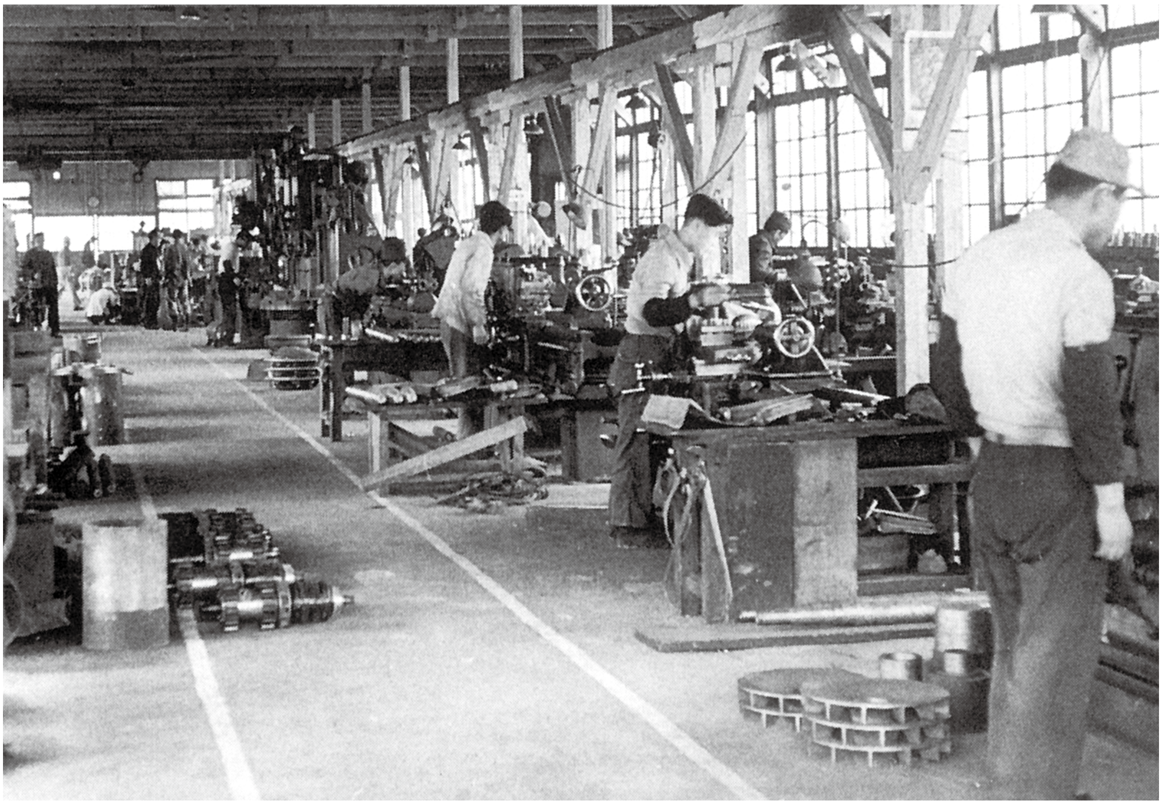
SANYO DENKI

Technical Report

Feature | Technologies Creating Change



1954
Ueda Works

46
November
2018

COLUMN

Cover image:

Ueda Works

1954

In the 1950s, as the Japanese electronics industry continued to grow, many broadcasting stations were established, with public radio broadcasts beginning in 1951, and television broadcasts beginning in 1953.

The dawn of the radio and television era was the construction of a microwave communication network by NTT Corporation (Nippon Telegraph and Telephone Public Corporation, the predecessor of the current NTT group).

Not just communications companies, all of society benefitted from the booming consumer economy of 1950 to 1953.

At the same time, orders took off for hand-powered generators and radio power supplies, and production at our Ueda Works was extremely busy.

Hand power generators were a necessity for powering lifeboat radios in the event of an accident. Much of the demand for these products, which would later be legally mandated, was met by SANYO DENKI.

We also received orders from the Defense Agency for portable gasoline generators.

These were used as power supplies for portable communications units, such as were carried in trailers.

In addition to such large orders, there was high demand for power supplies for emergency marine radios and for converters for fish detectors, and high production at Ueda Works continued into the latter half of the 1950s.

46 November 2018 **SANYO DENKI** TECHNICAL REPORT

C O N T E N T S

Chihiro Nakayama
Executive Operating Officer

Technologies Creating Change

SANYO DENKI Group's 8th Mid-term Management Plan is a 5-year plan started in April 2016, and marks its third year in 2018.

One of the 8th Mid-term Management Plan's key policies is "to establish a corporate culture capable of transforming environmental changes into business opportunities."

The business environment is constantly changing. We at SANYO DENKI Group will stay abreast of these changes and aim to build a strong corporate culture that enables us to transform change into opportunity.

To realize this key policy, we have implemented one of our action guidelines "challenge your weakness and turn it into your strength," promoting "specialists in change" objective. The results of these policies are starting to appear thanks to the various ideas and actions of all divisions and employees of SANYO DENKI Group.

Now, let's look to the theme of this issue of Technical Report: Technologies Creating Change. It has a keyword "change" in common with the abovementioned policy. What does it exactly mean?

The 8th Mid-term Management Plan has another key policy of "develop products that make new dreams come true." In more concrete terms, this means to "create new value to our customers and new products that realize dreams together with the customers."

In accordance with these policies, SANYO DENKI Group's Design and Development divisions have established the following product development themes: "performance and functions that are friendly to people and to the environment," "performance and functions characterized by safety and ease of use," and "performance and functions optimized for robotization and automation."

Products with such performance and functions bring about changes in our customers and our surroundings, which in turn produce “new value” and “new dreams,” thus leading to the realization of our policies. The products we develop create positive changes in our customers and our surroundings, and this can be entitled as “technologies creating change.”

By leveraging these “technologies creating change,” SANYO DENKI has developed unique, never-before-seen products and introduced them to the market.

Our Cooling Systems Division has produced fans offering various environmental durability features such as Long Life Fans, Splash Proof Fans, Oil Proof Fans, and Wide Temperature Range Fans. These fans that can be used in harsh environments are creating new value.

The Power Systems Division has developed and released UPSs that adopt lithium-ion batteries as an alternative to lead-acid batteries. These products are safe and user-friendly because they can be used in a broad range of environments from extreme cold to extreme hot, and require no maintenance for a period of ten years.

Our Servo Systems Division has developed servo amplifiers capable of transferring significantly larger amounts of data. These products can help equipment turn into an IoT-enabled system, and therefore perfectly conform to the theme of robotization and automation.

This issue of Technical Report introduces some of our “technologies creating change.”

SANYO DENKI will further accelerate the development of these technologies and endlessly create and launch products that make new dreams come true in order to contribute to society.

Technologies Creating Change

Masato Murata

1. Introduction

SANYO DENKI's product lineup is extremely diverse, ranging from AC fans to DC fans, the Long Life Fan, Splash Proof Fan, Counter Rotating Fan, Oil Proof Fan, Wide Temperature Range Fan, Centrifugal Fan, PWM Controller and more. Initially after development, these products were adopted to meet certain requirements in the market. However, each product has defining features, and in some cases, this leads to the product being adopted in new markets. For example, when our Long Life Fan was initially developed, it was primarily used to cool telephone switchboards. In recent years, the reliability of the product has received much attention, and this product is now used in high-reliability servers where constant availability is essential. In this way, products with defining features are creating changes in demand.

Focusing on fans with features that create change, this article will use the environmentally durable Endurance Fans series—namely the Long Life Fan, Splash Proof Fan, Oil Proof Fan, Wide Temperature Range Fan, and G Proof Fan—as examples to introduce both the circumstances that created market changes as well as the technologies found in our products.

2. Background to the Development of Endurance Fans and Market Changes

2.1 Long Life Fan

As the very first of the Endurance Fans series, the Long Life Fan was launched in 1991. Currently, this product is available in 12 sizes, ranging from 40 × 40 × 28 mm to ø172 × 51 mm, and features improved cooling performance.

When this fan was first developed, it had a shorter service life than the ICT equipment it was used in (e.g. telephone switchboards) and had to undergo maintenance every three to five years. High costs of maintenance lead to strong demand from customers to extend the service life of this fan, thus achieving a maintenance-free device. In response to this need, SANYO DENKI developed the Long Life Fan.

As a result of the Long Life Fan offering longer service life and maintenance-free features, the demand for it grew among customers wanting to improve the reliability of their products. For example, the product came to be adopted in high-reliability servers, public transportation facilities, data processing equipment for financial institutions, emergency UPS, PV and wind power generators, industrial inverters, medical equipment, and many more devices of new markets that did not exist when the fan was first developed.

2.2 Splash Proof Fan

The Splash Proof Fan was launched in 1996. Currently, this product is available in 12 sizes, from 40 × 40 × 28 mm to ø172 × 51 mm, and also features improved cooling performance.

At the beginning of this fan's development, base stations were increasing with the spread of mobile phones. Initially, fans were mounted within waterproof enclosures and circulated air to naturally cool large heat exchangers. However, as more devices became increasingly sophisticated and compact, forced air cooling became necessary. A demand emerged for a waterproof fan that could supply and discharge outside air, thus leading to SANYO DENKI's development of the Splash Proof Fan.

With its water-resistant features, the Splash Proof Fan harbors the potential to create a demand for use in all outdoor devices. Specifically, this fan is used in various new outdoor products including large LED displays, digital signage, EV quick charging station, and LED lighting. The Splash Proof Fan is also increasingly found in indoor devices that operate near water or moisture like food processing machines, plant factories, and dishwashers.

2.3 Oil Proof Fan

The Oil Proof Fan was launched in 2004 and is available in 9 sizes ranging from 40 × 40 × 15 mm to 120 × 120 × 38 mm.

When this fan was first developed, the cooling fans used in control amplifiers of FA machine tools and industrial robots would frequently lock up and fail due to built up dust and cutting oil from operating in oil mist. Such fan failures meant that maintenance was unavoidable. The Oil Proof Fan was adopted to meet the need to minimize breakdown frequency.

