics (hereinafter "power characteristics") settings to match the output characteristics of a specific wind power or hydroelectric power generator.

Moreover, operation-start/stop voltage can be set freely for use with various systems.

This enables efficient use of the power generated by wind power or hydroelectric power generators.

Figure 4 shows an example of power characteristics settings.

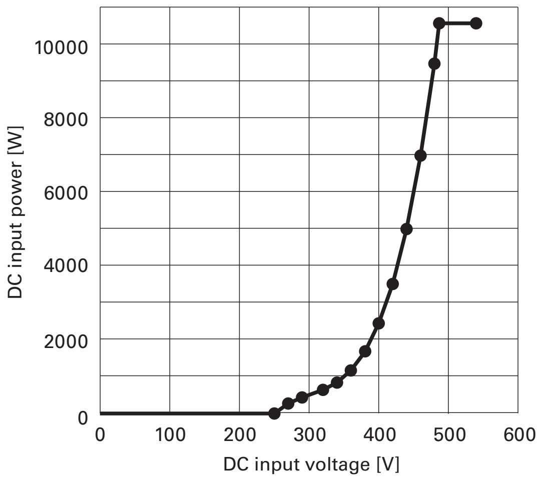

Fig. 4 Example of power characteristics settings

4.5 Voltage rise control standby function

The power conditioner is equipped with a voltage rise control function to maintain power grid voltage within the appropriate range as well as prevent breakdowns and reduced life of electrical products.

The two types of voltage rise control function are phase-advance reactive power control and output control. If the AC output voltage of the power conditioner exceeds the preset value during the grid-connected operation, phase-advance reactive power control will be activated. If the AC voltage does not stop rising, the output control will limit the output power and voltage. As such, if the output control of the voltage rise control function is activated, the power conditioner will generate less power.

This marks the first time the voltage rise control standby function was featured on a power conditioner for 3-phase output wind power generation and hydro power generation.*

From the 2016 version of the grid-interconnection code (JEAC 9701-2016), it became acceptable to have an operation time limit in the voltage rise control. As such, we set a 200-second operation time limit for the voltage rise control to come into action.** With this, grid voltage increases within 200 seconds will not cause the voltage rise control function to suppress the power conditioner's output.

This function can contribute to reducing the power generation loss from voltage rise control.

4.6 Power factor correction function

As a countermeasure to the problem of increased electrical current in the power distribution grid due to the large-scale introduction of renewable energy, the *SANUPS W73A* comes with a power factor correction function for grid-connected operation as standard.

This can correct the output power factor to a value between 0.8 and 1.0 during grid-connected operation, which means increases in grid voltage can be suppressed without the need to install special-purpose equipment or reinforced wiring.

4.7 Adoption of frequency feedback method with step injection of reactive power

The *SANUPS W73A* uses an active islanding detection method of a frequency feedback method with step injection of reactive power (hereinafter "new active method") which detects the frequency change caused by injecting the reactive power calculated from the frequency deviation that occurs when there is a power outage.

In principle, the new active method is characterized by not causing interference with other active methods, which is useful when connecting multiple renewable energy inverter units.

4.8 Remote monitoring service

The *SANUPS W73A* can be combined with our *SANUPS PV Monitor* for remote monitoring and data collection/ analysis via a network.

Furthermore, by using the *SANUPS NET* status monitoring service, the *SANUPS W73A* system status can be monitored via the internet from computers and smartphones.

SANUPS NET users can select either a power visualization service or system information management service, depending on their needs.

The power visualization service displays the power generation status and collects data. In addition to power visualization, the system information management service also provides notifications of operational status, the occurrence of trouble or alarms, and equipment fault recovery. It also provides alarm and fault recovery history for reference.

Figure 5 illustrates a remote monitoring system configuration using the *SANUPS PV Monitor* and *SANUPS NET*.

* Based on our own research as of March 27, 2019, among power conditioners for wind power and hydro power generation systems.

** The 200-second standby time limit was stipulated as the standard value from the maximum value of an SVR (step voltage regulator) with the longest operation time limit among voltage regulators in power distribution grids. This was the result of an investigation by the Federation of Electric Power Companies in Japan in accordance with the view that operation time limit should be coordinated with voltage regulators in power distribution as per grid connection regulations.

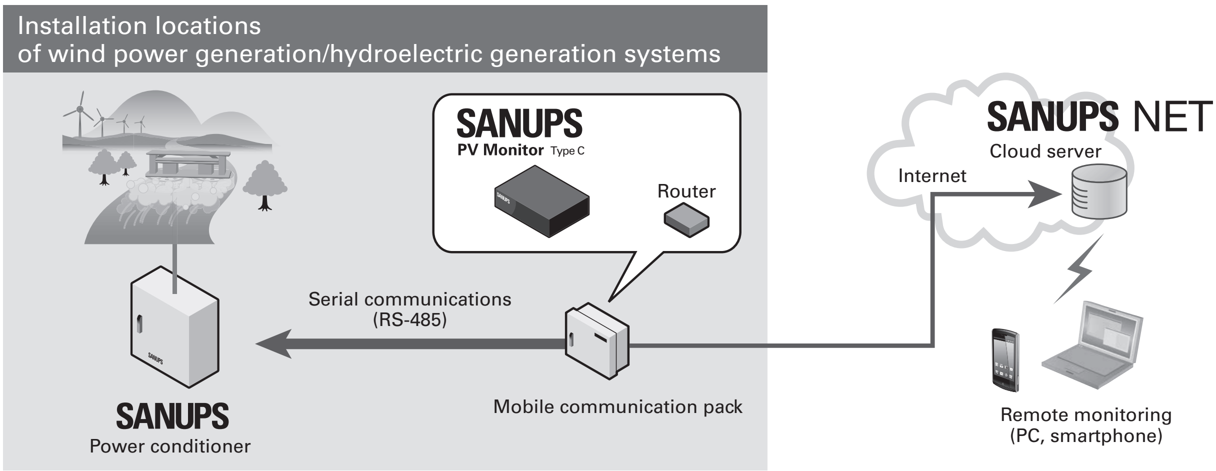

Fig. 5 Example of remote monitoring system configuration

4.9 Dustproof/waterproof performance

The *SANUPS W73A* has a protection rating of IP65 and a sealed structure with excellent dustproof and waterproof performance for outdoor use. This protects the product from the ingress of rain, dust, and small insects, and makes for a highly-reliable product that can be used with greater peace of mind.

