SANYO DENKI

Technical Report

Feature | Technical Developments in 2018

1960
Kawaguchi Works

47
May 2019

COLUMN

Cover image:

Kawaguchi Works

1960

In 1957, predicting that Tokyo Works would soon be outgrown, a plot of land was purchased in Aokicho, Kawaguchi, Saitama Prefecture earmarked to become a new production site.

Commencing operations in February 1961, the new factory in Kawaguchi operated by Tokyo Works was added to the production system and specialized in line production.

In its early days, Kawaguchi Works produced servo motors, automatic control devices for hot-topping, hand crank generators for radio equipment, and power supplies used for signal frequency meters. The following period saw a rise in production of various products including magnetic tape units for computer peripherals, disk units, reel motors, capstan motors, vacuum blowers, and sirocco fans.

It is during this period that the 1964 Tokyo Olympics were held, marking a major turning point for Japan.

Leading up to the Showa 40s (1965-1974), when the electronics industry, notably computers and semiconductors, would make great strides, SANYO DENKI made proactive decisions to secure its foothold in the market.

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May 2019

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Operating Officer
Jiro Sakamoto

Specialists in Change due to Technological Innovations

Founded in 1927, 2019 marks SANYO DENKI's 92nd year.

During this time, we have overcome several major economic fluctuations, and achieved steady growth through our original technologies and sound management while recognizing the changing times.

In 1927, Japan had just seen the change of eras from Taisho to Showa, and there were as yet no telephones or household appliances.

Later, after defeated in WW2, Japan rode a wave of high growth and, together with the development of electronics technology, experienced dramatic changes from lifestyle to business practices.

In the background of such lifestyle changes, new technological innovations are always present.

The biggest change in recent years must be the information innovations originating from the Internet.

The linking of computers resulted in the connection of people's knowledge and feelings all over the world. These information innovations led to technologies such as IoT, AI (artificial intelligence), and autonomous driving, and are now starting to change the world's various existing systems. Integrated with IoT and AI, robots today are expanding the range in which they can operate at their own decisions. Right now, we are at the beginning of the next paradigm shift.

SANYO DENKI supports these changes from the perspective of manufacturing (*monozukuri* in Japanese).

For example, lots of our Cooling Systems products are used to cool large data processing cloud servers to facilitate stable operation. These products are also used in non-cooling applications such as ventilation of highly-controlled plant factories and households.

Our Power Systems products support our information society by supplying power to mission-critical equipment that cannot afford to be cut off, and serve a major role in supporting lifelines in times of disaster.

Our Servo Systems products support high-speed and accurate movement of robots and machine tools.

In the future, in light of the declining birthrate and labor shortage, robots will expand into medical and food markets too, widening the collaboration with humans.

Technological innovations occur in a chain reaction, generating new innovations one after another. A number of possibilities that humans could only imagine in the past are becoming a reality today. Moving forward, there is no doubt that AI will come up with solutions far beyond human comprehension.

Even if the essence of human beings remains the same, technology can help us unlock our potential. Who could have predicted our modern way of life in which things and people around the world can be easily connected? Just like people 92 years ago at the time of our company's founding could not imagine the world we live today, what the world will look like in 92 years from now will be beyond our imagination for sure.

This year 2019 is a "year of change" where Japan said farewell to the Heisei period and entered the Reiwa period. To date, SANYO DENKI has strived to stay ahead of the changing times and constantly developed new products as an industry leader offering people happiness.

This issue of Technical Report provides a glimpse at some of our continuous technological development in "Technical Developments in 2018," including IoT-enabled products and technologies that consider environmental durability and people's safety.

We at SANYO DENKI will view these changing times due to technological innovations as opportunities to seize, and continue to "specialize in change." Moreover, we will aim to become a top global brand by offering products and services with value to our customers around the world in real time.

Cooling Systems Division

Tetsuya Yamazaki

In recent years, due to the full-scale spread of IoT, ICT equipment is required to offer larger capacity and higher speed than ever before.

Particularly for next-generation 5G communication systems, how to secure reliability and handle heat generation within equipment due to high-speed, high-capacity data processing and transmission are issues which need addressing.

Against such a backdrop, fans are now required to have higher performance and reliability than ever before.

Moreover, fans are expected to have water resistance due to an increasing amount of equipment for outdoor use, such as large heat exchangers, renewable energy inverters, EV charging stands, and digital signage.

Many of these equipment use DC-input fans, however, there is still a strong demand for AC-input fans.

Using AC fans can be an effective way to simplify equipment design because it eliminates the need for a converter or DC power supply.

To meet such market demands, in 2018, we developed and launched fans with the industry-leading performance and reliability.

Below is an overview of the products we developed in 2018.

■ High Airflow Long Life Splash Proof Fan

DC Fan

• 92 × 92 × 38 mm *San Ace 92W* 9WL type

In recent years, there has been a growing demand for fans with higher performance and longer service life in the markets of outdoor ICT equipment and renewable energy inverters.

Also, to cultivate markets such as quick charging stations and digital signage, we need to promote fans that feature high reliability, long service life, and water resistance.

To respond to such market demands, SANYO DENKI developed and launched the *San Ace 92W* 9WL type High Airflow Long Life Splash Proof Fan.

■ High Static Pressure Long Life Counter Rotating Fan

DC Fan

• 60 × 60 × 76 mm *San Ace 60L* 9CRLA type

With the development of communication technology and faster and larger data transfer, today's 2U-sized IT equipment is becoming denser and generating more heat, requiring fans with higher performance than ever before.

Moreover, for high-end equipment, high reliability and long service life are essential.

We offered 60 × 60 mm Long Life Counter Rotating Fans. However, to keep up with these market changes, we needed a product with higher performance and longer service life.

To respond to such market demands, we developed and launched the *San Ace 60L* 9CRLA type with the industry's highest[(1)] static pressure.

(1) Based on our own research as of March 29, 2018, conducted among equally-sized axial DC fans on the market.

■ High Airflow Splash Proof Centrifugal Fan

DC Fan

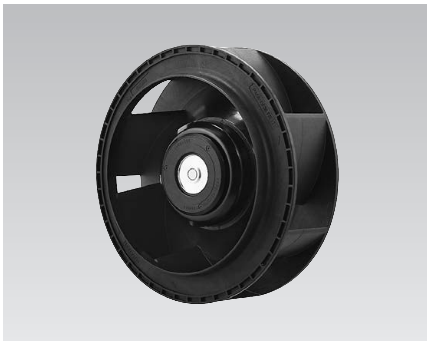
• ø175 × 69 mm *San Ace 175W* 9W2T type

With increased heat generation within our customers' equipment used outdoors, higher airflow is required for our Splash Proof Fans.

Moreover, in new markets such as refrigeration units, air conditioners, and dust collectors as well as outdoor ICT equipment and large inverters, there is a demand for waterproof centrifugal fans with ø175 × 69 mm size.

In response to such market demands, we developed and launched the *San Ace 175W* 9W2T type offering the industry's highest[(2)] airflow and static pressure among IP56-rated waterproof centrifugal fans on the market.

(2) Based on our own research as of August 8, 2018, conducted among equally-sized industrial waterproof centrifugal fans on the market.



■ Centrifugal ACDC Fan, Splash Proof Centrifugal ACDC Fan

AC Fan

• ø225 × 99 mm Centrifugal ACDC Fan *San Ace 225AD* 9AD type
• ø225 × 99 mm Splash Proof Centrifugal ACDC Fan *San Ace 225AD* 9AD type

With cooling fans for outdoor heat exchangers, residential air ventilation systems, and renewable energy inverters, upsizing the fan is a common way of achieving both high airflow and low noise.

In recent years, more and more AC-input large-sized centrifugal fans have been used for such equipment.

In response to such market demands, we developed and launched the *San Ace 225AD* 9AD type Centrifugal Fans and Splash Proof Centrifugal Fans which offer the industry's highest[(3)] airflow and static pressure.

(3) Based on our own research as of October 11, 2018, conducted among equally-sized waterproof or non-waterproof industrial centrifugal fans on the market.

■ High Static Pressure Fan

DC fan

• 36 × 36 × 28 mm *San Ace 36* 9HV type

Typical cooling fans used in 1U servers are 40 × 40 mm in size. However, with increased server and power supply capacities and improved server functionality, servers today are becoming denser, allowing less space for cooling fan installation.

As such, fans smaller than 40 × 40 mm with high cooling performance are required.

In response to such market demands, we developed and launched the *San Ace 36* 9HV type which offers the industry's highest[(4)] airflow and static pressure.

(4) Based on our own research as of December 13, 2018, conducted among equally-sized axial DC fans on the market.

Tetsuya Yamazaki
Joined SANYO DENKI in 1997.
SANYO DENKI PHILIPPINES, INC., Design Dept.
Works on the design and development of cooling fans.

ø225 × 99 mm Centrifugal ACDC Fan and Splash Proof Centrifugal ACDC Fan *San Ace 225AD* 9AD Type

Tomohide Nonomura   Masafumi Yokota   Yoshinori Miyabara

Sho Furihata   Ryo Shimizu   Masato Murata

1. Introduction

In markets for heat exchangers, residential air ventilation systems, and renewable energy inverters, an increasing amount of heat is generated due to higher performance and functionality of these devices. As such, high airflow, high static pressure centrifugal fans are used in a growing number of cases.

These devices are often used outdoors or in environments where there is only AC power available, requiring AC-driven fans with waterproof performance. Another need is to lower fan power consumption for achieving energy savings for devices.

As such, by using an AC-powered DC motor circuit in a centrifugal fan, we developed the *San Ace 225AD* Splash Proof Centrifugal ACDC Fan which offers low power consumption and waterproof performance.

In parallel, we also developed the ø225 × 99 mm Centrifugal ACDC Fan, a non-waterproof model with better airflow vs. static pressure characteristics, for applications that do not require waterproofing.

This article will introduce the performance and features of the new models as well as key points of development.

2. Product Features

Figure 1 shows the appearance of the new models.

The only external differences between the waterproof and non-waterproof models are in their harness and nameplate.

The features of the new models are as follows:

(1) No DC power supply required
(2) PWM control function
(3) High airflow and high static pressure
(4) Low power consumption
(5) Low sound pressure level (SPL)
(6) Dustproof and waterproof performance with an IP56 ingress protection rating[Note]

Note:IP56 ingress protection rating
The degree of protection (IP code) is defined by IEC (International Electrotechnical Commission) 60529 "DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP Code)" (IEC 60529:2001)

Fig. 1 *San Ace 225AD*

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new models.

3.2 Specifications

3.2.1 General specifications

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

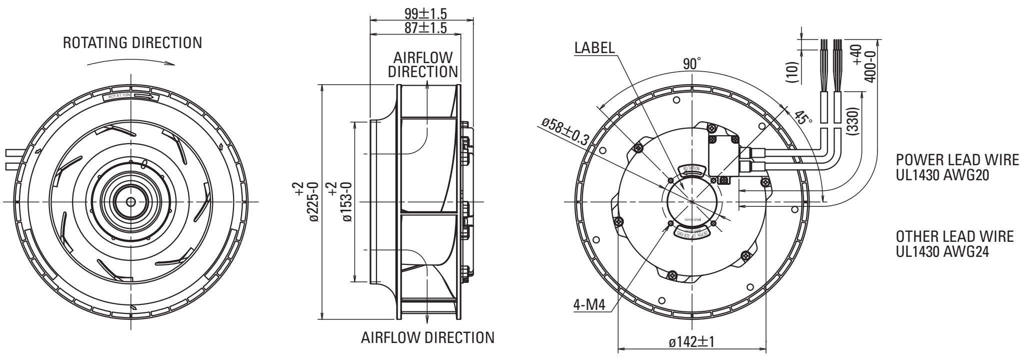


Fig. 2 Dimensions of the ø225 × 99 mm Centrifugal ACDC Fan (unit: mm)

Table 1 General specifications of the ø225 × 99 mm Centrifugal ACDC Fan

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow		Max. static pressure		SPL [dB(A)]	Operating temperature range [°C]	Expected life [h]
							[m³/min]	[CFM]	[Pa]	[inchH₂O]			
9ADTS11P0G001	115	90 to 132	100	3.6	155	3,200	23.0	812	815	3.27	74	-20 to +60	40,000/ 60°C
			20	0.3	10	1,000	7.1	252	80	0.32	50		
9ADTS11P0F001			100	1.6	70	2,450	17.6	621	480	1.93	68		
			20	0.3	10	1,000	7.1	252	80	0.32	50		
9ADTS23P0G001	230	180 to 264	100	2.0	155	3,200	23.0	812	815	3.27	74		
			20	0.2	10	1,000	7.1	252	80	0.32	50		
9ADTS23P0F001			100	0.9	70	2,450	17.6	621	480	1.93	68		
			20	0.2	10	1,000	7.1	252	80	0.32	50		

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

Table 2 General specifications of the ø225 × 99 mm Splash Proof Centrifugal ACDC Fan

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow		Max. static pressure		SPL [dB(A)]	Operating temperature range [°C]	Expected life [h]
							[m³/min]	[CFM]	[Pa]	[inchH₂O]			
9ADW1TS11P0H001	115	90 to 132	100	2.9	140	3,100	22.3	787	760	3.05	73	-20 to +60	40,000/ 60°C
			20	0.3	11	1,000	7.1	252	80	0.32	50		
9ADW1TS11P0M001			100	1.4	61	2,350	16.9	597	440	1.77	67		
			20	0.3	11	1,000	7.1	252	80	0.32	50		
9ADW1TS23P0H001	230	180 to 264	100	1.9	140	3,100	22.3	787	760	3.05	73		
			20	0.2	11	1,000	7.1	252	80	0.32	50		
9ADW1TS23P0M001			100	0.8	61	2,350	16.9	597	440	1.77	67		
			20	0.2	11	1,000	7.1	252	80	0.32	50		

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

3.2.2 Airflow vs. static pressure characteristics

Figures 3 and 4 show the airflow vs. static pressure characteristics for the new models.

3.2.3 PWM control function

The new models have PWM control function and are capable of controlling fan speed.

3.3 Expected life

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

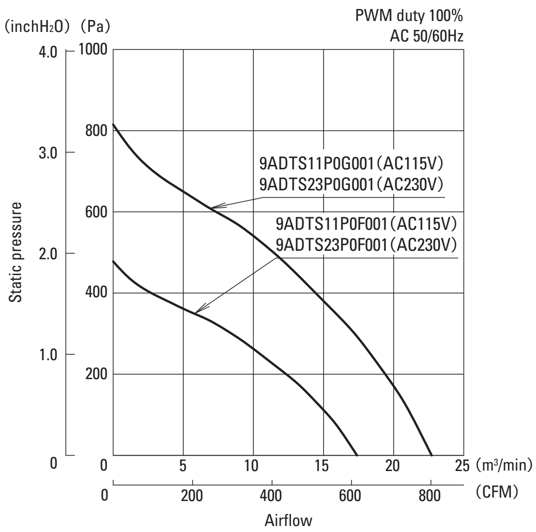


Fig. 3 Airflow vs. static pressure characteristics of the ø225 × 99 mm Centrifugal ACDC Fan

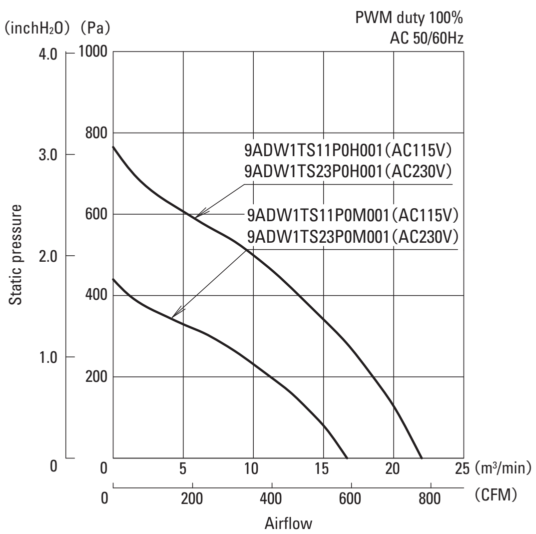


Fig. 4 Airflow vs. static pressure characteristics of the ø225 × 99 mm Splash Proof Centrifugal ACDC Fan

4. Key Points of Development

Even with an AC-DC converter installed, the new models have the same size as our current DC Centrifugal Fan and achieve high airflow and static pressure performance. Also, we successfully waterproofed the fan using a method different from our conventional method that covers live parts completely with epoxy resin.

The key points of development are explained as follows.

4.1 Waterproof design

The new models use an electrolytic capacitor in the AC-DC converter. As the pressure valve portion of the electrolytic capacitor must not be blocked, we couldn't use a waterproofing method that covers the capacitor completely with epoxy resin.

Consequently, we achieved waterproofing for the splash proof fan with a structure where only the motor portion is covered with epoxy resin while the circuit is enclosed in the space within the frame and top cover. Figure 5 shows the appearance of the live parts.

Moreover, we applied anti-corrosion coating for the aluminum frame and top cover, improving reliability.

4.2 PCB design

The new models are larger than our current models of 9AD type (92 × 92 mm, 120 × 120 mm). So, using the same circuit configuration as these would result in insufficient circuit capacity to operate the motor. To tackle this issue, we focused on the following: choosing components which can withstand high power levels, optimizing the circuit configuration, and re-examining the thermal distribution method for high heat emitting components. Through these improvements, we were successfully able to drive a motor that requires 30 times more power than conventional models.

Also, the new models are AC-input fans and need a high-voltage input. As such, they require more space between components than DC fans that only require a low-voltage input. But this allowed us to place fewer components on a PCB, making our PCB layout design difficult. Moreover, large components must be used to support high power. In the early stages of development, we placed a drive control circuit and AC-DC converter on two separate PCBs, causing an issue of increased frame volume.

As a solution to this issue, we placed the electrolytic capacitor on a spacer. Figure 6 shows how components are mounted with a spacer. Using a spacer enabled components to be placed even under the electrolytic capacitor, allowing both the drive control circuit and AC-DC converter laid out on a PCB. This solved the issue of increased frame volume.

4.3 Impeller design

The new models have an AC-DC converter and circuit configuration supporting high power, resulting in increased volume of the circuit and motor portion than our DC Centrifugal Fan of equal size. Figure 7 shows a comparison of the impellers. The new models have a smaller ventilation area than the DC Centrifugal Fan, therefore are disadvantaged performance-wise. As such, we carefully adjusted the impeller shape to obtain the maximum static pressure and airflow as possible with a limited ventilation area.