Thanks to its oil-proof performance, the Oil Proof Fan is used in industrial inverters and other factory equipment. In addition to factory equipment, this fan is also becoming increasingly popular for adoption in environments using cooking oil, such as food processing machines.

2.4 Wide Temperature Range Fan

The Wide Temperature Range Fan was launched in 2014, and is available in 6 sizes, ranging from 40 × 40 × 28 mm to 120 × 120 × 38 mm.

When this fan was first developed, photovoltaic and wind power generation had just begun growing in popularity. The fan was developed to meet the demand to withstand operating temperatures as low as -40°C and as high as 85°C, as it was assumed that such would be required in natural environments with harsh operating conditions.

The Wide Temperature Range Fan can operate in a wide range of operating temperatures, therefore it is used in LED displays, LED lighting, and other devices used outdoors that are exposed to severe temperature changes. In addition to catering to natural environments, this fan also has the potential for adoption in temperature-controlled devices such as freezers or high-temperature testing equipment.

2.5 G Proof Fan

The G Proof Fan was launched in 2017, and is available in 2 sizes: 120 × 120 × 38 mm and ø172 × 51 mm.

This fan was initially developed as a cooling fan able to withstand the large G-forces created by the gantry of medical CT scanners which rotates at high speeds.

Because the G Proof Fan features G-force tolerance, it can be adopted in devices with high-speed movement. For example, it could be used in amusement park rides allowing thrill-seekers to experience rapid acceleration, or used to cool elevator equipment.

Table 1 shows the initial and expanded target applications for each product series. Moreover, by developing and launching products with unique features, we anticipate that even more demand will be created.

Table 1 Initial target applications and expanded target applications

Series name	Initial targets	Expanded targets
Long Life Fan	ICT equipment	Public service devices Network communication systems Industrial printers Industrial power supplies UPS High-reliability servers PV / wind power generators Industrial inverters Base stations Medical devices
Splash Proof Fan	Base stations	Quick charging station Industrial inverters Displays Digital signage Food processing machines Dishwashers Plant factories LED lighting
Oil Proof Fan	Servo amplifiers	Industrial inverters Motor cooling Food processing machines
Wide Temperature Range Fan	PV / wind power generators	Quick charging station Displays Freezer/refrigerator related Plant factories LED lighting
G Proof Fan	Medical CT scanners	Amusement devices Elevators

3. Features and Technologies of Endurance Fans

This section introduces the features and technologies of the Endurance Fans that created changes in demands.

3.1 Features and Technologies of the Long Life Fan

[Feature] Maintenance-free

In order to minimize the maintenance work required for fans, the Long Life Fan has an expected life of over 2.5 times that of SANYO DENKI's standard fan (100,000 hours, L10, 60°C, rated voltage, in free air).

[Technologies]

To achieve long service life, we used material with improved durability for our magnets and other components, and selected parts and materials that do not change over time. Moreover, as bearing life is most affected by grease degradation in line with temperature increase, we adopted a frame with excellent thermal conductivity (aluminum die-cast) and improved motor efficiency, thus suppressing temperature increase. We also reduced bearing load and revised the grease type. These efforts improved bearing life. We reduced the usage ratio of the motor drive circuit and increased reliability.

Figure 1 shows the expected life of the standard fan and the Long Life Fan.

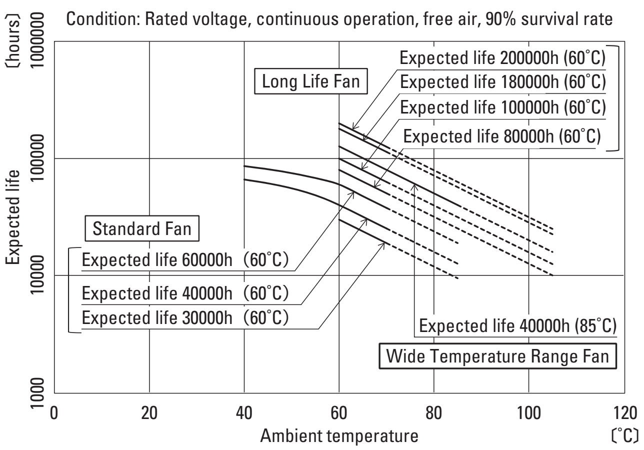


Fig. 1 Expected life of DC fans

3.2 Features and Technologies of the Splash Proof Fan

[Feature] Waterproof performance

Protection code: Waterproof and dustproof performance of IP68 and IP55* have been achieved.

[Technologies]

To ensure waterproof performance, we completely covered the coil and live parts with waterproof material and utilized highly water resistant material for the magnet and other parts exposed to air. We applied further waterproofing treatment to the frame and other components exposed to the air to improve rust resistance.

Figure 2 shows how the live parts of the Splash Proof Fan and the Oil Proof Fan are protected.

Fig. 2 Protection of live parts

3.3 Features and Technologies of the Oil Proof Fan

[Feature] Oil-proof performance

This fan was designed to prevent failures caused by dust and oil build-up making it ideal for environments exposed to cutting oil mist.

[Technologies]

To ensure oil-proof performance, we completely covered the coil and live parts with oil-proof material, and utilized highly oil resistant material on the frame, impeller, magnet, and other parts exposed to air. By increasing the clearance between the tip of the impeller blades and inner surface of the frame, we reduced the possibility of the impeller locking up even if there was oil or dust build-up.

3.4 Features and Technologies of the Wide Temperature Range Fan

[Feature] Wide operating temperature range: -40 to +85°C

[Technologies]

We verified the thermal characteristics and durability of materials used for components and selected parts and materials which could withstand the target operating temperature range. We selected electronic components with a wide operating temperature range and designed the fan paying close attention to thermal characteristics. We adopted a circuit configuration after sufficiently verifying its operating temperature range. All of this lead to the successful development of a fan capable of performing in a wide operating temperature range.

3.5 Features and Technologies of the G Proof Fan

[Feature] Ability to withstand G-forces: 75 G (at normal temperature, normal humidity, continuous operation)

[Technologies]

In order to create rotating parts able to withstand a G-force of 75 G, we adopted a structure that integrated the impeller and rotor cover. Additionally, an aluminum die-cast frame was adopted to achieve high rigidity. Through simulation analysis, we revised the structural design, including part joints, increased strength and, ultimately, achieved a G-force tolerance of 75 G.

Above we have introduced the technologies adopted in each fan series in order to realize their unique features. By adopting the appropriate new technology for each individual feature, we have successfully developed products with new defining features. Table 2 shows the features and technologies of each series.

Table 2 Features and technologies

Series name	Features	Technologies
Long Life Fan	Maintenance-free	• Uses parts and materials that change minimally over time • Improved bearing life • Improved reliability of the motor drive circuit
Splash Proof Fan	Splash Proof	• Protects live parts using highly waterproof material • Uses materials with excellent water-resistance • Rustproofing on necessary areas
Oil Proof Fan	Oil-proof	• Protects live parts using highly oil-proof material • Uses materials with excellent oil-resistance for the frame, impeller, and magnet • Secures sufficient clearance between the blade tips and inner surface of the frame
Wide Temperature Range Fan	Wide operating temperature range	• Uses parts and materials able to withstand high/low temperatures • Adopts a circuit configuration enabling trouble-free operation in both high and low temperatures
G Proof Fan	Ability to withstand G-forces	• The structure of the G Force Fan features an integrated impeller and rotor cover. • Adopts high-rigidity material for the frame • Adopts a structure of improved rigidity

4. Conclusion

This article introduced the Endurance Fans series as fans that have defining features and have been adopted in devices of new markets differing from the initial target market to show how these fans have created changes in demands.

SANYO DENKI will continue assessing market needs at an early stage and, through existing and new technologies, develop products with features that satisfy such needs and, ultimately, create new demands.

*Shows the protection rating for the *San Ace W* series.
The protection rating (IP code), is defined by IEC (International Electrotechnical Commission) 60529 "DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP Code)." (IEC60529:2001)
IP68: Completely protected against dust. Protection against submersion in water.
IP55: Protection against a level of dust that could hinder operation or impair safety. Devices operate stably even when directly exposed to water from any direction.

Reference

(1) Kesatsugu Watanabe and 6 others: Development of Long Life Fans
SANYO DENKI Technical Report No.1 pp. 5-8 (1996)

(2) Honami Osawa and 3 others: Development of Splash Proof Fans
SANYO DENKI Technical Report No.3 pp. 6–8 (1997)

(3) Hidetoshi Kato and 3 others: Oil Proof Fans *San Ace 40WF*, *San Ace 60WF*, and *San Ace 120WF*
SANYO DENKI Technical Report No.19 pp. 17–19 (2005)

(4) Osamu Nishikawa and 3 others: Wide Temperature Range Fan *San Ace T* Series 9GT Type
SANYO DENKI Technical Report No.39 pp. 9–12 (2015)

(5) Naoya Inada and 5 others: G Proof Fans *San Ace 120GP* and *San Ace 172GP*
SANYO DENKI Technical Report No.44 pp. 11–14 (2017)

Masato Murata
Joined SANYO DENKI in 1984.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

High Airflow Long Life Fan / High Airflow Long Life Splash Proof Fan *San Ace 140L* and *San Ace 140W*

Masahiro Koike Hiromitsu Kuribayashi Koji Ueno Yasuhiro Maruyama Osamu Nishikawa

1. Introduction

With the growth of the ICT and renewable energy markets, there is a demand for fans to have high airflow and long life to support an increase in the internal heat generation of equipment.

Furthermore, in addition to offering high airflow and long life, there is also a demand for fans to be waterproof to meet the needs of ICT equipment and power condensers, which are installed outdoors.

Also, from the perspective of protecting the environment, there has been a sudden increase in demand for photovoltaic (PV) power generation, electric vehicles and so forth, thus creating a need for highly reliable, long life, waterproof fans to support products such as quick charging stations.

SANYO DENKI had already manufactured and released the 140 × 140 × 51 mm Long Life Fan and Splash Proof Fan. In line with higher performance and higher efficiency of ICT equipment and PV power systems in recent years, fans used in such equipment have been required to have even longer life and higher airflow.

Even Splash Proof Fans are being required to offer higher airflow and longer life in addition to sufficient waterproof performance for outdoor equipment, such as PV inverters and EV quick charging stations.