4.10 Salt damage countermeasure

Assuming use in environments susceptible to salt damage, we verified that the *SANUPS W73A* would not have its functionality and performance impacted by performing a salt spray test (Severity 6 test in accordance with the IEC 60068-2-52 salt spray test method). As such, we have designed the product to be salt resistant so it can be installed in locations 500 meters or more away from a coastline.

5. Conclusion

This article has provided an overview of the *SANUPS W73A* grid-connected isolated type power conditioner for wind power and hydro power generation systems, and introduced its features.

The new model can meet the needs of customers who wish to use electrical power even in environments with no grid power or to secure power supply in times of emergency.

Moving forward, in addition to the development of new technologies such as smart grids for solving problems arising from the mass introduction of renewable energy, SANYO DENKI will swiftly develop products that use these new technologies and offer products that use all forms of renewable energy to contribute to a low-carbon society.

Reference

(1) "The 5th Strategic Energy Plan," Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry https://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf (2019.9.17)

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Specialty Technologies for Efficiently Producing Servo System Products

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1. Introduction

The aim of manufacturing ("monozukuri" in Japanese) is to create products with value through processing and assembling materials and parts based on the design information. This value is the value for our customers who use our products. Creating this value swiftly and simply is not only the essence of monozukuri but also our mission.

Since our founding, SANYO DENKI has been devising various ways to create technologies and equipment to deliver value in the form of products to our customers. Through this process, we have developed many "specialty technologies."

In April 2016, we began a five-year mid-term management plan which contained multiple initiatives aimed at "manufacturing innovation." The goal of the plan is to double productivity, cut production lead-time to one-quarter, and halve in-process inventory by building innovative manufacturing lines in pursuit of efficient production.

Using our so-called "Innovation Lines" as examples, this article will introduce the "specialty technologies and ingenuities" we leverage to produce Servo Systems products efficiently. First, we will look at the production process for servo motors, then that of servo amplifiers.

2. Specialty Technologies on the Servo Motor Innovation Line

Many customers use SANYO DENKI's customized products. As such, we have a wide variety of products which are often processed manually to maintain flexible production. In the building of our Innovation Lines, we utilized automation technologies such as robotics and sensing technologies to efficiently produce a wide variety of products with uniform high quality.

This section will introduce the specialty technologies and ingenuities incorporated in the servo motor Innovation Line.

2.1 Specialty technologies in the winding process

In the winding process, copper wire is changed for each motor model to suit its characteristics. During setup changes, the necessary equipment adjustments impede production efficiency.

On this Innovation Line, we developed a method to automatically remove insulation coatings from the copper

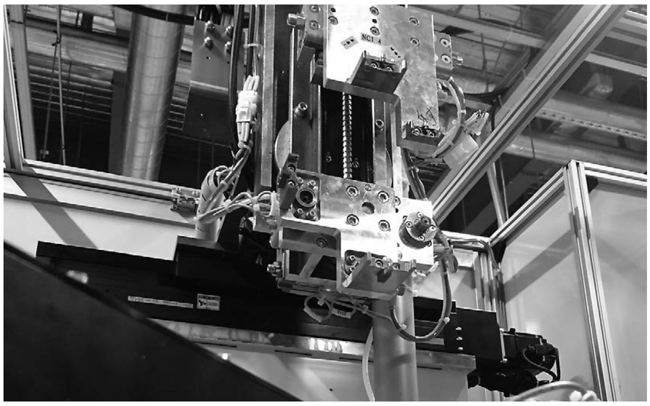

Fig. 1 Laser coating removal system

Table 1 Comparison of conventional technique and innovative technique (winding process)

Items	Conventional technique	Innovative technique
Removal method	Mechanical cutter	Laser irradiation
Jig change/adjustment	Cutter blade positioning adjustment Check using sample workpieces	None
Removal check	Visual	Image-based judgment

wiring using lasers. By focusing on improving production efficiency, we eliminated the need for equipment adjustment during changeovers. Figure 1 shows the laser coating removal system. Table 1 shows a comparison of the conventional technique and innovative technique.

Previously, a mechanical cutter would remove winding coatings. The cutter blades had to be replaced to match the wire diameter, which was time-consuming. We utilized an innovative technique that removes coating via laser, enabling more seamless production just by switching programs when changing copper wires. Moreover, by using image technology, the quality of coating removal is automatically inspected.

By automating the coating removal process for windings, we reduced the time required to change and adjust jigs. A motor production line applying this technology has 2.3 times higher productivity and one-quarter production lead-time compared to conventional lines, as well as zero in-process inventory.

2.2 Specialty technologies in the magnet bonding process

Assuring adhesion quality in the magnet bonding process is vital. Without sufficient bonding, the rotor would spin freely and fail to convey mechanical energy to equipment.

To minimize such occurrence, we integrated automated bonding robots into the Innovation Line. These precision robots delicately apply an even coat of bonding agent then automatically inspect the magnets for any minute fissures and flaws to ensure that parts leave the process defect-free.

Figure 2 shows a magnet bonding unit for a 20 × 20 mm AC servo motors, while Figure 3 shows a similar unit for 40 × 40 to 80 × 80 mm motors. Table 2 is an overview of the systems that these bonding units use to check the bonding condition.

Failure modes of bonding agent application include when bubbles in the bonding agent tank prevent the agent from discharging, and when the discharged agent does not adhere to the magnet. We have built a system that utilizes sensing technology to detect these failure modes and introduced it to the Innovation Line.

