SANYO DENKI

Technical Report

Feature | Building a Low-Carbon Society

1990
Fujiyama Works

56
November
2023

COLUMN

Cover image:

Fujiyama Works

1990

In the late 1980s to the 1990s, Japan experienced a period of economic boom known as a "bubble economy."

The Fujiyama Works was established to meet the anticipated increase in demand for large generators from the Power Systems Division. With the large manufacturing equipment used in the Midorigaoka and Tsuiji Works brought in, the Fujiyama Works began operations as a factory with efficient manufacturing capabilities.

In 2013, it underwent a further expansion, incorporating state-of-the-art equipment and efficient automated production lines. Today, it produces a variety of products, covering all of our businesses—Cooling Systems, Power Systems, and Servo Systems.

Equipped with a PV generation system, the factory makes good use of renewable energy sources and stands as an environmentally friendly manufacturing facility.

56 SANYO DENKI TECHNICAL REPORT
November 2023

C O N T E N T S

Building a Low-Carbon Society

Chihiro Nakayama Senior Executive Operating Officer

In March 2023, as part of its efforts to achieve carbon neutrality, SANYO DENKI CO., LTD. set the SANYO DENKI Group's* medium- to long-term CO_2 emissions reduction targets: a 46% reduction (from FY 2017) by FY 2030, and net-zero emissions by FY 2050.

The SANYO DENKI Group is engaged in three types of major initiatives to achieve a low-carbon society.

The first initiative involves the proactive development of Eco Products. We are working to reduce the environmental impact and CO_2 emissions of our products during use by incorporating the latest energy-saving technologies.

The second initiative is for energy savings at our factories. In 1997, we introduced a PV system to the Technology Center in Ueda, Nagano for the first time. Presently, the total electricity generation capacity of the entire Ueda facilities is a maximum of 2,520 kW. In addition, we achieved a significant reduction in power consumption by replacing all the factory lights by LED lights. Moreover, the introduction of automation equipment further increased production efficiency, reducing unnecessary power consumption.

The third initiative is for achieving carbon neutrality. In our Power Systems Division, we have developed many products that use natural energy, such as grid management systems and renewable energy inverters for photovoltaic, wind, and hydroelectric generation systems. We believe that the widespread use of our products in the carbon-neutral market will significantly contribute to a low-carbon society.

Among these three, we have been particularly committed to the proactive development of Eco Products.

Under our corporate philosophy to "aim to help all people achieve happiness," the SANYO DENKI Group has developed a number of high-efficiency and energy-saving products based on three core technologies: protecting the global environment, using new energy sources and saving energy, and protecting people's health and safety.

* On this matter, the following are applicable: SANYO DENKI CO., LTD., SANYO DENKI Techno Service CO., LTD., and SANYO DENKI IT Solution CO., LTD.

Newly developed products are subjected to comparison with competitors' products and our existing products. They will be certified as Eco Products only if our qualification standards are met. The more products that are certified as Eco Products, the greater our contribution to the environment. In FY 2022, a total of 20 models were additionally certified as Eco Products, raising the cumulative total to 358 models.

In FY 2022, the Cooling Systems Division launched a cooling fan that produces 40% less CO_2 emissions than its predecessor, which was developed through optimized impeller and frame design and newly developed motor and drive circuit.

The Servo Systems Division launched a linear servo motor that produces 13% less CO_2 emissions compared to its predecessor by improving the motor's winding fill factor to reduce power losses.

In April 2023, the Technology Center in Ueda, Nagano, the research and development base of Eco Products, shifted to using hydroelectric power named "Shinshu Green Electricity" to further accelerate our initiatives for achieving carbon neutrality. As a result, combined with its PV generation system, the electricity used in the Technology Center has been completely shifted to renewable energy, making CO_2 emissions from electricity use zero. In this way, the electricity used in the R&D site of Eco Products has been made carbon-free.

Under the feature's theme of "Building a Low-Carbon Society," this issue introduces our products of each business that are aligned with the theme, as well as technologies based on their roles and features.

The SANYO DENKI Group will continue to contribute to a sustainable and circular society while achieving both business growth and environmental protection.

Building a Low-Carbon Society

Naoki Murakami

1. Introduction

In recent years, global warming and climate change have become critical issues worldwide. To realize a "low-carbon society" with net zero emissions of greenhouse gases, including carbon dioxide, which is responsible for these phenomena, initiatives to reduce emissions are in progress around the world. Efforts include transitioning from gasoline-fueled vehicles to electric vehicles, expanding the use of clean energy, improving energy efficiency, and reducing waste.

A low-carbon society not only contributes to mitigating global warning and climate change but also is a central theme of multiple Sustainable Development Goals (SDGs). Companies, organizations, and individuals around the world are setting their own goals as they work to achieve a low-carbon society.

We, SANYO DENKI, are also proactively developing products to contribute to achieving a low-carbon society based on our corporate philosophy of "For society and the natural environment, we will help preserve the global environment and contribute to the prosperity of mankind through our corporate activities."

This article introduces technology that reduces power consumption of cooling fans, as well as our *San Ace* products that contribute to the realization of a low-carbon society.

2. Low Power Consumption and Long Life Technologies for Achieving a Low-Carbon Society

2.1 Fans with lower power consumption and longer life for a low-carbon society

Around the world, cooling fans are installed in equipment for a wide range of applications. As such, lowering power consumption in cooling fans is an effective means of reducing fossil fuel consumption and curbing greenhouse gas emissions. Also, cooling fans with longer service life will help improve resource efficiency and reduce waste. These technologies can contribute to the SDGs shown in Figure 1.

We believe that low power consumption and long service life are important qualities of cooling fans. As such, we have developed many cooling fans with these features.

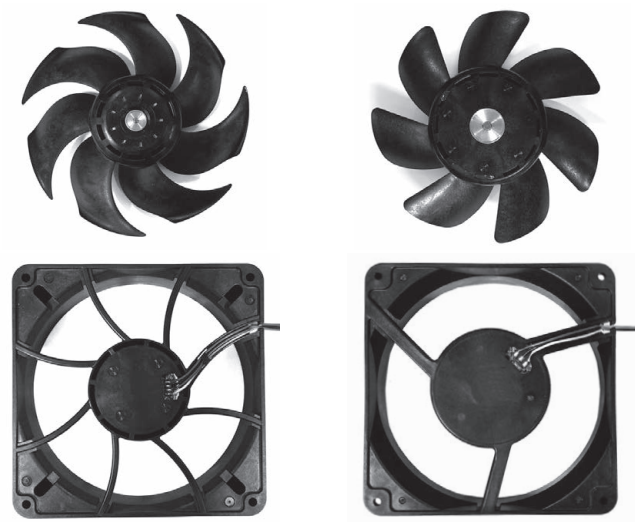
This chapter introduces some of the technologies to reduce the power consumption and extend the service life of cooling fans.

Fig. 1 The SDGs to which cooling fans with lower power consumption and longer service life can contribute

2.2 Simulation-based automated design optimization

To lower power consumption in cooling fans, it is essential for the impeller and frame to demonstrate good aerodynamic performance and for the stator core, windings, magnets, and drive circuit to provide high efficiency in motor performance. Conventionally, efficiency improvement used to be achieved through trial and error on actual equipment. In recent years, however, we have been using simulation-based design optimization to optimize efficiency. This involves importing the expertise we have accumulated over our past development efforts into simulations for automated design optimization. With this approach, we are now able to pursue even higher efficiency. Figure 2 compares the impeller and

frame shapes of our current product and our new 140 × 140 × 38 mm *San Ace 140* 9RA type, which was developed using simulation-based automated design optimization. Figure 3 compares the power consumption and noise level of them at equivalent cooling performance.



New product Current product

Fig. 2 Impeller and frame of the new *San Ace 140* 9RA type and current product

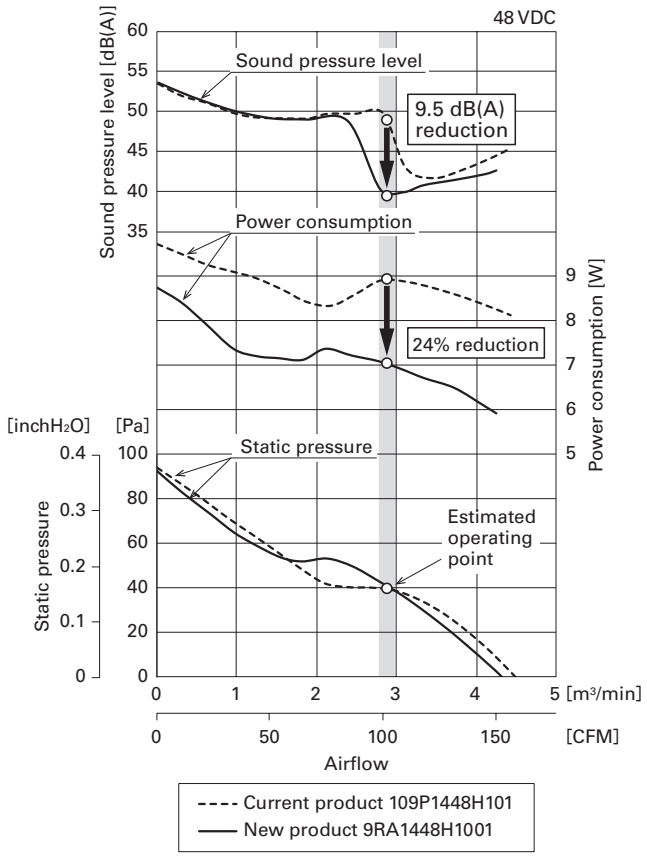
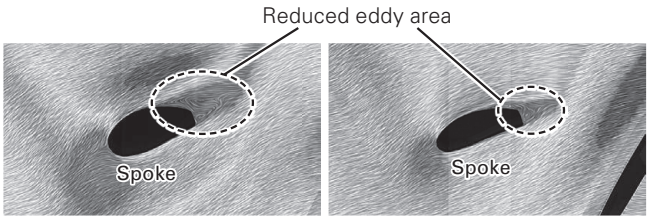


Fig. 3 Characteristics comparison between the new *San Ace 140* 9RA type and current product

The improved motor efficiency and aerodynamic performance have resulted in significantly lower power consumption and noise compared to the current product.

2.3 Visualization of airflow

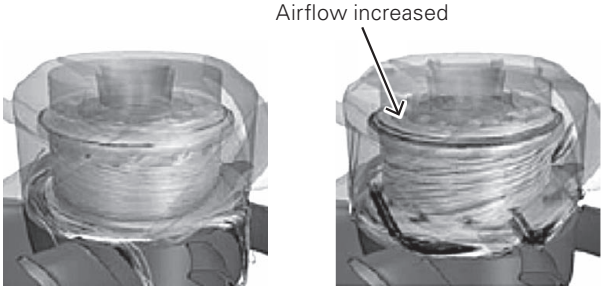
To refine the details of the impeller and frame shapes generated by the aforementioned automated optimization process, we have been using simulations to visualize airflow. Unsuitable impeller and frame shapes can cause significant turbulence and eddies around the impeller blades and frame spokes, leading to reduced efficiency and elevated noise levels. Simulation-based visualization of airflow enabled us to assess the extent of turbulence and eddies, providing insight into how changes in the impeller and frame shapes lead to improvements. Figure 4 shows an improvement in eddy reduction through the modification of the frame spoke's shape.



Before improvement After improvement

Fig. 4 Eddy suppression through redesigned spoke shape

We also use simulation-based visualization of airflow to achieve longer service life. To extend service life, it is effective to use a self-cooling structure that keeps the temperature of the motor and bearing low. The use of simulations to visualize the internal airflow has enabled us to design a structure with an improved self-cooling capability. Figure 5 shows the visualization of internal airflow. Compared to Structure A, Structure B has an increased internal airflow, indicating a better self-cooling capability.



Structure A Structure B

Fig. 5 Visualization of internal airflow

Simulation-based automated design and the visualization of airflow have clarified how the input (parameters and shapes) affects the output (efficiency and power consumption). As a result, we can now design impellers, frames, motors, and structures to make cooling fans that consume less power and last longer.

We will continue to improve our simulation technology and its precision to develop fans with even higher performance.

3. *San Ace* Fans Contributing to Achieving a Low-Carbon Society

Our *San Ace* lineup includes Low Power Consumption Fans, Long Life Fans, and many other products that contribute to a low-carbon society. This chapter introduces examples of these products and their features.

3.1 The *San Ace* 9RA type with low power consumption and low noise

The *San Ace* 9RA type, characterized by its low power consumption and low noise, has been developed as a replacement for our current products: the *San Ace* 9P, *San Ace* 9R, and *San Ace* 9G types. With sizes ranging from 60 × 60 mm to 140 × 140 mm, the new product consumes less power and produces less noise than the current products while maintaining the same size and cooling performance.

Thanks to its significantly reduced power consumption, the 140 × 140 × 38 mm *San Ace 140* 9RA type mentioned in section 2.2 produces 41% less CO_2 emissions over its product life cycle compared to the current product (according to our LCA calculation software).

3.2 The *San Ace* 9LG type High Airflow Long Life Fan and the *San Ace* 9WL type High Airflow Long Life Splash Proof Fan

Our lineup offers new fans that boast higher airflow and long service life: the *San Ace* 9LG type, and the *San Ace* 9WL type with water and dust protection. These cooling fans are ideal for cooling equipment in the renewable energy and EV markets, which require both long service life and water and dust protection.

Tables 1 and 2 compare the expected life and general specifications of the 140 × 140 × 51 mm *San Ace 140L* 9LG type and the *San Ace 140W* 9WL type with our current products, respectively. The *San Ace* 9LG and *San Ace* 9WL types have 1.1 times the maximum airflow and 2.7 times the maximum static pressure of the current products. Moreover, the expected life at an ambient temperature of 60°C is three times longer for the *San Ace* 9LG type and 1.7 times longer for the *San Ace* 9WL type (survival rate of 90%, run continuously at rated voltage and normal humidity in free air).

Table 1 Comparison of the new *San Ace 140L* 9LG type and current product

Model no.	Expected life [h]	Max. airflow [m^3/min]	Max. static pressure [Pa]
New product 9LG1412P5G001	180,000	9.0	655
Current product 9LB1412S501	60,000	8.1	240

Table 2 Comparison of the new *San Ace 140W* 9WL type and current product

Model no.	Expected life [h]	Max. airflow [m^3/min]	Max. static pressure [Pa]
New product 9WL1412P5G001	100,000	9.0	655
Current product 9WB1412S501	60,000	8.1	240

3.3 The *San Ace* 9AD type ACDC Fan and the *San Ace* 9ADW type Splash Proof ACDC Fan

The *San Ace* 9AD type ACDC Fan incorporates a DC-powered motor with low power consumption while operating on AC power, achieving lower power consumption and an extended service life compared to our current AC fan of the equivalent size. It comes with PWM control, a feature not available in AC fans, enabling fan speed control based on the operating conditions for further reduction in power consumption. We also offer the *San Ace* 9ADW type Splash Proof ACDC Fan serving as an effective energy-saving solution for various devices requiring AC power input.