Amid such circumstances, SANYO DENKI has developed and released two models: the High Airflow Long Life Fan, *San Ace 140L* 9LG type, with an expected life of 180,000 hours, and the High Airflow Long Life Splash Proof Fan, *San Ace 140W* 9WL type, with an expected life of 100,000 hours. This article introduces the features and performances of these products.

2. Product Features

Figures 1 and 2 show the external views of the two new models.

Fig. 1 New model *San Ace 140L*

Fig. 2 New model *San Ace 140W*

The new models maintain compatibility with the current models in regard to fan size and mounting hole position, while achieving higher airflow, longer service life, and greater waterproof performance.

The features of the new models are:

(1) Dustproof/waterproof performance: Protection rating IP68*
(2) High airflow
(3) Long life
(4) PWM control function

3. Product Overview

3.1 Dimensions

The fans' external dimensions and mounting hole positions are unchanged from our current models. Figures 3 and 4 show the dimensions of the new models.

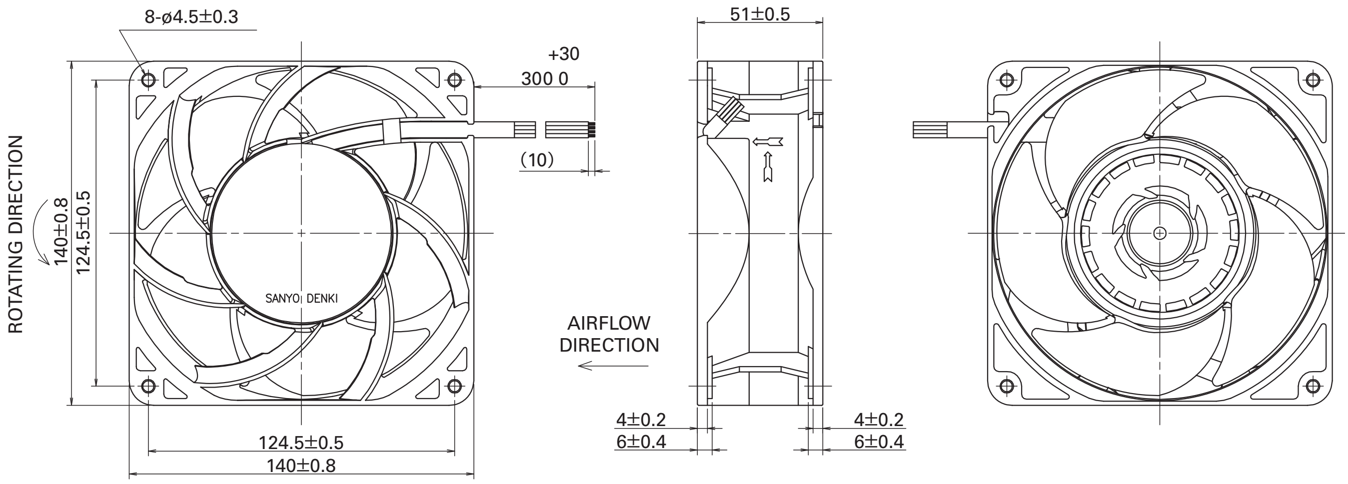


Fig. 3 Dimensions of the *San Ace 140L* (unit: mm)

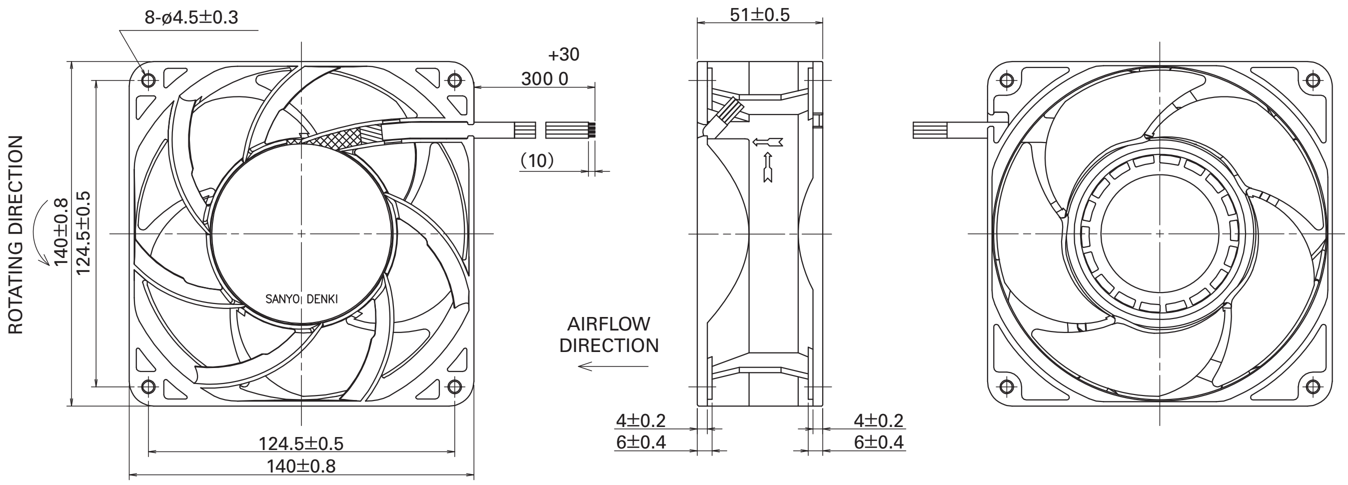


Fig. 4 Dimensions of the *San Ace 140W* (unit: mm)

3.2 Expected life

The new model has an expected life of 180,000 hours with the 9LG type and 100,000 hours with the 9WL type at 60°C (survival rate of 90%, run continuously at rated voltage in free air and at normal humidity).

3.3 Characteristics

3.3.1 General specifications

Tables 1 and 2 show the general specifications of both new models.

Table 1 General specifications for the new model *San Ace 140L*

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	SPL [dB (A)]	Operating temperature [°C]	Expected life [h]
9LG1412P5G001	12	10.2 to 13.8	100	5.16	62	7,500	9.0	318	655	2.63	69	-20 to +70	180,000 / 60°C
			20	0.31	3.72	2,300	2.75	97	80	0.32	38		
9LG1412P5S001			100	1.83	22	5,000	6.0	212	295	1.18	57		
			20	0.31	3.72	2,300	2.75	97	80	0.32	38		
9LG1424P5G001	24	20.4 to 27.6	100	2.58	62	7,500	9.0	318	655	2.63	69		
			20	0.16	3.84	2,300	2.75	97	80	0.32	38		
9LG1424P5S001			100	0.91	22	5,000	6.0	212	295	1.18	57		
			20	0.16	3.84	2,300	2.75	97	80	0.32	38		
9LG1448P5G001	48	40.8 to 55.2	100	1.29	62	7,500	9.0	318	655	2.63	69		
			20	0.12	5.76	2,300	2.75	97	80	0.32	38		
9LG1448P5S001			100	0.45	22	5,000	6.0	212	295	1.18	57		
			20	0.12	5.76	2,300	2.75	97	80	0.32	38		

• Does not rotate when PWM duty cycle is 0%.
• PWM frequency: 25 kHz

Table 2 General specifications for the new model *San Ace 140W*

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	SPL [dB (A)]	Operating temperature [°C]	Expected life [h]
9WL1412P5G001	12	10.2 to 13.8	100	5.16	62	7,500	9.0	318	655	2.63	69	-20 to +70	100,000 / 60°C
			20	0.31	3.72	2,300	2.75	97	80	0.32	38		
9WL1412P5S001			100	1.83	22	5,000	6.0	212	295	1.18	57		
			20	0.31	3.72	2,300	2.75	97	80	0.32	38		
9WL1424P5G001	24	20.4 to 27.6	100	2.58	62	7,500	9.0	318	655	2.63	69		
			20	0.16	3.84	2,300	2.75	97	80	0.32	38		
9WL1424P5S001			100	0.91	22	5,000	6.0	212	295	1.18	57		
			20	0.16	3.84	2,300	2.75	97	80	0.32	38		
9WL1448P5G001	48	40.8 to 55.2	100	1.29	62	7,500	9.0	318	655	2.63	69		
			20	0.12	5.76	2,300	2.75	97	80	0.32	38		
9WL1448P5S001			100	0.45	22	5,000	6.0	212	295	1.18	57		
			20	0.12	5.76	2,300	2.75	97	80	0.32	38		

• Does not rotate when PWM duty cycle is 0%.
• PWM frequency: 25 kHz

3.3.2 Airflow vs. static pressure characteristics

Figure 5 shows the airflow vs. static pressure characteristics of the new models.

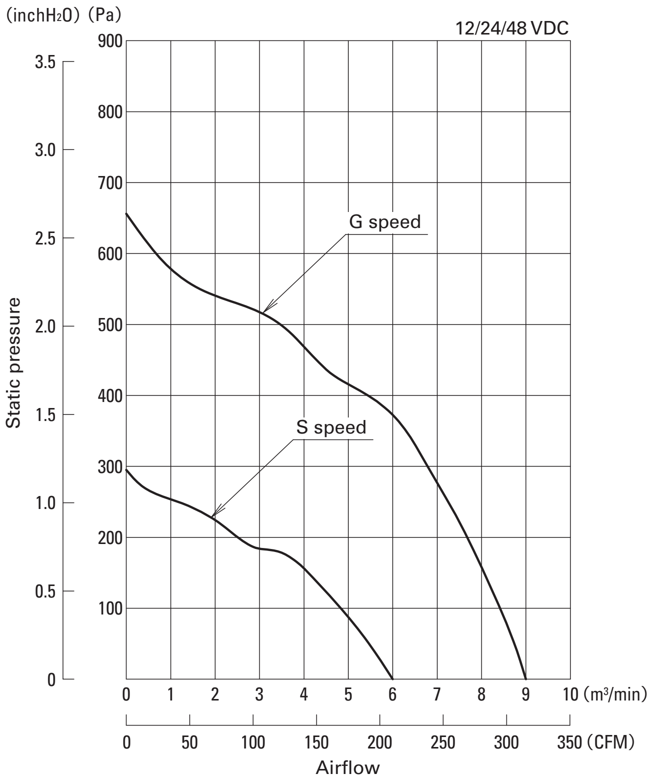


Fig. 5 Airflow vs. static pressure characteristics of the new models *San Ace 140L* and *San Ace 140W*

3.3.3 PWM control function

Both of the new models have a PWM control function and are capable of high-speed control.