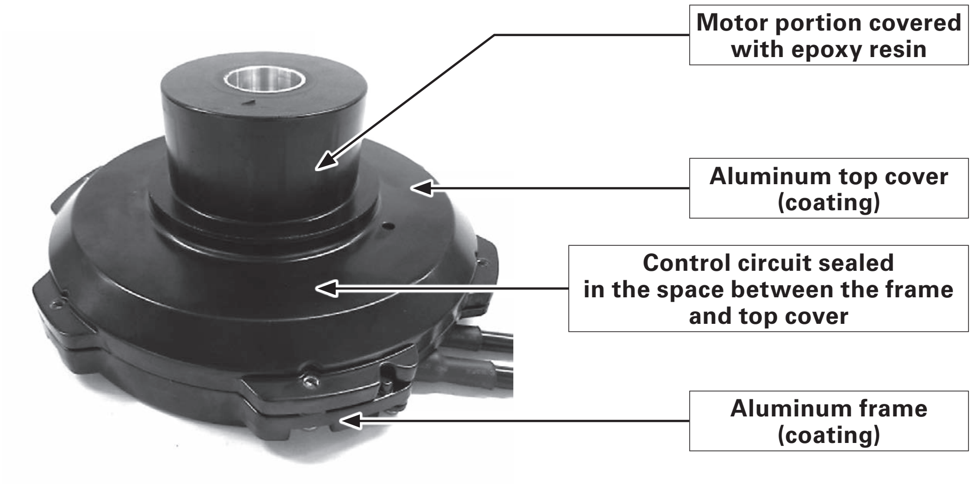


Fig. 5 Appearance of the live parts

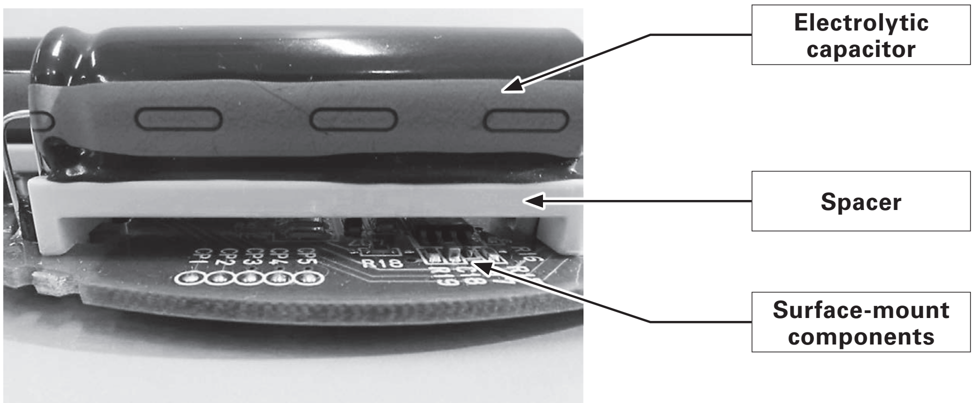
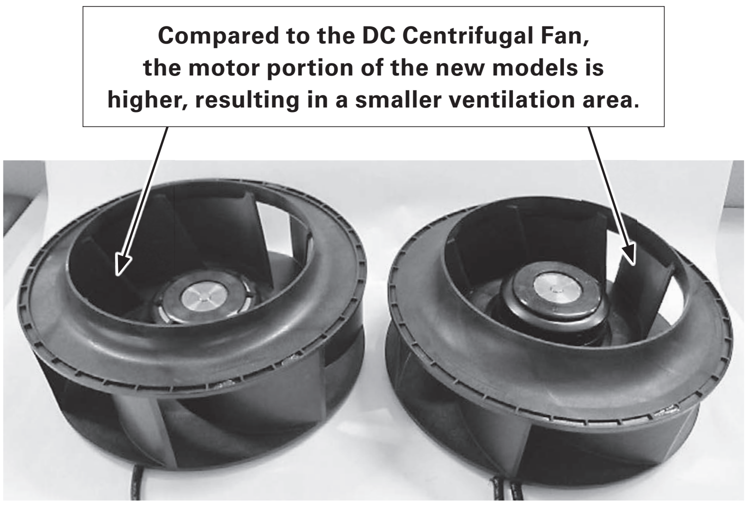


Fig. 6 Components mounted using a spacer



DC Centrifugal Fan (*San Ace C225*)   New model

Fig. 7 Comparison of new model and DC Centrifugal Fan impellers

We employed fluid analysis during impeller design and optimized the impeller shape through repeated cycles of model-making with a 3D printer and measurements. As a result, we succeeded in achieving high airflow and high static pressure performance at the same speed as the DC Centrifugal Fan despite the reduced ventilation area.

5. Conclusion

This article introduced some of the features and performance of the ø225 × 99 mm *San Ace 225AD* Centrifugal ACDC Fan and Splash Proof Centrifugal ACDC Fan.

The new models, with an AC-DC converter equipped and the same size as the current DC Centrifugal Fan, achieve equivalent airflow and static pressure. Moreover, these were our first products to have IP56-rated dustproof and waterproof performance with an AC-DC converter.

We believe that the new models will significantly contribute to energy savings and the cooling of devices used outdoors or in environments with only AC power.

Moving forward, we will continue to stay ahead of the changing market and develop products that create new value for customers and make customers' dreams come true.

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High Static Pressure Fan *San Ace 36* 9HV Type

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Grace Rico Jovelyn Villar Michinori Watanabe

1. Introduction

Recently, 1U servers and ICT equipment are processing greater volumes of data. This results in greater heat generation that needs to be properly handled. Moreover, due to higher functionality of the equipment itself, there is less internal space available for power supplies.

As such, fans mounted in such equipment need to be small yet offer high cooling performance.

To satisfy these requirements, SANYO DENKI developed and launched the High Static Pressure Fan *San Ace 36* 9HV type (hereinafter, new model) with an equivalent or better cooling performance than our 38 × 38 mm and 40 × 40 mm fans.

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

2. Product Features

Figure 1 shows the appearance of the new model.

Fig. 1 36 × 36 × 28 mm *San Ace 36* 9HV type

The features of the new model are:

(1) High static pressure
(2) Low power consumption
(3) Space saving

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new model.

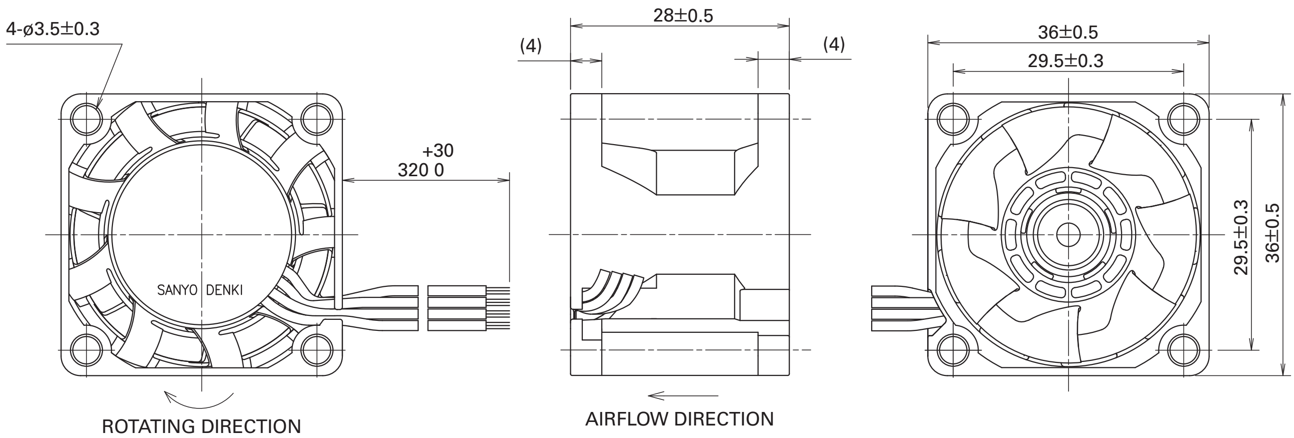


Fig. 2 Dimensions of the new model (unit: mm)

3.2 Characteristics

3.2.1 General specifications

Table 1 shows the general specifications for the new model.

It is available in 12 VDC rated voltage only and its rated speed is 32,500 min^{-1}.

Table 1 General specifications for the new model

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow		Max. static pressure		SPL [dB(A)]	Operating temperature range [°C]	Expected life [h]
							[m^3/min]	[CFM]	[Pa]	[inch H_2O]			
9HV3612P3K001	12	10.8 to 13.2	100	1.75	21	32,500	0.72	25.4	1,400	5.62	67	-20 to +60	30,000/60°C
			20	0.05	0.6	6,000	0.12	4.2	47.2	0.19	26		

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

3.2.2 Airflow vs. static pressure characteristics

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

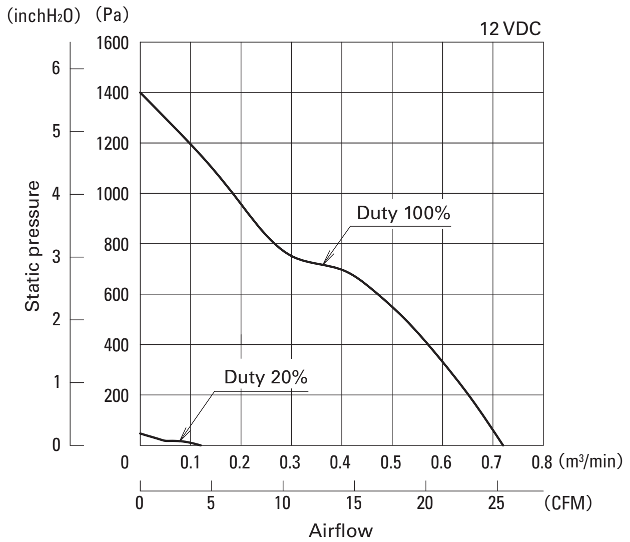


Fig. 3 Airflow vs. static pressure characteristics of the new model

3.2.3 PWM control function

The new model has PWM control function that enables external control of the fan speed.

3.3 Expected life

The new model has an expected life of 30,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage and normal humidity in free air).

4. Key Points of Development

The new model offers significantly improved static pressure performance compared to the current model. To achieve an equivalent or better cooling performance than our 38 × 38 mm and 40 × 40 mm size products, we needed to improve overall static pressure performance. Increased fan speed is essential to improve cooling performance, and this is our first product exceeding 30,000 min^{-1}.

To develop a product with high speed, we newly designed the impeller and frame, and changed to a 3-phase motor.

Below, we explain the key development points as well as the differences between the new model and the current model, the *San Ace 36* 9GX type.

4.1 Impeller and frame design

For the new model, to achieve high static pressure, we used our simulation technology, and combined various parameters such as blade number, length, angle, and frame static blade shape to find optimal impeller and frame shapes. Then, based on these optimal shapes, we performed repeated product evaluations and simulations to determine the final shape.

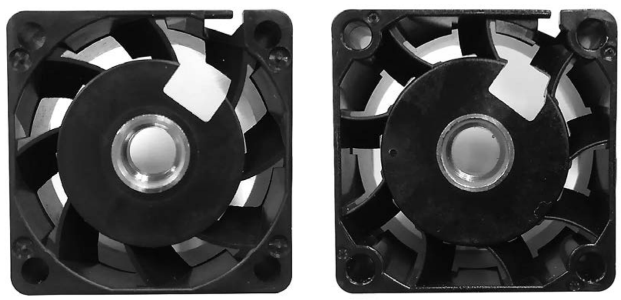
Moreover, to increase fan speeds, the impeller design must be strong enough to withstand the generated stress. As such, we made sure to maintain sufficient strength by using our stress simulation technology.

Figure 4 shows a comparison of the impeller shape for the new and current models.

Figure 5 shows a comparison of the frame shape for the new and current models.

Current model　　New model

Fig. 4 Comparison of the impeller shapes for the new and current models



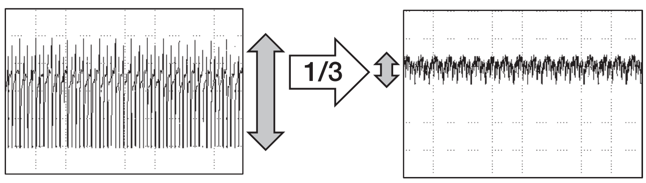
Current model　　New model

Fig. 5 Comparison of the frame shape for the new and current models

4.2 Motor and circuit design

Power consumption increased in line with the increased fan speed, so we changed to a 3-phase motor. By doing so, we successfully minimized peak fluctuation of the current waveform and lightened the load on the motor.

Figure 6 shows the comparison of current waveforms during steady operation.



Current model
9GX3612P3K001
Steady-state current waveform

New model
9HV3612P3K001
Steady-state current waveform

Fig. 6 Comparison of current waveforms during steady operation

5. Comparison with Current Model

5.1 Comparison of airflow vs. static pressure characteristics

Compared to the current model, the new model's maximum static pressure has increased by 67%.

Figure 7 shows the comparison of the airflow vs. static pressure characteristics of the current and new models.

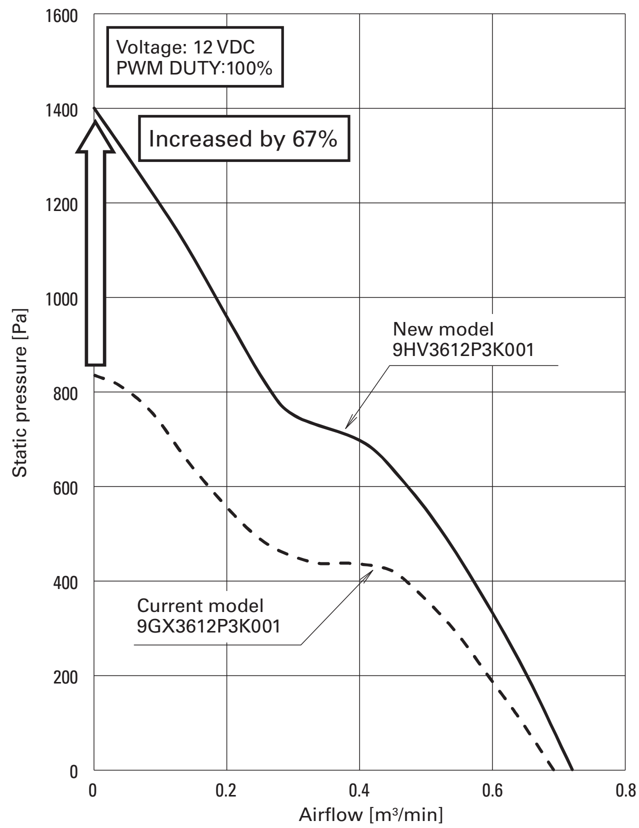


Fig. 7 Airflow vs. static pressure characteristics of current and new models

5.2 Power consumption comparison

Figure 8 gives a comparison of the power consumption for the airflow vs. static pressure characteristics of the current and new models at equivalent cooling performance.

This graph compares airflow vs. static pressure characteristics when the speed of the new model is reduced to match the cooling performance of the current model. It is evident that, overall, the new model has a lower power consumption than the current model, and we have succeeded in reducing power consumption by up to 10% in the high load area.

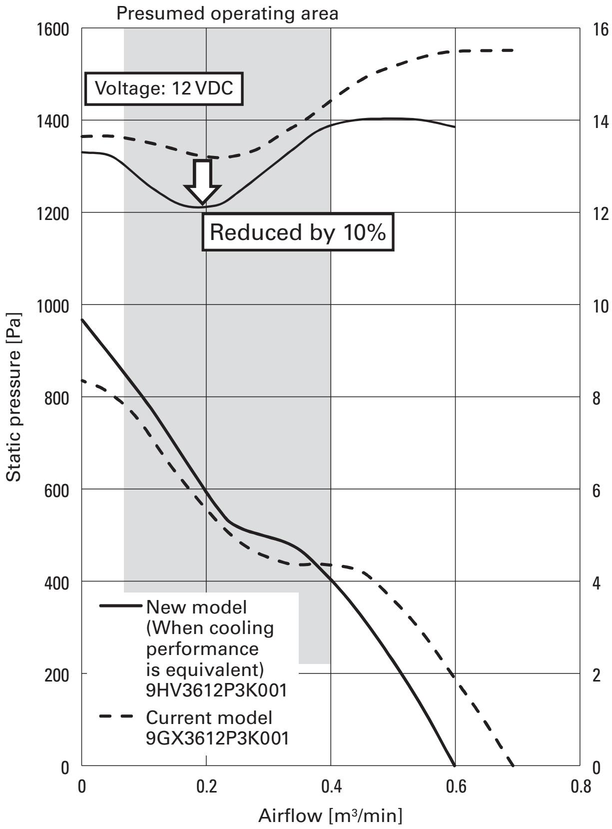


Fig. 8 Example of the airflow vs. static pressure characteristics (comparison with current model)

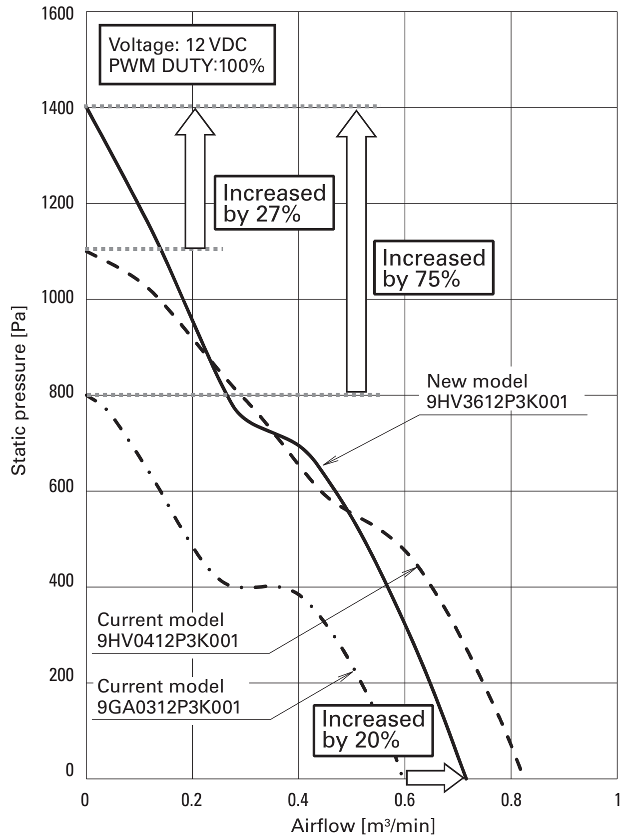


Fig. 9 Example of the airflow vs. static pressure characteristics (comparison with 38 × 38 mm and 40 × 40 mm fans)

5.3 Comparison with 38 × 38 mm and 40 × 40 mm size products

Figure 9 shows a comparison of the airflow vs. static pressure characteristics for our two current models (38 × 38 mm and 40 × 40 mm sizes), and the new model.

Compared with the 38 × 38 mm model, 9GA0312P3K001, the new model has a 20% higher maximum airflow and 75% higher maximum static pressure.

Furthermore, compared with the 40 × 40 mm model, 9HV0412P3K001, the new model has a 27% higher maximum static pressure, achieving an equivalent or better cooling performance in the presumed operating area.

In this way, the new model is capable of providing the cooling performance offered by the 38 × 38 mm and 40 × 40 mm models.