Figure 6 compares the power consumption of the ø172 × 150 × 51 mm *San Ace 172AD* 9AD type and 9ADW type with our current product at equivalent cooling performance. It shows that the new product consumes 48% less power than the current product when the fan speed of the new product is reduced by PWM control to match the cooling performance of the current product (60 Hz). The *San Ace 172AD* 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), which is 1.6 times longer than the current product's expected life of 25,000 hours.

In June 2023, we launched the 120 × 120 × 25 mm *San Ace 120AD* ACDC Fan, the slimmest of our ACDC fans. Details are covered in a separate article in this Technical Report.

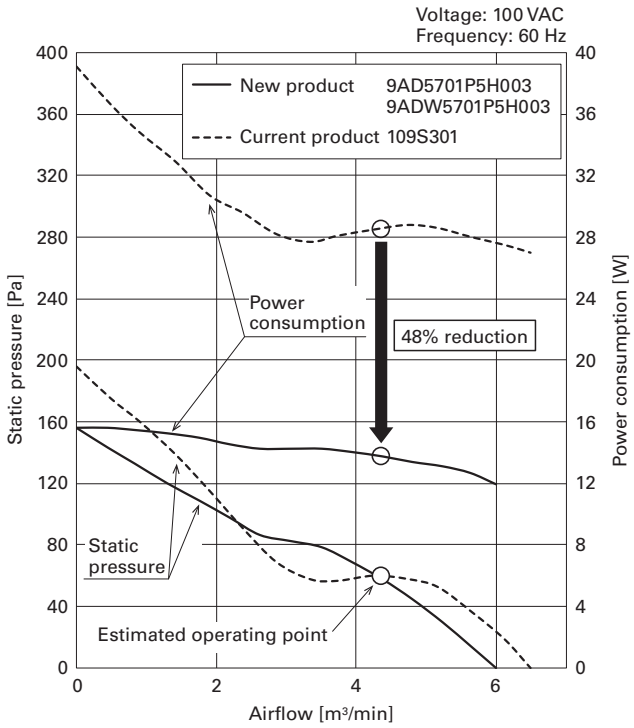


Fig. 6 Comparison of the new *San Ace 172AD* 9AD/9ADW types and current products

3.4 Fan controller

Our lineup also includes the *San Ace Controller,* an IoT-ready fan controller. Figure 7 shows an example system configuration for the *San Ace Controller.* The *San Ace Controller* allows PWM fan speed to be optimized, reducing excessive power consumption. Combined with a dedicated sensor, it can provide automatic control of cooling fans. For instance, with a temperature sensor, it enables the monitoring of the temperature inside equipment and automatically controls fan speed based on the measurement. This contributes to maintaining optimal fan speed, leading to a reduction in power consumption.

In addition, as the San Ace Controller can remotely monitor the fan speed and current of the cooling fans, alarms can be issued when necessary. These functions help users estimate the service life of a cooling fan in its actual operating environment and perform maintenance at optimal intervals.

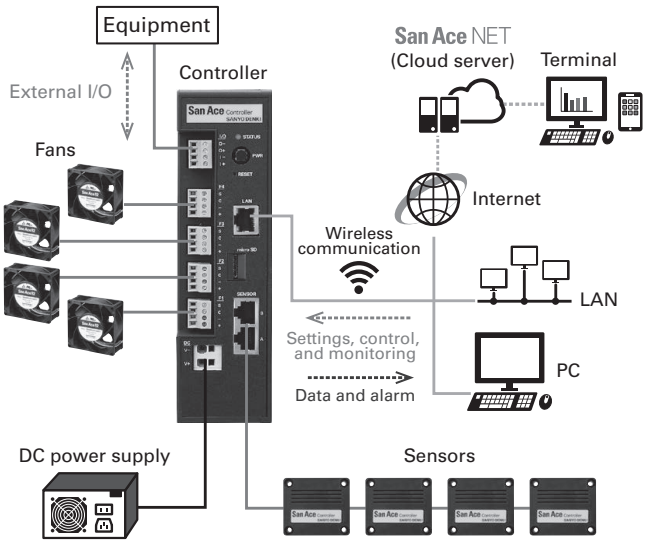


Fig. 7 *San Ace Controller* system configuration

4. Conclusion

This article has introduced technologies to lower power consumption and extend the service life of cooling fans, as well as our *San Ace* products that contribute to the realization of a low-carbon society.

Achieving a low-carbon society is crucial not only for meeting the SDGs, curbing global warming, and addressing climate change but also a global imperative. Accordingly, companies, organizations, and individuals around the world are setting their own goals to tackle this global challenge. In addition to our commitment to achieving our environmental impact reduction targets, we, as a global manufacturer with worldwide product reach, will continue to contribute to achieving a low-carbon society by developing and providing products designed for this overarching goal.

Reference

(1) Masahiro Koike and 4 others: "High Airflow Long Life Fan / High Airflow Long Life Splash Proof Fan *San Ace 140L* and *San Ace 140W*"
SANYO DENKI Technical Report No. 46, pp. 7-12 (2018.11)

(2) Naoya Ozumi and 4 others: "⌀172 × 150 × 51 mm *San Ace 172AD* 9AD Type ACDC Fan and *San Ace 172AD* 9ADW Type Splash Proof ACDC Fan"
SANYO DENKI Technical Report No. 46, pp. 9-13 (2021.11)

(3) Satoshi Tateyama and 5 others: "140 × 140 × 38 mm *San Ace 140* 9RA type"
SANYO DENKI Technical Report No.55, pp. 9-13 (2023.5)

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40 × 40 × 28 mm *San Ace 40L* 9LG Type High Static Pressure Long Life Fan

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1. Introduction

ICT equipment is becoming increasingly important in supporting our society and economy. Our Long Life Fans have been widely used in mission-critical facilities and remotely installed equipment as they require high reliability and long service life to ensure long-term, reliable operation.

As equipment rapidly advances in performance, it's becoming denser and generating more heat, requiring fans with both high cooling performance and long service life. To address these needs, we had offered our 40 × 40 × 28 mm 9L type Long Life Fan (hereafter, "current product") for a while. In recent years, however, it has become increasingly more difficult for this fan to meet the latest market demands.

In response, we have developed and launched the *San Ace 40L* 9LG type High Static Pressure Long Life Fan (hereinafter, "new product").

This article introduces the features and performance of the new product.

2. Product Features

Figure 1 shows the appearance of the new product.

Fig. 1 40 × 40 × 28 mm *San Ace 40L* 9LG type

The new product achieves high airflow, high static pressure, and long service life while maintaining the same size as the current product.

The new product is available in two voltages of 12 and 24 V, while the current product only offers 12 V.

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new product. The new product was designed to be compatible in size and mounting with the current product.

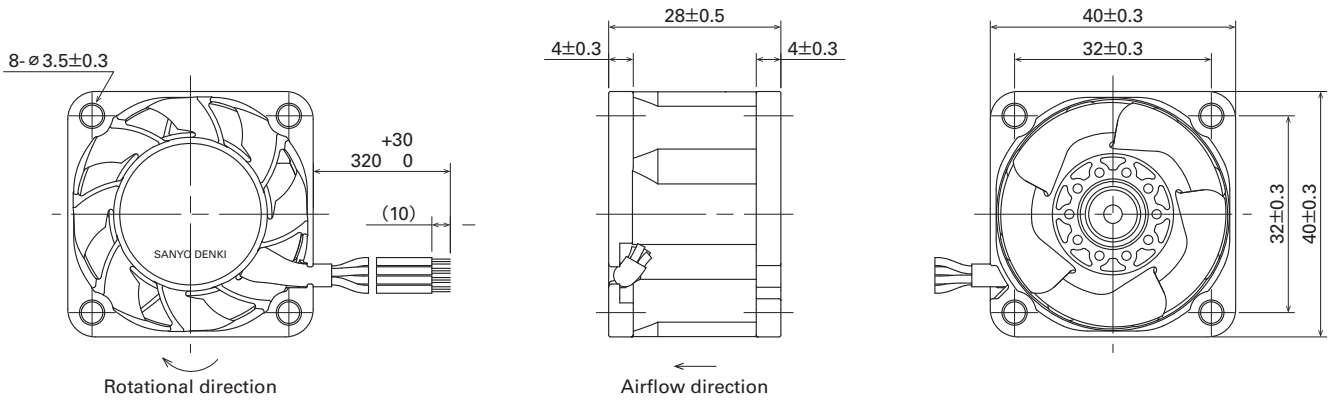


Fig. 2 Dimensions of the *San Ace 40L* 9LG type (Unit: mm)

3.2 Specifications

3.2.1 General specifications

Table 1 shows the general specifications of the new product.

Table 1 General specifications of the *San Ace 40L* 9LG type

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9LG0412P3G001	12	10.2 to 13.8	100	1.9	22.8	33500	0.93	32.9	1780	7.15	68	-20 to +70	80000 at 60°C (115000 at 40°C)
			20	0.09	1.08	7500	0.2	7.07	89	0.36	33		
9LG0412P3S001			100	1.23	14.8	28000	0.77	27.2	1290	5.18	65		100000 at 60°C (135000 at 40°C)
			20	0.07	0.84	5700	0.15	5.3	53	0.21	28		
9LG0412P3H001			100	0.69	8.28	22500	0.62	21.9	830	3.33	62		
			20	0.07	0.84	5700	0.15	5.3	53	0.21	28		
9LG0424P3G001	24	21.6 to 26.4	100	0.95	22.8	33500	0.93	32.9	1780	7.15	68		80000 at 60°C (115000 at 40°C)
			20	0.07	1.68	6800	0.18	6.36	73	0.29	32		
9LG0424P3S001			100	0.61	14.6	28000	0.77	27.2	1290	5.18	65		100000 at 60°C (135000 at 40°C)
			20	0.05	1.2	5000	0.13	4.59	41	0.16	27		
9LG0424P3H001			100	0.34	8.16	22500	0.62	21.9	830	3.33	62		
			20	0.05	1.2	5000	0.13	4.59	41	0.16	27		

Speed is 0 min^{-1} at 0% PWM duty cycle for models without ratings at 0% listed.
Note: The expected life at an ambient temperature of 40°C is for reference purposes only.

3.2.2 Airflow vs. static pressure characteristics

Figure 3 shows the airflow vs. static pressure characteristics of the new product, between different models.

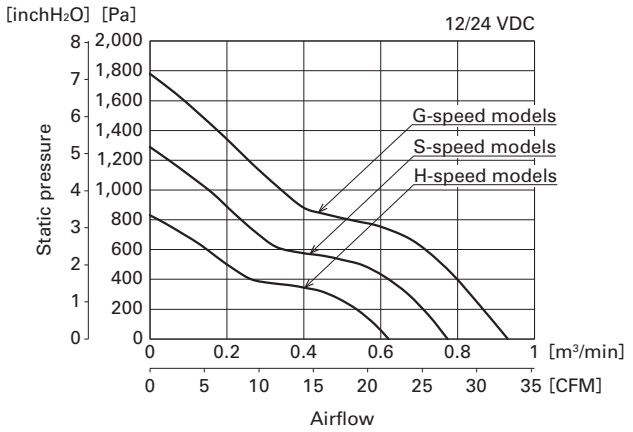


Fig. 3 Airflow vs. static pressure characteristics of the *San Ace 40L* 9LG type (different models)

3.2.3 PWM control

The new product comes with PWM control for controlling fan speed.

3.3 Expected life

The new product is available in three speed variations. G-speed models, the fastest with significantly improved cooling performance, have an expected life of 80,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage and normal humidity in free air). S-speed and H-speed models have improved airflow and static pressure while maintaining the same expected life of 100,000 hours as the current product.

4. Key Points of Development

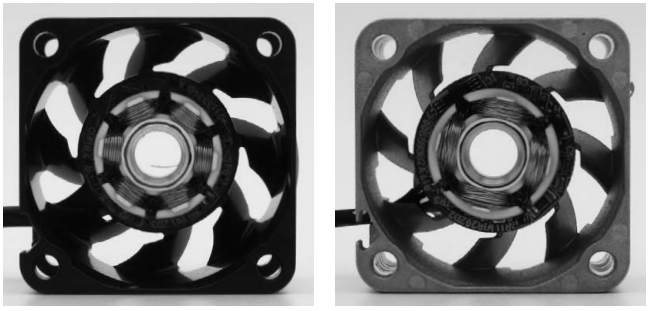
The new product achieves faster speed of up to 33,500 min^{-1}, higher airflow, higher static pressure, and longer service life, thanks to its highly efficient 3-phase drive motor,new impeller and frame shapes designed for better aerodynamic performance, and effective cooling and heat dissipation.

The key points of development are as follows.

4.1 Motor design

Achieving higher airflow and static pressure required a faster speed than the current product. To ensure longer service life, it was essential to suppress the temperature rise in the bearings and improve the motor efficiency. To achieve these, the new product uses a 3-phase drive motor, which is suitable for achieving both high speed and high efficiency, while a bipolar drive (single-phase full-wave) motor is used in the current product.

Figure 4 compares the motors of the new and current *San Ace 40L* fans.



New product　　Current product

Fig. 4 Motors of the new and current products

4.2 Impeller and frame design

To achieve the impeller's target durability required for the increased fan speed, we leveraged simulations to design an impeller with improved strength and excellent aerodynamic performance. Also, the impeller has vent holes for better heat dissipation of the motor.

The frame uses the same aluminum material as the current product for strength and effective heat dissipation. Furthermore, the shape of the stator blades was optimally designed to match the impeller shape.

Figure 5 compares the impeller and frame shape between the new and current products.

New product　　Current product

Fig. 5 Appearance of the new and current products compared

5. Comparison of New and Current Products

5.1 Comparison of airflow vs. static pressure characteristics

Figure 6 compares the airflow vs. static pressure characteristics of the new (with different models) and current products.

The new fastest model, 9LG0412P3G001, has 1.8-times maximum airflow and 8.7-times higher maximum static pressure, compared to the current product. Its expected life is 80,000 hours, which is close to that of the current product, while significantly improving airflow and static pressure.