4. Comparison with our Current Models

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

4.1 Comparison of airflow vs. static pressure characteristics

Figure 6 provides an example of the airflow vs. static pressure characteristics of the new and current models.

Compared to the current models, the new models have a 1.1 times greater maximum airflow and 2.7 times greater maximum static pressure, thus offer an improvement in airflow vs. static pressure characteristics.

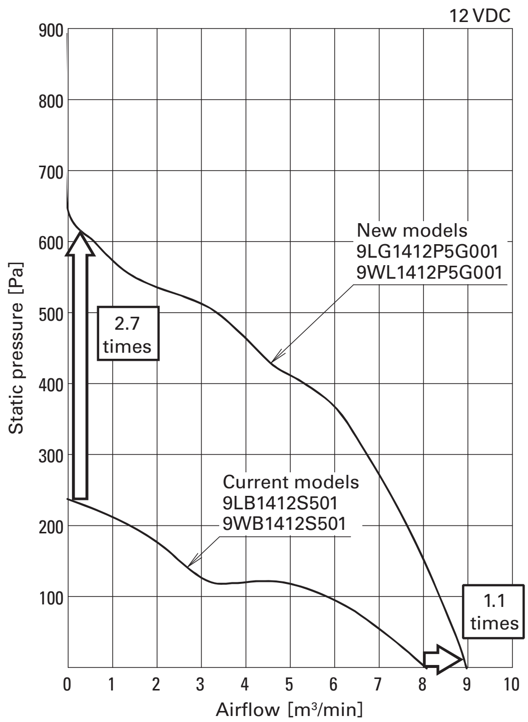


Fig. 6 Airflow vs. static pressure characteristics of the new models *San Ace 140L* and *San Ace 140W* in comparison with current models

4.2 Comparison of expected life

Tables 3 and 4 give comparisons for the expected life and general specifications of the new models and current models. The values shown are for the high performance types of each model.

Table 3 Comparison of the new model *San Ace 140L* with the current model

Model no.	Expected life [h]	Max. airflow [m³/min]	Max. static pressure [Pa]
New model 9LG1412P5G001	180,000	9.0	655
Current model 9LB1412S501	60,000	8.1	240

Table 4 Comparison of the new model *San Ace 140W* with the current model

Model no.	Expected life [h]	Max. airflow [m³/min]	Max. static pressure [Pa]
New model 9WL1412P5G001	100,000	9.0	655
Current model 9WB1412S501	60,000	8.1	240

Both the 9LG and 9WL type models offer improved airflow vs. static pressure characteristics, yet the 9LG type has an expected life (with 60°C ambient temperature, 90% survival rate, run continuously at rated voltage in free air and at normal humidity) of 180,000 hours, which is 3 times greater than the 60,000 hour lifespan of current models. The 9WL type has an expected life of 100,000 hours, which is 1.7 times greater than the 60,000 hour lifespan of current models.

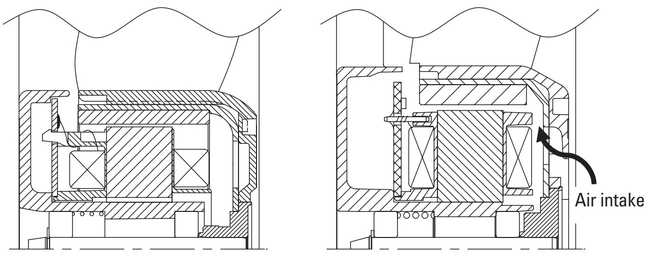
5. High Airflow/Long Life and Waterproof Performance Technologies

The new models were designed to be waterproof while offering both an airflow and lifespan surpassing that of the current models.

For the new models, the impeller shape and frame were optimized to achieve higher airflow, and an aluminum die-cast frame was adopted for longer life. The following sections briefly introduce the design points contributing to higher airflow and longer life on the new models compared to the current models.

5.1 Impeller shape

We newly developed the impeller and adopted a structure with an intake route in order to suppress bearing/motor temperature. (Fig. 7) Moreover, we improved the number and angle of blades and achieved higher airflow by improving airflow efficiency, thus minimizing power consumption. Figure 8 shows an impeller shape comparison of the current and new models.



Current model New model

Fig. 7 Impeller cooling structure of the current and new models

Current model New model

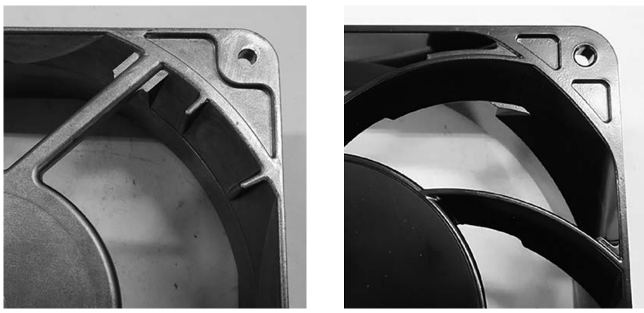
Fig. 8 Impeller shape comparison of the current and new models

5.2 Frame

For the frame, we used aluminum die-cast as the material and adopted a design whereby the frame was integrated with the bearing house. By newly developing the frame spoke shape, airflow efficiency was improved, thus achieving higher airflow and higher static pressure.

Furthermore, the aluminum die-cast frame surface has been coated to protect it from corrosion due to rust, etc. as a result of exposure to external environments. This has made it possible to use the fans for a prolonged period of time even in environments where it is splashed with water.

Figure 9 shows a frame shape comparison of the current and new models.



Current model New model

Fig. 9 Frame shape comparison of the current and new models

5.3 Drive motor

For the Splash Proof Fan, to prevent breakdowns due to water penetration, we have coated the live parts (motor, control circuit) in resin, as shown in Figure 10.

Furthermore, in order to achieve a dustproof/waterproof performance rating of IP68*, the below structure was adopted.

(1) Live parts (motor, control circuit) protected with highly waterproof material (Fig. 10).
(2) Magnets made from material with excellent water resistance compared to the material normally used for fans.
(3) Rustproofing applied to the necessary areas.

The new models are faster than the current models so the drive motor was enlarged to improve motor efficiency.

This has made it possible to achieve low power consumption and, regardless of the live parts being coating in resin, reduce the heat generated by the motor coil, thus minimizing bearing temperature rise.

Fig. 10 Coating condition of live parts

6. Conclusion

This paper has introduced some features and performance of the High Airflow Long Life Fan and High Airflow Long Life Splash Proof Fan, *San Ace 140L* and *San Ace 140W*.

Both new models offer higher airflow and longer service life. As such, they contribute toward maintenance-free fans for adoption in indoor/outdoor equipment and help to reduce fan replacement frequency (no. of units).

With today's diversifying global market, we believe this development contributes significantly to optimal cooling solutions.

* Shows the protection rating for the *San Ace W* series.
The protection rating (IP code), is defined by IEC (International Electrotechnical Commission) 60529 "DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP Code)." (IEC60529:2001)
IP68: Completely protected against dust. Protection against submersion in water.

Reference

(1) Kakuhiko Hata and others: High Airflow, High Static Pressure Splash Proof Fan *San Ace W*
SANYO DENKI Technical Report No. 32 pp. 20-24 (2011-11)

(2) Katsumichi Ishihara and others: High Airflow Long Life Splash Proof Fan *San Ace W*
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Masahiro Koike
Joined SANYO DENKI in 2006.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Hiromitsu Kuribayashi
Joined SANYO DENKI in 1996.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Koji Ueno
Joined SANYO DENKI in 2001.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Yasuhiro Maruyama
Joined SANYO DENKI in 2001.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Osamu Nishikawa
Joined SANYO DENKI in 2009.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

High Static Pressure Long Life Counter Rotating Fan *San Ace 60L* 9CRLA Type

Yoshihisa Yamazaki　Haruhisa Maruyama　Seiji Takeuchi　Yusuke Okuda　Honami Osawa

1. Introduction

With the rapid shift to high-performance ICT equipment in recent years, there is a greater requirement for the high-density design of such equipment, further increasing heat generation. Amid such market trends, many customers are adopting counter rotating fans, and there is a demand for such fans to offer even higher cooling performance. Customers also require equipment with longer life expectancy, giving rise to a demand for long-life fans with high cooling performance. SANYO DENKI had already developed and launched the high static pressure counter rotating fan, *San Ace 60L* 9CRL type, however we recognized the need to improve static pressure performance in order to realize even higher cooling performance.

Fig. 1 60 × 60 × 76 mm *San Ace 60L* 9CRLA type

In response to such a requirement, we newly developed and launched the high static pressure long life counter rotating fan, *San Ace 60L* 9CRLA type (hereinafter, "new model").

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

2. Product Features

Figure 1 shows an external view of the new model.
The features of the new model are:

(1) High static pressure
(2) Long life
(3) Low power consumption

3. Product Overview

3.1 Dimensions

Figure 2 shows the dimensions of the new model.