Figure 10 shows a comparison of the sound pressure level (SPL) when cooling performance is equivalent (operating airflow 0.22 m³/min). When cooling performance is equivalent, the new model is 4dB(A) quieter than 9HV0412P3K001, contributing to a lower SPL for the equipment overall.

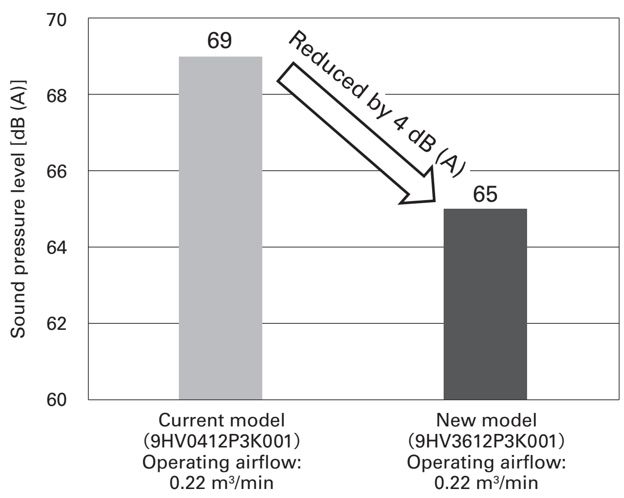


Fig. 10 SPL comparison when operating airflow is equivalent

6. Conclusion

This article has introduced some of the features and performance of the 36 × 36 × 28 mm High Static Pressure Fan *San Ace 36* 9HV type we developed.

Although the new model is 36 × 36 mm in size, it achieves a cooling performance equivalent or better than the 38 × 38 mm and 40 × 40 mm models, and offers significantly higher static pressure.

Reducing the size of the fan allows our customers greater freedom regarding equipment design. We believe the features of the new model will significantly contribute to the cooling of equipment that will have even higher mounting density and heat generation in the future.

We will continue developing products in response to various market needs and offering products which contribute to the creation of new values for our customers to help make their dreams come true.

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Power Systems Division

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In 2018, Japan endured a succession of natural disasters including torrential rains and earthquakes, such as the Osaka earthquake in June, torrential rains in West Japan in July, and the Hokkaido Eastern Iburi earthquake in September. This served to remind us of the reality that Japan truly is a disaster-prone country. The Japanese government is therefore investing in infrastructure to prepare for a potential mega earthquake in the Nankai Trough or Tokyo metropolitan area.

The private sector is also focusing on disaster management and BCP (business continuity planning), with particular attention is being paid to the importance of "securing power."

Power outage countermeasures include uninterruptible power supplies (UPS) for short-term use and diesel engine generators (DEG) for long-term use.

As a well-established manufacturer of power supplies, SANYO DENKI has developed various types of UPSs and DEGs offering high efficiency and high reliability, and is making continuous efforts to contribute to such countermeasures.

In 2018, the Power Systems Division developed and launched the following products.

In the small-capacity UPS field, we developed the *SANUPS N11B-Li*, *SANUPS N11C-Li,* and *SANUPS A11K-Li*, which are all equipped with lithium-ion batteries (LIB).

The N11B-Li and N11C-Li are passive standby UPSs. The A11K-Li is a double-conversion online UPS, and we added short-term backup models to the existing lineup.

We also developed a 1 kVA model for the *SANUPS E11B,* a hybrid UPS.

In the medium-capacity UPS field, we developed the *SANUPS A22A*, a highly reliable, modular double-conversion online UPS, for which 5 kVA modules can be configured for parallel operation.

In the engine generator field, we developed the *SANUPS G53A*, an emergency diesel generator for outdoor use compliant with Japan's Fire Service Law, a building disaster management requirement.

This article will provide an overview of these products and technologies, and summarize their features.

■ Small-Capacity UPS *SANUPS N11B-Li*, *SANUPS N11C-Li*, and *SANUPS A11K-Li*

We developed the following new models to expand our lineup of LIB-equipped UPSs characterized by wide operating temperature ranges and maintenance-free operation.

SANUPS N11B-Li: 3 kVA 100 V model[1] and 1 kVA 200 V model;

SANUPS N11C-Li[2]: 1.5 kVA, 3 kVA, and 5 kVA 100 V models; and

SANUPS A11K-Li short-term backup model: 1 kVA, 1.5 kVA, 2 kVA, 3 kVA, and 5 kVA 100 V models.

Fig. 1, 2, and 3 show the appearance of the *SANUPS N11B-Li*, *SANUPS N11C-Li*, and *SANUPS A11K-Li* short-term backup models, respectively.

The *SANUPS N11B-Li* features the passive standby topology and an ingress protection rating of IP65 for outdoor use.

The *SANUPS N11C-Li* features the passive standby topology and is for indoor use only.

The *SANUPS A11K-Li* short-term backup model has a backup time of 8 to 15 minutes and features the double conversion online topology. By developing a dedicated LIB, we successfully reduced the product weight by up to 44% compared with our current UPS (A11K lead-acid battery type).

The operating temperature range of the *SANUPS N11B-Li* is -20°C to +50°C, while that of the *SANUPS N11C-Li* and the *SANUPS A11K-Li* is -20°C to +55°C, meaning that all three products can be used with confidence even in extremely cold or hot environments.

All series are equipped with a battery management unit and feature a data interface between the UPS and LIB. LIBs can be used safely because their status is monitored, and mutual protective operations and error detections are performed between the UPS and LIB.

(1) For details, see Technical Report No. 45.
(2) For details, see Technical Report No. 46.

Fig. 1 *SANUPS N11B-Li*

Fig. 2 *SANUPS N11C-Li*

Fig. 3 *SANUPS A11K-Li* short-term backup model

■ Small-Capacity UPS *SANUPS E11B*

For backup applications such as servers, we developed the *SANUPS E11B*, a UPS featuring the hybrid topology.[3]

This new series is available in 1 kVA output capacity and in 100 and 200 VAC single-phase 2-wire input/output voltages.

Figure 4 shows the appearance of the *SANUPS E11B (1 kVA).*

The hybrid topology allows the UPS to automatically select the optimal operation mode for any given input power condition, achieving energy savings while stably supplying high-quality power to loads.

The input voltage range is 55 to 150 V for the 100 V model, and 110 to 300 V for the 200 V model. In addition, this product has a wide input frequency range from 40 to 120 Hz. Even when input power is unstable, it can minimize switching over to battery operation, preventing battery drain.

Its wide -10 to +55°C operating temperature range enables the UPS to operate stably even in extreme temperature environments.

The input plug and output outlet shapes can be selected to suit the specific country or region, and the wide input voltage and operating temperature ranges described above positions this as a product that can be used globally.

In 2019, we plan on launching 1.5 kVA, 2 kVA, and 3 kVA models.

(3) A UPS design that automatically switches between double conversion and standby topologies according to the input power conditions.

Fig. 4 *SANUPS E11B* (1 kVA)

■ Modular UPS, *SANUPS A22A*

We developed a highly reliable modular UPS, the *SANUPS A22A*, as a power solution for mission-critical infrastructure equipment, such as 24-hour data centers.

With this UPS, you can connect 5 kVA inverter modules (up to 21) in parallel. This enables us to suggest a system optimized for customer load conditions.

This UPS is available in two models with the same input of 3-phase 4-wire 400 VAC and different output and scalability: a model scalable up to 105 kVA with 3-phase 4-wire 400 VAC output, and a model scalable up to 50 kVA with and single-phase 2-wire 200 VAC output.

We also developed a model that can connect to up to 4 inverter modules specifically designed for applications 20 kVA or less.

Figure 5 shows the appearance of the *SANUPS A22A*.

This UPS uses a system in which the 5 kVA inverter modules suppress circulating current individually. The overall system reliability has been improved by not depending on the reliability of common parts.

The inverter module can be used for both the 3-phase 4-wire 400 VAC model and the single-phase 2-wire 200 VAC model.

By adopting the 3-level circuit method for both the rectifier and inverter, we have achieved the industry-leading(4) efficiency level of 94.5%. This reduces running costs and contributes to energy saving.

With a wide input voltage range from -40% to +15%, even when input power is unstable, it can minimize switching over to battery operation, thereby preventing battery drain.

Furthermore, backup time can be easily extended by adding battery modules with the same dimensions as the inverter module.

The A22A uses a simple plug-in connection for the inverter modules and battery modules so they can be added or removed while running, making maintenance work quick and easy.

Details of this product are provided in the "New Product Introduction" section of this report.

(4) Based on our own market research as of August 7, 2018, conducted among online UPSs on the market with equivalent voltage and capacity.

Fig. 5 *SANUPS A22A*

■ Emergency Diesel Generator *SANUPS G53A*

We developed the *SANUPS G53A*, an emergency diesel generator for outdoor use compliant with Japan's Fire Service Law for building disaster management in the emergency diesel generator market.

This product comes with three rated output capacities: 200/230 kVA, 250/290 kVA, and 290/320 kVA.

Figure 6 shows the appearance of the *SANUPS G53A*.

The *SANUPS G53A* satisfies the Nippon (Japan) Engine Generator Association requirements: Design Requirements for Emergency Use Engine-driven Power Generators (NEGA C 311), so it can be used safely.

The main feature of this product is its IoT functions, that is, it can connect to a LAN or peripheral devices via a general purpose interface such as Ethernet or RS-485 thanks to the on-board general-purpose programmable logic controller.

A broad, flexible range of customization is available, and customers can choose from various options to suit their specific application, such as cold climate specifications, salt-resistant coating, and a 400 V output.

Combined with our UPSs, it can supply stable power without interruptions. Standard operation time is 2 to 3 hours. However, extended long-term backup is possible by connecting an optional large-capacity fuel tank.

Details of this product are provided in the "New Product Introduction" section of this report.

Fig. 6 *SANUPS G53A*

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Development of the *SANUPS A22A* Modular Uninterruptible Power Supply

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Toshifumi Nishizawa Yoshimi Sunohara Tomoharu Tanaka Yuta Abe Mika Takehara

1. Introduction

In recent years, due to the advancement of information and communications technology and the popularization of applied products, stoppages of 24/7 data centers and public infrastructure have an even greater impact on society. For this reason, uninterruptible power supplies (UPS) which provide backup power to load devices in those facilities must also be highly reliable.

SANYO DENKI has developed the *SANUPS A22A*, a modular double conversion online UPS, to back up devices requiring high reliability by using a parallel redundant operation system, which, in combination with modular 5 kVA units, also makes it possible to perform maintenance on individual UPS modules while supplying power to the devices.

This article describes the overview and features of the *SANUPS A22A*.

2. Product Overview

The *SANUPS A22A* was designed to provide backup power for mission-critical devices used in data centers and public infrastructure facilities which require high reliability. It consists of inverter modules, battery packs, and a cabinet. Up to twenty-one 5 kVA inverter modules can be paralleled in the cabinet.

The lineup includes a 3-phase 4-wire model with a maximum output capacity of 105 kVA, and a single-phase 2-wire model with a maximum output capacity of 50 kVA. With the modular configuration of the 5 kVA units, optimal output capacity can be selected by adjusting the number of inverter modules used. In addition, backup time can be extended by adding optional battery modules. As such, this UPS can be flexibly arranged in an optimal system configuration for the operating environment.

Moreover, the same inverter module is used for both the 3-phase 4-wire model and the single-phase 2-wire model, and cabinets are available in either 3-phase or single-phase output configuration.

Figure 1 shows the appearance of the cabinets, and Figure 2 shows the appearance of the inverter module and battery packs. The cabinets are available in two types: one which accommodates up to four inverter modules for output capacities up to 20 kVA, and one which accommodates up to seven inverter modules for output capacities up to 35 kVA.

Fig. 1 Cabinets

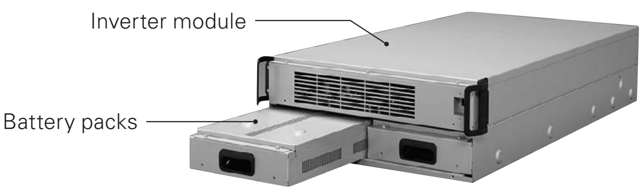


Fig. 2 Inverter module and battery packs

The circuit configuration features a double conversion online topology (3-level type) which supplies high-quality power unaffected by input voltage or input frequency, thereby achieving the highest efficiency in the industry.*

The output voltage setting options are 380 V, 400 V, and 415 V for the 3-phase 4-wire model, and 220 V, 230 V, and 240 V for the single-phase 2-wire model, making this device suitable for the various voltage standards of Asia and Europe.

Moreover, the cabinets have a user-friendly operating touch screen for intuitive operation.

3. Features

3.1 Parallel redundant operation

The *SANUPS A22A* features parallel redundant operation, and in the 3-phase output configuration, up to twenty-one 5 kVA inverter modules can be connected in parallel. Figure 3 shows a parallel redundant circuit diagram. With this feature, if you have at least one inverter module more than that which is required to cover the load capacity, even if one inverter module fails, inverter operation can continue with remaining inverter modules, offering a highly reliable power supply.

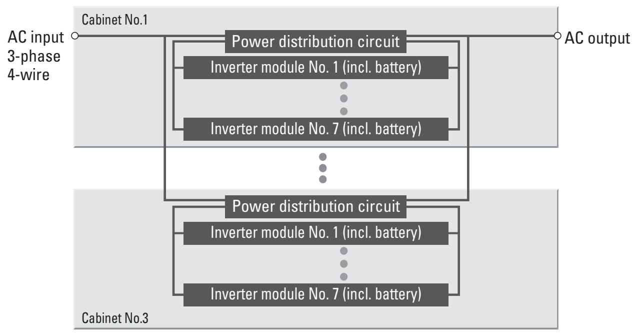


Fig. 3 Parallel redundant circuit diagram

3.2 Flexible system configuration

The modular design allows users to select the output capacity in 5 kVA increments depending on the number of inverter modules connected in parallel. The output capacity options are up to 105 kVA for the 3-phase 4-wire model, and up to 50 kVA for the single-phase 2-wire model. Also, backup time can be extended by adding optional battery modules. As such, this UPS can be flexibly arranged in an optimal system configuration to satisfy the needs of the operating environment.

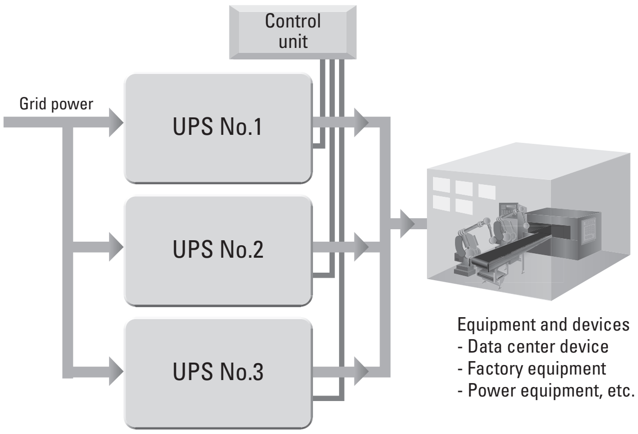
3.3 Fully autonomous control method

For this product, the inverter modules can operate in parallel using a fully autonomous control method.

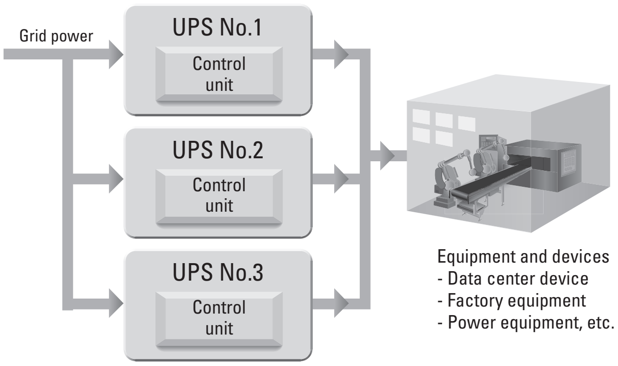
In general, when paralleling the inverters in UPS units, the output of each inverter is in alternating current, so it is necessary to synchronize their voltage amplitude, phase, and frequency. If the AC output from the inverter modules operating in parallel gets out of sync with each other, even slightly, this may cause a potentially damaging voltage disparity. Moreover, the output of each inverter is connected only with wiring, so the resistance between inverters is extremely small and even a slight voltage difference causes excess current (called cross-current) to flow between inverters as per Ohm's law, that is, "current = voltage difference/resistance." In such cases, an individual inverter would be unable to supply this excess current, causing the inverter to stop. To suppress this cross-current, there is a control unit, as shown in Figure 4 (a), which enables parallel operation. This form of parallel operation by distributing the same voltage command and phase/frequency command to each inverter is known as the "central control method."

However, if this central control unit fails, the whole system would stop. Even if the inverter module was very reliable, if the reliability of the central control unit was low, the reliability of the whole system would be low.

Therefore, this product uses a fully autonomous control method characterized by a control unit on each individual inverter module instead of a central control unit for the parallel operation. Parallel operation is achieved by each inverter module independently suppressing cross-currents. As a result, by individually controlling each inverter module and eliminating the risk brought by the central control unit, the reliability of the whole system is improved.



(a) Central control method



(b) Fully autonomous control method

Fig. 4 Control methods for parallel operation

3.4 Improved maintainability

The modular design makes service work such as replacing inverter modules and battery packs much easier. Figure 5 shows how the inverter module and battery packs are installed.

The inverter module and battery packs are plug-in types, allowing them to be installed and removed from the front of the UPS. Even in the unlikely event that one of the inverter modules fails during parallel redundant operation, it would be possible to hot swap (insertion/removal while connected to a load) it without interrupting the inverter power, enabling maintenance work to be performed swiftly.

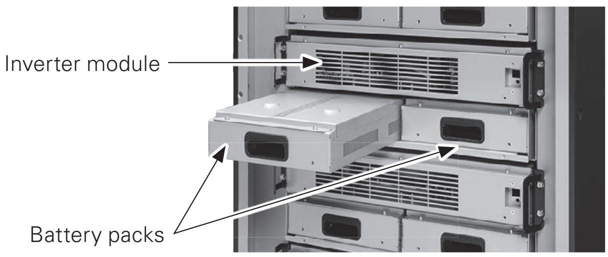


Fig. 5 Installation image

3.5 Industry's highest efficiency

By adopting the 3-level method for the rectifier and inverter conversion circuit, we have achieved the highest efficiency in the industry * (94.5%). This reduces running costs and contributes to energy saving.

3.6 Output power factor of 1.0

In recent years, an increasing number of power supplies for servers are equipped with an input current power factor correction function, meaning that load power factors are also increasing.

In light of such circumstances, we achieved an output power factor of 1.0 for this product. As such, it is possible to supply sufficient power even for load devices with high input power factors, which are predicted to increase in the future.

3.7 Wide input range

The allowable input voltage range is wide: -20 to +15% at a load level above 70%, and -40 to +15% at a load level 70% or below.

This wide input voltage range reduces the frequency of switching to battery operation even when the input power source is unstable, as well as minimizes battery drain and wear caused by frequent discharging.