The new 9LG0412P3S001 model, with the same expected life of 100,000 hours as the current product, achieves 1.5-times higher maximum airflow and 6.3-times higher maximum static pressure.

5.2 Power consumption comparison

Figure 7 compares power consumption between the new and current products at the same airflow.

At the estimated system impedance (equipment ventilation resistance) shown in the figure, the new product consumes 46% less power than the current product demonstrating a high efficiency.

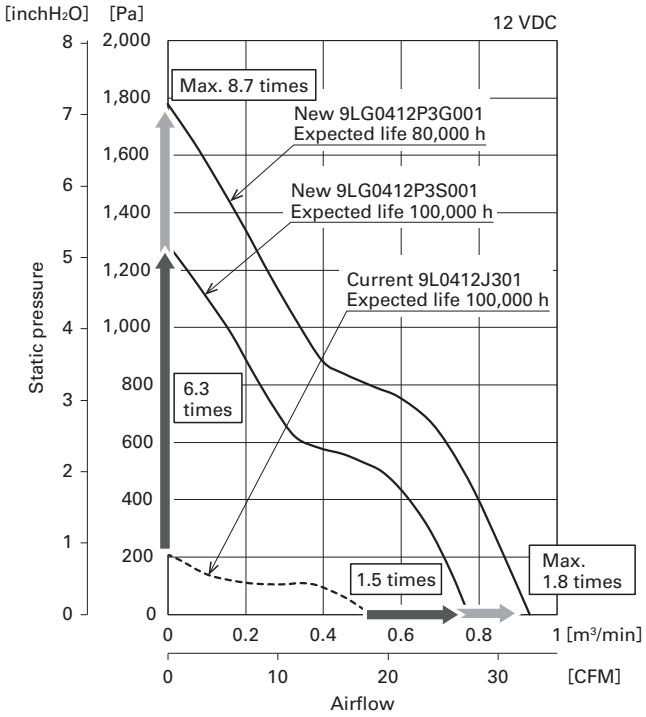


Fig. 6 Airflow vs. static pressure characteristics of the new and current products

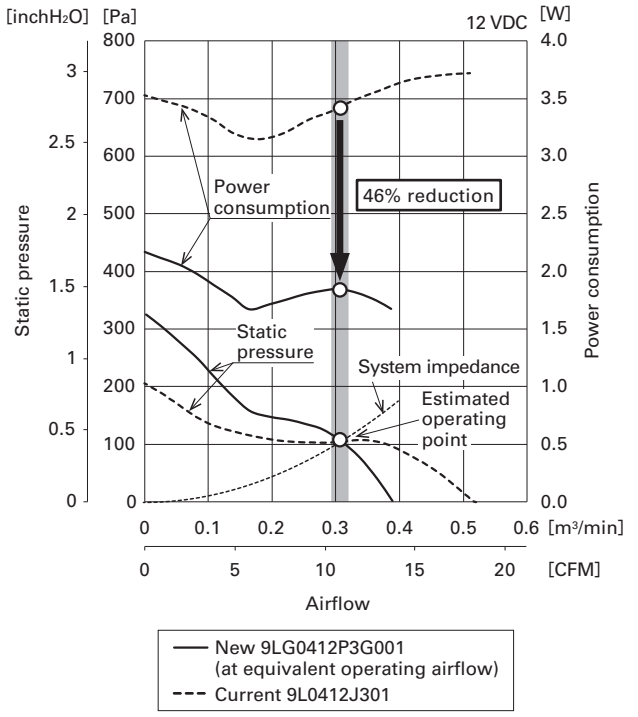


Fig. 7 Power consumption comparison between the new and current products

5.3 Environmental impact comparison

Figure 8 compares the CO_2 emissions of the new and current products over their life cycles.

The new product produces 50% less CO_2 emissions over its product life cycle compared to the current product thanks to its greatly reduced power consumption.

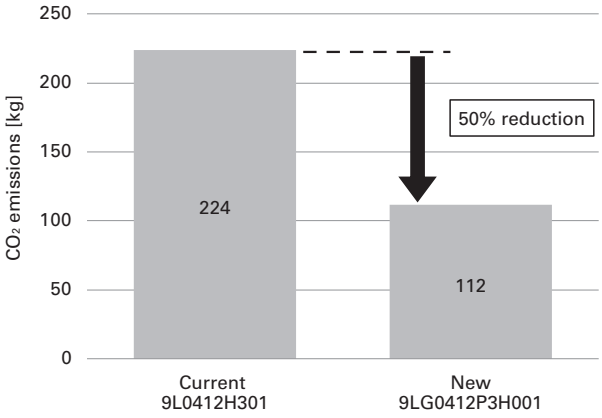


Fig. 8 CO_2 emissions comparison using our LCA calculation software (100,000 hours, when operating with the same operating airflow)

6. Conclusion

This article introduced the features and performance of the *San Ace 40L* 9LG type High Static Pressure Long Life Fan.

The new product achieves significantly higher airflow and static pressure than the current product while maintaining a long service life.

Furthermore, it is available in 12 and 24 V voltages, and this extends the range of applications, contributing to improving performance, extending service life, and reducing size of various types of equipment.

We will continue to help our customers create new value by providing products that promptly address market demand.

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120 × 120 × 25 mm *San Ace 120AD* 9AD Type ACDC Fan

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Shuji Miyazawa Kento Oshima Masato Murata

1. Introduction

In recent years, the accelerating trend to a low-carbon society to combat global warming has led to greater demand for cooling fans with low power consumption and long service life. In addition, cooling fans are required to have PWM control to adjust the fan speed in response to the operating conditions of equipment as well as a wide input voltage range for use in various countries.

Since our conventional AC Fans had become unable to meet these requirements, we have developed and expanded the lineup of our ACDC Fan, which has a built-in AC-DC conversion circuit to drive a DC motor.

Furthermore, for today's smaller, more advanced control panels and industrial equipment, there is an increasing demand for thin-profile cooling fans, including ACDC fans, to fit in the reduced and confined spaces. To meet these requirements, we have developed our slimmest 25 mm ACDC Fan. This article introduces the performance and features of the new product, as well as the key points of development.

2. Product Features

Figure 1 shows its appearance.

Its product features are as follows:

(1) Energy savings
(2) Long service life
(3) Wide operating temperature range
(4) High static pressure and high airflow
(5) PWM-based fan speed control

Fig.1 120 × 120 × 25 mm *San Ace 120AD* 9AD type fan

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new 120 × 120 × 25 mm *San Ace 120AD* 9AD type.

3.2 Specifications

3.2.1 General specifications

Table 1 shows the general specifications of the new product.

The lineup of the product is available in: a high-speed model with PWM control, constant high-speed model, medium-speed model, and low-speed model.

With an operating voltage range of 90 to 264 VAC, they can be used both with 100 and 200 VAC systems.

3.2.2 Airflow vs. static pressure characteristics

Figure 3 shows the airflow vs. static pressure characteristics of the high-speed, PWM-control model, 9AD1201P4H001. Figure 4 shows the airflow vs. static pressure characteristics of the high-speed 9AD1201H4002, medium-speed 9AD1201M4002, and low-speed 9AD1201L4002 models. The airflow vs. static pressure characteristics of all new models remain the same over their input voltage range from 100 to 240 V.

3.2.3 PWM control

The 9AD1201P4H001 model comes with PWM control for controlling the fan speed.

3.3 Expected life

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

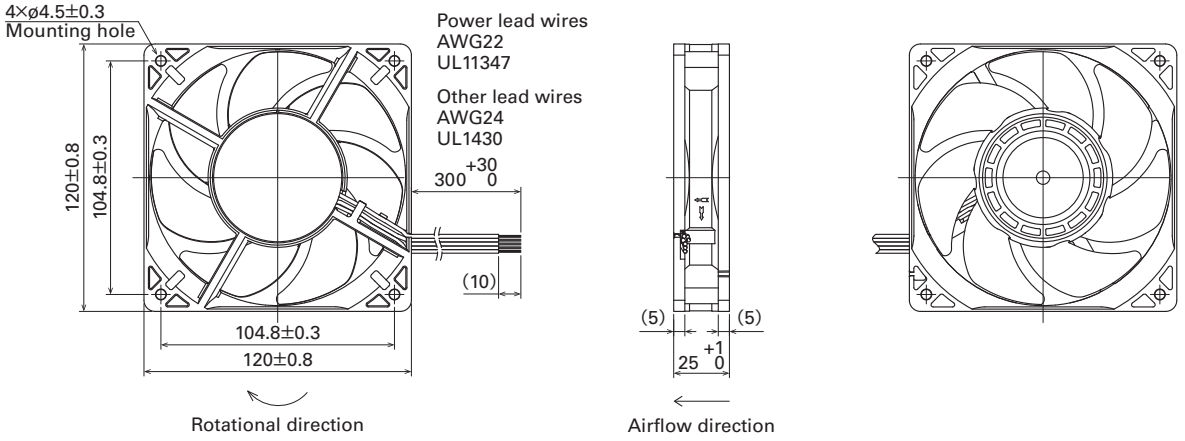

Fig. 2 Dimensions of 120 × 120 × 25 mm *San Ace 120AD* 9AD type fan (Unit: mm)

Table 1 General specifications of 120 × 120 × 25 mm *San Ace 120AD* 9AD type fan

Model no.	Rated voltage [V]	Operating voltage range [V]	Frequency [Hz]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9AD1201P4H001	100 to 240	90 to 264	50/60	100	0.06	3.4	3000	2.35	83	62	0.249	40	-20 to +70	60000 at 60°C (90000 at 40°C)
				30	0.02	0.7	900	0.7	24.7	6.6	0.03	14		
9AD1201H4002				—	0.06	3.4	3000	2.35	83	62	0.249	40		
9AD1201M4002				—	0.04	1.6	2250	1.76	62	35	0.140	34		
9AD1201L4002				—	0.03	1.1	1800	1.41	49	22	0.088	26		

* Input PWM frequency: 25 kHz. Speed is 0 min^{-1} at 0% PWM duty cycle.
Note: The expected life at an ambient temperature of 40°C is for reference purposes only.

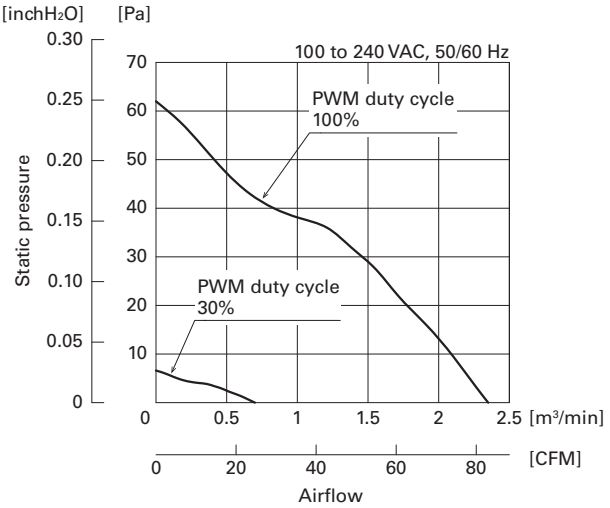

Fig. 3 Airflow vs. static pressure characteristics of 9AD1201P4H001

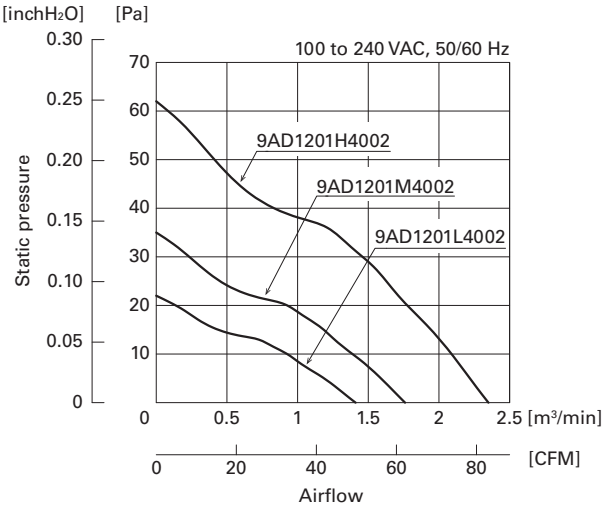

Fig. 4 Airflow vs. static pressure characteristics of new 9AD1201H4002, 9AD1201M4002, and 9AD1201M4002 models

4. Key Points of Development

The new product achieves lower power consumption, longer service life, higher static pressure, and higher airflow while maintaining the same size as our current AC Fan.

The key points of development are as follows.

4.1 Design techniques that achieved a 25 mm thin-profile frame

ACDC fans need to incorporate a large high-capacitance capacitor and, reactor to convert AC input power into low-voltage DC power. Figure 5 shows the cross-sectional views of new and current ACDC Fans.

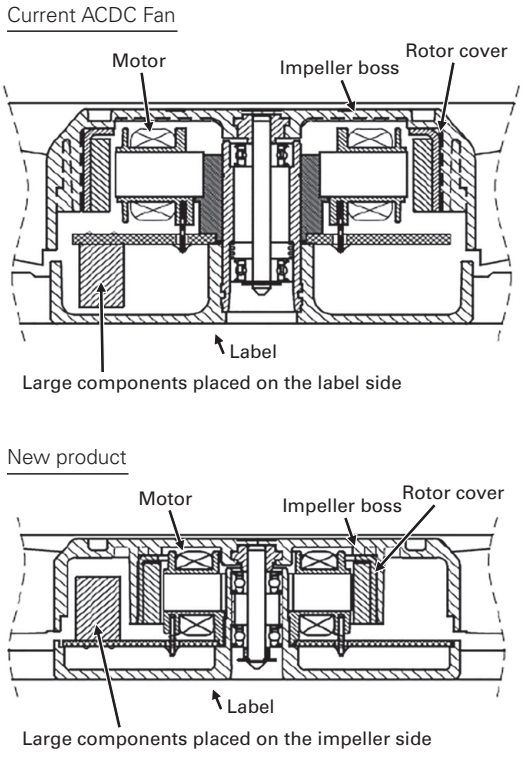

Fig. 5 Cross-sectional views of new and conventional ACDC Fans

With our conventional ACDC fans, these large components were mounted on the label side, which created unused space inside, leaving little room for downsizing. To address this, the new product uses a relatively compact motor for a 120 mm sq. fan, securing space for large components between the inner surface of the impeller boss and the rotor cover. This design has helped achieve a thickness of 25 mm, making it the slimmest among all of our ACDC Fans.