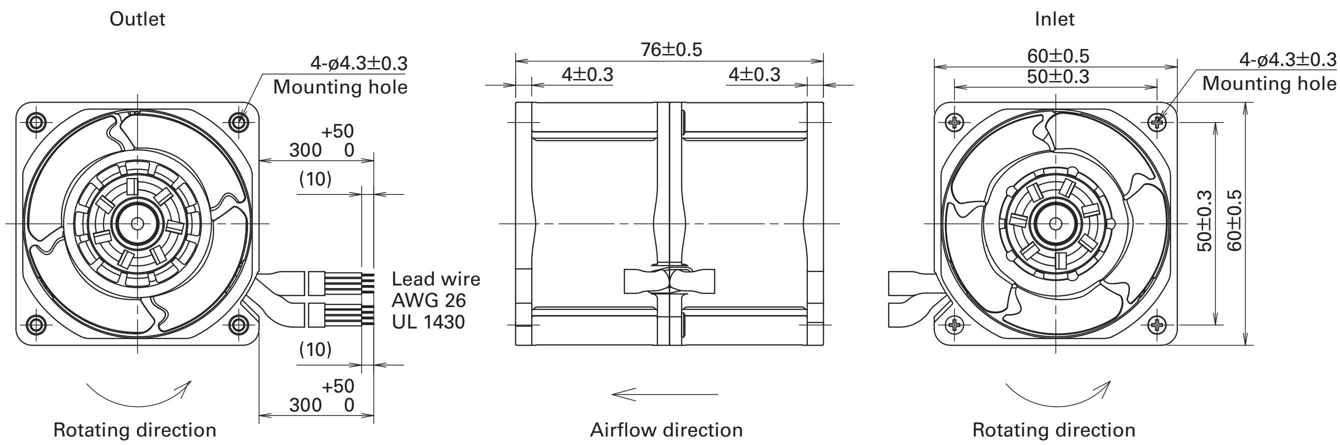


Fig. 2 Dimensions of the new model (unit: mm)

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}] Inlet	Rated speed [min^{-1}] Outlet	Max. airflow [m³/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	SPL [dB (A)]	Operating temperature [°C]	Expected life [h]
9CRLA0612P0G001	12	10.8 to 13.2	100	3.0	36.0	16,500	17,800	2.1	74.1	1,400	5.62	70	-20 to +70	100,000 / 60°C
			20	0.4	4.8	5,000	5,400	0.64	22.6	128	0.51	43		

3.2 Characteristics

3.2.1 General specifications

Table 1 shows the general specifications for the new model.

3.2.2 Airflow vs. static pressure characteristics

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

3.2.3 PWM control function

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

3.3 Expected life

The new model has an expected life of 100,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage in free air and at normal humidity).

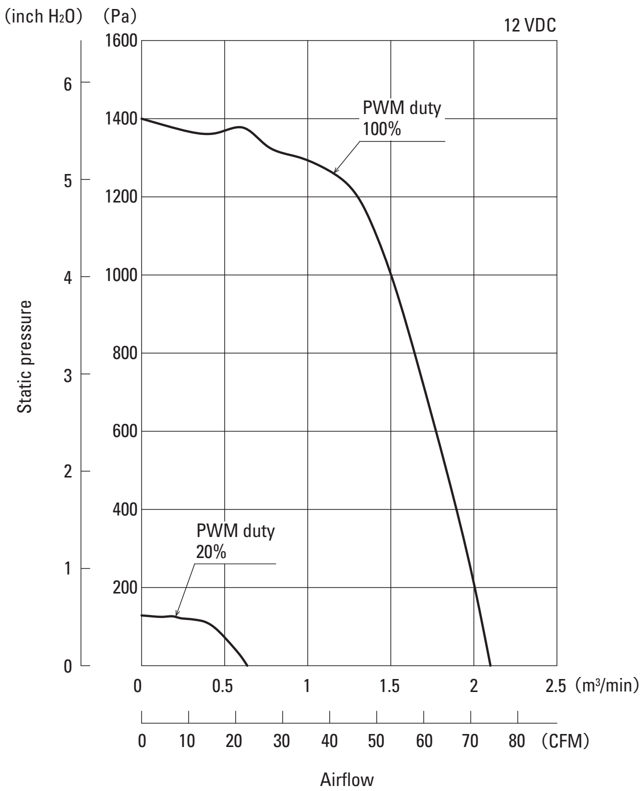


Fig. 3 Airflow vs. static pressure characteristics of the new model

4. Key Points of Development

The new model features a newly-designed impeller and frame which improves static pressure. Moreover, we increased rotational speed, which is effective in improving static pressure performance, and increased the impeller strength accordingly.

The key points of development are explained below.

4.1 Impeller and frame design

For the new model, there was a need to improve the overall static pressure performance in terms of airflow vs. static pressure characteristics. Generally speaking, increasing impeller rotation speed makes it possible to improve static pressure performance. As such, we attempted increasing rotational speed compared to the current model for this new model, however this created the issue of higher power consumption.

Figure 4 shows a dynamic blade shape comparison of the current and new models.

Figure 5 shows the flow of air of the new model.

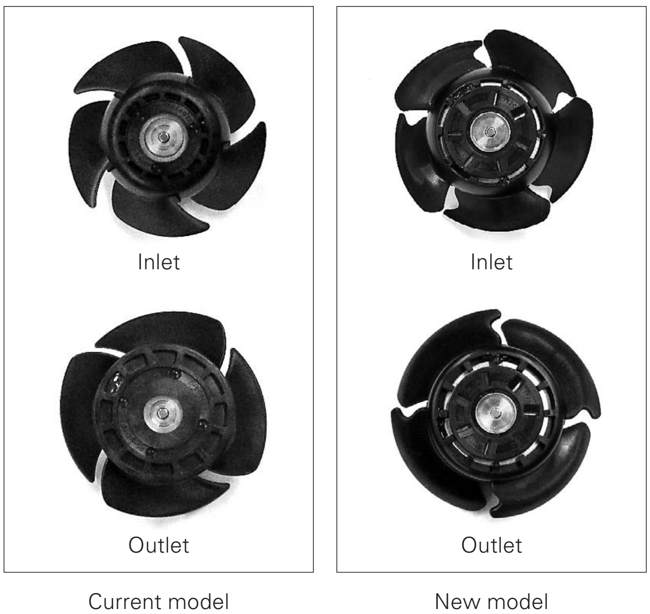


Fig. 4 Dynamic blade shape comparison of current and new models

To resolve this issue, we leveraged fluid analysis to design optimal shapes for the dynamic and static blades, and reduce power consumption. Figure 4 shows a comparison of the shapes of the current and new models. The dynamic blades straightened the wind flow. By changing the shape in this way, we increased impeller efficiency compared to the dynamic blades of the current model, and reduced the load torque of the dynamic blades, increasing the impeller's rotational speed. Figure 5 shows the airflow of the new model. Flow lines are used to indicate the airflow across the surface of the dynamic and static blades, and it is apparent that the air flows smoothly along the blade profile. Moreover, the figure expressing airflow speed distribution demonstrates the straightness of the airflow.

Through this optimization of the dynamic and static blades, we succeeded in significantly increasing static pressure performance and achieved our high static pressure and low power consumption targets. Moreover, by reducing power consumption, we were able to suppress the amount of heat generated by the motor, enabling longer service life.

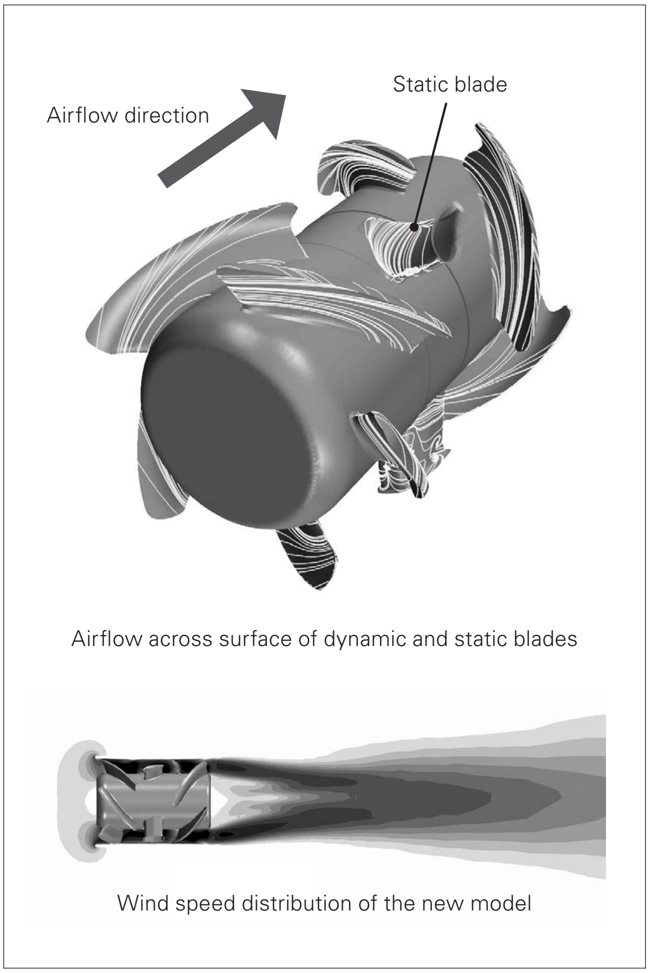


Fig. 5 Airflow of the new model

4.2 Integrated type

With increased fan rotational speed, impellers require a structure that can withstand high rotation. As such, we employed a structure that integrated the impeller and rotor cover. By increasing joint strength, the impeller can withstand high rotation.

5. Comparison with Current Model

5.1 Comparison of airflow vs. static pressure characteristics

Compared to the current model, the new model's maximum airflow has increased by 5%, and its maximum static pressure has increased by 40%.

Figure 6 provides an example of the airflow vs. static pressure characteristics of the current and new models.

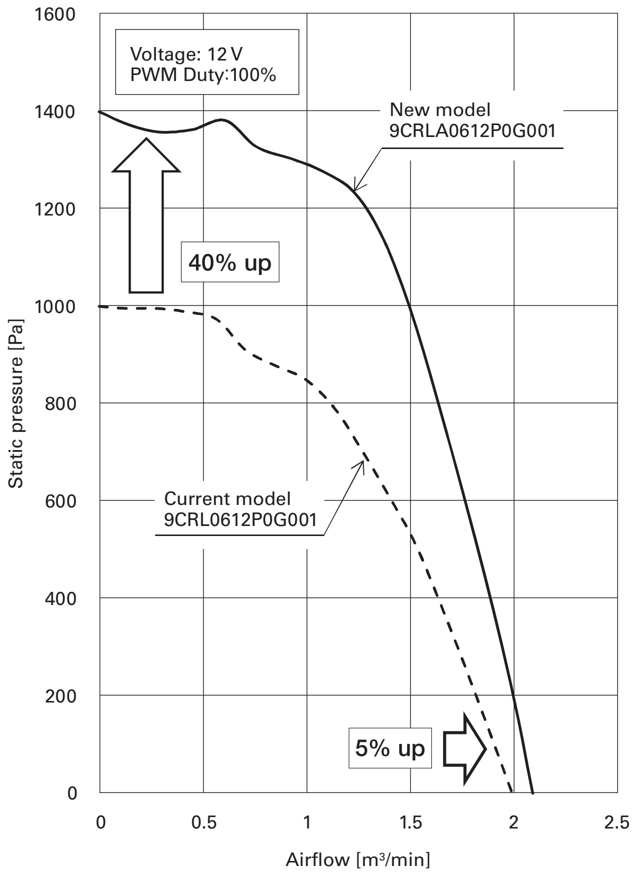


Fig. 6 Airflow vs. static pressure characteristics of current and new models

5.2 Power consumption comparison

Figure 7 gives a comparison of the power consumptions for the airflow vs. static pressure characteristics of the current and new models when both have equivalent maximum static pressure.