3.8 Improved user experience

The *SANUPS A22A* features a vibrant touch screen user interface arranged in an intuitive, user-friendly screen layout. Figure 6 shows the UPS system's operation status screen. On the current model, operation status is displayed using LEDs, however, this product has a touch screen that vividly illustrates the status using easy-to-understand animations. Each menu is permanently displayed with tabs, and by pressing the desired menu tab, the operator can jump swiftly to another screen, making the UPS easier to navigate.

Furthermore, servicing has been simplified thanks to the intuitive user interface as maintenance personnel can operate the touch panel, for example, to set the output voltage of the UPS.

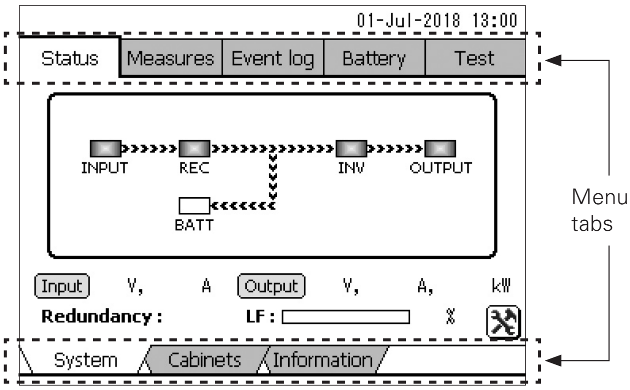


Fig. 6 UPS operation status screen

3.9 Battery management function

The product is equipped with self-diagnosis functions such as an automatic battery self-test and a battery service life management function to ensure reliable backup of load equipment during power outages. There are also battery management functions that improve reliability. Such functions include a battery service life warning, a display of total battery run time, and an estimated backup time.

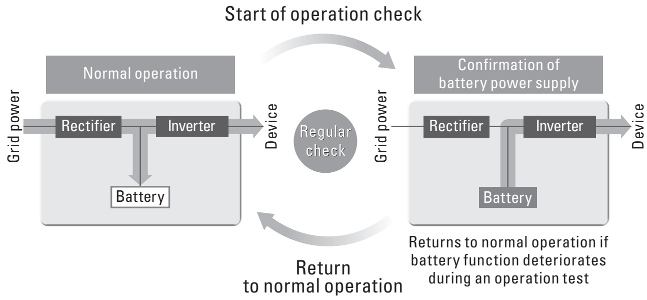


Fig. 7 Battery self-test

4. Circuit Configuration

Figure 8 shows the circuit diagram for this product.

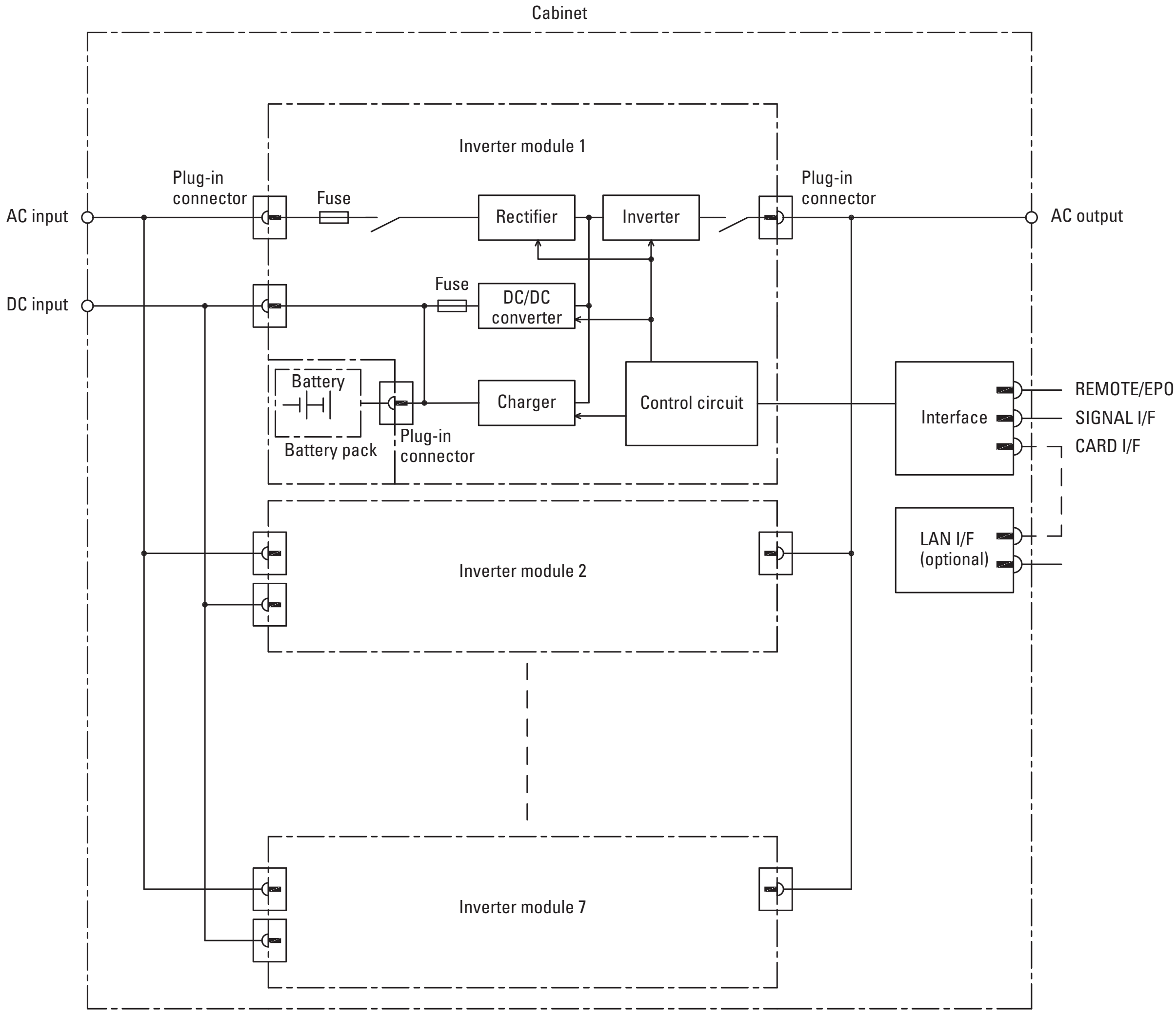


Fig. 8 Circuit diagram

4.1 Main circuit configuration

The *SANUPS A22A* consists of a cabinet and an inverter module.

The cabinet contains power distribution circuits for AC input and AC output, and an interface.

The inverter module contains components such as a rectifier, an inverter, a DC/DC converter, a charger, and battery packs. The rectifier and inverter use the 3-level method for high efficiency.

The inverter modules and battery packs are connected to the cabinet via a plug-in connection using plug-in connectors, and therefore can be hot-swapped (inserted/removed while connected to a load) from the front of the UPS.

4.2 Control circuit configuration

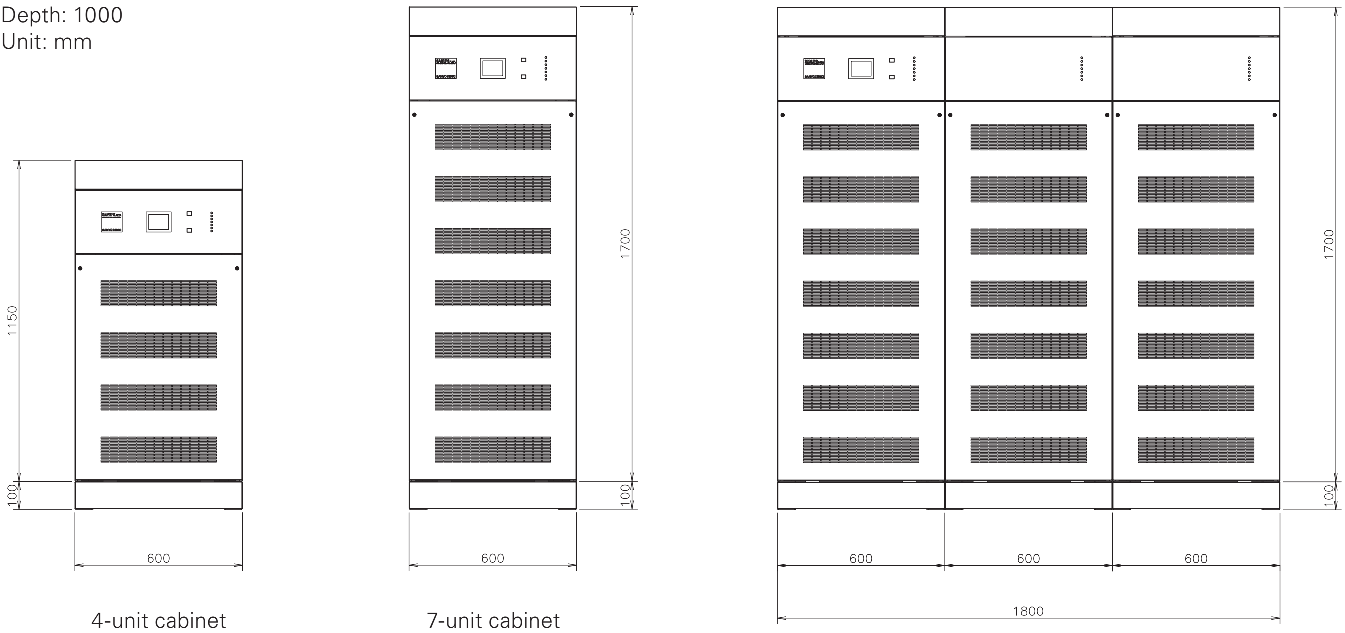
In contrast to the current model, the control circuit in the *SANUPS A22A* predominantly uses surface-mount components to create a smaller footprint.

The control power circuit adopts the quasi-resonant RCC method for high efficiency.

5. Specifications

Table 1 shows the specifications of this UPS and Figure 9 shows the dimensions.

Depth: 1000
Unit: mm



4-unit cabinet
Max. output capacity 20 kVA

7-unit cabinet
Max. output capacity 35 kVA

7-unit cabinet x 3
Max. output capacity 105 kVA
3-phase 4-wire model

Fig. 9 Dimensions

Table 1 Specifications

Item		3-phase 4-wire model	Single-phase 2-wire model	Remarks
Type	**UPS topology**	Double conversion online	Double conversion online	
	Cooling method	Forced air cooling	Forced air cooling	
	Inverter system	High-frequency PWM	High-frequency PWM	
	Inverter structure	Modular	Modular	Hot-swappable
	Battery structure	Modular	Modular	Hot-swappable
AC input	**No. of phases/wires**	3-phase 4-wire	3-phase 4-wire	
	Rated voltage	380 V, 400 V, 415 V	380 V, 400 V, 415 V	
	Voltage range	Within -40% to +15% of rated voltage	Within -40% to +15% of rated voltage	At load level < 70% Recovery voltage is -20% of rated voltage or more
		Within -20% to +15% of rated voltage	Within -20% to +15% of rated voltage	At load level ≥ 70%
	Rated frequency	50/60 Hz (auto-sensing)	50/60 Hz (auto-sensing)	
	Frequency range	Within ± 8% of rated frequency	Within ± 8% of rated frequency	
	Power factor	0.97 or more	0.95 or more	When input voltage harmonic distortion is less than 1%
AC output	**Rated capacity**	5 kVA / 5 kW	5 kVA / 5 kW	Apparent power / active power
	No. of phases/wires	3-phase 4-wire	Single-phase 2-wire	
	Rated voltage	380 V, 400 V, 415 V	220 V, 230 V, 240 V	
	Voltage regulation	Within ± 2% of rated voltage	Within ± 3% of rated voltage	At rated output
	Rated frequency	50/60 Hz	50/60 Hz	Same as input rated frequency
	Frequency regulation	Within ± 1, 3, 5% of rated frequency	Within ± 1, 3, 5% of rated frequency	Configurable
		Within ± 0.5%	Within ± 0.5%	During battery operation
	Voltage harmonic distortion	2% or less / 5% or less	3% or less / 7% or less	At linear load / rectifier load, rated output
	Transient voltage fluctuation – **For abrupt load change**	Within ± 3% of rated voltage	Within ± 5% of rated voltage	For 0 ⇔ 100% load step changes
	Transient voltage fluctuation – **Loss or return of input power**			At rated output
	Transient voltage fluctuation – **Input voltage during rapid change**			For ± 10% rapid voltage changes
	Load power factor	0.7 (lagging) to 1.0	0.7 (lagging) to 1.0	
	Overload capability	120% (30 min)	120% (30 min)	
		150% (1 min)	150% (1 min)	
Overcurrent protection		Drop (instantaneous), inverter shutdown	Drop (instantaneous), inverter shutdown	
Efficiency		94.5%	94.5%	At rated output
Acoustic noise		55 dB or less	55 dB or less	1 m from front of device, A-weighting
Operating environment	**Ambient temperature**	0 to +40˚C	0 to +40˚C	During operation
		-15 to +40˚C	-15 to +40˚C	During storage, transportation
	Relative humidity	10 to 95% (non-condensing)	10 to 95% (non-condensing)	During operation, storage, transportation
Installation location		Indoors	Indoors	
Operating altitude		2000 m or less	2000 m or less	
Battery	**Battery type**	Small-sized valve-regulated lead-acid (VRLA) battery	Small-sized valve-regulated lead-acid (VRLA) battery	
	Battery configuration	12 V, about 9 Ah	12 V, about 9 Ah	
	Batteries per inverter module	16	16	
	Backup time	10 min	10 min	At 25˚C ambient temperature, load power factor of 0.75, using new, fully charged batteries.

6. Conclusion

This article has introduced the overview and features of the *SANUPS A22A* modular uninterruptible power supply.

This device, with its adaptable modular design and resilient parallel redundant operation, can meet the power supply requirements of mission-critical applications that demand high reliability and availability. Furthermore, it offers a wide output capacity range and backup time to achieve a flexible and optimal system configuration for our customers' operating environments.

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

* Based on our own market research as of August 7, 2018, conducted among double conversion online UPSs on the market with equivalent voltage and capacity.

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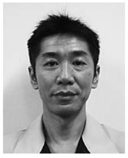

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Development of the *SANUPS G53A* Emergency Diesel Generator

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Masakazu Uchida Masato Yamada

1. Introduction

To date, SANYO DENKI has delivered many emergency diesel generators to telecommunications carriers and power companies, and the majority of these have been custom-made products tailored for each customer's requirements.

Meanwhile, in the emergency diesel generator market, there are generators standardized to meet Japan's Building Standard Law and Fire Service Law. In recent years, our customers have also demanded standardized emergency diesel generators to reduce installation and operating costs.

Against such a backdrop, we developed the *SANUPS G53A*, an outdoor emergency diesel generator that complies with Japan's Fire Service Law, as a solution for building disaster management that can also satisfy a wide-variety of customer requirements.

This article describes the details and features of the new product.

2. Product Overview

The *SANUPS G53A* is available in three different output capacities of 200/230 kVA, 250/290 kVA, and 290/320 kVA.

Figure 1 shows the appearance of the *SANUPS G53A*. It has a cubicle suitable for outdoor installation that contains a diesel engine, AC generator, and control panel.

Fig. 1 *SANUPS G53A*

Figure 2 shows the control panel mounted inside the cubicle.

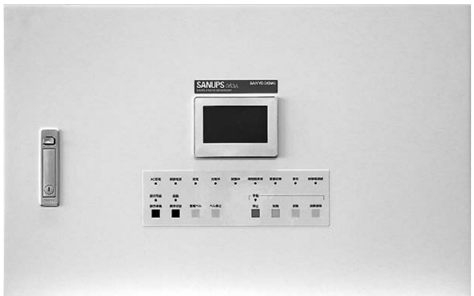


Fig. 2 Control panel front

3. Features

3.1 IoT-enabled

By using a general-purpose programmable logic controller (hereinafter "PLC"), we made the new product IoT-ready. It can connect to LAN and peripheral devices via general-purpose interfaces such as Ethernet and RS-485.

3.2 Broad customization options

This product has a broad range of made-to-order customization options including cold climate specifications, salt-resistant coating, 400 V voltage model, added measurement items, and a logging function.

3.3 Compliant with Japan's Fire Service Law

This product is safe for use as it satisfies the Nippon (Japan) Engine Generator Association requirements: Design Requirements for Emergency Use Engine-driven Power Generators (NEGA C 311).

3.4 Long-term backup

Combined with our uninterruptible power supplies (UPS), this product can supply power without interruptions.

Moreover, by connecting an optional large-capacity fuel tank, even longer extended backup is possible.

4. Product Functions

Figure 3 shows a function block diagram of the *SANUPS G53A*.

The *SANUPS G53A* consists of an output panel that has a generator output circuit (main circuit) and a control panel that has a generator control circuit containing a PLC, measurement circuit board, relay circuit board, and switch/LED circuit board.

4.1 Real-time monitoring of generator information

By combining a PLC that manages the generator information with a customer's management system via network connection, the generator information (status, power generation status, various measurement values) can be remotely monitored in real time.