As shown in Figure 2, the bonding agent application unit for 20 × 20 mm AC servo motors measures the thickness of the applied bonding agent using a non-contact sensor to verify its condition. Similarly, Figure 3 shows the unit for 40 × 40 to 80 × 80 mm motors using an image sensor to verify the uniformity of the application. These specialty technologies realize an automatic line with uniform bonding quality. Since its installation, the new line has increased productivity six-fold, cut production lead time to a quarter, and eliminated in-process inventory.

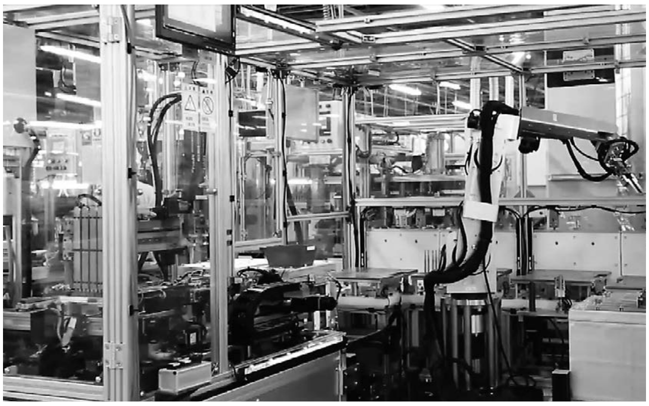

Fig. 2 Magnet bonding unit for 20 × 20 mm AC servo motors

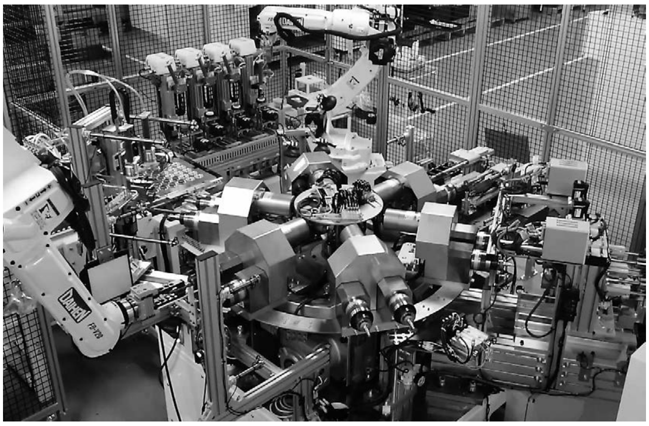

Fig. 3 Magnet bonding unit for 40 × 40 to 80 × 80 mm AC servo motors

Table 2 Overview of the bonding application check systems

Items	Flange size 20 × 20 mm line	Flange size 40 × 40 to 80 × 80 mm line
Inspection sensor	Laser	Camera + Image processing
Detection method	Measure the thickness of the applied bonding agent	Verify whether or not the bonding agent is applied uniformly

2.3 Specialty technologies in the part machining process

This section will introduce an example of the part machine process: machining the sheet metal plates used for linear servo motors.

As Figure 4 shows, this process consists of an automatic line combining an articulated robot and machine tool.

Table 3 is a comparison of the conventional line and the Innovation Line. Conventionally, plates were loaded and unloaded in and out of the machine manually. The heavy plates put a significant burden on operators, making handling difficult. Metal scraps and chips also had to be removed in the middle of the process.

On the Innovation Line, however, a robot and machine tool operate in tandem to automatically load plates, process, remove scraps, and unload plates. When loading a plate to the machine tool, we fashioned a way to utilize a sensor to detect whether or not the plate is seated properly to prevent machining defects.

2.4 Specialty technologies in motor inspection

For motor inspection, we built an automatic inspection line that can “swiftly and simply” inspect a wide variety of products.

Figure 5 shows a section of this automatic inspection line. Table 4 compares the new line with a conventional inspection line.

Previously, different equipment was required for each inspection criteria, causing in-process inventory to build up before and after each task. Furthermore, motors had to be manually attached and removed at each equipment.

For the Innovation Line, we developed an inspection unit integrated with a conveyor. We built a line which connects to this unit and conveys motors on pallets. Each inspection unit scans the 2D code on the motor nameplate, enabling it to automatically load the inspection program with required settings, then secure and connect the motor. The result is zero in-process inventory.

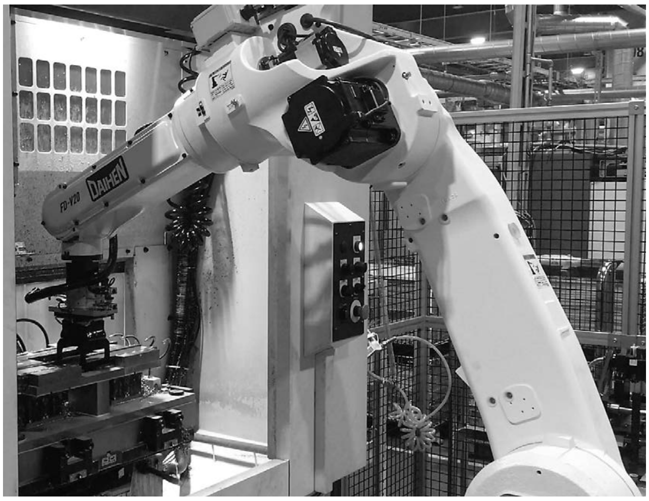

Fig. 4 Tandem operation of a robot and machine tool

Fig. 5 Automatic inspection line for motors

Table 3 Comparison of a conventional line and the Innovation Line (part machining process)

Items	Conventional line	Innovation Line
Conveying method	Operator carries heavy parts	Robot conveyance
Scrap removal	By operator	By robot

Table 4 Comparison of conventional line and Innovation Line (inspection process)

Items	Conventional line	Innovation Line
Conveyance and attachment/removal	By operator	Automatic
In-process inventory	Yes	None
Equipment setting/adjustment	By operators	Automatic

3. Specialty Technologies in the Servo Amplifier Innovation Line

Of our servo amplifier manufacturing processes, we revamped the processes for electronic component mounting, assembly, and inspection. For the Innovation Lines, by utilizing robots and sensing technologies, we engineered a way to automate work once done exclusively by our workers.