This graph compares the airflow vs. static pressure characteristics when the rotational speed of the new model is reduced, and the maximum static pressures are equivalent for both the new and current models. It is evident that, overall, the new model has lower power consumption than the current model, and we have succeeded in reducing power consumption by 20% in the vicinity of maximum static pressure.

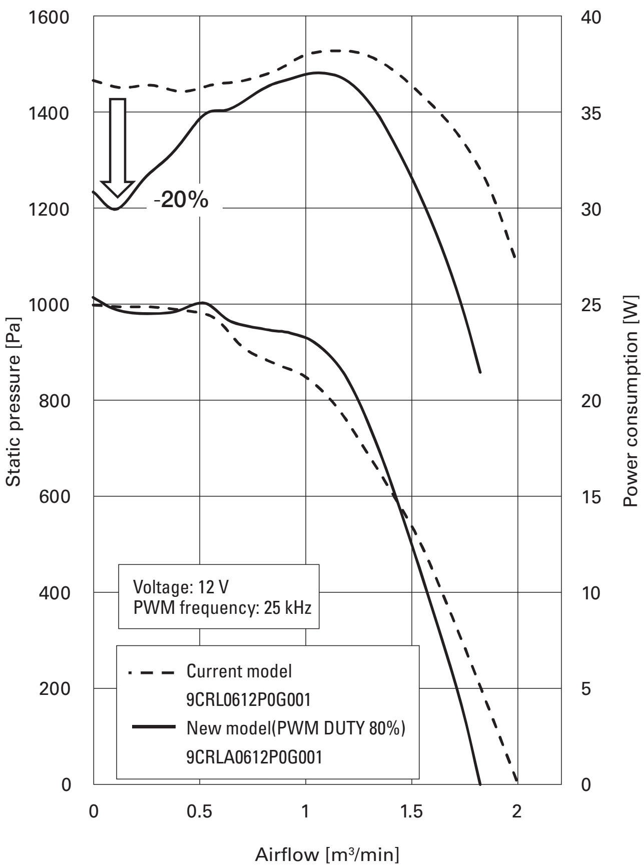


Fig. 7 Example of the airflow vs. static pressure characteristics (comparison with current model)

6. Conclusion

This article has introduced some of the features and performance of the 60 × 76 mm high static pressure long life counter rotating fan *San Ace 60L* 9CRLA type, developed by SANYO DENKI.

The new model offers longer service life at the same time as significantly higher static pressure.

As such, we believe it will significantly contribute to the cooling of high heat-generating, high-density equipment, for which demand will continue to increase.

SANYO DENKI wishes to continue developing products responding to market needs and offering products which contribute to creating new values for our customers.

Yoshihisa Yamazaki
Joined SANYO DENKI in 2016.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Haruhisa Maruyama
Joined SANYO DENKI in 1997.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Seiji Takeuchi
Joined SANYO DENKI in 2006.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Yusuke Okuda
Joined SANYO DENKI in 2010.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Honami Osawa
Joined SANYO DENKI in 1989.
Cooling Systems Div., Design Dept.
Works on the development and design of cooling fans.

Development of UPS Products Equipped with Lithium-Ion Batteries Creating Change and Offering New Value

Masahiko Nagai

1. Introduction

SANYO DENKI develops and releases uninterruptible power supplies (UPS) to protect important equipment such as servers and ICT equipment in the event of power outages.

Conventionally, lead-acid batteries have been used in UPSs due to their lower cost and ease of use. Lead-acid batteries are excellent in terms of availability, safety, and cost. However, lead-acid batteries and the UPSs which use them have the following problems.

(1) The characteristics and lifespan of lead-acid batteries are easily affected by operating temperature, so they need to be installed in temperature-controlled environments. For example, if the average operating temperature is 25˚C, the lower the temperature falls below this, the smaller the battery capacity becomes, reducing UPS backup time. Moreover, in environments above 25˚C, battery life shortens relative to the temperature.

(2) In the case of lead-acid batteries, generally the capacity at the end of battery service life is set at 50% of the initial value, so UPS backup time is shorter when a battery nears the end of its life. Moreover, service life is shortened if there is a high charge/discharge frequency. As such, the battery must be replaced at an early stage to ensure load equipment will be properly backed up in the event of a power outage.

(3) Lead-acid batteries have a relatively small energy density, so if a UPS requires prolonged backup time, the number of batteries must be increased, therefore a large installation space must be secured.

2. UPSs Creating Change in the Market

SANYO DENKI solved these problems of UPSs using lead-acid batteries by developing UPSs equipped with lithium-ion batteries (hereinafter LIBs) that can be installed in harsh environments that were previously impossible, broadening the scope of UPS utilization, creating change in the market, and offering new value.

The features of these UPS models are (1) a wide operating temperature range that can be used with peace of mind in both extremely cold and extremely hot regions, (2) significantly smaller size than SANYO DENKI's current models, and (3) reduced battery replacement costs by extending the battery replacement interval from five to ten years.

Moreover, the safety of these UPSs have been improved by monitoring LIB information on the UPS side, in addition to the management system on the LIB side. The following sections will introduce SANYO DENKI's LIB-equipped UPS product lineup.

2.1 *SANUPS A11K-Li* series

The *SANUPS A11K-Li* series are LIB-equipped UPSs which adopt the highly reliable double conversion online topology, and are suitable for backup of computers and production equipment. They are space-saving, and offer extended backup time.

The lineup is available with output capacities of 1.5, 3, and 5 kVA. Figure 1 is an external view of the *SANUPS A11K-Li* series. All models can be installed in 19-inch racks.

Fig. 1 *SANUPS A11K-Li* (1.5 kVA)

2.2 *SANUPS N11B-Li* series

In recent years, there has been an increasing demand for backup power for outdoor facilities such as base stations, traffic lights, paid parking lots, and surveillance cameras.

Hence, SANYO DENKI developed the *SANUPS N11B-Li* series, which can be used outdoors due to having a design where the UPS main unit and LIB are housed in a single enclosure with IP65* dustproof and waterproof protection.

This product is available with output capacities of 1, 1.5, and 3 kVA. Figure 2 is an external view of the *SANUPS N11B-Li* series.

This UPS adopts a passive standby topology to minimize power consumption and achieve high efficiency. This makes it possible to install the UPS outdoors where the ambient temperature is high, as well as helps to reduce running costs and save energy.

*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)
IP65: No ingress of dust. Devices operate stably even when directly exposed to water from many directions.

Fig. 2 *SANUPS N11B-Li* series

2.3 *SANUPS N11C-Li* series

There is a demand for backup power for disaster management facilities such as floodgates, warning sirens, and emergency management radios as well as for the system power source that monitors them.

Monitoring systems for disaster management facilities are installed in confined spaces such as small-scale unmanned buildings or containers, with no form of air-conditioning; therefore, it is assumed that they will be required to operate in harsh environments. As such, UPSs are required to offer high-efficiency, long backup times, space-saving, low maintenance, and have a wide operating temperature range.

To meet these needs, SANYO DENKI developed the *SANUPS N11C-Li* series which features a small footprint and adopts the passive standby topology with minimal heat dissipation.

This product is available with output capacities of 1.5, 3, and 5 kVA.

With minimal heat dissipation and high-efficiency, it can be used in extreme temperature environments, such as outdoor cubicles without air-conditioning, and contributes to lower running costs and energy-saving.

Figure 3 is an external view of the *SANUPS N11C-Li* series. All models can be installed in 19-inch racks.

Fig. 3 *SANUPS N11C-Li* (5 kVA)

3. Common Features of the Newly Developed UPSs

The above-mentioned UPS products share common features that offer new value. These features are described below.

3.1 Low maintenance

Conventional lead-acid battery-equipped UPSs have to be replaced approximately every five years. The expected life of the LIBs used in these UPSs is ten years, which means no battery replacement work is required for approximately ten years. The expected life of the UPS main unit is also ten years, so no maintenance work, such as battery replacement, is required during this period, meaning that maintenance and operating costs are reduced.

3.2 Wide operating temperature range

LIB-equipped UPSs have an operating temperature range between -20˚C and +50˚C or 55˚C, which is wider than that of conventional models.

By widening the operating temperature range we have significantly expanded the scope of UPS application, so they can now be used in harsh temperatures, which was previously impossible with conventional UPSs.

3.3 Compact and lightweight

Compared to lead-acid batteries, LIBs have higher energy densities. When comparing products with equivalent backup times, LIB-equipped UPSs are around half the volume and mass of conventional UPSs. Figure 4 illustrates the configuration differences between UPSs using lead-acid batteries and UPSs using LIBs.

The LIB-equipped UPS occupies less space than the lead-acid battery UPS, contributing to efficient usage of space in the locations in which they are installed.