(1) Measurement circuit board

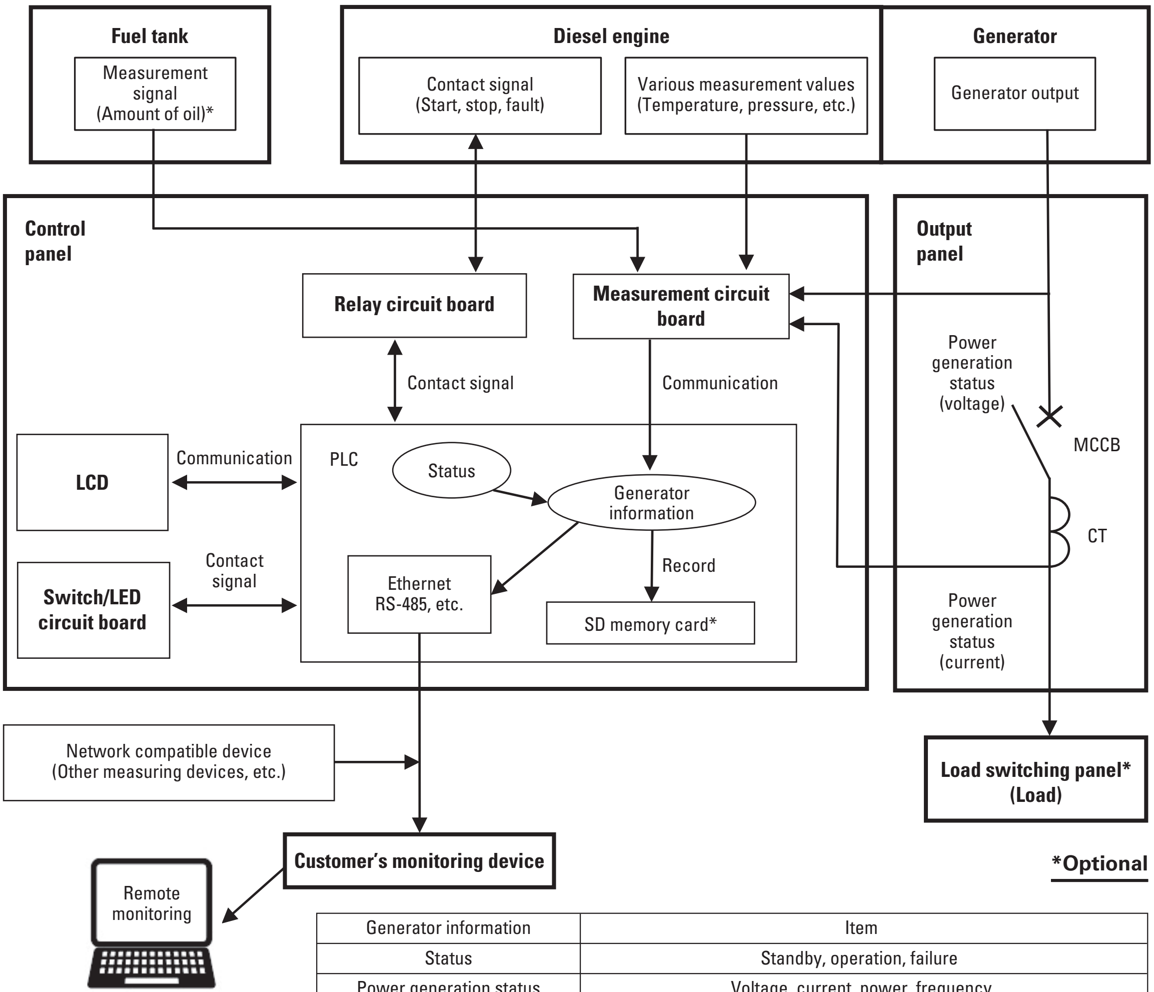
The measurement circuit board measures various measurement values such as output panel's output power and current, as well as the diesel generator's temperature and pressure. These measurement values are sent to the PLC and used for displaying generator measurements and controlling the generator.

(2) PLC

Manages and controls the generator status (standby, operation, failure) and measurement circuit board information. Can connect to a network via general-purpose interfaces such as Ethernet and RS-485.

(3) Logging function

An optional function for recording generator information when failures occur on an SD memory card.



Generator information	Item
Status	Standby, operation, failure
Power generation status	Voltage, current, power, frequency
Various measurement values	Cooling water temperature, lubricating oil pressure, battery voltage, etc.

Fig. 3 Function block diagram of the SANUPS G53A

5. Specifications

Table 1 shows the specifications of the *SANUPS G53A*.

Table 1 Specifications of the *SANUPS G53A*

Items			Unit	G53A204P	G53A254P	G53A294P
Generator	Rated output capacity	Apparent power	kVA	200/230	250/290	290/320
		Active power	kW	160/184	200/232	232/256
	Protection rating / Cooling system			IP20/IC01		
	Rated voltage		V	200/220		
	Current		A	578/604	722/762	838/840
	No. of phases/wires		–	3-phase 3-wire		
	Rated frequency		Hz	50/60		
	Speed		min^{-1}	1500/1800		
	No. of poles		–	4		
	Power factor		–	0.8		
	Excitation type		–	Brushless		
	Thermal class		–	F		
Engine	Name		–	DP086LA	P126TI	P126TI-II
	Type		–	Vertical water-cooled 4-stroke cycle diesel engine		
	Output power		kW	196/220	234/267	258/296
	Turbo charger		–	Included		
	No. of cylinders		–	6		
	Bore × stroke		mm	111 × 139	123 × 155	123 × 155
	Displacement		L	8.071	11.051	11.051
	Cooling system		–	Radiator type		
	Radiator exhaust airflow		m^3/min	190/224	370/433	450/530
	Amount of cooling water		L	44	51	51
	Fuel	Type	–	Diesel fuel (JIS No. 2)		
		Specific consumption	L/h	43.7/51.2	54.6/67.3	62.4/70.8
		Consumption rate	g/kWh	207/211	206/218	203/208
		Tank capacity	L	110	170	170
		Running time	h	2.5/2.1	3.1/2.5	2.7/2.4
	Lubricating oil capacity		L	15.5	23	23
	Starting system		–	Electric starting motor		
	Starting motor		V-kW	24-6.0	24-6.0	24-6.0
	Battery	Battery type	–	Valve-regulated lead-acid (VRLA) battery (MSE series)		
		Battery capacity	V-Ah	24-150	24-150	24-150
Acoustic noise			dB(A)	85 max.(1)		
Operating environment			–	Ambient temperature: -10 to +40˚C, Relative humidity: 85% max. (non-condensing), Altitude: 300 m or less (2)		
Communication		Interface	–	Ethernet port: 100 BASE-TX / 10 BASE-T (4) Serial port (3): RS-422/RS-485		
		Protocol	–	MODBUS TCP, MODBUS RTU (4)		

(1) The average of the 4 points in each direction in each 1-meter interval.
(2) Output will have to be offset if the operating environment differs from this.
(3) Optional
(4) Ethernet is a trademark of Xerox Corporation, USA. MODBUS is a trademark of Schneider Electric SA.

6. Conclusion

This article introduced the *SANUPS G53A*, which is equipped with IoT functions and can be customized with a wide variety of options to suit each customer's particular application.

With the IoT functions, the new product enables remote monitoring of generator information, reducing labor time of the management staff. Also, its wide customization options can meet the various needs of customers.

In recent years, Japan has faced numerous natural disasters, and securing emergency power supplies in the event of prolonged power outages has become a point of focus for customers in charge of disaster management for local governments or corporate crisis control.

In addition to generators capable of long-term backup such as the *SANUPS G53A*, we also manufacture and sell uninterruptible power supply (UPS) products that supply continuous power during power outages. SANYO DENKI is a one-stop provider of systems enabling long-term and high-quality power backup with our products, services, and technologies.

We will continue to contribute to the realization of a safe and secure society for customers through the supply of emergency power.

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Servo Systems Division

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The applications and requirements for servo systems are diversifying in line with changes in industrial structure and *monozukuri*, such as globalization and the spread of information and communication technology. Against such a backdrop, the Servo Systems Division is working alongside customers to develop new products that create new values.

This report will focus on new products developed in FY 2018 such as servo motors, servo amplifiers, and controllers, and introduce the various features of each product to explain how they create value for our customers.

First, we launched the *SANMOTION R1* series (flange size 40mm sq. to 80mm sq.), a small-capacity, low-inertia AC servo motor optimal for high hit rate applications. This servo motor meets the need for high acceleration/deceleration driving and high-responsiveness, and achieves higher torque and rotation speed than our current model. This helps to shorten equipment cycle time and improve productivity.

By adding this product to the R series lineup, we have further expanded our selection of motors that are suitable for the required performance and characteristics.

Next, regarding servo amplifier products, we have developed the *SANMOTION R 3E Model* 400 VAC input (150 A, 300 A) for rated outputs ranging from 5.5 to 30 kW that can be used in regions with 400 VAC power sources, such as Europe and Southeast Asia. The depth of this servo amplifier has been reduced while maintaining mounting compatibility with our current model. When changing from a 200 VAC input servo system, a transformer to convert input voltage is no longer required, which helps to make the system more compact. We also enhanced the monitoring functions in order to confirm the remaining component life of the holding brakes and relays, as well as the quality of encoder communication. These monitoring functions can contribute to systematic maintenance of the servo system, as well as breakdown/predictive maintenance.

For controller products, we launched the *SANMOTION C* Motion Controller SMC100. This motion controller is only one-quarter of the volume of our current model, contributing to the space-saving of production equipment such as control panels. EtherCAT communication is used for the motion network, enabling real-time motion control to be performed at high-speed. Moreover, this product also supports an OPC-UA server and Modbus TCP communication, so it can easily be connected to a production management system and peripheral devices. These abundant communication functions contribute to flexible and highly productive *monozukuri* using information and communication technologies.

This article will provide an overview of each new product and their respective features.

■ *SANMOTION R1* Small-Capacity 40, 60, 80mm sq. Low Inertia AC Servo Motor

In recent years, needs have diversified due to the globalization of markets, and there is an increasing demand for multiple motor lineups enabling customers to choose the optimal motor for their specific device and application. In particular, for applications where the main purpose is high-hit rate operation, a small servo motor with a low self moment of inertia is necessary to reduce cycle time.

Due to such circumstances, for applications requiring high-acceleration/deceleration and high responsiveness, we newly developed a small-capacity low inertia AC Servo Motor *SANMOTION R1* series (flange size 40mm sq. to 80mm sq.).

The features of this new model are as follows.

1. Expansion of the torque and rotational speed characteristics

Compared to our current model, the new model R1 has a peak torque approximately 20% higher and a maximum rotational speed approximately 20% faster, thereby achieving a wider operating range. We have designed motor characteristics which not only shorten short-stroke cycle time, but also improve equipment performance in long-stroke applications.

2. Improvement of acceleration performance

Self moment of inertia has been decreased while peak torque has been increased. Peak power rate, which is an indicator of acceleration performance, is up to 1.9 times greater than that of our current model. This makes quick response possible even with a load ten or more times greater than the self moment of inertia. With the new model R1, acceleration/deceleration time, including that of machinery with loads, has been dramatically reduced, enabling optimal performance for high hit rate operation.

3. Optimal proposals for applications

By adding the new R1 model to the R series lineup, customers are able to choose the optimal motor for each axis to suit the device's drive characteristics. By combining the R2 series, which has the versatility to cover a wide-range of applications, the R5 series, which has low torque and ripple for axes which require precision control, and this new model R1 series, which targets high acceleration/deceleration and high responsiveness, it is possible to significantly improve the overall operating characteristics of devices, and increase operating time.

Details of this new product are provided in the "New Product Introduction" section of this Technical Report.

■ *SANMOTION R 3E Model* 400 VAC Input Servo Amplifier (150 A, 300 A)

In line with the globalization of industry, there is an increasing need for 400 VAC input servo systems, primarily in European and Asian regions. As such, we newly developed the *SANMOTION R 3E Model* 400 VAC input servo amplifier (150 A, 300 A) to drive large-capacity servo motors with rated outputs ranging from 5.5 kW to 30 kW. With the addition of the 400 VAC input servo system, which can drive the same motor output as the 200 VAC input servo system, there are even more choices to realize optimal servo systems that suit our customers' particular power supply specifications.

The features of this new model are introduced below.

1. Downsized

While maintaining mounting compatibility with the current *SANMOTION R* 400 VAC input servo amplifier, we have reduced the depth of the product by as much as 10% by reducing heat generation.

Also, to use a 200 VAC input servo system in a 400 VAC environment it was necessary to use a step-down transformer to convert power voltage. However, 400 VAC can be directly supplied with this product, eliminating the need for a step-down transformer, thus contributing to downsizing of the system.

2. Enhancement of monitoring functions

This new model maintains the same performance and functions as *SANMOTION R 3E Model* 200 VAC input servo amplifiers while also featuring monitoring functions that monitor remaining life for components such as holding brakes and relays, as well as confirm quality of communication with the servo amplifier and encoder.

For example, the remaining life of the holding brakes is monitored by estimating brake wear from the accumulated braking rotation amount. By assessing remaining component life, the systematic maintenance of servo systems is possible. Monitoring the communication quality between the servo amplifier and encoder is a function enabling confirmation of the communication error frequency using a qualitative value. By using this monitor function, any drops in communication quality from degradation of the communication cable or environmental changes can be detected, and necessary actions can be taken before the equipment stops due to a fault.

3. Usability

A plastic cover that can be opened and closed covers the terminal block that connects the power cables and motor power cables. Wiring work is simplified, as there is no longer a need to take the cover on and off.

Moreover, both the 150 A and 300 A capacity models have a common front side depth of 150 mm. This means that individual cables can be connected easily within the control panel.

Also, a safety module can be added without changing the size of the servo amplifier exterior. This means that this product can also be used as a safety servo amplifier without having to change the mounting.

■ *SANMOTION C* Motion Controller

In recent years, various initiatives have been promoted on manufacturing lines using information and communication technology with the aim of achieving flexible and high productivity *monozukuri*. As such, the controllers used on manufacturing lines are required to have a communication function that enables the necessary information for production management systems to be collected from and transferred to production equipment to achieve effective usage of production information. Moreover, to effectively use space on manufacturing lines and flexibly respond to small-lot, high-mix production, it is preferable to have compact control equipment so the control panel can be downsized.

Against such a backdrop, we developed the *SANMOTION C SMC100*, a compact motion controller with a strengthened function for communication with information devices. The features of this new model are introduced below.

1. Downsized

The volume of this new model has been decreased by one-quarter over that of our current model through high multilayer formation of the PCBs and increasing the density of components. This reduces the space required by control panels and other production equipment, contributing to cost reduction of the system overall.

2. Strengthened network functions

This new model is equipped with an Ethernet-based OPC-UA server/ Modbus TCP communication function to connect to SCADA and other production management systems. These abundant communication functions improve connectivity with peripheral equipment, such as PCs and touch panel displays. Moreover, because EtherCAT is used for the motion network, there is the advantage of being able to connect all devices with Ethernet cables. Being able to wire the network with the same cable also contributes to reduced system costs. Moreover, with the web visualization function, workers can assess the status of production equipment in real-time on their smart phones or other devices. When a problem occurs, the worker is notified immediately of the situation on their smartphone, so they can know instantly when equipment has stopped or is malfunctioning, minimizing manufacturing line downtime.

3. Improved Maintainability

By designing the chassis with high heat dissipation properties, we have been able to eliminate the cooling fan, making the product highly reliable. Moreover, because the data retention function uses nonvolatile memory, there is no need for data recovery work at the end of the service life of a backup battery, which contributes to reduced maintenance costs.

Details of this new product are provided in the “New Product Introduction” section of this Technical Report.

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Development of the *SANMOTION C* Motion Controller SMC100

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1. Introduction

The manufacturing industry is pushing ahead with the development of production equipment embedded with information and communication technology (ICT) to respond faster to changing market conditions and demands. ICT makes it possible to monitor production status in real time, predict when equipment will require maintenance, and respond swiftly to potential issues—all which are vital to maintaining high production standards. As such, motion controllers require communication functions to gather and transmit data from production equipment to production management systems. Moreover, to effectively utilize space on the production line and achieve high-mix low-volume production, compact controllers, which can free up space in control panels, are in demand.

To meet such needs, we developed a compact motion controller which features sequence, motion, and robot control functions, as well as enhanced capabilities for communicating with ICT equipment.

This article introduces the main functions and features of the SMC100—the newest addition to the *SANMOTION C* motion controller lineup.

Fig. 1 Appearance of the SMC100

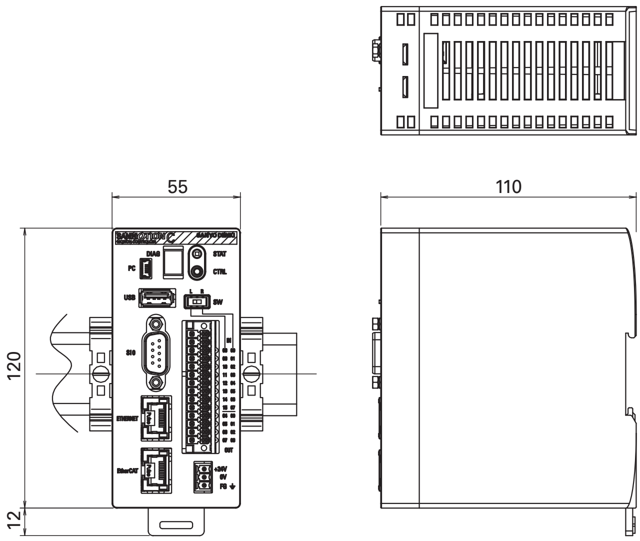

Fig. 2 Dimensions of the SMC100

2. Product Overview

2.1 Appearance and dimensions

Figure 1 shows the appearance of the new *SANMOTION C* motion controller, SMC100, while Figure 2 shows its dimensions.

The product is mounted on a DIN rail for easy installation into a control panel.

2.2. Basic specifications

Table 1 shows the basic specifications of the SMC100. The new product is available in two configurations: the SMC100-A for controlling robots, and the SMC100-B, which specializes in PTP (Point-to-Point) positioning control.

Each model comes standard with EtherCAT interface—an industrial open network—to support motion networks. The high-speed EtherCAT enables real-time monitoring of equipment status. This product is equipped with Ethernet, RS-485, and USB interfaces, and also supports the open protocol Modbus TCP, making it compatible with a variety of devices.

An onboard digital I/O allows the new product to control contacts such as sensors and switches without the need for an additional module.

The new product conforms to the international standards EMC Directive (Europe), UL/cUL (North America), and KC Mark (Korea).

Table 1 Basic specifications

Model no.		SMC100-A	SMC100-B
Interface		EtherCAT (100 Mbps) master function, FoE-compatible	
		Ethernet (10/100/1000 Mbps) protocols (Modbus TCP, OPC-UA)	
		RS-485 (9600 to 115200 bps)	
		USB 2.0 (for memory storage)	
Digital I/O		Digital input: 16 points, 24 VDC, positive/negative common input	
		Digital output: 8 points, 24 VDC, 0.5 A/point, sink output	
Input power supply		19.2 to 30 VDC, 0.8 A (main power supply) 19.2 to 30 VDC, 20 mA (I/O power supply)	
Power consumption		19.2 W	
Cooling method		Passive	
Dimensions (W, H, D)		55 × 120 × 110 mm	
Mass		300 g	
Control function		Sequence control Motion control (electronic cam, electronic gear, linear interpolation, circular interpolation) Robot control (cartesian coordinate robot, SCARA robot, and parallel link robot)	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 visualization	
Standards	UL/cUL	UL 61010-1, UL 61010-2-201	
	EMC Directive	EN 61131-2:2007	
	KC Mark	KN 61000-6-2, KN 61000-6-4	

3. Main Functions

The new product combines the three functions of sequence, motion, and robot control on a single controller. Furthermore, with its web server function, the status of production equipment can be checked from a PC or smartphone. The details of each function are provided below.

3.1 Motion control function

The new product not only features a sequence control function using digital I/O, but also a PTP positioning function, multi-axis synchronization, and an interpolation control function. These features give operators the ability to effortlessly create sophisticated control patterns. Table 2 provides details of the motion control function.

Table 2 Motion control function

Number of controllable axes	8 axes max.
Communication cycle	2 to 16 ms
Control system	Position control, speed control, torque control
Acceleration/ deceleration profile	Trapezoidal, sin², trapezoidal with jerk limit
Unit for positioning control	Arbitrary (pulse, mm, inch, degree)
Programming language	Complies with IEC 61131-3 IL, ST, LD, FBD, SFC, CFC
Motion function block	Homing, incremental mode, absolute mode, constant speed mode, electronic cam, electronic gear

3.2 Robot control function

The SMC100-A is equipped with three types of kinematics to control robot mechanisms. By combining special-purpose motion function blocks, it is possible to perform operations for each robot axis and interpolation control. These functions make it possible to program robot operations in a short period. Table 3 provides details of the robot control function.