3.1 Specialty technologies in the mounting line

Roughly speaking, we have two PCB related processes: surface mounting technology (SMT) and through-hole technology. Our SMT process, where small electronic components are mounted to PCBs, have already been automated using chip mounters and other SMT equipment. However, inserting larger through-hole components with leads (known as lead components) had to be done manually by our workers.

Operators would intuitively correct positioning while inserting leads, without paying much attention to the lead component and through-hole positions.

Figure 6 shows the newly built component insertion line with an array of robots. For this line, we crafted a way to measure and reproduce the “unconscious movements” of our component insertion operators to make our robots more human-like.

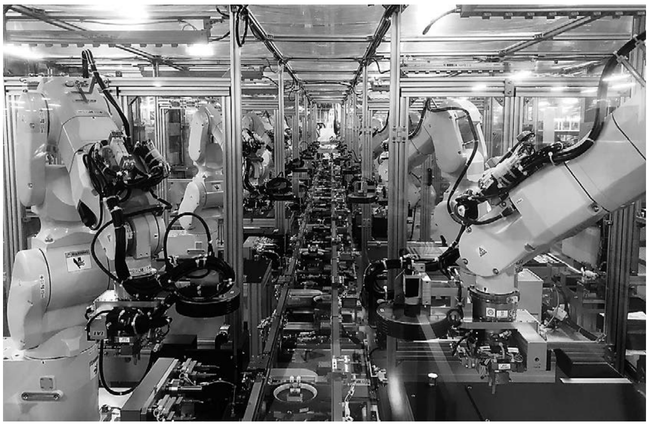

Fig. 6 Component insertion line with robots

3.1.1 Lead component picking

We came up with two solutions to ensure that the robots would accurately pick up the correct components.

First, we used pattern matching to search for components. Figure 7-1 shows an example of using pattern matching for connectors. Using pattern data, the robot will identify then pick up components to be inserted within the robot camera’s search area. With this function, even if components are arranged haphazardly during setup, robots can pick up the right ones.

The second solution involves using a camera to check the orientation and position of components in relation to the robot gripper. Figure 7-2 shows an example of the positional relationship between a component and robot gripper. This function quantifies the displacement between the gripper and lead component, and the amount of lead bend so that the robot can judge whether it is correctly picking up the component. Moreover, this function is used to correct positioning during insertion.

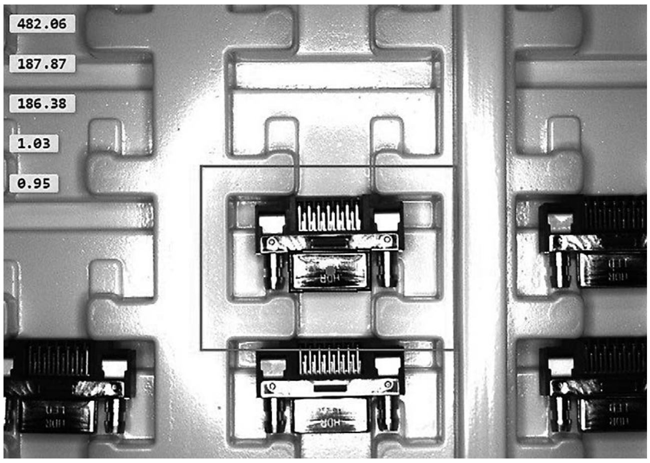

Fig. 7-1 Component coordinate detection using pattern matching

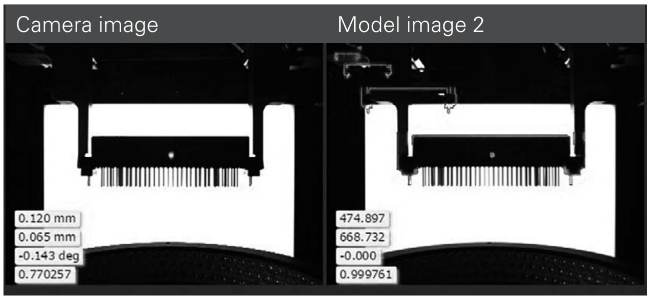

Fig. 7-2 Positional relationship between components and robot gripper

3.1.2 Lead component insertion

As shown in Figure 8, we added a force sensor and an image sensor to ensure that the robots correctly inserted components into the correct position.

First, the image sensor detects the PCB’s through-hole position. Next, the robot corrects positioning, then inserts the component. When a lead component contacts the PCB, force is exerted. A force sensor detects this force, allowing the system to calculate the positional relationship of the lead and through-hole.

If a force greater than the set value is detected, the sensor will determine that the lead position and through-hole position are misaligned then direct the robot to perform a search operation. This search operation involves monitoring force at the time of insertion with a force sensor, then moving the robot arm slightly along a horizontal plane. If the force detected in the search operation is less than the set value, the sensor will determine that the lead and through-hole position are aligned, then signal the robot to insert the component.

3.1.3 Post-insertion checks

To check that a component is correctly inserted, we installed the mechanism shown in Figure 8, which uses a laser displacement sensor.

After the insertion operation, a laser is applied to multiple points of the lead component's top face to detect its height. If the measurement exceeds the set height, it will be judged as not sitting correctly. This prevents defects caused by a component not being fully inserted.

As described above, we combined robotics and sensing technology to allow robots to perform the same movements that human workers do unconsciously. Compared to the conventional process, the new component insertion process is four times more productive, has one-third the production lead-time, and produces zero in-process inventory.