4.2 Impeller and frame design

The motor needed to be downsized to achieve a thickness of 25 mm. In general, however, reducing the motor size makes it more difficult to improve the airflow vs. static pressure characteristics while also suppressing power consumption and heat generation. We addressed this issue by testing various combinations of parameters such as the number, length, angle, and shape of impeller blades as well as the frame shape through simulations and evaluations on actual equipment to determine the optimal design for excellent airflow efficiency.

4.3 Low power consumption and long service life

The new product internally converts AC power into DC power to drive a DC motor, improving motor efficiency and reducing losses compared to AC motors. With the reduced power losses and high-efficiency impeller and frame designs reducing the temperature rise of the motor and bearings, the new product achieves improved airflow vs. static pressure characteristics, lower power consumption, and longer service life compared to our current AC Fans.

Compared to the current product, power consumption has been reduced by 72% from 12 W to 3.4 W.

The expected life (at 60°C, survival rate of 90%, run continuously at rated voltage and normal humidity in free air) of the new product is 60,000 hours, 2.4-times longer than the 25,000 hours of the current product.

5. Comparison of New and Current Products

5.1 Comparison of airflow vs. static pressure characteristics

Figure 6 compares the airflow vs. static pressure characteristics of the new 9AD1201P4H001 and the current product. Compared to the current product, the maximum airflow and maximum static pressure have been improved by 2% and 19%, respectively. In addition, the operating airflow has been improved in the actual operating zone.

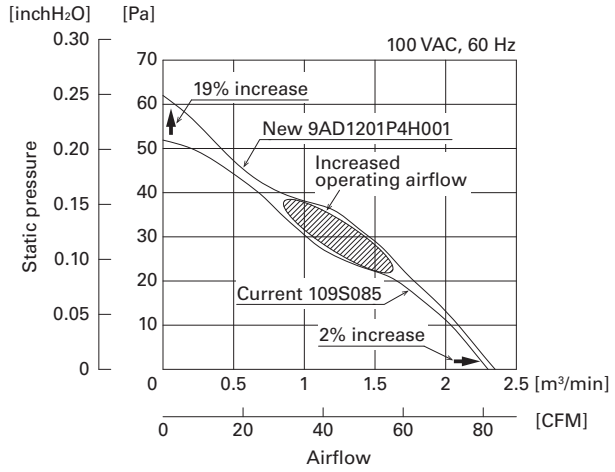

Fig. 6 Airflow vs. static pressure characteristics of the new and current products

5.2 Power consumption comparison with the current product at equivalent performance

Figures 7 and 8 compare power consumption for the current and new products at equivalent cooling performance.

These figures show that, when the fan speed of the new product is reduced through PWM control to match the cooling performance of the current product, power consumption at the estimated operating point has been reduced by 76% at 60 Hz and 81% at 50 Hz.

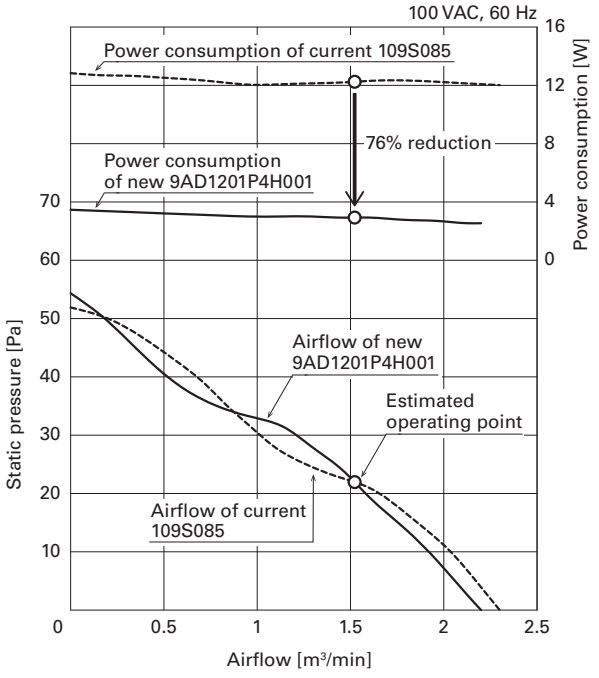

Fig. 7 Airflow vs. power consumption characteristics of the new and current products (60 Hz)

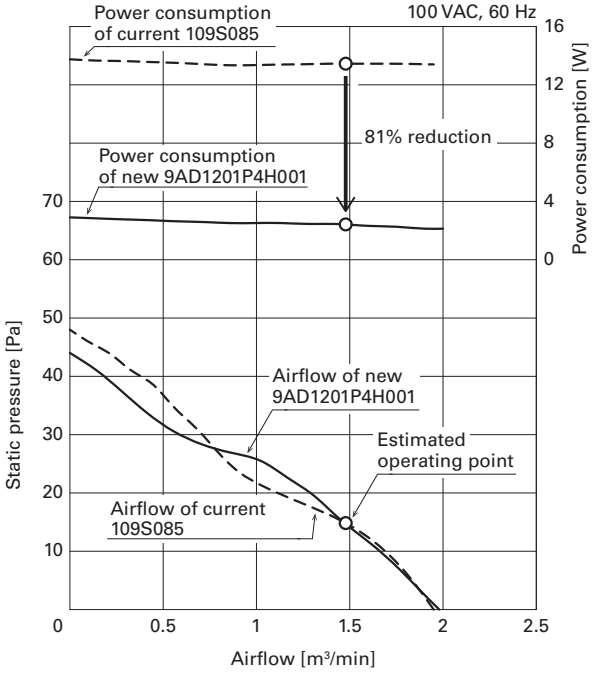

Fig. 8 Airflow vs. power consumption characteristics of the new and current products (50 Hz)

5.3 Environmental impact comparison

Figure 9 compares the CO_2 emissions of the new and current products over their life cycles.

The new product produces 77% less CO_2 emissions over its product life cycle compared to the current product thanks to its greatly reduced power consumption.

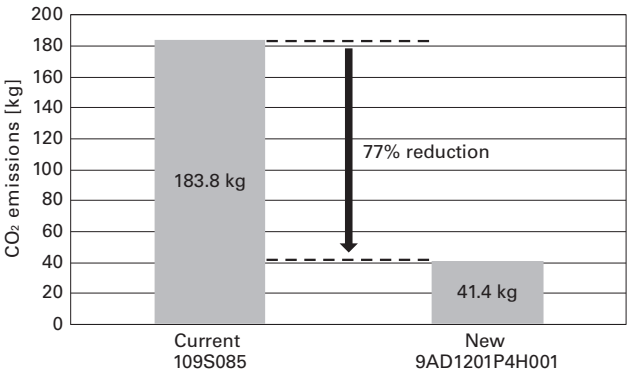

Fig. 9 CO_2 emissions comparison using our LCA calculation software (operated continuously for 25,000 hours in free air)

6. Conclusion

This article has introduced the features and performance of our new 120 × 120 × 25 mm *San Ace 120AD* 9AD type ACDC Fan equipped with an AC-DC conversion circuit. The new product has a built-in AC-DC conversion circuit and its impeller, frame shape, motor, and circuit are designed for high efficiency. This realized higher airflow, higher static pressure, lower power consumption, longer service life, PWM control, and a wider input voltage range than our current product.

With the trend toward a low-carbon society accelerating, the demand for products with low power consumption and long service life will continue to increase.

We will continue to help our customers create new value by providing products that address changing market demands.

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Products and Technology for a Low-Carbon Society

Masahiko Nagai

1. Introduction

To achieve a low-carbon society, the entire world now must transition away from the dependence on fossil fuels.

To contribute to this, we have made design efforts by developing products with a higher energy conversion efficiency and products that promote the expansion of renewable energy.

This article introduces Power Systems products designed for a low-carbon society and the technologies applied therein. We begin by describing our power conditioners (or renewable energy inverters) that use renewable energy along with an implementation example. We then go on to introduce our energy-saving initiatives for uninterruptible power supplies (hereinafter, "UPSs"), which protect mission-critical customer equipment from power outages, followed by a practical solution.

2. Products That Use Renewable Energy

Renewable energy has been attracting attention as a means of reducing the greenhouse gases that cause global warming. We offer a lineup of products for using renewable energy.

2.1 Power conditioner for wind power and hydro power generation systems[1]

The *SANUPS W73A* is a power conditioner for wind power and hydro power generation systems. It effectively extracts the energy generated by wind and hydro power generation systems and feeds it to the power grid. The *SANUPS W73A*'s main feature is that its input power characteristics can be set freely to suit the output characteristics of the customers' wind and hydroelectric generators, capitalizing energy from various generators. Figure 1 shows the *SANUPS W73A*. Its main electrical specifications are as follows.

- Output capacity: 9.9 kW
- DC input voltage range: 150 to 570 VDC
- AC output voltage: 3-phase 3-wire 202 VAC (50/60 Hz)
- Isolated operation output: 3-phase 3-wire 202 VAC, for 9.9 kVA model*
  (* for grid-connected isolated type only)

Fig. 1 The *SANUPS W73A* power conditioner for wind power and hydro power generation systems

In addition, we offer the *SANUPS W75A* rectifier unit, which converts the AC power generated by wind and hydro power generators into DC power for use with power conditioners. Featuring protection functions, when combined with a power conditioner, the *SANUPS W75A* helps customers build a highly reliable power generation system with ease.[2] Figure 2 shows a configuration example.

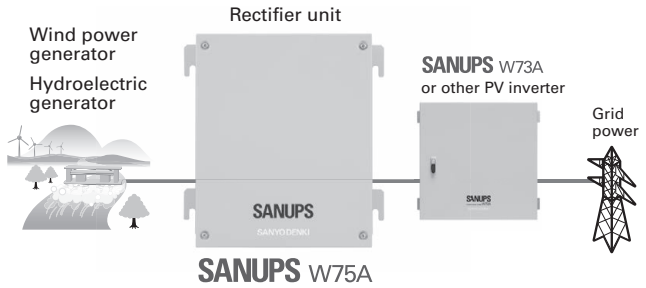

Fig. 2 Configuration example of the *SANUPS W75A* rectifier unit for wind power and hydro power generation systems

2.2 Power conditioners for photovoltaic generation systems[3]

The *SANUPS P83E* is a power conditioner for photovoltaic generation systems (or PV inverter). The following are two of its features for effectively extracting the energy generated by solar panels.

2.2.1 High conversion efficiency

The *SANUPS P83E* achieves a high conversion efficiency of 95%, by reducing switching losses and optimizing the transformer and switching frequency. This allows the generated energy to be more capitalized.

2.2.2 Wide AC input voltage range

On the *SANUPS P83E*, the maximum DC input voltage has been increased from that of our current product to 600 V to cover the recent diversified solar panels. The increased options for solar panels make it easy to build a high-efficiency PV system. Figure 3 shows the *SANUPS P83E*.

Fig. 3 The *SANUPS P83E* power conditioner for photovoltaic generation systems

The main electrical specifications of the *SANUPS P83E* are as follows.

- Output capacity: 100 kW
- DC input voltage range: 240 to 600 VDC
- AC output voltage: 3-phase 3-wire 202 VAC (50/60 Hz)
- Isolated operation output: 3-phase 3-wire 202 VAC, for 100 kVA model**

  (** For models with isolated operation)

2.3 Renewable energy introduced to our facilities

As a part of our low-carbon initiatives, we have PV systems installed at several of our facilities and factories. As the latest example, this section introduces a 300 kW PV system introduced at the expanded Technology Center in Ueda, Nagano in May 2021. Figure 4 shows the facility with solar panels installed on the rooftop.

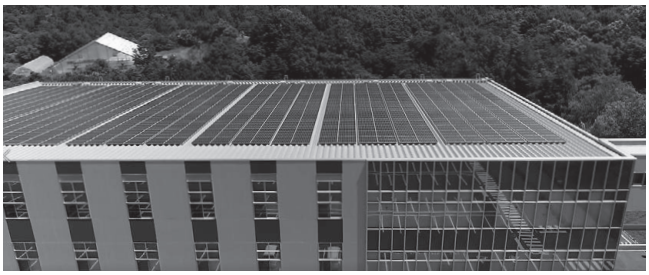

Fig. 4 Solar panels installed on the rooftop of our Technology Center

This PV system uses three units of the aforementioned *SANUPS P83E* power conditioner to form a system of 300 kW in total. It generates and powers the facility, and the power generated in excess can be sold. This system generates approximately 25% of the power consumed in the facility.

The *SANUPS P83E* power conditioner features a multiple unit control function. With multiple unit control, the power conditioners automatically identify the optimal number of units to operate according to the amount of power generated by the solar panels, reducing losses and increasing efficiency. This multiple unit control function enables highly efficient operation even when only a small amount of power is generated, making the most of the energy from the solar panels.

As an additional feature, in a system of three power conditioners, with one of them being an isolated operation model, the system can be used as an emergency power source during outages using the PV-generated power.

3. UPS Energy-Saving Efforts

We offer various types of UPSs to protect public infrastructure that supports society and mission-critical customer equipment from power outages. The role of a UPS is to supply stable power continuously to customer equipment. Meanwhile, to achieve a low-carbon society, we are also tasked with the important mission of offering products that contribute to the reduction of CO_2 emissions and reduce the running costs of our customers by further increasing power conversion efficiency for more energy savings.

In the following sections, we introduce some of our efforts to achieve higher efficiency in our UPSs.

3.1 The *SANUPS A11N*[4] UPS with high efficiency and reliability

The *SANUPS A11N* is a high-efficiency double conversion online UPS that features reliable parallel redundancy and scalable capacity.

The *SANUPS A11N* is scalable in a 5 kVA base unit and can be expanded up to 20 kVA by combining up to four base units in parallel. Figures 5 and 6 show models of the *SANUPS A11N*.

Fig. 5 The *SANUPS A11N* UPS, 5 kVA model

Fig. 6 The *SANUPS A11N* UPS, 20 kVA model

The input/output voltage can be set to single-phase 200, 208, 220, 230, or 240 V, allowing the UPS to be used not only in Japan but also in global markets.

To improve power conversion efficiency, the *SANUPS A11N* uses a 3-level inverter circuit. By performing tuning to match the latest switching semiconductor devices, this product achieves a maximum efficiency of 95.1% (94% at rated output), which is best-in-class† among UPSs with double conversion online topology on the market. This helps customers reduce running costs and CO_2 emissions.

3.2 The *SANUPS A23D*[5] UPS with high efficiency and functionality

The *SANUPS A23D* is a double conversion online UPS featuring high efficiency and high performance. The input/output voltage is 3-phase 3-wire 200 V and can also be set to 210 or 220 V.

Figure 7 shows a 100 kVA model of the *SANUPS A23D*.