Table 3 Robot control function

Number of controllable axes	Robot: 4 axes max.
Communication cycle	8 to 16 ms
Control system	PTP motion, 3D linear interpolation, 3D circular interpolation
Teaching method	Numeric input
Unit for positioning control	Arbitrary (pulse, mm, inch, degree)
Programming language	Motion function block
Robot mechanisms	Cartesian coordinate (3 axes), SCARA (4 axes), parallel link (4 axes)

3.3 Web visualization function

The SMC100 can be accessed via a web browser from a PC or smart device. Figure 3 shows a conceptual image of the web visualization function in use.

The web visualization function has a drawing tool for designing screens to display controller information on smart devices. There is an alarm display, user management, and various other drawing parts, making it possible to create complex programs and movements in a short time.

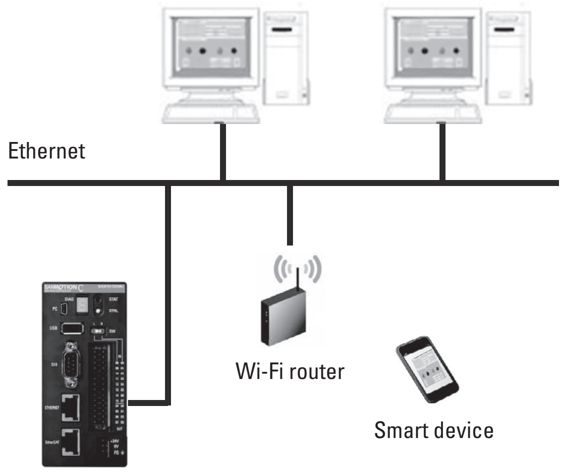

Fig. 3 Conceptual image of the web visualization function in use

3.4 Integrated development software (SANMOTION C Software Tool)

We have developed an integrated development tool for batch management of tasks like configuration, programming, screen creation for web visualization, and data tracking in a tree structure.

3.4.1 Configuration function

Figure 4 shows the configuration screen while configuring SMC100 and fieldbus devices. The layout of this screen enables simple configuration of the parameters for connected devices.

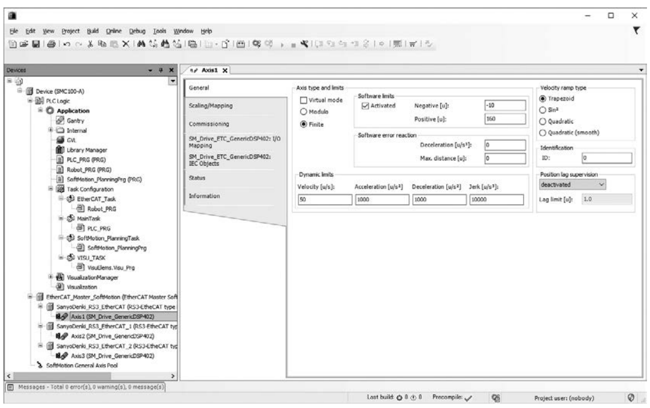

Fig. 4 Configuration screen

3.4.2 Programming function

Figure 5 shows an example of a screen for creating application programs. IEC 61131-3-compliant programming languages IL (instruction list), LD (ladder diagram), ST (structured text), SFC (sequential function chart), FBD (function block diagram), and CFC (continuous function chart) are available. Moreover, motion function blocks for motion and robot control streamline programming tasks.

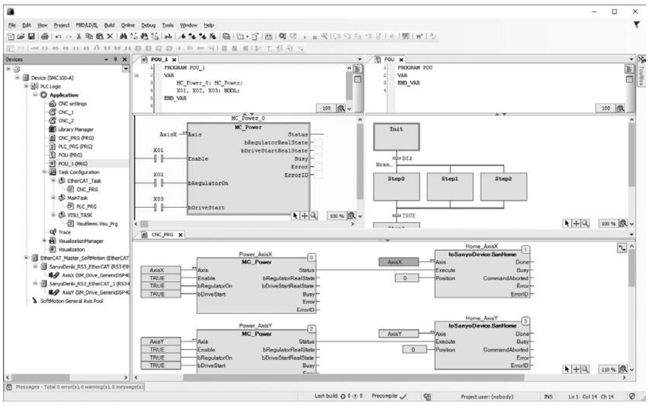

Fig. 5 Programming screen

3.4.3 CNC editor function

The new product also has a function to automatically convert CAD data (DXF file) into DIN 660250-compliant G-code. Figure 6 shows the CNC editor screen. This function automatically generates the G-code control program, reducing the time needed for application development.

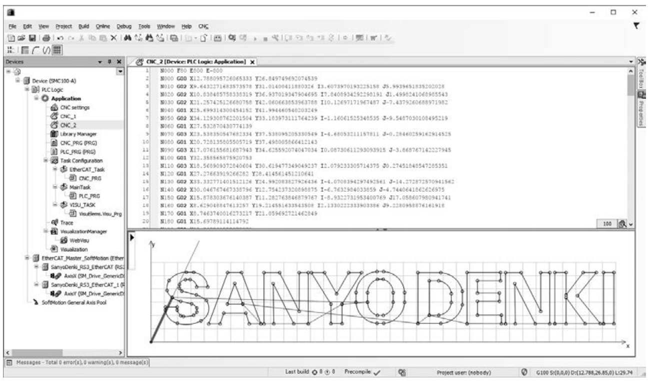

Fig. 6 CNC editor screen

4. Product Features

4.1 Downsizing

The volume of the new model has been reduced to one-quarter of the current model's by adopting multi-layer PCBs and high-density component mounting. Reducing the product size can help optimize control panel design. Table 4 shows a size comparison with the current model.

Table 4 Size comparison with the current model

Item	SMC100 series (new model)	SMC26x series (current model)
Dimensions (W, H, D) [mm]:	55 × 120 × 110	270 × 120 × 110
Volume [cm^3]	726	3240

4.2 Strengthened network functions

Figure 7 shows the connection configuration of the network.

The SMC100 features Ethernet-based OPC-UA and Modbus TCP communication protocols for sharing data with SCADA and other management systems. OPC-UA is a communication protocol that is not manufacturer or device-dependent. Additionally, the built-in Modbus TCP open protocol delivers improved compatibility with PCs, touch panel displays, and other peripherals. Also, using EtherCAT for the motion network provides the added benefit of being able to connect to all devices via an Ethernet cable. The ability to connect a network with the same kind of cable helps reduce system costs.

Furthermore, with a wireless environment and the web visualization function, operators can view the status of production equipment in real time via a smart device. If a fault occurs, operators will be immediately notified via their smartphone so that equipment downtime can be minimized.

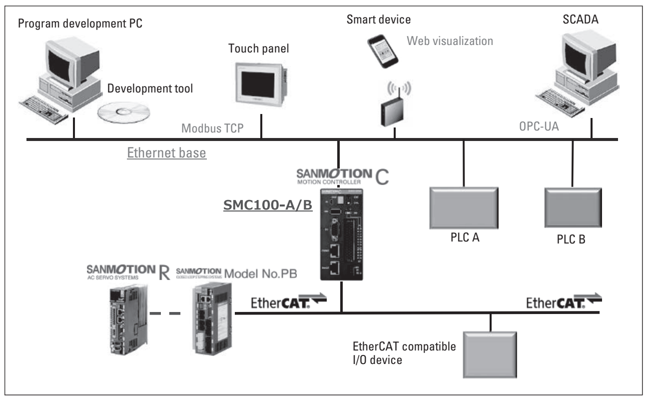

Fig. 7 Network connection configuration

4.3 Improved maintainability

The innovative design of the casing resulted in better heat dissipation, which eliminated the need for a cooling fan, further enhancing the reliability of the new model. Data storage uses non-volatile memory to eliminate backup battery life worries and data loss risks, reducing maintenance or data recovery costs.

5. Conclusion

This article introduced the main functions and features of the SMC100-A and SMC100-B, which are the newest additions to our *SANMOTION C* motion controller lineup. Compared to the current model, the new model

(1) is smaller to help optimize control panel design and save space;
(2) supports a variety of communication protocols such as Ethernet-based OPC-UA and Modbus TCP, for improved compatibility with production management systems such as SCADA, and peripheral equipment; and
(3) features a web-based data visualization function for checking the operating status of equipment via smartphone or PC so that operators can quickly respond to any problems that may arise.

The new model helps save space on the production line, enables efficient data transmission between devices, and helps develop production equipment that effectively utilizes production data.

We will continue to develop products with features that meet market requirements to help create new value.

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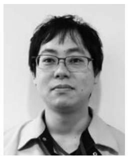

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Development of the *SANMOTION R1* Series Small-Capacity 40, 60, and 80 mm sq. Low Inertia AC Servo Motors

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Jun Kitajima Mai Shimizu Takashi Matsushita

1. Introduction

Since SANYO DENKI's compact, high torque, high efficiency medium inertia R2-Series was released in 2006, it has contributed to creating value for our customers' devices and built a reputation as a long-running solution around the world by demonstrating its high standard of performance.(1) To date, we have released various models, including small-capacity R2 motors ranging in size from 40 to 80 mm sq., as well as medium and large-capacity models, ranging from 86 to 275 mm sq.(2) These products are being used for FA and a wide variety of other applications. However, with the globalization of markets in recent years, needs are becoming increasingly diversified. In order to offer our customers the optimal product for their equipment and application, there is a pressing need to offer a more diverse series lineup.(3) (4) In particular, in industrial equipment where high-hit rate operation is paramount, there is an increasing demand for servo motors with small motor inertia in order to shorten cycle time.

Acknowledging this trend, we newly developed the *SANMOTION R1* series small-capacity low inertia AC servo motor (flange size: 40 to 80 mm sq.) for applications requiring high-acceleration/deceleration drive and high response. This new product exhibits high acceleration performance in applications with low load inertia, which gives customers the optimal solution bundled together with our current models. This article focuses on the following three topics.

(1) Significance of low inertia motors
(2) Technical points of low inertia motor development
(3) Advantages of low inertia motors

2. Significance of Low Inertia Motors

If a servo motor is described as being "*low* inertia," it merely identifies its relative position compared to other models in a series, and there is no clear quantitative definition as to what constitutes as "*low* inertia."

As such, when determining the various figures concerning a motor's moment of inertia at the outset, one should consider the fundamental significance of such a motor in order to discuss what is best-suited to our customers. Here, let's consider the significance of the moment of inertia from three angles.

(1) Improved peak angular acceleration under load

Figure 1 provides a simple model of a two-inertia system. The load is connected to the motor's output shaft via a coupling. The angular acceleration, α, of the motor connected to a load is derived with the following formula:

$$\alpha = \frac{T_m}{J_m + J_L} \quad [\mathrm{rad/s^2}] \qquad (1)$$

where T_m is torque [N m], J_m is motor inertia [kg m^2], and J_L is load inertia [kg m^2].

To be deemed low inertia, the motor inertia must not only be low, but the torque must also meet acceleration requirements while under load.

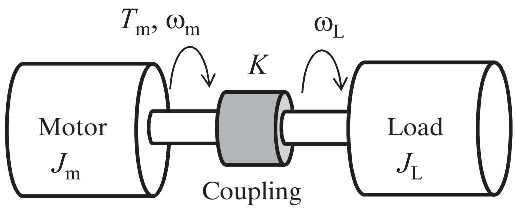

Fig. 1 Simple model of a two-inertia system

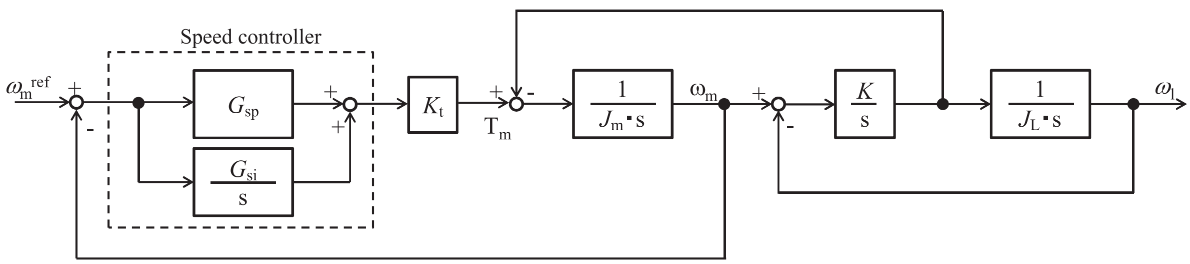

Fig. 2 Two-inertia system speed feedback control with a speed controller

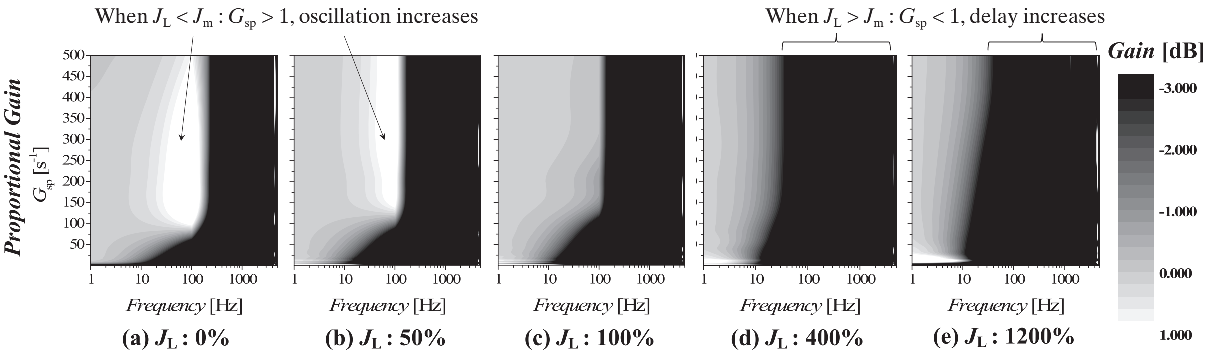

Fig. 3 Effect of different load inertia ratios on the frequency response characteristic of the speed loop

(2) Improved stability of servo systems

Figure 2 shows a block diagram of a two-inertia system speed feedback control with a speed controller.(5) This figure expresses the relationship between the speed of the motor shaft, ω_m, in relation to the velocity command, ω_m^{ref}, and the speed of the load, ω_L , shown in the simple model of Figure 1.

In this figure, a sine wave with the frequency f was entered into ω_m^{ref} as the command value and used to measure the frequency response of the output ω_m. Based on this, using f and proportional gain G_{sp} as independent variables, and the amplitude gain is expressed as contours in Figure 3. This figure expresses a Bode plot in contour display. Gray indicates zero gain, the whiter levels indicate positive gain, and the darker levels indicate negative gain. Either positive or negative changes means that control is not stable.

Here, in Figure 1, if the load inertia is varied relative to the motor inertia, changes will occur in the stable, gray areas, as shown in Figure 3. J_L is defined as 100% when J_L equals J_m. For loads where J_L increases (Fig. 3 (d) and (e)), the darker area, which means the gain is lower than 0 dB, will spread. In contrast, if J_L is less than 100%, that is, the load inertia is lower than the motor inertia (Fig. 3 (a) and (b)), the positive gain region grows, causing the system to oscillate. By increasing proportional gain, G_{sp}, the stable region can be improved; however, in fact, oscillation will occur if a certain value is exceeded. Regarding this loss of control system stability due to the load inertia ratio, stability can be improved by a compensator for loads where $J_L > J_m$.(6) However, the servo system becomes fundamentally unstable for loads where $J_L < J_m$.(7)

(3) Energy-saving

Concerning section (2), motor input energy also changes depending on the load inertia ratio. If the moment of inertia ratio is J_L = 100%, the kinetic energy of the load's rotating body will be the local and absolute maximum.(8) At the same time, even if the two-inertia system includes a transfer function, there exist conditions that minimize the input energy.(9) (10)

It is clear from the preceding sections (1) through (3) that to improve servo performance the ratio of motor inertia to load inertia is important. This confirms the importance of offering a motors that have a wide range of inertia ratios and offer high acceleration for industrial equipment.

With this in mind, in the early days of developing this product, SANYO DENKI first analyzed a vast amount of servo motor sizing data gathered from customers in order to determine what was the appropriate level of moment of inertia for products by each rated output. Figure 4 shows the distribution of applications in relation to load inertia and rated output. This figure expresses the motor inertia of low inertia and medium inertia motors using a dash-dotted line and solid line, and the 20-fold value as a dotted line and dashed line. Through this figure, we can tell that many devices can be stably controlled using a medium inertia motor. However, for some devices, even if the motor's required rated output increases, it is clear that there are applications where the device's load inertia is small. Moreover, if this plot were analyzed by equipment industry, in the case of robots and machine tools, the load inertia increases in proportion to the required motor output. However, for semiconductor manufacturing equipment, conveyors, and other applications that require high acceleration and speed, the load inertia is low.

In other words, the concept of the low inertia R1-Series was to develop motors optimized for particular applications by offering more stable control of loads in areas not covered by medium inertia models, as well as improve the acceleration and responsiveness of devices.

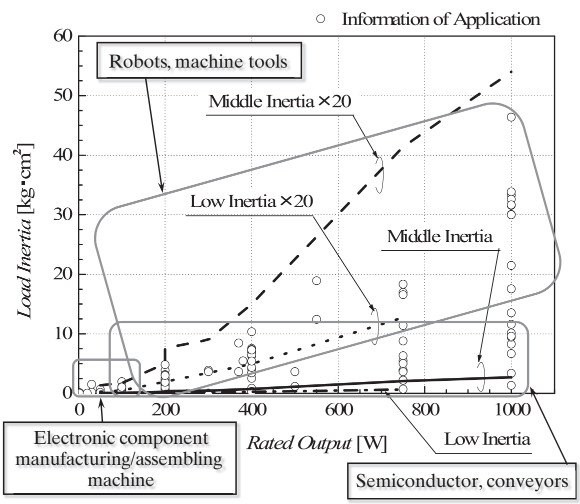

Fig. 4 Distribution of applications in relation to load inertia and rated output

3. Technical Points of Low Inertia Motor Development

Next, we will look at our approach for improving the performance of low inertia motors.

The moment of inertia around the center axis of the cylinder, J, is obtained from the following formula:

$$J=\frac{1}{32}\pi\rho l d^4 \quad [\mathrm{kg\cdot m^2}] \tag{2}$$

where ρ is density [kg/m³], l is length [m], and d is outer diameter [m].

Meanwhile, the torque generated by the motor armature, T, is determined using the following formula:[11] [12] [13]

$$T=\frac{\pi}{2}\cdot\frac{\pi}{2\sqrt{2}}\cdot k_w\cdot ac\cdot B_g\cdot D^2 l \quad [\mathrm{N\cdot m}] \tag{3}$$

where k_w is winding factor, ac is specific electric loading [A/m], B_g is specific magnetic loading [Wb/m²], D is armature internal diameter [m], and l is armature core thickness [m].