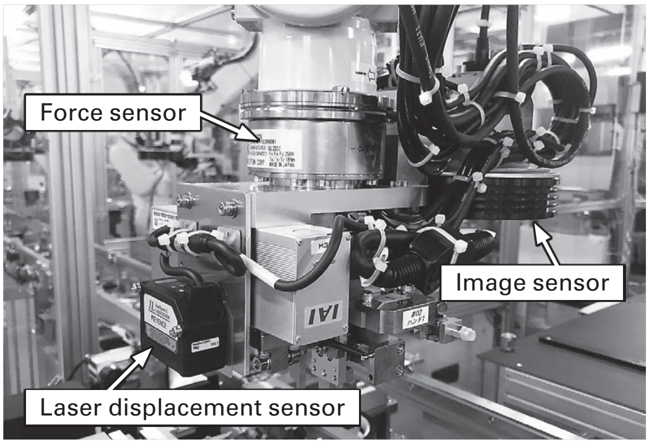

Fig. 8 Sensors on a robot arm

3.2 Specialty technologies in the assembly and inspection line

Following component mounting is servo amplifier assembly, inspection, and packing. Figure 9 shows the newly built assembly and inspection line.

On this Innovation Line, as with the mounting process, manual work has been replaced by robot work, creating an automated line capable of efficient product manufacturing.

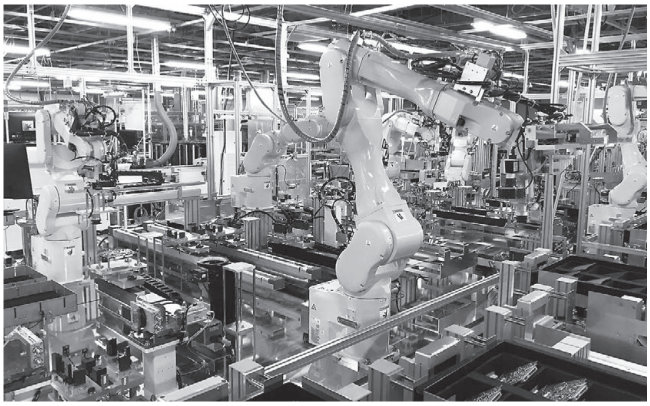

Fig. 9 Assembly and inspection line

3.2.1 Automation of the assembly process

The assembly process consists of a part supply section and a product assembly section.

In the part supply section, robots pick and place parts from the stocker to the assembly station. Here, image sensors prevent incorrect part supply by confirming that it is the correct part, and that it is placed in the correct position.

In the product assembly section, for each part positioned on the assembly station, a robot performs screw tightening, grease application, and cover mounting.

Torque screwdrivers ensure that screws receive the appropriate amount of torque. When grease is applied, an image sensor verifies grease application. Moreover, when the cover is mounted, the force sensor detects the engagement force while the image sensor checks engagement.

We introduced tool changers, as shown in Figure 10, to enable a robot to perform multiple tasks. A tool for the specific application is set in the tool changer, and the robot changes tools automatically for each task. This has made it possible to assemble efficiently within a limited space.

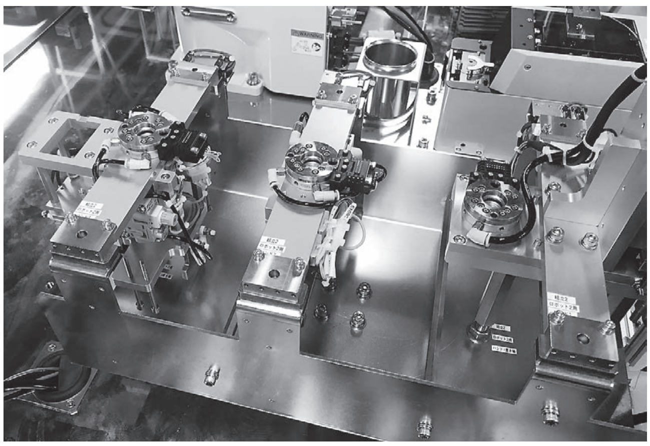

Fig. 10 Tool changer

3.2.2 Automation of the inspection process

In the inspection process, characteristics are inspected to check that servo amplifiers operate correctly.

During characteristics inspection, various cables and connectors must be connected to the servo amplifiers. This work, previously done by human operators, is now done by robots. Multiple connectors are used for inspection; therefore, as shown in Figure 11, an image sensor captures images of the various connector shapes to differentiate them.

The image sensor detects the positions of the connectors on both the receiving and insertion sides. Then robots insert the connectors while the force sensors ensure that the appropriate force is applied. Because the required insertion force differs depending on the connector shape, we set the insertion force for each connector to enable automation.

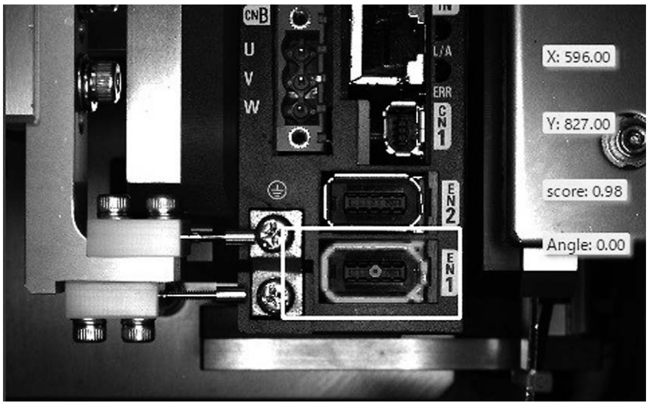

Fig. 11 Connector imaging screen

3.2.3 Automation of the packing process

Figure 12 shows a line where completed servo amplifiers are automatically packaged. Robots complete all the tasks (i.e. box making, bagging, boxing, and sealing) previously done by human operators.

When building the packaging line, we focused on packaging form. The conventional packaging form was designed around human workers and was not suited to automation. However, we changed packaging specifications to enable robots to perform packaging. Changing the product design to suit automatic assembly was one area in particular where we took an uncompromising stance.

We optimized everything from robot operations and gripper shape to outer box size, fold shape, and cushioning material shape in order to make automation possible. Moreover, by changing the label sticker attached to the cardboard box to direct inkjet printing, we eliminated the sticker attachment process.