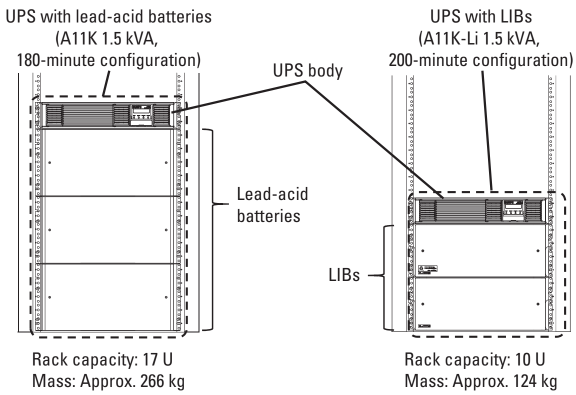


Fig. 4 Comparison of UPS configurations (when mounted in a 19-inch rack)

Table 1 compares the features of an LIB-equipped UPS with a conventional lead-acid battery-equipped UPS.

Table 1 Features of the newly developed UPS

	Conventional UPS (with lead-acid batteries)	**Newly developed UPS (with LIB)**
Expected battery life	5 years* (ambient temperature: 25˚C)	**10 years*** (ambient temperature: **30˚C**)
Operating temperature range	-10 to 40˚C	**-20 to 55˚C**
Volume, mass	1	**Approx. 1/2**

*: Assuming ten power outages a year

4. Technology Achieving High Safety and Offering Peace of Mind

4.1 LIB protection function

Due to the high energy density of LIBs, there is some concern about smoke and fire. But by carefully monitoring LIB status, they can be used safely.

SANYO DENKI's LIB-equipped UPSs feature safety management of LIB with a battery management system (BMS), as well as monitor the LIB on the UPS to protect the LIB in the event of an abnormality being detected. Overviews of these protection functions are as follows.

(1) Protection by BMS

BMS monitors LIB current, cell voltage, and cell temperature, and turns the switch off to disconnect and protect the LIB if it detects an overcurrent, overcharge, or excessive temperature.

(2) Protection by UPS

A UPS communicates with the BMS and monitors LIB status during operation. If a communication error occurs, the UPS stops charging to protect the LIB. Also, if the LIB's charging voltage or cell voltage increases, the UPS stops the charger to protect the LIB. Furthermore, the UPS stops charging or discharging if the LIB's cell temperature becomes too high.

If any other abnormality occurs in the UPS or LIB, the circuit is disconnected on both UPS and LIB-side switches for protection. Moreover, in the event of a short circuit, the LIB is isolated via a fuse to protect wiring.

Figure 5 shows how the UPS and LIB configure the protection.

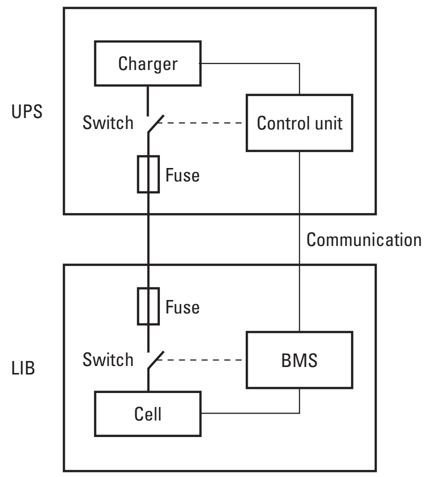


Fig. 5 LIB protection functions

4.2 Optimal device internal layout

Conventionally, UPSs are mostly installed indoors. However, as described above, we designed the *SANUPS N11B-Li* to be used outdoors, which required a protection as high as IP65.

The heat generated within an IP65 rated enclosure cannot directly escape to the outside. If heat is trapped inside the UPS and becomes concentrated in one area, it may raise the temperature of the electronic components or LIB, which in turn could hasten component deterioration or trigger a malfunction. In such cases, the UPS may not reach its expected life, possibly leading to a fail in backing up load equipment properly.

With consideration to this aspect, in designing the UPS, SANYO DENKI used a thermal fluid analysis simulation to verify internal heat flow, and optimized the structure and layout design to effectively circulate and discharge heat to the outside by using the entire enclosure. Figure 6 shows one example of thermal fluid analysis.

As a result, we succeeded in designing an enclosure with an IP65 protection without reducing UPS performance and reliability by preventing heat from concentrating in particular spots, thus developing a UPS with high reliability capable of operating outdoors.

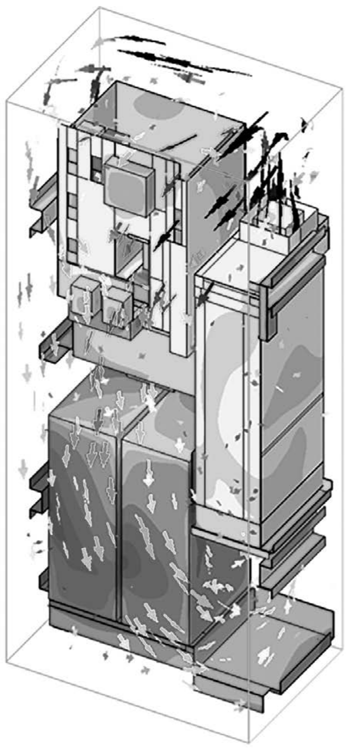


Fig. 6 Thermal fluid analysis model of the *SANUPS N11B-Li* (3 kVA)

5. Conclusion

This article has introduced new UPS products equipped with LIBs and the technologies that we used to realize their performance.

These products and technologies broaden the scope of UPS application as they enable UPSs to back up equipment in harsh environments, which was previously impossible with conventional products. Moreover, by not requiring battery replacement for approximately ten years, these products help to reduce maintenance costs.

We will continue to pursue technologies that broaden UPS applications and create major market changes, and develop products that offer our customers new value.

Masahiko Nagai
Joined SANYO DENKI in 1993.
SANYO DENKI PHILIPPINES, INC.
Works on the development and design of UPS and PV power systems.

Development of the Small-Capacity UPS *SANUPS N11C-Li* Series

Shota Ozawa Shinichiro Yamagishi Hideaki Yoda Yasuhiko Ogihara

Hirofumi Kimura Yuhei Shoyama Takeo Murai Kazuya Yanagihara

Hiroyuki Saito Kazuya Hiraguri Shota Takahashi

1. Introduction

Uninterruptible Power Supplies (UPSs) are used for backing up disaster management facilities such as floodgates and warning sirens. As such, they are installed inside small unmanned buildings, cubicles, or containers, therefore must operate in extreme temperatures.

For this reason, UPSs are required to be space-saving, maintenance-free, have a wide operating temperature range, and offer prolonged backup. Moreover, these small-scale buildings often have no form of air-conditioning; therefore UPSs for these applications must be highly efficient and have reduced heat dissipation so as not to increase the temperature inside and affect equipment.

The lead-acid batteries that have conventionally been adopted in small-capacity UPSs have a limited operating temperature range, therefore requires replacement approximately every five years. Moreover, to achieve prolonged backup, more batteries are needed, which in turn requires more installation space.

Compared with UPSs with conventional lead-acid batteries, however, ones with lithium-ion batteries (LIB) can be used in a wider operating temperature range, require less space, offer long backup time, and operate without maintenance.

Our UPS products using LIB include the *SANUPS A11K-Li*, a double conversion online UPS for indoors and *SANUPS N11B-Li*, a standby UPS for outdoors. We expanded this lineup with the addition of the *SANUPS N11C-Li* that can be used inside small unmanned buildings or in other extreme temperature environments. This article introduces the features of this new model.

2. Product Overview

The *SANUPS N11C-Li* is available in three models with 1.5, 3, and 5 kVA output capacities.

Figures 1 (1) through (3) show an appearance of each model.

All the models are designed compatible with battery expansion as shown in Figure 1 (4) and mountable on a rack as shown in Figure 1 (5).

3. Features

3.1 Wide operating temperature range

Adoption of LIB has enabled a wide operating temperature range of -20 to +55°C. The *SANUPS N11C-Li* can be used in extremely hot and cold regions, inside small unmanned buildings without air-conditioning, and the like.

3.2 Maintenance-free

While our conventional UPSs with lead-acid batteries require battery replacement approximately every five years, this UPS, thanks to the employed LIB, can operate for roughly ten years without battery replacement. This maintenance-free operability reduces battery replacement costs.

3.3 Improved maintainability

Works such as battery replacement have been made easy through the modularization of the inverter. Figure 2 shows how an inverter module and battery modules are installed in the *SANUPS N11C-Li*.

All the models have a maintenance bypass circuit; therefore, module replacement and other maintenance work can be performed with the grid power supply continued.

Fig. 1 *SANUPS N11C-Li* series

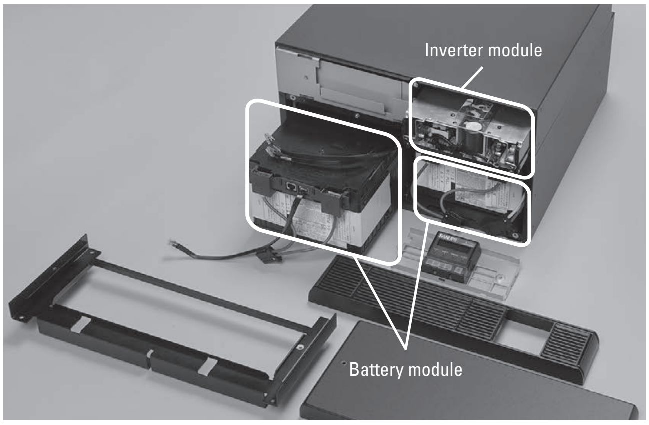


Fig. 2 Inverter module and battery modules (*SANUPS N11C-Li* 1.5 kVA)

3.4 Improved functionality

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

3.5 Compact and lightweight

UPSs with LIB are around half the volume and mass of conventional UPSs with lead acid batteries, provided that both have equivalent initial backup time.

3.6 Energy saving and reduced heat dissipation

With the passive standby topology, the *SANUPS N11C-Li* suppresses power consumption and achieves a conversion efficiency of 95%. This reduces running costs and contributes to energy saving. Furthermore, because it does not generate much heat, the temperature increase in small-scale buildings with no air-conditioning can be minimized.

3.7 Extended LIB installation

By installing additional LIB, even longer backup time can be realized.

* (Max. of 400 minutes for 1.5 kVA model)

3.8 Rack-mountable

This UPS can be mounted on a 19-inch rack (EIA standard), therefore can easily be built into indoor equipment.