Fig. 7 The *SANUPS A23D* UPS, 100 kVA model

The lineup is available in output capacities of 30, 50, 75, and 100 kVA. The input voltage range is normally 200 V ±15% for 200 V output, but if the load level is 60% or less, the UPS can support a wider range with the lower limit extended to -30%. Accordingly, the UPS maintains inverter operation without switching to battery power and continues powering customer equipment even in places with large power fluctuations.

On the *SANUPS A23D*, a 2-phase modulation is used in the rectifier and inverter control system to further improve the conversion efficiency of our current product. This 2-phase modulation stops switching devices sequentially in phase order in approximately 1/6 the cycle of the input/output frequency, leading to reduced switching loss and improved efficiency. However, when shifting between the switching devices to stop, a large fluctuation will occur at the neutral point shown in Figure 8. Moreover, if the rectifier and inverter control timings are not synchronized, a large

circulating current will flow via the neutral point. These issues will lead to lower efficiency and higher costs due to increased filter circuit capacity.

With this new product, the 2-phase modulation timings of the rectifier and inverter have been synchronized. Also, the 2-phase modulation period and AC filter circuit constant have been optimized. These improvements have reduced neutral point fluctuations and suppressed circulating current, improving efficiency without additional cost. The new product achieves an industry-leading†† conversion efficiency of 94% or higher (max. 95.6%), which suppresses power consumption and heat generation, reducing running costs and CO_2 emissions.

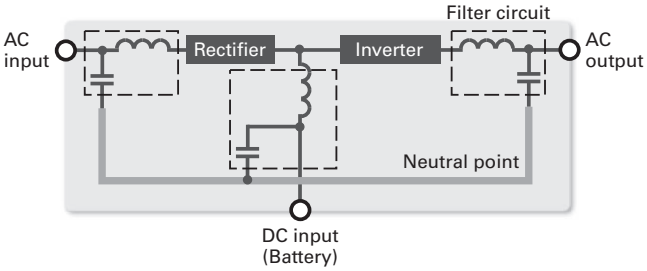

Fig. 8 Circuit block diagram of the *SANUPS A23D*

3.3 Energy-saving UPS system solution

The primary role of a UPS is to continuously supply power to customers' mission-critical equipment to protect the equipment and its data. At the same time, with the recent expansion of the IoT, the roles of UPSs have also diversified. We are developing products to meet various needs beyond the scope of merely a UPS. These demands include server power management in the latest security environments and the monitoring of power supply conditions, temperature, and humidity of the operating environment of customer equipment.

Against this backdrop, we introduce an example of our low-carbon efforts—a proposal of an energy-saving UPS system solution leveraging the IoT. The proposal is illustrated below.

To save energy with equipment, the first thing to know is how the equipment consumes power. A system combining our UPS and LAN Interface Card makes it easier to understand the power consumption of customer equipment. Figure 9 shows a configuration example of such a system. This system enables the monitoring of equipment power consumption through a web browser on a smartphone or computer, visualizing how the data changes over time on a graph for easier understanding.

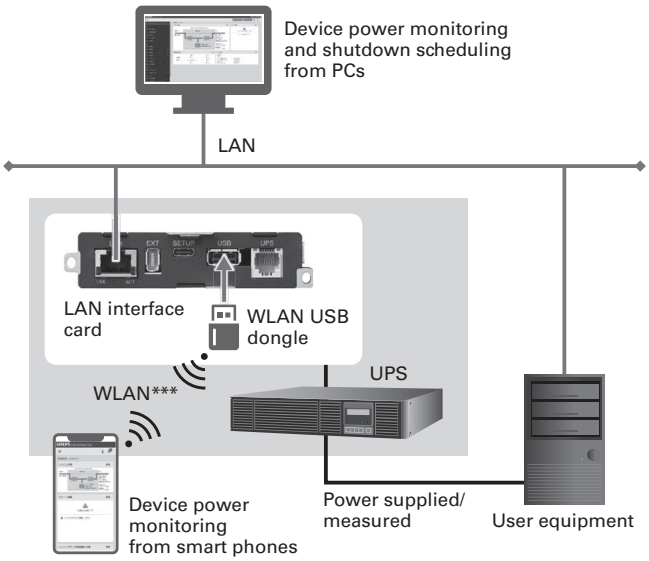

Fig. 9 Proposal example of energy-saving UPS system solution

*** To use wireless LAN, the user will need to prepare a WLAN USB dongle that we recommended and connect it to the LAN Interface Card. (USB is a trademark or registered trademark of USB Implementers Forum.)

It also allows customer equipment connected to the UPS to be started and stopped remotely. Computers and other devices that require a shutdown can be safely stopped after shut down.

In addition, the UPS output can be scheduled to systematically start and stop customer devices. For example, devices can be scheduled to stop during the night or over long holidays for systematic reductions in power consumption.

As described above, UPSs are not only able to protect mission-critical customer equipment from power outages but also serve as an energy-saving solution leveraging the IoT.

4. Conclusion

This article has introduced our Power Systems products and technologies that contribute to the realization of a low-carbon society.

The following three products have been presented for their use of renewable energy.

(1) The *SANUPS W73A* power conditioner for wind power and hydro power generation systems
(2) The *SANUPS W75A* rectifier unit
(3) The *SANUPS P83E* power conditioner for photovoltaic generation systems

In addition, as an example of our low-carbon initiative, we have introduced a PV system combining solar panels

and *the SANUPS P83E* installed in our facilities.

Furthermore, we also described our energy-saving UPS efforts, including our efficiency improvement technology and our proposal example of an energy-saving UPS system solution.

We are committed to making continual contributions to a low-carbon society by developing technologies for using and saving renewable energy while continually providing products that satisfy our customers.

† Based on our own market research as of June 2022, conducted among online UPSs on the market with equivalent voltage, capacity, and backup time.
†† Based on our own market research as of March 2022, conducted among online UPSs on the market with equivalent voltage, capacity, and backup time.

Reference

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(2) Ryu Yoshizawa and 3 others: "Development of the *SANUPS W75A* Rectifier Unit for Wind Power and Hydro Power Generation Systems"
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(3) Masahiro Inukai and 8 others: "Development of a 100 kW Power Conditioner *SANUPS P83E*"
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The Development of the *SANUPS LiB Pack*, a Lithium-Ion Battery Pack

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1. Introduction

In general, lithium-ion batteries (LIB) are suitable for downsizing thanks to their higher energy density, both by weight and volume, than lead-acid batteries. In addition, since lithium-ion batteries do not contain substances such as lead, cadmium, or mercury, they also help reduce environmental impact at the time of disposal. These features have increased the demand for uninterruptible power supplies (hereinafter, "UPSs") equipped with lithium-ion batteries. It is against this backdrop that we have been expanding our lineup of UPSs with LIB.

In response to the growing demand, we have in-house developed the *SANUPS LiB Pack*, a high-quality, high-safety LIB pack.

In this article, we begin by presenting the electrical specifications, appearance, and circuit block diagram of the new battery pack. Following that, we will introduce its features—high safety, high environmental durability, long life, and high performance. Furthermore, we will also discuss the advantages of its built-in battery management system.

2. Product Overview

Figure 1 shows the *SANUPS LiB Pack*. Table 1 shows its electrical specifications. Its dimensions measure 151 mm wide, 64.5 mm deep, and 93.1 mm high, with a mass of about 1 kg.

Fig. 1 The *SANUPS LiB Pack*

Table 1 Electrical specifications of the *SANUPS LiB Pack*

Items		Specifications	Remarks
Model no.		LFPB12050AU	
Cell configuration		2P4S (2 parallel 4 series)	
Characteristics	**Nominal energy**	66 Wh	Value at the time of factory shipment
	Nominal capacity	5.0 Ah	Value at the time of factory shipment
	Nominal voltage	13.2 V	3.3 V/cell
Discharge characteristics	**Discharge cut-off voltage**	9.2 V	2.3 V/cell
	Recommended discharge current	5 A	
	Maximum discharge current (continuous)	45 A	
	Maximum discharge current (pulse)	100 A	Pulse duration 100 ms
Charge characteristics	**Charge voltage range**	13.8 to 14.4 V	
	Recommended charge current	2 A	At ambient temperature ≥ 0°C
	Recommended charge current	0.5 A	At ambient temperature < 0°C
	Maximum charge current (continuous)	10 A	At ambient temperature ≥ 15°C
Ambient temperature	**In operation**	-20 to +60° C	
Dimensions		151 × 64.5 × 93.1 mm	Width × depth × height, excluding protruding parts
Mass		Approx. 1 kg	
Standards		UL 1973	

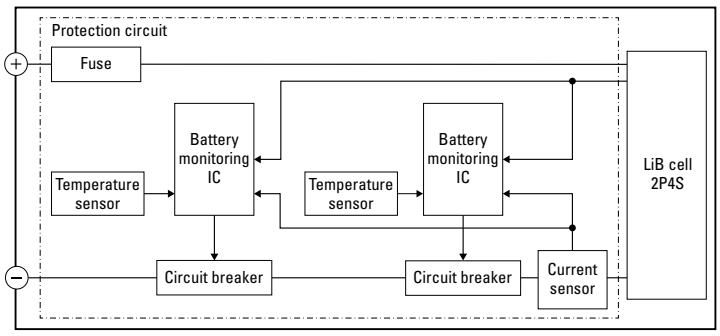

Fig. 2 Circuit block diagram of the battery pack

Figure 2 shows the circuit block diagram of the battery pack. The battery pack has a nominal voltage of 13.2 V and a nominal capacity of 5 Ah. Its LIB cells use lithium iron phosphate in the cathode material and are connected in a 2-parallel 4-series (2P4S) configuration. It employs built-in protection circuits to monitor and protect the battery cells. Up to four battery cells can be connected in series without an external battery management system.

3. Features

3.1 High safety[1]

Due to its high energy density, LIBs could potentially cause serious accidents if mishandled. Ensuring safety is of the utmost importance.

To ensure a high level of safety, we devised and applied to the battery pack the following three measures.

(1) Use of iron phosphate battery cells
(2) Protection circuits with a circuit breaker
(3) Full redundancy of each protection circuit

The battery cells in this product use lithium iron phosphate in the cathode material, featuring high thermal stability and electrolyte stability. Therefore, even in the event of battery pack malfunctions, such as overcharge and overdischarge, the risk of explosion or ignition is extremely low.

The protection circuits come with a circuit breaker. Upon detecting a malfunction, such as overcurrent, overcharge, and overdischarge in the battery pack, the built-in circuit breaker is activated and protects the battery pack by shutting off the charging/discharging circuit. In the case of an accidental short circuit of a terminal, the protection circuit will likewise be activated and prevent the short-circuit current from flowing, ensuring safety.

Furthermore, as each protection circuit is fully redundant, the backup circuit will provide protection even if one circuit fails. (UL1973-certified*)

Table 2 shows the built-in protection functions of the battery pack.

* UL 1973 is "the UL standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications."

Table 2 Protection functions

Protection functions	Functions explained
Overcharge protection	This function detects overcharge in cell voltages and shuts off the charging circuit.
Overdischarge protection	This function detects overdischarge in cell voltages and shuts off the discharging circuit.
Overcurrent charging protection	This function detects overcurrent charging and shuts off the charging circuit.
Overcurrent discharging protection	This function detects overcurrent discharging and shuts off the discharging circuit.
High-temperature protection	This function detects high temperatures in batteries and shuts off the charging/discharging circuit.
Low-temperature protection	This function detects low temperatures in batteries and shuts off the charging/discharging circuit.

3.2 High environmental durability

The lead-acid batteries currently used in our UPSs have an operating temperature range of -20˚C to 50˚C during discharge and 0˚C to 40˚C during charging. In contrast, that of the new battery pack is -20˚C to 60˚C, enabling the UPS to be used at an extended temperature range. This means UPSs combined with this battery pack can be used in harsher environments than lead-acid battery UPSs.

3.3 Long life

Figure 3 shows the estimated cycle life of the battery pack. The battery pack maintains 80% or more of its capacity even after 3,800 charge/discharge cycles at an ambient temperature of 30˚C. When used at a rate of one

charge/discharge cycle a day, it can be expected to last approximately 10 years. In contrast, when used at the same rate, the lead-acid batteries used in our conventional UPSs require battery replacement around every six months. As it lasts longer than lead-acid batteries, the battery pack helps realize maintenance-free operation of equipment and reduce replacement costs.

Note: Battery service life may vary depending on the operating environment and operating conditions.

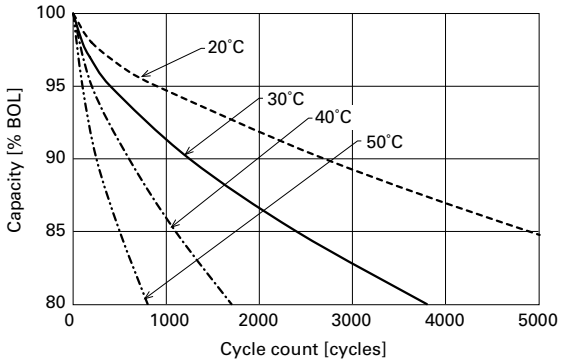

Fig. 3 Estimated cycle life (calculated)

3.4 High performance

Figure 4 shows the discharging characteristics of the battery pack and Figure 5 shows the charging characteristics. The new battery pack allows rapid charging and discharging, featuring a maximum charge and discharge current of 2C (10 A) and 9C (45 A), respectively, making it ideal for applications requiring large current output. Furthermore, being capable of rapid charging, it is suitable for use in equipment that requires frequent charging and discharging such as automated guided vehicles (AGVs). Its short charging time reduces equipment downtime, improving operational efficiency.

Note: The C-rate is a measure of the rate at which a battery is charged or discharged, with a 1C rate defined as the current that completes the charge/discharge of the entire battery in one hour.