As a result of the above efforts, productivity increased by 4.7 times, production lead-time was cut to one-quarter, and in-process inventory was eliminated on the new assembly and inspection line compared to the conventional line.

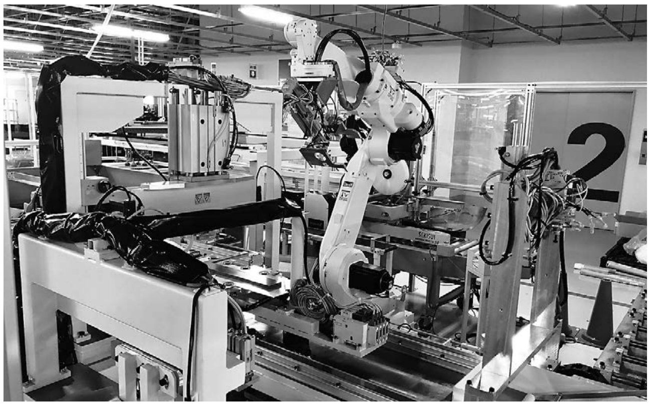

Fig. 12 Automatic packaging line

4. Conclusion

This article has introduced the specialty technologies and ingenuities of the Innovation Lines for our Servo Systems products. Each process incorporates specialty technologies and ingenuities unique to SANYO DENKI.

Our uncompromising stance is “efficiently making a wide variety of products with stable quality.” To achieve this, we engineered various robotics and sensing technology techniques for our Innovation Lines.

Moving forward, SANYO DENKI will pursue manufacturing innovation to continue providing customers with products and services that deliver value.

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SANMOTION K Series DC Servo Motor

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1. Introduction

With over sixty years of history, SANYO DENKI's DC servo motors have contributed to the advancement of industry in Japan.(1) Recently, they have even been adopted in precision measuring equipment such as coordinate measuring machines and medical equipments. These applications require low motor speed fluctuation and temperature rise to improve measurement accuracy. Also, low voltage and noise are necessary because such machinery operates near people.

Our new *SANMOTION K* series DC servo motors significantly reduce cogging torque, which causes speed fluctuation, and have low temperature rise and reduced loss. Moreover, we have devised the brushes and body structure to lower noise.

As with our current model, the lineup includes four flange sizes (42, 54, 76, and 88 mm). We have added a low-voltage model to the standard lineup in flange sizes of 42 × 42 and 54 × 54 mm.

This article will introduce the lineup of the new model, as well as its specifications and features. While developing this new model we devised manufacturing technologies to ensure stable performance.

2. Specifications

2.1 Appearance and dimensions

Figure 1 depicts one example of the new model, a 54 × 54 mm 110 W motor with an encoder. Figure 2 and Table 1 provide the main dimensions of the new model. The new model has the same mounting dimensions as our current T series. As such, replacement is possible without needing to change equipment-side mounting specifications.

Fig. 1 Appearance
(54 × 54 mm 110 W motor with encoder)

2.2 Lineup and main specifications

Table 2 shows the standard lineup and options. As with the current model, incremental encoders, tachogenerators, and brakes can be mounted to the new model. Options can be combined, so we can flexibly respond to the requirements of individual customers. The standard lineup models also conform to the UL, cUL, and IEC safety standards.

Table 3 lists the main specifications of the low-voltage model, while Table 4 lists the main specifications of the standard voltage model. By adding 42 × 42 mm and 54 × 54 mm low-voltage motors to the standard lineup, even machines operating close to people can be used safely. For this reason, the new model can be used for a wider range of applications while having optimal specifications for precision measurement equipment and medical equipment.

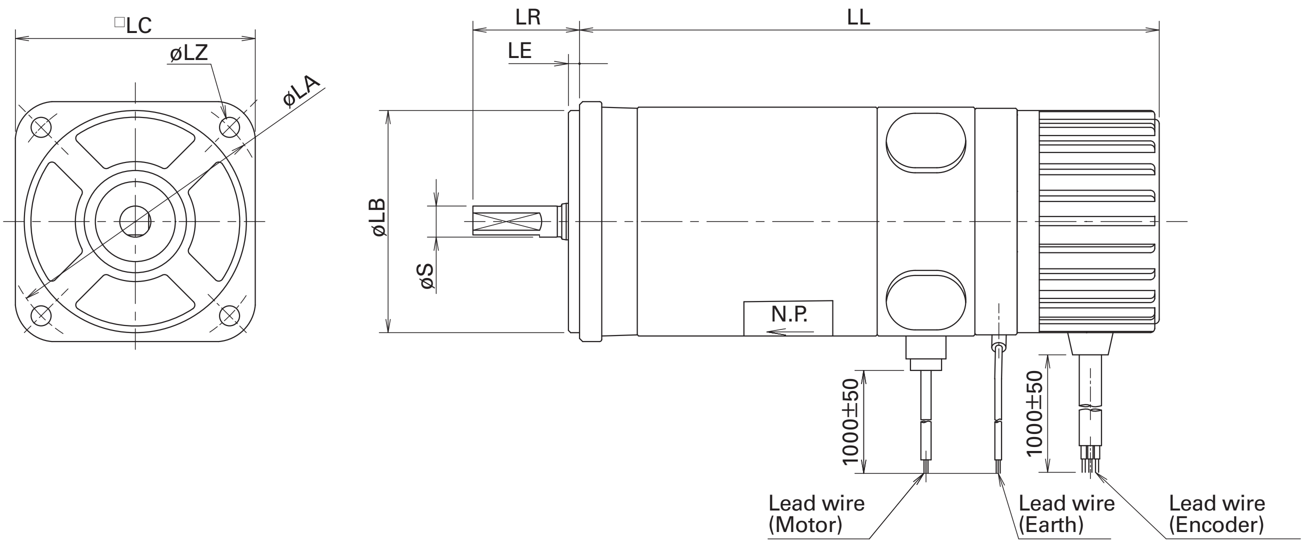


Fig. 2 Main specifications (with encoder)

Table 1 List of main specifications (with encoder)