Armature inner diameter, D, and rotor outer diameter, d, are separated by a certain air-gap length. Accordingly, we can ascertain from formula (2) and formula (3) that the moment of inertia and torque are in a correlative relationship through the stator's internal diameter D; therefore, as the moment of inertia grows smaller, so too does the amount of torque generated. Of course, it is possible to increase the working area of the electromagnetic force by increasing the thickness of the armature's iron core l. However, due to a recent demand for servo motors to be compact while delivering high output, it is difficult for manufacturers to increase motor length. Therefore, to fundamentally improve torque, specific electric loading and specific magnetic loading must be increased.

To increase specific magnetic loading, the field flux source, that is, the magnetic force of the permanent magnet, must be strengthened. However, as Figure 5 shows, the growth trend for maximum energy products of rare-earth magnets has plateaued since around 2006;[14] therefore, achieving high torque by increasing field magnetic force is difficult. In light of this, SANYO DENKI decided to focus on improving torque for acceleration by increasing specific electric loading. In other words, we improved motor performance by improving the fill factor of the armature winding. SANYO DENKI has state-of-the-art winding technology specializing in high fill factor.[4] By combining production technology, our windings maximize the utility of slot areas.

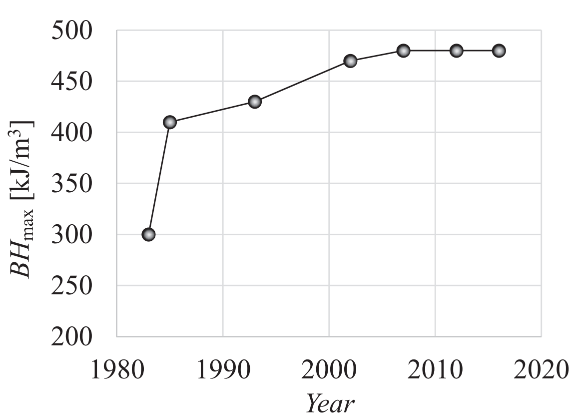

Fig. 5 Growth trend for maximum energy product of rare-earth permanent magnets

4. Advantages of Low Inertia Motors

Figure 6 shows the appearance of the newly developed R1-Series AC servo motors, while Table 1 is a list of their corresponding specifications. Figure 6 shows a typical example of the torque vs. speed characteristics. In Figure 7, the solid line shows the new model's characteristics, while the dashed line shows that of the current models. Compared with the current model, the new model has higher torque and speed, and achieves a wide output range. During high-hit rate and short stroke PTP control, triangular wave drive often begin deceleration before the motor reaches maximum speed, limiting the benefit of improving maximum speed. Meanwhile, as seen by the industry-specific plot shown in Figure 4, conveyors requiring low inertia often use trapezoid drive which moves at a constant speed when the motor is at maximum speed. By boosting maximum speed, the new models can raise device performance for this type of long stroke application.

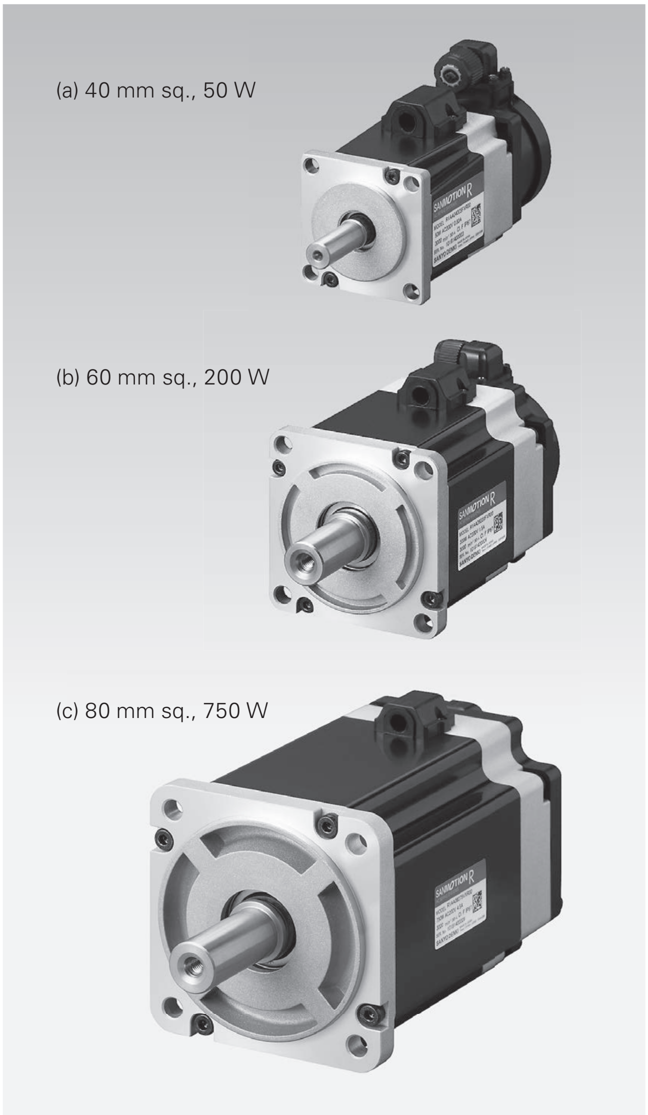

Fig. 6 Developed motors

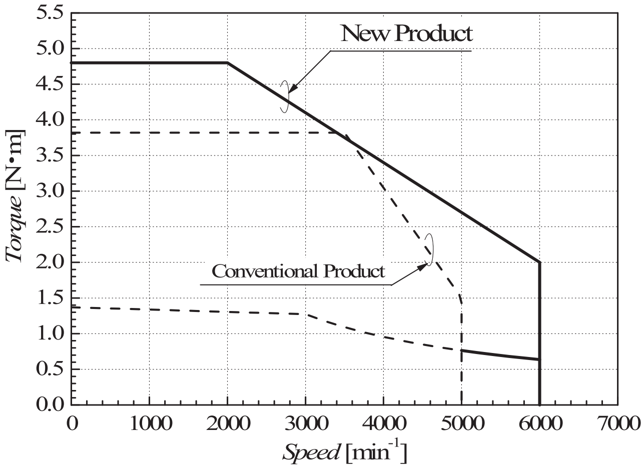

Fig. 7 Typical example of torque vs. speed characteristics
Model: 60 mm sq., 400 W, 200 VAC input

Table 1 Specifications

Items	Unit	Specifications				
Model no.	–	R1AA04005F	R1AA04010F	R1AA06020F	R1AA06040F	R1AA08075F
Flange size	mm	40 × 40		60 × 60		80 × 80
Power supply	V	200 AC				
Rated output	W	50	100	200	400	750
Rated torque	N·m	0.159	0.318	0.637	1.27	2.39
Peak stall torque	N·m	0.56	1.18	2.2	4.8	8.5
Rated speed	min^{-1}	3000	3000	3000	3000	3000
Maximum speed	min^{-1}	6000	6000	6000	6000	6000
Motor inertia	$\times 10^{-4}$ kg·m^2	0.0146	0.0242	0.122	0.203	0.719
Length	mm	84	103	96.5	121	133

4.1 Comparison of new model performance

In section 2(1), we discussed the significance of low inertia motors vis-à-vis acceleration performance. In the motor specification table, power rate and angular acceleration are indicators of acceleration performance. However, to clearly understand acceleration under load, we conducted acceleration simulation, as shown in Figure 8. In Figure 8, the motor in a static state starts rotational motion triggered by the peak torque. Then, the speed increases in line with the torque vs. speed characteristic curve, until maximum speed is reached. Here, we defined the time taken to reach the commanded speed as “response time,” and changed load inertia to calculate how response time would change.

For the simulation, we followed a simple calculation flow using motion equations only, as shown in Figure 9. We calculated the angular acceleration, α_n, and angular velocity, ω_n, and carried out calculations repeatedly until the commanded rotational angular velocity, ω_1, was reached. For torque T_n, the value of angular velocity ω_n is obtained from the torque vs. speed characteristics.

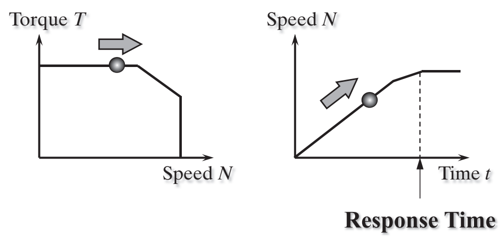

Fig. 8 Motor torque vs. speed characteristics and accelerated motion

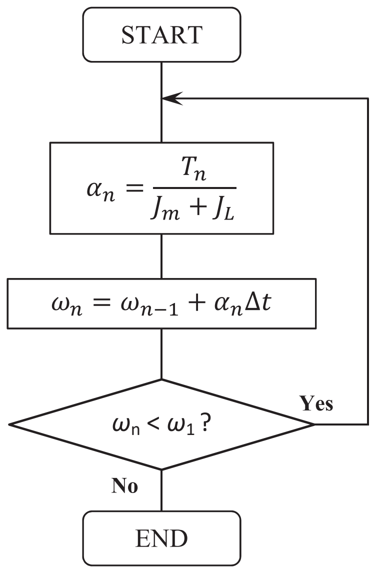

Fig. 9 Calculation flow of motor acceleration motion simulation

Figure 10 shows the relationship of load inertia and motor acceleration time. The figure also shows the response time of the 40 mm sq., 100 W motor if accelerated with a speed command of 5000 min^{-1} in the calculation flow of Figure 9. In contrast to the medium inertia R2-Series, the response speed of the current low inertia model reverses when load inertia increases. By shifting the load inertia to be as large as possible and become this cross point, the motor’s superior acceleration performance can be demonstrated across a broader area.

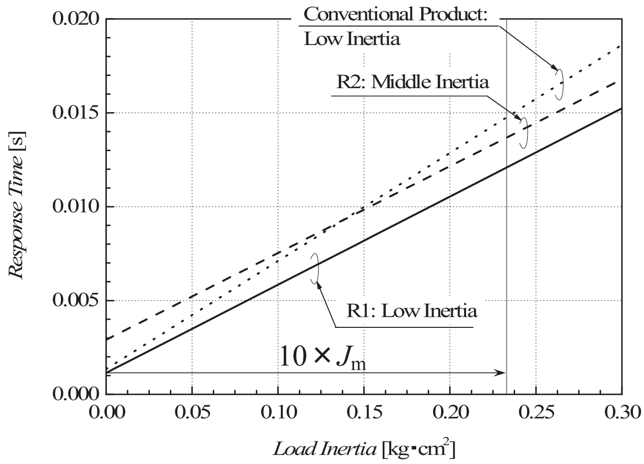

Fig. 10 Relationship between load inertia and motor acceleration time

Model: 40 mm sq., 100 W

Command speed: ω_1=523.6 rad/s (5000 min^{-1})

The new R1-Series can respond faster than the current R2-Series even with a load inertia more than 10 times the motor inertia. In this way, by exhibiting performance which sets it apart from medium inertia motors, the advantageous features of low inertia motors are more apparent.

4.2 Positioning of low inertia motor within the R-Series

In this development, by adding the small-capacity low inertia R1-Series to our current R-Series lineup, we can propose the optimal motor to suit the customer’s application. For example, when we consider the device layout image shown in Figure 11, it is necessary to incorporate various elements such as acceleration/deceleration performance in relation to the XYZ axes respectively, contouring control performance, stabilization performance, cycle-time, occupied space, and mass. In addition to this, however, it is natural that each application has its own general requirements, original customer preferences, and requirements depending on the axis even within the same device. The general-purpose medium inertia R2-Series covers a broad area in terms of wide-ranging elements; however, if the motor is tuned to perform at the limit of the device's capability, in many cases, the axis which only received a pass mark during servo tuning then becomes a bottleneck, impacting the device's overall performance. As such, it is possible to significantly improve several motion characteristics and the cycle time of the device on the whole by using products best suited for the application in relation to elements which may constrain performance. To balance the movement of multiple axes, a possible scenario may be as shown in Table 2, whereby the R5-Series(3) is used for those axes which require precision control, the compact R2-Series(4) is used if the emphasis is on weight reduction and a smaller footprint, and the new R1-Series is used for high acceleration and high response applications.

If we envision a lineup configuration map, we believe that the servo motor product lineup could be expressed three-dimensionally as shown in Figure 12. Relative to the compact, high torque, high efficiency general-purpose R2-Series model, which covers a broad area, the R5-Series, which specializes in low-speed precision feeding and positioning, and the R1-Series, which primarily offers high response and high acceleration/deceleration, are positioned as shown in this figure. Unlike a one-dimensional lineup, which was the standard for moment of inertia to date, we believe the new product lineup map is best viewed with

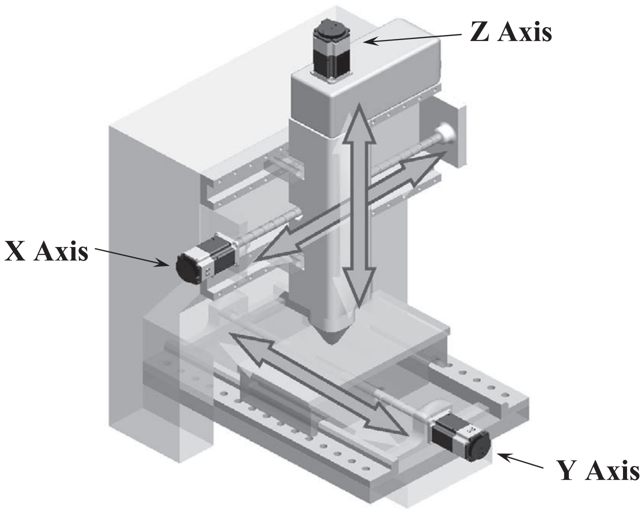

Fig. 11 Equipment configuration

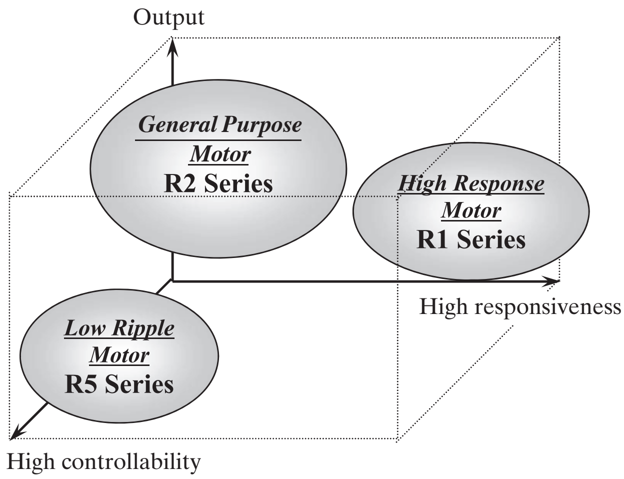

Fig. 12 3D conceptual image of the R-Series motor lineup

Table 2 Example of motor application for each shaft

<table>
<tr><th>Axis</th><th>General-purpose equipment</th><th>Precision control</th><th colspan="2">High-speed drive</th></tr>
<tr><td>X</td><td rowspan="3">R2-Series</td><td rowspan="2">R5-Series
Low-speed precision feeding/positioning of the feed axis
〈Example applications〉
For applications seeking precision movement where using large motors (with a large motor inertia) and linear motors is difficult due to device layout, size, and/or cost.
Etc.</td><td colspan="2" rowspan="2">R1-Series
〈Example applications〉
Applications where the speeds of the moving X- and Y-axes themselves become bottlenecks to the device's overall cycle-time.
Etc.</td></tr>
<tr><td>Y</td></tr>
<tr><td>Z</td><td>—</td><td>Compact R2-Series
〈Example applications〉
(1) Applications where the mass of the moving Z axis itself become a bottleneck to the device's overall cycle-time.
(2) Applications where the user wants to arrange multiple axes in a narrow space to increase the occupancy of working axes.
Etc.</td><td>R1-Series
〈Example applications〉
Applications where the speed of the Z-axis itself become a bottleneck to the device's overall cycle-time.
Etc.</td></tr>
</table>

each multifaceted dimension claiming a unique concept. By establishing a new value standard in this way, we believe we can constantly renew the significance of SANMOTION in the market to continue creating value using both our new and current models.

5. Conclusion

This article has covered the technical accomplishments of the new *SANMOTION R1* Series small-capacity 40, 60, and 80 mm sq. low inertia AC servo motor.

This motor offers both small motor inertia and improved peak torque. This drastically reduces the time required to accelerate/decelerate machines under load.

Furthermore, by promoting the new product as the perfect solution for applications requiring high acceleration and high response, together with the current models of the R2-Series and R5-Series, SANYO DENKI is now able to propose the best product for each individual shaft to suit the drive characteristics of the customers' equipment.

We hope that, with this new product, we can contribute to the creation of new value in the development of next-generation products by our customers.

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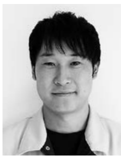

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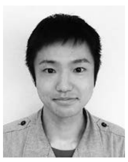

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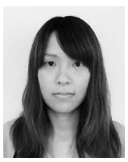

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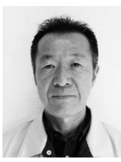

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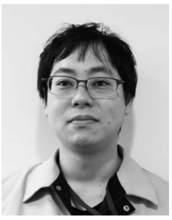
List of Technical Award Engineers of 68th JEMA of 2019

Heavy Electrical Category			
Prize	**Subject**	**Division**	**Name**
Encouragement Award	For development of a compact motion controller	Servo Systems Div., Design Dept. 2 Servo Systems Div., Design Dept. 2 Servo Systems Div., Design Dept. 2	Tomonobu Tazaki Manabu Nakamura Masayuki Mizutani
Encouragement Award	For development of a modular mid-capacity parallel Redundant UPS	Power Systems Div., Design Dept. Power Systems Div., Design Dept. Power Systems Div., Design Dept.	Yoshiko Kondo Hiroyuki Kaneko Toshifumi Nishizawa
Encouragement Award	For development of a ø225 ACDC Centrifugal Fan and a Splash Proof Centrifugal Fan	Cooling Systems Div., Design Dept. Cooling Systems Div., Design Dept. Cooling Systems Div., Design Dept.	Masafumi Yokota Yoshinori Miyabara Tomohide Nonomura
	For development of a UPS equipped with lithium-ion batteries	Power Systems Div., Design Dept. Power Systems Div., Design Dept. Power Systems Div., Design Dept.	Hirofumi Kimura Shota Ozawa Hiroyuki Saito
	For development of a low inertia AC servo motor for machine tool spindles	Servo Systems Div., Design Dept. 1 Servo Systems Div., Design Dept. 1 Servo Systems Div., Design Dept. 1	Kojiro Kawagishi Hiraaki Tanaka Kenta Matsushima
	For development of a 140 × 140 × 51 mm High Airflow Long Life Fan and Splash Proof Fan	Cooling Systems Div., Design Dept. Cooling Systems Div., Design Dept. Cooling Systems Div., Design Dept.	Koji Ueno Masahiro Koike Osamu Nishikawa
Manufacturing Category			
Prize	**Subject**	**Division**	**Name**
Encouragement Award	For improving productivity by automating rotor assembly	Servo Systems Div., Production Engineering Dept., Production Engineering and Development Sect. Servo Systems Div., Production Engineering Dept., Production Engineering and Development Sect. Servo Systems Div., Production Engineering Dept., Process Engineering Sect. 1	Kazuhiro Yoshihara Shinichi Takeda Kenichi Kawashima

Division names are those at the time of nomination.