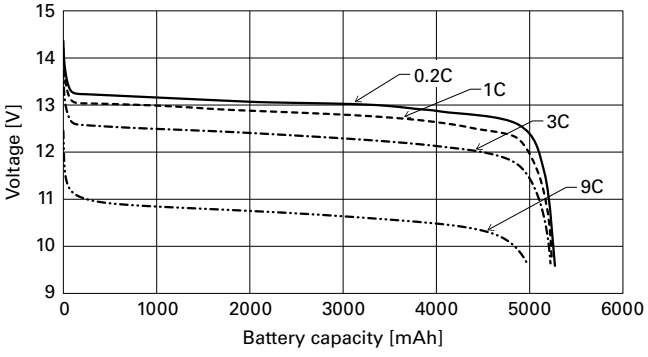

Fig. 4 Discharge characteristics

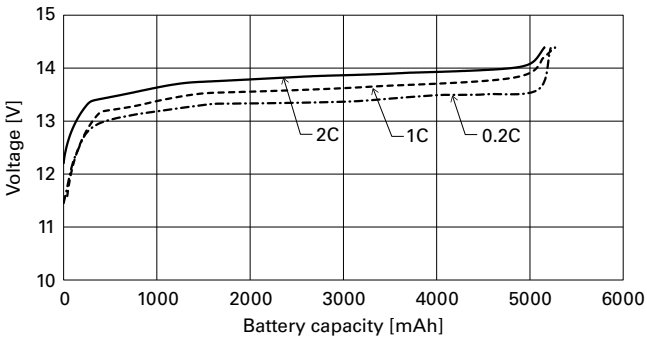

Fig. 5 Charge characteristics

3.5 Built-in battery management system

To be used safely, LIBs must be used in combination with a battery management system for monitoring the battery status and providing protection. This LIB battery pack has a built-in battery management system with features such as cell voltage monitoring and circuit protection. Therefore, the battery pack can be readily used without requiring an external battery management system. Moreover, the *SANUPS LiB Pack* can readily replace the battery of existing lead-acid battery UPSs, which do not require a battery management system.

4. Conclusion

This article provided an overview and features of the *SANUPS LiB Pack*, a lithium-ion battery pack we newly developed. The features of the product are as follows.

(1) High safety
(2) High environmental durability
(3) Long life
(4) High performance
(5) Built-in battery management system

With the *SANUPS LiB Pack*, with the above-mentioned advantages, developed successfully, we can now offer high-quality, high-safety UPSs to the increasingly demanded LIB UPS market.

Besides use in UPSs, this battery pack is also suitable for a wide range of applications that have traditionally relied on lead-acid batteries, including automated guided vehicles (AGVs), power backup systems for communications equipment, and power supply equipment.

We are confident that the *SANUPS LiB Pack* can meet the needs of a diverse range of customers, serving as a compact, lightweight, safe, high-performance, and environmentally friendly solution.

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Building a Low-Carbon Society
—Energy- and resource-saving initiatives—

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Akira Tsukada Takahiro Yoneta

1. Introduction

In recent years, the increasing impact of global warming and the natural disasters caused by climate change have brought the urgent need to realize a low-carbon society.

We, SANYO DENKI, have been engaged in initiatives of "technology for protecting the global environment" and "technology for saving energy," and developed and offered various Servo Systems products aligned with them. In our production sites, we have made consistent efforts such as reducing power and raw material usage.

This article introduces Servo Systems products and technologies that contribute to energy and resource conservation with the aim of realizing a low-carbon society. It also introduces the energy-saving technologies and the 3 R's initiatives (Reduce, Reuse, and Recycle) in our production.

2. Products and Technologies for Achieving Low-Carbon Society

This chapter introduces our products and technologies that contribute to a low-carbon society.

First, regardng our servo motors, we present the features of the *SANMOTION G* servo motor, which is more compact, lightweight, and energy-efficient than its predecessor. Next, regarding our servo amplifiers, we present the *SANMOTION G* servo amplifier, which boasts significantly reduced CO_2 emissions compared to its predecessor, as well as a power regeneration device, which contributes to the effective use of electricity.

2.1 Servo motor and technology

Servo motors are energy conversion devices that convert electrical energy into mechanical energy. To contribute to a low-carbon society, it is crucial that the conversion of electrical energy into mechanical energy is done more efficiently.

The *SANMOTION G* AC servo system, which we launched in May 2022, features a higher energy conversion efficiency than its predecessor and is one of our low-carbon products. This section introduces the *SANMOTION G*'s servo motors.

2.1.1 The *SANMOTION G* servo motors

We pursue compactness, light weight, and high efficiency in the development of servo motors. The latest *SANMOTION G* servo system not only achieves improved servo performance than its predecessor, the *SANMOTION R* servo system, but is also environmentally friendly.

Figure 1 shows the *SANMOTION G* servo motor and amplifier. The following sebsections describe the features of the servo motor, as well as our energy-saving and industrial waste reduction initiatives related to it.

(a) Servo motor (GAM2A6040F0XRK0) (b) Servo amplifier (GADSA02AH24)

Fig. 1 The *SANMOTION G* servo system

(1) Reduced size and weight, increased output, and resource savings

For the *SANMOTION G* servo motor, we have optimized the electromagnetic field design and winding of the motor unit and holding brake. Moreover, improvements have been made to the connector arrangement and motor construction, and the size of the encoder has been reduced, significantly

shortening the motor length. Figure 2 compares the lengths of the motors. With the *SANMOTION R*'s high torque and high power maintained, the new motors have been made up to 22% shorter and up to 26% lighter. As a result, the volume of the servo motor components has been reduced by up to 28%, saving resources.

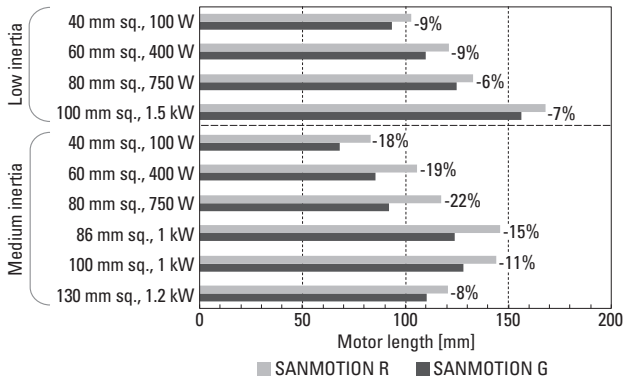

Fig. 2 Motor length comparison

(2) Increased energy efficiency

Although there is a trade-off between shortening the motor length and improving efficiency, we achieved reduced power loss and up to 9% higher efficiency by optimizing the electromagnetic field design as mentioned earlier, improving the winding fill factor, and using low-loss materials. Furthermore, for the holding brake, we have optimized the electromagnetic field design and structure, along with improvements in the winding fill factor, achieving up to 44% lower power consumption. In addition, current consumption of the encoder has been reduced by 26% compared to our current product. It was eco-designed and features high efficiency and energy savings.

Thanks to these efforts, based on the Life Cycle Assessment (LCA), the new product demonstrates substantial reductions in CO_2 emissions, achieving up to a 48.3% decrease.[1] In this way, the product contributes more to achieving a low-carbon society than the current product.

Table 1 shows the LCA results of servo motors, presenting a comparison of energy usage and CO_2 emissions between the current *SANMOTION R* and the new *SANMOTION G*.

(3) Higher encoder resolution and reduced industrial waste

The built-in encoder is a high-resolution battery-less absolute encoder with a maximum resolution of 27 bits. The high resolution enables stable repetitive motion and high-precision positioning. This encoder eliminates the need for battery backup for retaining multi-turn data when the power is turned off. Consequently, there are no batteries that need to be periodically replaced, contributing to natural resource saving, reduced industrial waste, and improved maintainability.

2.2 Servo amplifier and technology

Servo amplifiers have been required to have: high-efficiency conversion technology, effective use of energy, and motion control technology linked with the IoT (Internet of Things) technology and AI (artificial intelligence) to share information with and manage machinery.

In the following subsections, we present two low-carbon products: the *SANMOTION G* servo amplifier, which emits less CO_2 than its predecessor; and a power regeneration device, which makes effective use of the regenerative power from servo motors.

2.2.1 The *SANMOTION G* servo amplifiers

When developing a new servo amplifier, we aim to achieve a weight reduction and higher energy conversion efficiency.

In order for the *SANMOTION G* servo amplifier to have

Table 1 LCA results of servo motors

LCA results	Size	Rated output	SANMOTION R (R2) (Current product)	SANMOTION G (GAM2) (New product)	Reduced by
Energy usage	40 mm sq.	100 W	1,727 Mcal	1,643 Mcal	4.8%
	60 mm sq.	400 W	2,728 Mcal	2,575 Mcal	5.6%
	80 mm sq.	750 W	4,347 Mcal	3,401 Mcal	21.8%
	100 mm sq.	1 kW	4,382 Mcal	3,374 Mcal	23.0%
	130 mm sq.	1.2 kW	10,585 Mcal	5,443 Mcal	48.6%
CO_2 emissions	40 mm sq.	100 W	447 kg	426 kg	4.8%
	60 mm sq.	400 W	706 kg	670 kg	5.1%
	80 mm sq.	750 W	1,127 kg	881 kg	21.8%
	100 mm sq.	1 kW	1,141 kg	877 kg	23.1%
	130 mm sq.	1.2 kW	2,739 kg	1,416 kg	48.3%

Table 2 LCA results of servo amplifiers

LCA results	Amplifier capacity	SANMOTION R 3E Model (Current product)	SANMOTION G (New product)	Reduced by
Energy usage	10 A	905 Mcal	736 Mcal	18.7%
	20 A	2,412 Mcal	2,259 Mcal	6.3%
	30 A	3,797 Mcal	3,654 Mcal	3.8%
	50 A	6,257 Mcal	5,826 Mcal	6.9%
CO_2 emissions	10 A	233 kg	189 kg	18.9%
	20 A	638 kg	602 kg	5.6%
	30 A	1,000 kg	963 kg	3.7%
	50 A	1,630 kg	1,520 kg	6.7%

an improved power density, we have improved the maximum output current by up to 5% by using a power semiconductor device with low heat generation and optimizing the thermal design. Moreover, we selected and used components that have low current consumption ratings, reducing the total power consumption by up to 22%. At the same time, the selected components are also smaller in size, achieving a weight reduction of up to 5.5%.

Compared based on Life Cycle Assessment (LCA) using these values in the calculation, it can be said that the new product produces up to 18.9% less[1] CO_2 emissions than the current product, contributing to achieving a low-carbon society.

Table 2 shows the LCA results of servo amplifiers, providing a comparison of energy usage and CO_2 emissions between the current *SANMOTION R 3E Model* and new *SANMOTION G* amplifiers.

The servo amplifiers feature the monitoring of power consumption of servo systems by calculating the data collected from sensors. By displaying the electricity consumption status to customers who use our servo systems, this feature can contribute to the efficient use of electricity, both in machinery and across entire factories.

2.2.2 Power regeneration device

Systems that are used for machinery consume electricity the most when powering a motor to drive a load equipment. On the other hand, however, when decelerating or coming to a halt during motion, the load applied to the motor acts in the reverse direction of the driving force, causing the motor to function as a generator.

Conventionally, the regenerative power generated used to be for the most part dissipated as heat through resistors, a process we refer to as the regenerative resistor method. However, electricity cannot be used effectively with this method.

Recently, we have developed a product equipped with the power regeneration capabilities to effectively use regenerative power, and this is used by many of our customers. Figure 3 shows an example configuration of a power regeneration device.

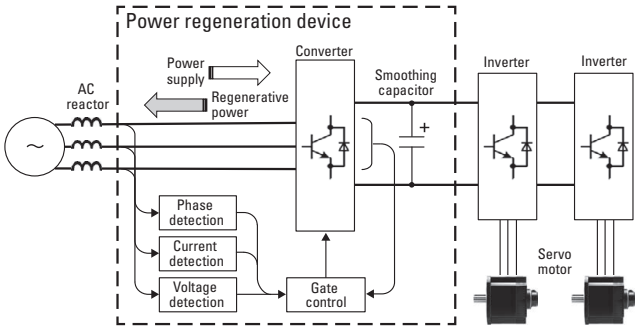

Fig. 3 Power regeneration device

A power regeneration device comprises a converter featuring an IGBT bridge with a free-wheeling diode. This circuit is designed for both forward and reverse power conversion. The regenerative power generated by the servo motor flows through the inverter and charges the smoothing capacitor. Subsequently, the energy is fed back to the power grid through reverse conversion by the converter.

The control method of power regeneration is the 120° current method,[2] which involves detecting the phase of the power supply voltage and only regenerates power in 120° intervals of the power supply voltage. With this method, the frequency of IGBT switching is much smaller than that of the PWM method, resulting in minimized loss and leakage current. In this way, the power regeneration method avoids converting the regenerative power into wasted heat. Unlike the regenerative resistor method, it can be used more effectively as energy for other machinery.

The power regeneration technology in products results in lower losses and reduced power consumption. This not only enables the efficient use of energy but also significantly contributes to the realization of a low-carbon society.

3. Low-Carbon Initiatives in Production

This chapter introduces examples of our energy-saving and waste-reduction initiatives in production. It first presents energy-saving technologies for the electroplating line and the bonding process as initiatives in the manufacturing processes. Then, it introduces examples of the 3 R's (Reduce, Reuse, and Recycle) efforts as initiatives on our production sites.

3.1 Energy-saving technology in production processes

We put quite an energy-saving design effort when revising our existing manufacturing equipment and developing new equipment. This section highlights examples of our initiatives in the electroplating line as an improvement of existing equipment, and energy-saving technology in the newly developed magnet bonding unit.

3.1.1 Energy-saving initiative in electroplating line

The electroplating line includes a rinsing process that sprays water to clean products. Figure 4 shows the rinsing process of the electroplating line. During rinsing, the discharge flow rate must be adjusted to prevent workpieces from falling or water from splashing due to the water pressure. Before improving the equipment, the pump operation of drawing water up from the tank used to be working at full capacity at all times, and workers had to manually adjust the flow rate with a regulator valve, resulting in wasted power.

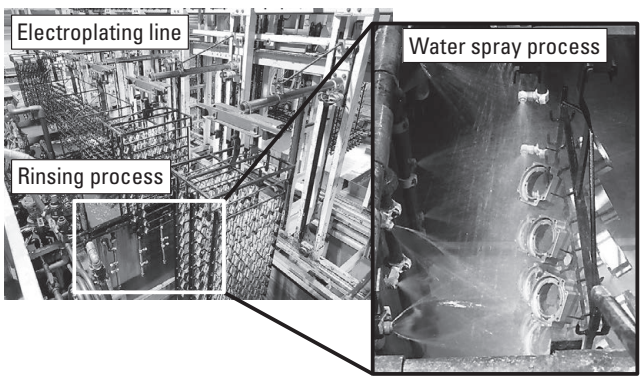

Fig. 4 Rinsing process of electroplating line

Modifications were made to adjust the discharge flow rate by controlling the pump operation using the inverter installed for the drive motor of the pump, leading to a reduction in power consumption.

This improvement has resulted in significant energy savings by controlling the pump operation, which used to be at full capacity all the time, through control of the drive motor. Power consumption of the rinsing process was reduced to approximately 1/2 compared to before the improvement.

3.1.2 Energy-saving technology in the magnet bonding process (from heating furnace to high-frequency induction heater)

Along with the new *SANMOTION G* servo motors, we also developed a new magnet bonding unit.