Dimensions (mm)	Model								
	KB402XS0	**KB404XS0 KA404XS0**	**KB406XS0 KA406XS0**	**KB506XS0 KA506XS0**	**KB511XS0 KA511XS0**	**KA720XS0**	**KA730XS0**	**KA840XS0**	**KA850XS0**
LL	83±1	96±1	109±2	110.5±2	130.5±2	134.5±2	158.5±2	166±2	181±2
LA	48±0.2			60±0.3		90±0.3		100±0.3	
LB	$34^{0}_{-0.025}$			$50^{0}_{-0.025}$		$70^{0}_{-0.030}$		$80^{0}_{-0.030}$	
LE	2±0.3			2.5±0.3		3±0.4			
LC	42±0.5			54±0.5		76±0.8		88±0.8	
LZ	4−ø3.5			4−ø4.5		4−ø5.5		4−ø6.6	
LR	24±0.8					30±0.8		35±0.8	
S	$7^{0}_{-0.009}$					$14^{0}_{-0.011}$		$16^{0}_{-0.011}$	

Table 2 List of standard lineup and options

Flange size (mm)	Rated output (W)	Rated armature voltage		Rated speed (min^{-1})	Protection rating	Safety standards	Options		
		Low voltage (KB) 24 V class	**Standard voltage (KA) 75 V class**				**Tachogenerator**	**Brake**	**Incremental encoder**
42	23	○	–	3000	IP43	UL cUL IEC	3 V/krpm	–	Standard 2000 P/R (A phase, B phase, Z phase)
	40	○	○						
	60	○	○						
54	60	○	○				7 V/krpm	90 VDC	
	80	○	–						
	110	–	○						
76	200	–	○						
	300	–	○	2500					
88	400	–	○						
	500	–	○						

Table 3 List of main specifications (low-voltage model)

Model number	KB402	KB404	KB406	KB506	KB511
Rated armature voltage (V)	20 DC	24 DC			
Rated output (W)	23	40	60	60	80
Rated speed (min^{-1})	3000	3000	3000	3000	3000
Max. speed (min^{-1})	5000	5000	5000	5000	5000
Rated torque (Nm)	0.074	0.13	0.19	0.19	0.26
Peak torque (Nm)	0.42	0.76	1.2	1.8	2.16
Rotor inertia ($\times 10^{-4}$ $kg \cdot m^2$) (Note)	0.047	0.084	0.108	0.22	0.37
Motor weight (kg) (Note)	0.3	0.4	0.5	0.8	0.85

(Note) Value of motor only

Table 4 List of main specifications (standard voltage model)

Model number	KA404	KA406	KA506	KA511	KA720	KA730	KA840	KA850
Rated voltage (V)	72 DC	70 DC	75 DC	75 DC	80 DC	75 DC	85 DC	80 DC
Rated output (W)	40	60	60	110	200	300	400	500
Rated speed (min^{-1})	3000	3000	3000	3000	3000	2500	2500	2500
Max. speed (min^{-1})	5000	5000	5000	5000	5000	4000	4000	3000
Rated torque (Nm)	0.13	0.19	0.19	0.35	0.64	1.15	1.53	1.91
Peak torque (Nm)	0.76	1.2	1.8	3.4	5.4	9.8	12	16.7
Rotor inertia ($\times 10^{-4}$ $kg \cdot m^2$) (Note)	0.084	0.108	0.22	0.37	1.47	2.7	5	6
Motor weight (kg) (Note)	0.4	0.5	0.8	0.85	1.8	2.5	3.4	4.1

(Note) Value of motor only

3. Features

3.1 Reduction of cogging torque

Cogging torque causes speed to fluctuate when motors rotate, and vibration and noise in machinery. Cogging torque has been significantly reduced on the new model to help improve performance of customers' equipment.

Figure 3 shows a comparison of cogging torque waveforms. With the new model, cogging torque for both sizes has been reduced by more than half compared to our current model.

For the new model, from the initial development phase, product design and production line design were advanced simultaneously, and we devised manufacturing technologies to ensure stable performance.

The magnet and armature core shapes were designed to minimize cogging torque while maintaining torque characteristics. Specifically, we determined the pole arc angle that optimizes the magnet's inner and outer radii and minimizes cogging torque, as shown in Figure 4. In addition to devising a method for laminating electromagnetic steel plates, we introduced a technique for automating magnet attachment. We applied our knowledge of manual assembly to automated assembly, and developed manufacturing technologies to stably minimize cogging torque.