Tomonobu Tazaki


Manabu Nakamura

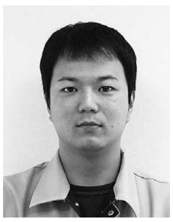

Masayuki Mizutani


Yoshiko Kondo


Hiroyuki Kaneko


Toshifumi Nishizawa


Masafumi Yokota


Yoshinori Miyabara


Tomohide Nonomura


Hirofumi Kimura


Shota Ozawa


Hiroyuki Saito


Kojiro Kawagishi


Hiraaki Tanaka


Kenta Matsushima


Koji Ueno


Masahiro Koike


Osamu Nishikawa


Kazuhiro Yoshihara


Shinichi Takeda


Kenichi Kawashima

Major Patents

■ Patents registered in 2018

Registration Number	Name	Inventor(s)
Patent 6391942	LINEAR MOTOR	Akihiko Takahashi
Patent 6280761	STATOR CORE AND PERMANENT MAGNET MOTOR	Toshihito Miyashita, Manabu Horiuchi
Patent 6321393	MASTER-SLAVE INTERCOMMUNICATION DEVICE AND COMMUNICATION METHOD OF THE SAME	Makoto Kitazawa
Patent 6316035	MOTOR STRUCTURE	Toshihito Miyashita, Manabu Horiuchi
Patent 6282916	STRUCTURE FOR ATTACHING COOLING FAN	Daigo Kuraishi
Patent 6312517	MOTOR CONTROLLER	Yuji Ide, Michio Kitahara, Satoshi Yamazaki, Toshio Hiraide
Patent 6280816	WIRE FIXTURE	Tetsuya Yamazaki
Patent 6300649	PRODUCT SPECIFICATION SETTING APPARATUS AND FAN MOTOR HAVING THE SAME	Tetsuya Yamazaki, Takahisa Toda
Patent 6316714	STEPPER MOTOR	Yasushi Yoda, Koji Nakatake, Masaaki Ohashi
Patent 6282963	POWER SUPPLY VEHICLE	Shinya Otsuki, Mamoru Tomioka
Patent 6450538	FAN AND METHOD FOR MANUFACTURING THE SAME	Yoshinori Miyabara, Naoto Maeda
Patent 6282966	MOTOR CONTROL UNIT	Yuji Ide, Takao Oshimori, Hiroaki Koike
Patent 6312584	MOTOR CONTROL APPARATUS	Yuji Ide, Masahisa Koyama, Shintaro Koichi
Patent 6391431	BRAKE TORQUE MEASUREMENT DEVICE	Norio Nakamura
Patent 6391489	MOTOR CONTROL APPARATUS	Yuji Ide, Michio Kitahara, Toshio Hiraide
Patent 63645289	FAN CONTROL DEVICE AND FAN CONTROL SYSTEM	Naoki Murakami, Masashi Murakami
Patent 6289712	FAN MOTOR APPARATUS AND METHOD FOR MANUFACTURING THE SAME	Naoya Inada, Masato Kakeyama, Atsushi Yanagisawa
Patent 6420411	FAN MOTOR APPARATUS	Naoya Inada, Jiro Watanabe, Masaki Kodama
Patent 6352056	COIL INSULATING STRUCTURE / Bobbin with Grooves for Inserting Insulating Slot Closer (OF ELECTROMAGNETIC MOTOR STATOR)	Koji Nakatake, Yasushi Yoda, Masaaki Ohashi
Patent 6424078	STATOR, METHOD FOR MANUFACTURING STATOR, AND MOTOR	Toshihito Miyashita, Masashi Suzuki, Manabu Horiuchi, Masaki Musha
China Patent ZL201310098880.6	AXIAL FLOW FAN	Naoya Inada, Jiro Watanabe
China Patent ZL201310547935-7	SPLIT-CORE TYPE MOTOR AND METHOD OF MANUFACTURING ARMATURE OF SPLIT-CORE TYPE MOTOR	Toru Takeda, Shintaro Koichi, Kenta Matsuhashi
China Patent ZL201310351506-2	PERMANENT MAGNET TYPE MOTOR AND METHOD FOR MANUFACTURING PERMANENT MAGNET TYPE MOTOR	Toshihito Miyashita, Manabu Horiuchi
China Patent ZL201310351583.8	MOTOR CONTROLLER	Yuji Ide
China Patent ZL201310236622.X	BRUSHLESS MOTOR	Yoshinori Miyabara, Haruhisa Maruyama, Kei Sato, Haruka Sakai
China Patent ZL201310607207-0	WIRING STRUCTURE OF STATOR COIL	Yukio Miura, Masaaki Ohashi, Koji Nakatake
China Patent ZL201410027278.8	MOTOR CONTROLLER	Yuji Ide, Satoshi Yamazaki
China Patent ZL201410026004-7	MOTOR CONTROLLER	Yuji Ide, Satoshi Yamazaki
China Patent ZL201410128528-7	MOTOR CONTROLLER	Yuji Ide, Shunichi Miyazaki
China Patent ZL201410047974-5	SEALING-MEMBER-EQUIPPED SHIELDED CABLE	Yoshihiro Shoji, Kazuhiro Makiuchi
China Patent ZL201410118300-X	MOTOR SPEED CONTROL APPARATUS	Yuji Ide, Satoshi Yamazaki
China Patent ZL201410112800.2	LINEAR MOTOR	Yu Qi Tang, Satoshi Sugita
China Patent ZL201410231395.6	FAN MOTOR, INLINE TYPE FAN MOTOR AND ASSEMBLY METHOD OF THE SAME	Katsumichi Ishihara, Masashi Nomura, Tomoko Hayashi
China Patent ZL201410325664-5	MOTOR CONTROL DEVICE	Yuji Ide, Michio Kitahara, Satoshi Yamazaki
China Patent ZL201410492041.7	LINEAR MOTOR	Yu Qi Tang, Takashi Matsushita
China Patent ZL201410492010.1	LINEAR MOTOR UNIT	Yu Qi Tang, Kazuhito Yamaura
China Patent ZL201410681568.4	MOTOR CONTROLLER	Yuji Ide, Masahisa Koyama, Satoshi Yamazaki
China Patent ZL201510024862.2	MOTOR CONTROLLER	Yuji Ide, Satoshi Yamazaki, Michio Kitahara
China Patent ZL201510064153.7	MAGNETIC SHIELD COVER FOR ENCODER OF MAGNETIC DETECTION TYPE AND ENCODER OF MAGNETIC DETECTION TYPE	Kazuhiro Makiuchi, Yoshihiro Shoji
China Patent ZL201510245788.7	WIRE FIXTURE	Tetsuya Yamazaki
EP Patent 1847716	AXIAL FLOW FAN	Katsumichi Ishihara, Honami Osawa

Registration Number	Name	Inventor(s)
EP Patent 1983199	COUNTER-ROTATING AXIAL-FLOW FAN	Toshiya Nishizawa, Yasuhiro Maruyama, Hayato Murayama
EP Patent 1983198	COUNTER-ROTATING AXIAL-FLOW FAN	Toshiya Nishizawa, Yasuhiro Maruyama, Hayato Murayama
EP Patent 2172655	COUNTER-ROTATING AXIAL-FLOW FAN	Toshiyuki Nakamura, Atsushi Yanagisawa, Katsumichi Ishihara
EP Patent 2226507	METHOD OF CONTROLLING COUNTER-ROTATING AXIAL-FLOW FAN	Honami Osawa, Naruhiko Kudo, Yoshihiko Aizawa
EP Patent 2093865	AIRTIGHT-TYPE ELECTRIC MOTOR	Shigenori Miyairim, Ikuo Takeshita, Koji Nakatake, Hisayuki Miyajima
EP Patent 2317149	AXIAL FLOW FAN	Toshiyuki Nakamura, Masahiro Koike, Naoya Inada
EP Patent 2221947	ELECTRICAL APPARATUS	Haruhisa Maruyama, Tomoaki Ikeda, Takahisa Toda
EP Patent 2226918	STATOR FOR ROTARY ELECTRIC MACHINE	Masaaki Ohashi, Yoichi Horiuchi, Yasushi Yoda, Koji Nakatake
EP Patent 2256908	HEAT RADIATION STRUCTURE OF ELECTRIC APPARATUS	Toshihito Miyashita, Hiroshi Hioki, Junichi Chiku
EP Patent 2624437	MOTOR CONTROL DEVICE AND CONTROL METHOD OF THE SAME	Noriaki Taniguchi, Takahisa Toda, Yo Muramatsu
EP Patent 2706656	MOTOR CONTROL DEVICE AND MOTOR CONTROL METHOD	Yo Muramatsu, Takahisa Toda
EP Patent 2852045	CONTROL DEVICE OF FAN MOTOR	Takahisa Toda, Takashi Kaise, Jiro Watanabe
EP Patent 2886871	WATERPROOF AXIAL FLOW FAN	Katsumichi Ishihara, Akira Nakayama, Tatsuya Midorikawa, Masato Kakeyama
Hong Kong Patent 1199558	SHAFT ROTARY TYPE LINEAR MOTOR AND SHAFT ROTARY TYPE LINEAR MOTOR UNIT	Yu Qi Tang, Satoshi Sugita
Korea Patent 101865230	SPLIT-CORE TYPE MOTOR AND METHOD OF MANUFACTURING ARMATURE OF SPLIT-CORE TYPE MOTOR	Toru Takeda, Shintaro Koichi, Kenta Matsuhashi
Korea Patent 101820100	PERMANENT MAGNET TYPE MOTOR AND METHOD FOR MANUFACTURING PERMANENT MAGNET TYPE MOTOR	Toshihito Miyashita, Manabu Horiuchi
Korea Patent 101874002	THREE-PHASE PERMANENT MAGNET TYPE MOTOR	Toshihito Miyashita, Masahiro Yamaguchi
Korea Patent 101897635	PERMANENT MAGNET-EMBEDDED MOTOR AND ROTOR THEREOF	Toshihito Miyashita
Korea Patent 101883334	MOTOR CONTROLLER	Yuji Ide, Shunichi Miyazaki
Korea Patent 101919477	SEALING-MEMBER-EQUIPPED SHIELDED CABLE	Yoshihiro Shoji, Kazuhiro Makiuchi
Korea Patent 101897637	LINEAR MOTOR	Yu Qi Tang, Satoshi Sugita
Korea Patent 101916894	MOTOR CONTROL DEVICE	Yuji Ide, Michio Kitahara, Satoshi Yamazaki
Korea Patent 101854386	COIL INSULATING STRUCTURE / Bobbin with Grooves for Inserting Insulating Slot Closer (OF ELECTROMAGNETIC MOTOR STATOR)	Koji Nakatake, Yasushi Yoda, Masaaki Ohashi
Korea Patent 101904446	LINEAR MOTOR UNIT	Yu Qi Tang, Kazuhito Yamaura
Korea Patent 101826126	THREE－PHASE ELECTROMAGNETIC MOTOR	Toshihito Miyashita, Manabu Horiuchi
Philippine Patent 1-2013-000181	MOTOR CONTROLLER	Takahisa Toda
Philippine Patent 1-2013-000163	BRUSHLESS MOTOR	Yoshinori Miyabara, Haruhisa Maruyama, Kei Sato, Haruka Sakai
Philippine Patent 1-2013-000262	AXIAL FLOW FAN	Atsushi Yanagisawa
Philippine Patent 1-2004-000274	POWER CONVERTER	Masahiko Nagai
Philippine Patent 1-2014-000377	WATERPROOF AXIAL FLOW FAN	Katsumichi Ishihara, Akira Nakayama, Tatsuya Midorikawa, Masato Kakeyama
Taiwan Patent 620875	FAN FRAME	Masahiro Koike, Soma Araki, Toshiki Ogawara
Taiwan Patent I 631283	AXIAL FLOW FAN	Naoya Inada, Jiro Watanabe
Taiwan Patent I 632767	MOTOR CONTROLLER	Yuji Ide, Satoshi Yamazaki
Taiwan Patent 618344	MOTOR CONTROLLER	Yuji Ide, Satoshi Yamazaki
Taiwan Patent 613880	LINEAR MOTOR	Yu Qi Tang, Satoshi Sugita
Taiwan Patent 618338	SHAFT ROTARY TYPE LINEAR MOTOR AND SHAFT ROTARY TYPE LINEAR MOTOR UNIT	Yu Qi Tang, Satoshi Sugita
Taiwan Patent I 638504	FAN MOTOR, INLINE TYPE FAN MOTOR AND ASSEMBLY METHOD OF THE SAME	Katsumichi Ishihara, Masashi Nomura, Tomoko Hayashi
Taiwan Patent I 632768	MOTOR CONTROL DEVICE	Yuji Ide, Michio Kitahara, Satoshi Yamazaki
Taiwan Patent I 641203	THREE－PHASE ELECTROMAGNETIC MOTOR	Toshihito Miyashita, Manabu Horiuchi
U.S. Patent 9871421	SPLIT-CORE TYPE MOTOR AND METHOD OF MANUFACTURING ARMATURE OF SPLIT-CORE TYPE MOTOR	Toru Takeda, Shintaro Koichi, Kenta Matsuhashi
U.S. Patent 10050481	PERMANENT MAGNET TYPE MOTOR AND METHOD FOR MANUFACTURING PERMANENT MAGNET TYPE MOTOR	Toshihito Miyashita, Manabu Horiuchi

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U.S. Patent 10014736	PERMANENT MAGNET-EMBEDDED MOTOR AND ROTOR THEREOF	Toshihito Miyashita
U.S. Patent 9929631	INTERIOR MAGNET LINEAR INDUCTION MOTOR	Satoshi Sugita, Yu Qi Tang, Yasushi Misawa, Shigenori Miyairi
U.S. Patent 9874215	FAN MOTOR CONTROL UNIT	Yo Muramatsu, Takahisa Toda, Kenta Nishimaki
U.S. Patent 9859765	WINDING INSULATION STRUCTURE OF STATOR OF ELECTROMAGNETIC MOTOR	Kazuhiro Yoda, Masaaki Ohashi, Shogo Yoda
U.S. Patent 10044241	COIL INSULATING STRUCTURE / Bobbin with Grooves for Inserting Insulating Slot Closer (OF ELECTROMAGNETIC MOTOR STATOR)	Koji Nakatake, Yasushi Yoda, Masaaki Ohashi
U.S. Patent 10069365	THREE－PHASE ELECTROMAGNETIC MOTOR	Toshihito Miyashita, Manabu Horiuchi
U.S. Patent 9869321	WATERPROOF AXIAL FLOW FAN	Katsumichi Ishihara, Akira Nakayama, Tatsuya Midorikawa, Masato Kakeyama
U.S. Patent 9899889	MOTOR STRUCTURE	Toshihito Miyashita, Manabu Horiuchi
U.S. Patent 9958025	STRUCTURE FOR ATTACHING COOLING FAN	Daigo Kuraishi
U.S. Patent 14987847	FAN CASING AND FAN APPARATUS	Naoya Inada, Honami Osawa
U.S. Patent 9857209	MEASUREMENT DEVICE	Katsumichi Ishihara, Takahisa Toda, Yo Muramatsu
U.S. Patent 9857202	SENSOR FOR MOTOR	Takayoshi Seki
U.S. Patent 10036660	MEASUREMENT DEVICE	Katsumichi Ishihara, Takahisa Toda, Yo Muramatsu, Masahiro Koike, Hikaru Urushimoto

Internal Recognition: Invention Grand Prize (Excellence Award)

April 2018 Commendations

Prize	Subject	Division	Name
Excellence Award	Stator for Rotary Electric Machine and its Assembling Method	Servo Systems Div., Design Dept. 1	Mitsuaki Shioiri, Koji Nakatake, Yasushi Yoda, Kazuhiro Yoda, Shogo Yoda
		Servo Systems Division Application Engineering Dept.	Hong Zhang
Excellence Award	Fan Motor Protection Cap	Cooling Systems Div., Design Dept.	Haruhisa Maruyama, Yusuke Okuda, Yoshihisa Yamazaki

Internal Recognition: Manufacturing Grand Prize (Excellence Award)

May 2018 Commendations

Prize	Subject	Division	Name
Excellence Award	Insulator Mold Mechanism with Excellent Releasability	Cooling Systems Div., Production Dept. Production Engineering Sect. 2	Shinsuke Okubo, Shunya Yamada
Excellence Award	For automating the rotor assembly process for compact AC servo motors	Servo Systems Division Production Engineering Dept., Production Engineering and Development Sect.	Kazuhiro Yoshihara, Shinichi Takeda
		Servo Systems Division Production Engineering Dept., Process Engineering Sect. 1	Kenichi Kawashima

Technical Papers Published Outside the Company in General Technical Journals

January to December 2018

Title of Paper	Authors	Name of Journal	Issued on	Publisher
Feature: Product and Technology Development of Member Companies and the Results of 2017	SANYO DENKI CO., LTD.	Denki (Electrical Appliances)	2018.2	The Japan Electrical Manufacturers' Association (JEMA)

Technical Papers Published Outside the Company

January to December 2018

Title of Paper	Authors	Name of Journal	Issued on	Publisher
Estimation of Temperature in SPMSM by Estimated Stator Resistance Robast to Rotor Flux	Yuji Ide, Daigo Kuraishi, Akihiko Takahashi (Co-author: Nagaoka University of Technology)	The papers of Technical Meeting on Semiconductor Power Converter, IEEJ	2018.1	Joint Technical Meeting on Semiconductor Power Converter and Motor Drive, IEEJ
Parameter Variation Insensitive Armature Temperature Estimation Method for SPMSM	Yuji Ide, Daigo Kuraishi, Akihiko Takahashi (Co-author: Nagaoka University of Technology)	IPEC- Niigata 2018 paper collection	2018.5	IEEJ Industrial Applications Category
Robust Armature Temperature Estimation of SPMSM Considering Inductance Variation	Yuji Ide, Daigo Kuraishi, Akihiko Takahashi (Co-author: Nagaoka University of Technology)	2018 IEEJ Industrial Applications Category Conference lecture paper collection	2018.8	IEEJ Industrial Applications Category
Study on Supply Demand Operation of AC/DC Micro-Grid at Power System Failure	Takuya Ota, Hiroaki Miyoshi (Co-authors: Aichi Institute of Technology, Kinden Corporation)	Conference paper collection	2018.9	International federation of automatic control the 10th symposium on control of power and energy systems (IFAC CPES2018)

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