This unit uses high-frequency induction heating technology to accelerate the thermal curing of the adhesive to bond the magnets to the rotor to achieve greatly reduced power consumption.

Figure 5 illustrates the principle behind high-frequency induction heating technology.

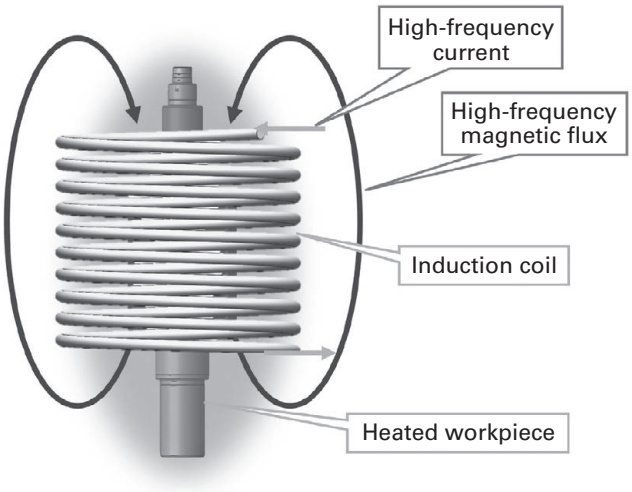

Fig. 5 High-frequency induction heater illustrated

In the magnet bonding process for the current product, a drying oven is used for thermal curing of the adhesive. The drying oven needs to maintain the heating temperature, which requires the heater to be left turned on from the beginning to the end of the operation regardless of whether workpieces are present, continuously consuming power.

The high-frequency induction heating technology used for the newly developed unit allows quick heating of workpieces and consumes power only during the heating process. This has led to a significant reduction in power consumption compared to the drying oven. The power consumption per

rotor has been reduced to approximately one-third that of the drying oven method.

3.2 The 3 R's in production

At the production sites of Servo Systems products, we are promoting the principles of the 3 R's (Reduce, Reuse, and Recycle). These principles guide our behaviors, aiming to mitigate environmental impact and facilitate the capitalization of resources. This section introduces specific examples of the initiatives.

3.2.1 The "Reduce" initiative

We are promoting an initiative to change the packaging materials for delivering Servo Systems products to customers, replacing corrugated cardboard boxes with reusable, returnable boxes, as shown in Figure 6. The use of returnable boxes reduces the energy required for the production of corrugated cardboard boxes and the consumption of forest resources.

Fig. 6 Returnable delivery boxes for servo amplifiers

3.2.2 The "Reuse" initiative

To promote resource circulation by reducing and recycling plastic waste, the Plastic Resource Circulation Act was enacted in April 2022.

Our Servo Systems Division promotes the sustainable use of resources by returning plastic containers for electronic components, as shown in Figure 7, to the manufacturer for reuse. The reuse of plastic containers also helps component manufacturers avoid procurement risks such as soaring resin material prices and material shortages.

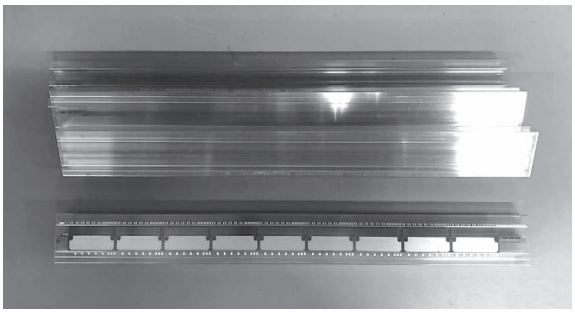

Fig. 7 Plastic containers for electronic components

3.2.3 The "Recycle" initiative

We promote material recycling by selling expired solder generated in the PCB manufacturing process and solder scrap oxidized in manufacturing processes to waste recyclers. Figure 8 illustrates the flow of solder scrap recycling. Recycling valuable mineral resources such as tin and silver contained in solder makes consumption and production more sustainable. It also reduces the need to mine for new mineral resources, reducing the impact on the global environment and ecosystems.

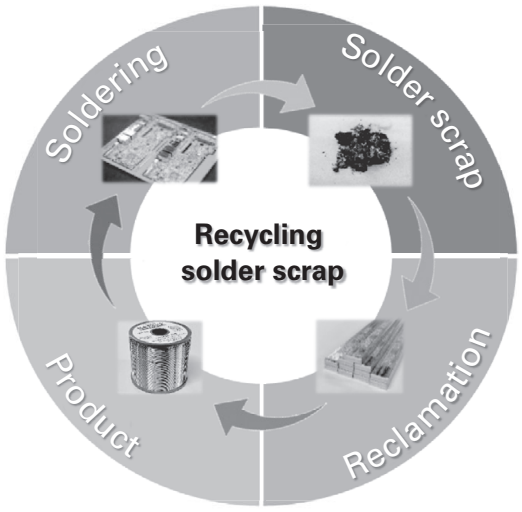

Fig. 8 Flow of solder scrap recycling

4. Conclusion

This article has introduced Servo Systems products and technologies that contribute to the reduction of CO_2 emissions by saving resources and energy to achieve a low-carbon society. It has also presented the electroplating line and the magnet bonding unit as examples of energy-saving technologies in the production processes. Furthermore, it has introduced examples of the 3 R's initiatives at our production sites.

The *SANMOTION G* servo motors and amplifiers, which

are compact and lightweight, contribute to energy and resource savings thanks to their high conversion efficiency. The power regeneration device achieves power savings by effectively supplying the regenerative power of motors to other machinery.

The electroplating line reduces power consumption by controlling pump operations in the rinsing process. In the magnet bonding process, use of the high-frequency induction heating technology has achieved reductions in production time and power consumption.

In the 3 R's initiatives in production, we have reduced our environmental impact by using returnable boxes to reduce the use of corrugated cardboard boxes, reusing plastic containers, and recycling solder scraps.

In the future, expectations for servo system technologies that contribute to a low-carbon society are anticipated to grow even higher. We intend for our servo systems to continue to meet these expectations and protect the global environment and human life.

Reference

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Development of the *SANMOTION C S200* Motion Controller

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Yoshitaka Kobayashi Hyukjun Kwon Shigeki Sato

1. Introduction

In recent years, IoT technologies have been increasingly used in various industries to improve productivity and quality. To ensure efficient, stable production, motion controllers must be capable of detecting changes in the operating status and the ambient environment of equipment to allow users to monitor the conditions of production sites. Controllers are also required to collect and store real-time error data in the event of a failure to minimize recovery time.

Against this backdrop, we developed a motion controller that accurately monitors the operating status of equipment and enables users to remotely perform maintenance.

This article introduces the main functions and features of the *SANMOTION C S200* (hereinafter, "new product")—the latest addition to the *SANMOTION C* motion controller lineup.

2. Product Overview

2.1 External view

Figure 1 shows the new product and Figure 2 shows its external dimensions.

Fig. 1 The *SANMOTION C S200* motion controller

It comes with a DIN rail[1] for easy installation on a control panel.

(1) DIN stands for Deutsche Industrie Norm (German Institute for Standardization). The DIN rail is a metal rail that conforms to this standard.

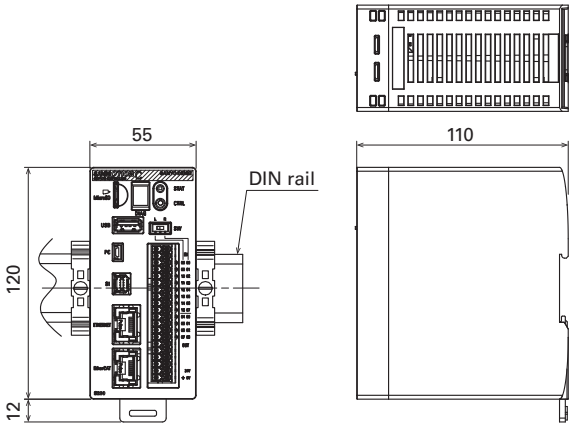

Fig. 2 Dimensions of the new product (Unit: mm)

2.2 Specifications

Table 1 shows the product lineup and general specifications, and Figure 3 shows a system configuration example.

The new product is available in two models: an advanced model for complex interpolation control and a basic model specialized in PTP (Point-to-Point) positioning control.

Both models support EtherCAT (as master), Ethernet, RS-485, and 1-Wire[2] communications to connect to sensor devices from which environmental data can be collected. Furthermore, the USB (Type-A) port can connect to both memory storage media and a webcam for obtaining image data. It comes with a built-in microSD card slot as standard for recording and storing equipment status changes and error log data.

It is also equipped with MQTT[3] communication and authentication functions to facilitate connection to cloud systems for storing the recorded data.

Table 1 General specifications

Items		Advanced model	Basic model
Interface		EtherCAT (100 Mbps) master function, FoE-compatible	
		Ethernet (10/100/1000 Mbps) protocols (Modbus TDP, OPC UA, Ethernet/IP)	
		RS-485 (9600 to 115200 bps), 1-Wire (15400 bps, half-duplex bidirectional communication)	
		USB 2.0: Type A (for memory storage and webcam), Mini-B (for PC)	
		MicroSD card slot (up to 32 GB)	
Digital input/output		Digital input: 16 points, 24 VDC, positive/negative common input Digital output: 8 points, 24 VDC, 0.5 A/point, sinking output	
Analog output		Analog output: 2 points, output range 4 to 20 mA, resolution 4000	
Input power supply		19.2 to 30 VDC, 0.9 A (main power supply) 19.2 to 30 VDC, 140 mA or more (I/O power supply)	
Power consumption		22 W	
Cooling method		Passive air cooling	
Dimensions (W × H × D)		55 × 120 × 110 mm	
Mass		300 g	
Control functions		Sequence control Motion control (Electronic cam and gear, linear interpolation, circular interpolation) Robot control: CNC function (Cartesian coordinate, SCARA, parallel link)	Sequence control Motion control (PTP control)
Control language		Programming languages conforming to international standard (IEC 61131-3)	
		G-code (complies with DIN 66025)	–
Network functions		Web-based data visualization[4]	
		Edge Gateway	
		MQTT protocol	
		Email notification (SMTP protocol)	
		Web-based application	
Compliance with standards	**UL/cUL**	UL 61010-1, 3rd Ed., UL 61010-2-201, 2nd Ed. CSA C22.2 No. 61010-2-201:18, 2nd Ed., CSA C22.2 No. 61010-1-12, 3rd Ed.	
	EMC Directive	EN 61131-2:2007	
	UKCA Mark	EN 61131-2:2007	
	KC Mark	KS C 9610-6-4:2017, KS C 9610-6-2:2019	

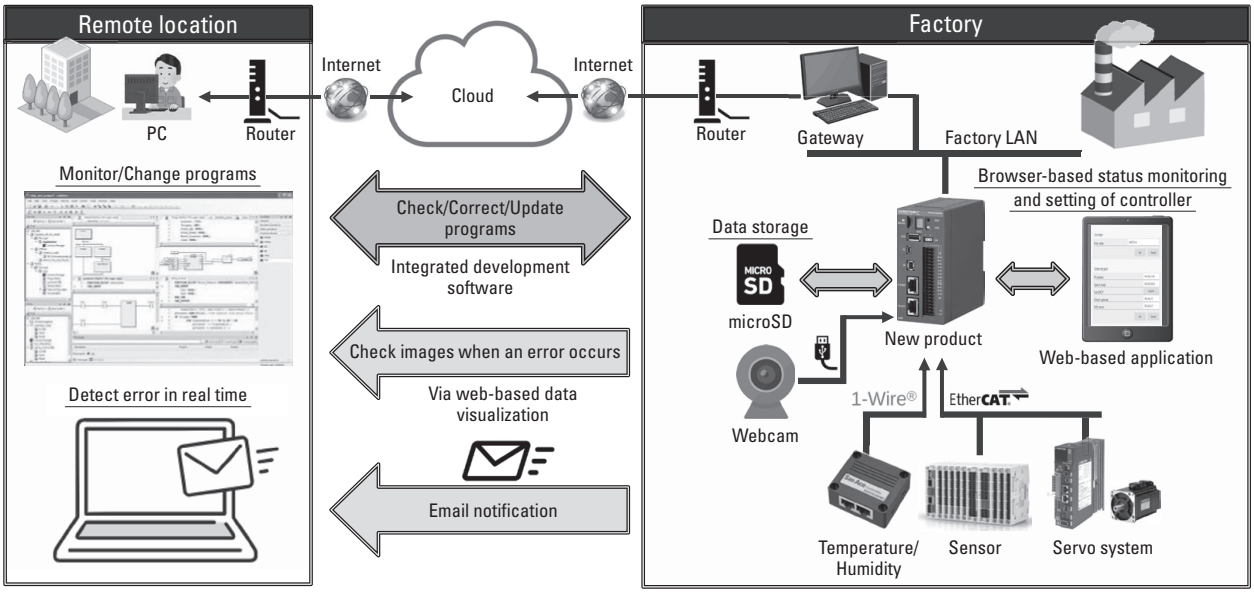

Fig. 3 System configuration

The new product features a remote maintenance and an email notification to inform users of detailed information in the event of equipment failure.

The new product complies with the following international standards: UL/cUL (North America), EMC Directive (Europe), UKCA Mark (United Kingdom), and KC Mark (South Korea).

(2) 1-Wire is a communication bus protocol for transferring data using only a ground wire and a single signal/power line.
(3) MQTT, or Message Queuing Telemetry Transport, is a lightweight communication protocol suitable for frequent sending and receiving of TCP/IP-based short messages.
(4) A drawing tool feature for designing screens on a web browser.

3. Features

This new product maintains the same dimensions and mass as the industry's smallest-in-class(5) *SANMOTION C S100* with the addition of IoT capabilities. It can collect and store image data and environmental data of the equipment in real time while simultaneously performing motion control. It is also now possible to remotely monitor the equipment status and perform maintenance thanks to the connections to Automation Server(6) or a cloud system. Moreover, it allows users to check the status of the new product and set parameters from a web browser. The details of each function are provided below.

3.1 Data collection and storage

Figure 4 shows the interface designed for data collection and storage. The new product can collect time-series data on connected servo systems, digital input/output, and environmental conditions. It can easily collect and store servo system position and status information by simply specifying the applicable motor axes in the program (see Figure 5). The new product stores the collected data on its built-in storage (32 GB) or a microSD card (max. 32 GB), enabling users to check the operation status of equipment over a long period. The new product also records the status as an image by connecting to a webcam. For example, when an error occurs, the new product records images before and after the error, enabling prompt identification of the root cause.