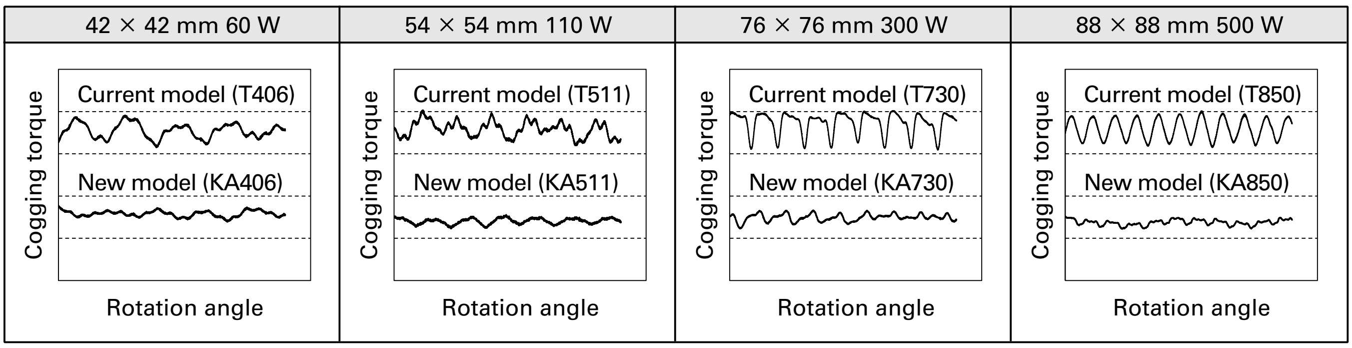


Fig. 3 Comparison of cogging torque waveforms

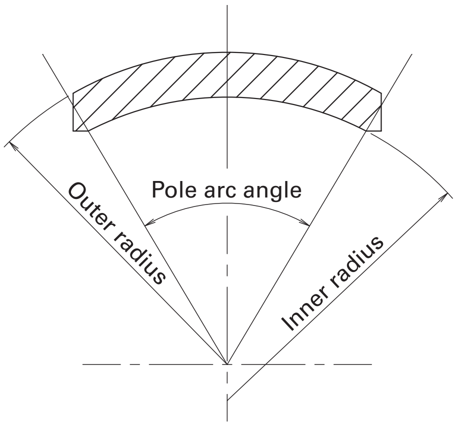
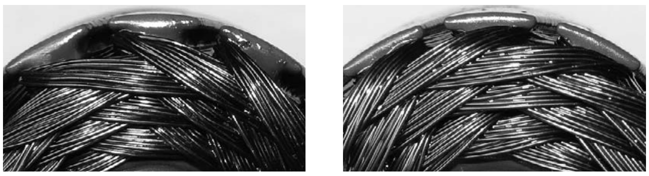


Fig. 4 Magnet shape

3.2 Improved efficiency and low heat generation due to reduced loss

Generally, increasing the winding space factor within a slot can reduce copper loss. Moreover, in DC motors there is mechanical loss that occurs with the mechanical sliding of the brushes and commutators. For the new model, we have increased the winding space factor to reduce copper loss, and optimized the material and number of brushes, consequently reducing mechanical loss.

As one example, Figure 5 shows a comparison of the armature windings for the 54 × 54 mm 110 W model. For the new model, innovations include using a nozzle-type coil winding machine and the control method thereof, and we reduced copper loss by using thick windings with a high space factor.



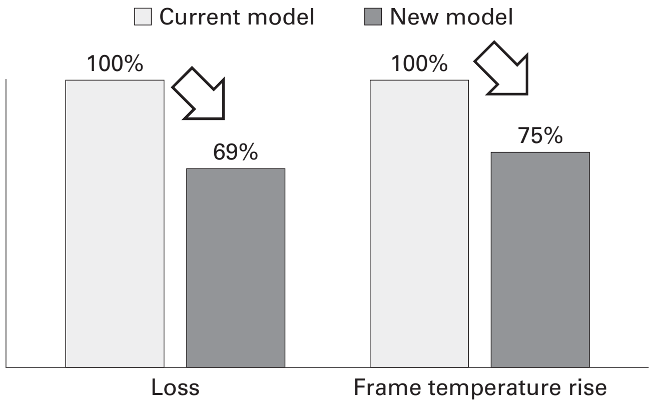
(a) Current model (b) New model

Fig. 5 Comparison of armature windings (54 × 54 mm 110 W motors)

Moreover, by optimizing the number and material of brushes, we have reduced mechanical loss from friction between brushes and commutators while maintaining equivalent brush life to the current model.

Figure 6 shows a comparison of loss and frame temperature rise between the new and current 42 × 42 mm 60 W models. In line with a 31% reduction in loss compared to the current model, frame temperature rise has been reduced by 25%. Also, motor efficiency has been improved by around 10%.

This high efficiency limits temperature rise, so it has little impact on the temperature of customers' equipment, and contributes to energy-saving in equipments.



Note: Test conditions: Rated output (according to in-house heat dissipation conditions)

Fig. 6 Comparison of loss and temperature rise values (42 × 42 mm 60 W motors, at rated output)

3.3 Low noise

A structural feature of DC servo motors is that they have a mechanical sliding portion consisting of brushes and commutators. The vibrations from the brush and commutator contact is one of the main causes of noise during motor rotation.

For the new model, vibrations and noise caused by brush and commutator contact have been suppressed and noise levels have been reduced by optimizing the number of brushes and improving the rigidity of the bracket portion that supports the brushes.

Figure 7 is a comparison of noise levels for 54 × 54 mm 110 W models. For the new model noise is lower across a wide rotational speed range. Compared to the current model, noise has been reduced by up to around 8 dB.

The low noise levels of the new model allow it to be used comfortably near people, such as in medical equipment.

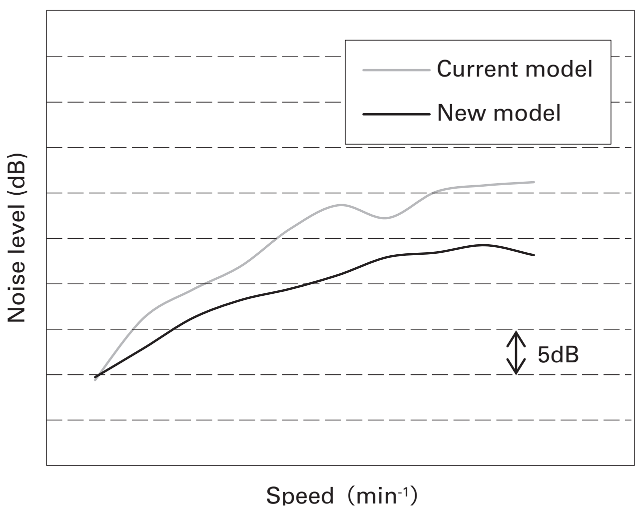


Fig. 7 Noise level comparison (54 × 54 mm 110 W motors, no-load)

4. Conclusion

This article has introduced the lineup, specifications, and features of the *SANMOTION K* series DC servo motor.

The new model features high efficiency, low torque fluctuation, and low motor temperature rise. Moreover, a low-voltage model has been added to the standard lineup. This product can help improve the performance of customers' equipment and create new value. Because the mounting size of the new model is the same as our current model, they can easily replace the current model customers have been using .

We will continue to pursue the ease-of-use unique to DC servo motors, and meet the needs of current and new applications and markets by combining product design and manufacturing technologies.

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