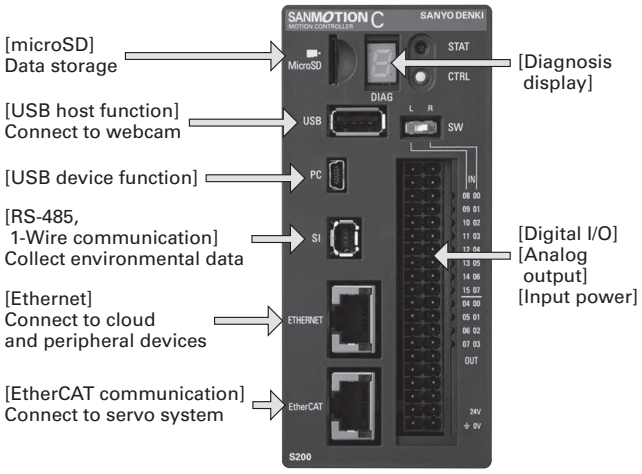

Fig. 4 Interface for data collection and storage

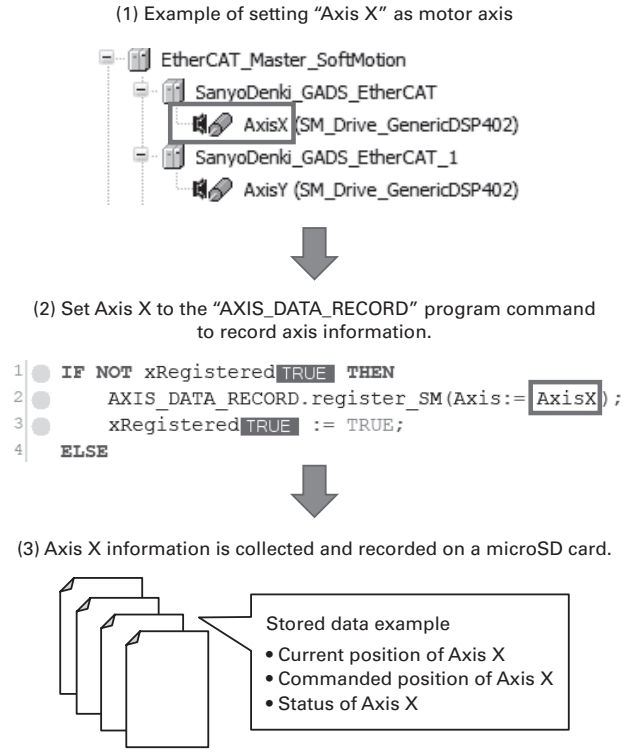

Fig. 5 Collecting and storing information on servo system axes

3.2 Remote status monitoring and maintenance functions

As shown in Figure 6, the new product can establish communication with a remote computer through Automation Server. The Edge Gateway is a function for connecting a computer to the new product via Automation Server. It has been incorporated into the new product and the integrated development tool (software for programming and configuring the servo system).

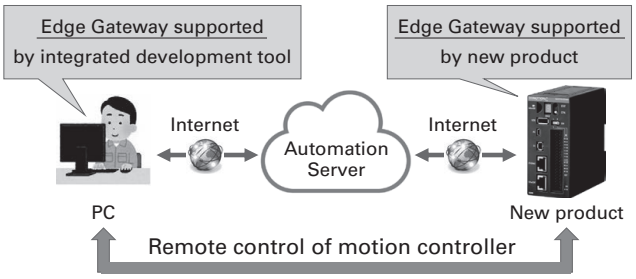

Fig. 6 Remote control of motion controller

Users can check the program variables of the new product by using the dashboard function of the Automation Server. Furthermore, since users can operate the new product remotely by connecting to a VPN,(7) they can monitor and modify programs without actually visiting the work site.

(5) Based on our research comparing IoT-ready motion controllers for 8-axis control (as of August 2023).
(6) The name of the cloud service provided by CODESYS for remotely operating controllers.
(7) VPN, or Virtual Private Network, is a technology for connecting locations with dedicated virtual lines and securely exchanging information.

3.2.1 Remote status monitoring

To monitor the equipment status from remote locations, users can use the dashboard to check the collected data, including the position of each axis, error information, and the digital signal status, as shown in Figure 7. Furthermore, users can grasp the equipment status by checking the running program variables in the new product.

Fig. 7 Dashboard

3.2.2 Remote maintenance

Users can monitor and modify programs, as shown in Figure 8, from remote locations by connecting the integrated development tool and the new product via the Automation Server's VPN. This enables users to perform maintenance on the new product from anywhere at any time, reducing the recovery time in case of equipment abnormality.

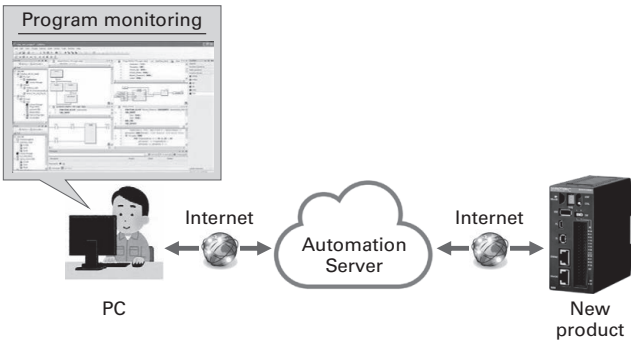

Fig. 8 Remote monitoring of programs

3.3 Email notification

Figure 9 shows the notification process flow in the event of equipment abnormalities.

Its email notification function uses the SMTP protocol, promptly informing the administrator when equipment errors are detected. Notifications can be set not only for errors but also for production conditions, such as when the planned production volume is reached. This enables the administrator to check the production status without being physically present on-site.

This feature allows the administrator to monitor the equipment and production status in real time, ensuring efficient, stable production.

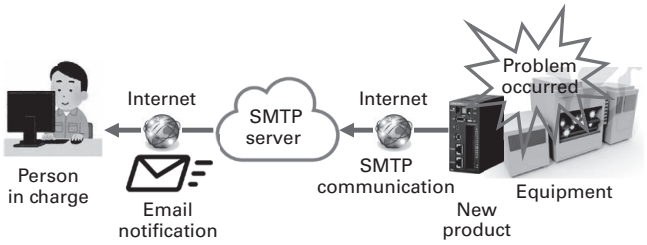

Fig. 9 Email notification

3.4 Connecting to cloud services

As shown in Figure 10, the new product performs communication using the MQTT protocol and implements authentication functions to connect to cloud systems. Security certificate and private key files can be configured from the screen shown in Figure 11 using a web browser.

This function enables quick connection to cloud systems.

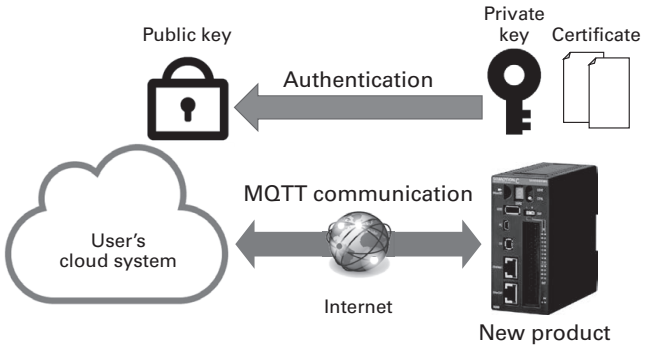

Fig. 10 Connecting to cloud system

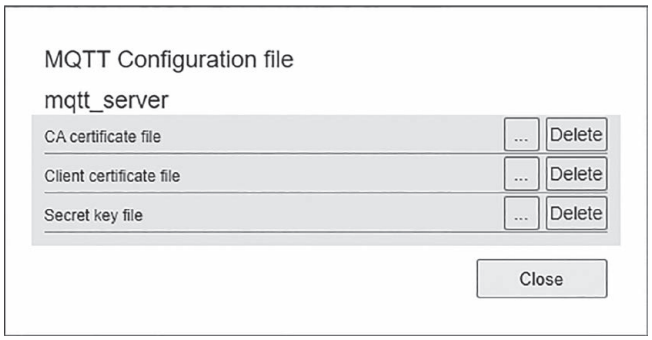

Fig. 11 Settings screen of certificate and private key files

3.5 Browser-based status display and settings

The new product provides improved usability with its web-based applications, which enable users to check the controller status and adjust settings on a web browser.

3.5.1 Product status display

Table 2 shows the status items to monitor, and Figure 12 shows the corresponding status display screen. Users can check the product's device name, serial number, version information, and the Ethernet port settings. Additionally, the new product has a feature to graphically display its status including CPU load and memory usage in real time. This feature can be used to check the performance of the new product and to help troubleshoot problems in the event of abnormal CPU load level fluctuations.

Users can check the storage space of the new product and the capacity and storage usage of a microSD card, preventing data storage errors caused by insufficient storage space.

Table 2 Status check items

Monitored items	Function
Controller information	Device name, serial no., etc.
Status	CPU usage, memory usage, etc.
Network settings	Ethernet and WLAN IP address, etc.
Digital/Analog signal	Status of input/output signals
1-wire device in connection	Information of connected device
Log data	Program running status
Webcam	Monitoring with live streaming and images
Service startup status	Status check of Edge Gateway and others

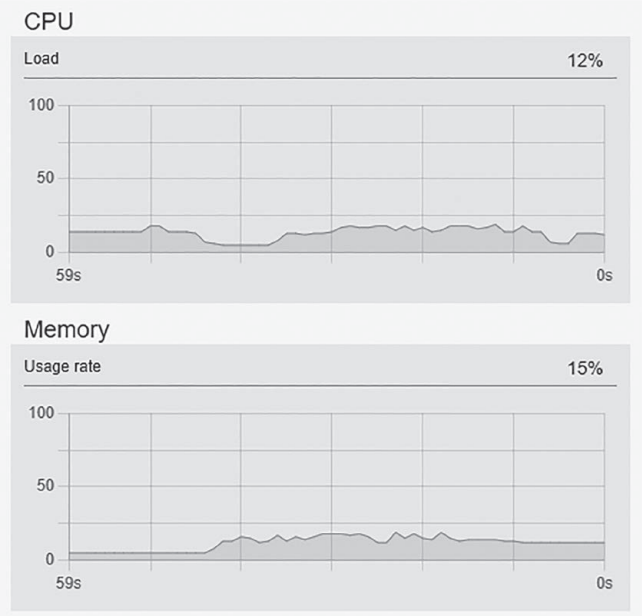

Fig. 12 Status display screen for the new product

3.5.2 Setting parameters

Table 3 shows the configurable parameters for the new product.

The new product allows users to configure network settings using a web browser instead of dedicated software, unlike previously. Users can also specify the sender and recipient email addresses on the email settings screen and check the email-sending status as shown in Figure 13. Additionally, the parameter setting screen for the webcam, shown in Figure 14, enables users to adjust the camera settings while viewing the images.

Table 3 Setting parameters

Setting parameters	Function
Network settings	Settings of Ethernet and WLAN IP address, etc.
Notification email settings	Destination settings, send test email
Webcam settings	Setting of contrast and other parameters
Service startup settings	Automatic startup settings of Edge Gateway and other services

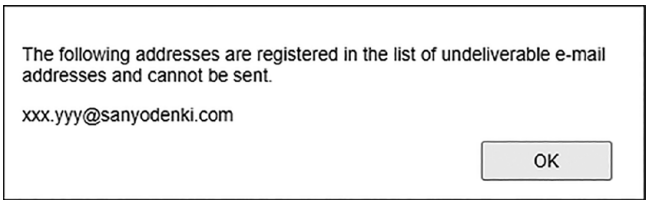

Fig. 13 Sent email status

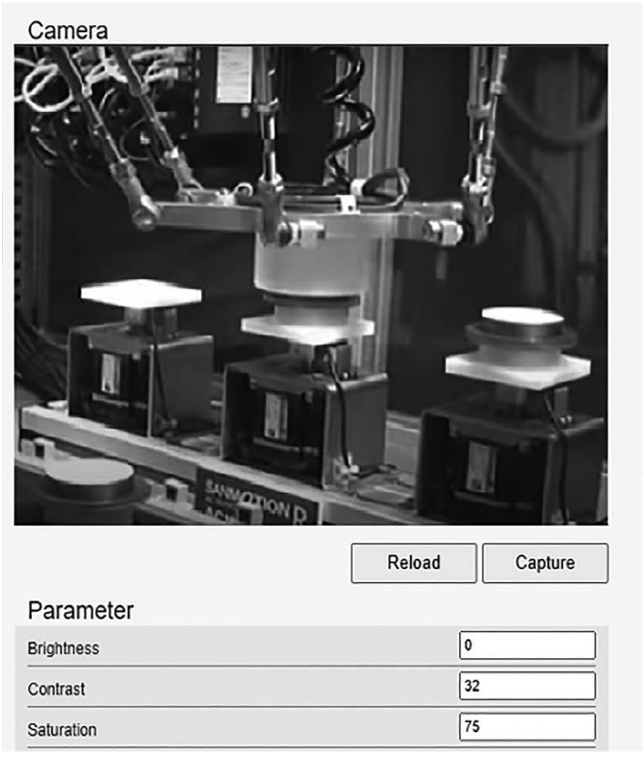

Fig. 14 Webcam settings screen

4. Conclusion

In this article, we introduced the *SANMOTION C S200* motion controller and described some of its features.

The following is a brief summary of the new features it offers.

- Can collect and store equipment data in real time. Users can quickly identify the cause of problems by using stored abnormality data for failure analysis.
- Employs Edge Gateway that connects the new product to remotely located computers via Automation Server. Automation Server's dashboard enables remote monitoring of equipment status. Furthermore, users can remotely perform equipment maintenance via a VPN, reducing the recovery time in the event of failure.
- Can send notification emails based on error and production status, enabling users to quickly understand equipment status and production conditions, helping maintain stable, efficient production.
- Improved in usability by featuring browser-based status monitoring and settings application.

SANMOTION C S200 is a motion controller designed to detect changes in the operating status and ambient environment of equipment, promptly notifying users of the status. It collects and stores error log data in real time, minimizing recovery time in the event of a failure. Furthermore, it contributes to improving the productivity of equipment by enabling users to remotely monitor the operating status of equipment and perform maintenance when necessary.

Moving forward, we will continue to leverage IoT and digital technologies to develop products that help create new value for our customers.

Note: The company names, product names, and network protocol names mentioned in this article are the trademarks or registered trademarks of their respective owners.

Reference

(1) Hideaki Kodama and 7 others: "Development of the *SANMOTION C SMC100* Motion Controller" SANYO DENKI Technical Report No. 47, pp. 30-34 (2019.5)

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