4. Circuit configuration

Figure 3 shows the circuit diagram for the *SANUPS N11C-Li*.

The *SANUPS N11C-Li* comprises a power supply unit consisting of a main circuit, control circuit, communication interface circuit, and other components, and battery unit consisting of a battery module, battery management unit (hereinafter BMU), and other components.

4.1 LIB monitoring circuit configuration

Equipped with a BMU, this product features a data interface between the UPS and LIB. The safety of the UPS has been increased by monitoring detailed LIB data and performing mutual protective operations and fault detections between UPS and LIB,

(1) UPS error detection

A UPS error will be notified by the UPS to BMU via CAN communication. After notified, the BMU disconnects the UPS and LIB.

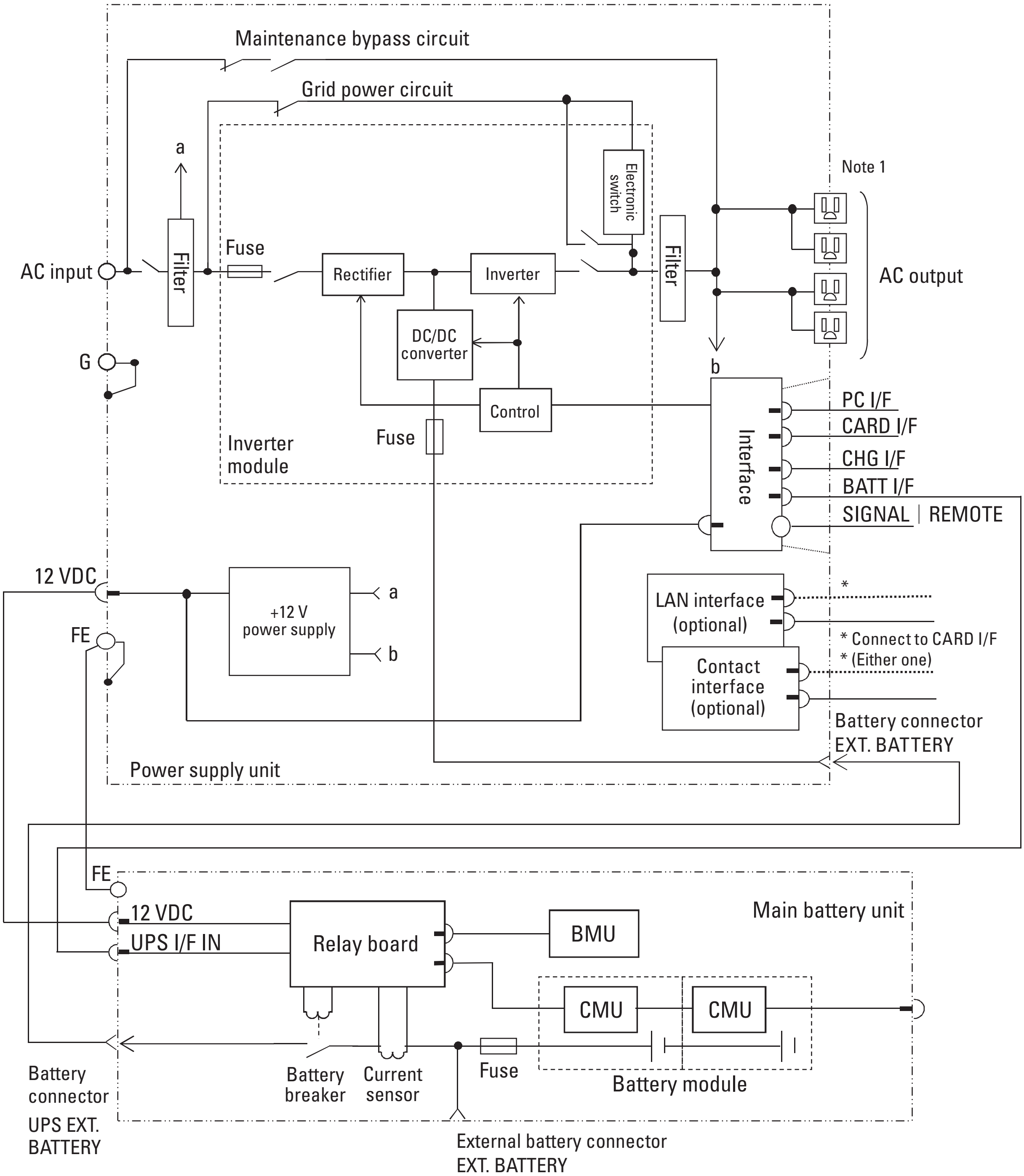
(2) LIB error detection

An LIB error will be notified by the BMU to the UPS via CAN communication. In response, the UPS stops the charger's output. Moreover, if the BMU detects an LIB error, it will disconnect the UPS and LIB.

(3) Monitoring LIB cell voltage and cell temperature

Cell voltage and temperature are measured in the battery module, and the measurement values are then notified to BMU through CAN communication. If the cell becomes over-charged, over-discharged, or reaches an abnormal temperature, the BMU determines that an LIB error has occurred, and isolate the UPS from the LIB.

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



Note 1: For the *SANUPS N11C-Li* 3 kVA and 5 kVA models, output power is available from both the output power outlet and terminal block.

Fig. 3 Circuit diagram for the *SANUPS N11C-Li* (1.5 kVA)

5. Specifications

Table 1 shows the standard specifications of the *SANUPS N11C-Li*.

Table 1 Specifications of the *SANUPS N11C-Li*

Item			Unit	Ratings and characteristics			Remarks
Model			–	N11CL152	N11CL302	N11CL502	
Rated power capacity			kVA/kW	1.5/1.2	3.0/2.4	5.0/4.0	Apparent power / active power
Type	**UPS topology**		–	Passive standby			
	Cooling method		–	Forced air cooling			
	Inverter system		–	High-frequency PWM method (during battery operation)			Grid synchronous double conversion online
AC input	**No. of phases/wires**		–	Single-phase 2-wire			
	Rated voltage		V	100, 110, 120			Same as output voltage
	Voltage range		%	Within ±10 of rated voltage			
	Rated frequency		Hz	50/60			Frequency is automatically detected
	Frequency range		%	Within ±1, 3, 5, or 7 of rated frequency			(The fluctuation range is the same as the selected output frequency regulation)
	Required capacity		kVA	2.1 max.	4.0 max.	6.7 max.	Max. capacity during battery recovery charging
AC output	**No. of phases/wires**		–	Single-phase 2-wire			
	Rated voltage		V	100, 110, 120			Voltage waveform: Pure sine wave
	Voltage regulation		%	During grid operation: Same as input voltage range			
				During battery operation: Within ±2 of rated voltage			At rated output
	Rated frequency		Hz	During grid operation: Same as input voltage range			
				During battery operation: 50/60			
	Frequency regulation		%	During grid operation: Same as input voltage range			
				During battery operation: Within ±0.5 of the rated frequency			At rated output
	Voltage harmonic distortion		%	3 or less / 7 or less			Linear load/rectifier load, at rated output
	Transient voltage fluctuation	**Rapid load change**	%	Within ±7 of rated voltage			During battery operation, for 0⇔100% load step changes / At output switch
		Loss or return of input power	%	Within ±5 of rated voltage			During battery operation, at rated output
	Load power factor		–	0.8 (lagging)			Variation range: 0.7 (lagging) to 1.0
	Overcurrent protection		%	105 or greater			Automatic transfer to bypass
	Overload capability	**Inverter**	%	105 or greater			200 ms
		Bypass	%	200/800			30 s / 2 cycles
Battery		**Type**	–	Lithium-ion battery (LIB)			
		Backup time	Minute	100/200/300/400	50/100/150/200	30/60/90/120	Ambient temperature 25°C, at rated output, under factory conditions
Acoustic noise			dB	45 max.	46 max.	46 max.	1 m from front of device, A-weighting (Where the ambient temperature is 40°C or lower)
				51 max.	55 max.	55 max.(1)	1 m from front of device, A-weighting (Where the ambient temperature exceeds 40°C)
Operating environment		**Ambient temperature**	°C	-20 to +55			(2)
		Relative humidity	%	10 to 90			Non-condensing
Storage environment		**Ambient temperature**	°C	-20 to +55			(3)
		Relative humidity	%	10 to 90			Non-condensing

(1) 60 dB or less when battery voltage drops.
(2) Battery charging stops when battery temperature exceeds 55°C.
(3) To extend battery life, avoid storage for extended periods of time in environments exceeding +30°C. If the UPS is stored without being operated for a long period, the batteries may require recharging once a year.

6. Conclusion

This article has introduced the *SANUPS N11C-Li* series as a new UPS with LIB.

With the features of a wide operating temperature range, maintenance-free operability, compact size, and high-efficiency, this product can create new UPS markets such as installation in small unmanned buildings and indoor equipment without air-conditioning.

With UPSs becoming increasingly important to society and their applications and installation environments diversify, UPSs that are even more compact and have longer backup time will be required. We will expand our product lineup of UPSs with LIB to meet these market needs, aiming to develop products that can provide our customers with new value.

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SANYODENKI Technical Report No. 45

Shota Ozawa
Joined SANYO DENKI in 2014.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

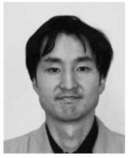
Shinichiro Yamagishi
Joined SANYO DENKI in 1991.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Hideaki Yoda
Joined SANYO DENKI in 1991.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Yasuhiko Ogihara
Joined SANYO DENKI in 1991.
Power Systems Div., Design Dept.
Works on the mechanism and design of UPS.

Hirofumi Kimura
Joined SANYO DENKI in 2007.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Yuhei Shoyama
Joined SANYO DENKI in 2009.
Power Systems Div., Design Dept.
Works on the development and design of UPS.



Takeo Murai
Joined SANYO DENKI in 2012.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Kazuya Yanagihara
Joined SANYO DENKI in 2013.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Hiroyuki Saito
Joined SANYO DENKI in 2015.
Power Systems Div., Design Dept.
Works on the mechanism and design of UPS.

Kazuya Hiraguri
Joined SANYO DENKI in 2016.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Shota Takahashi
Joined SANYO DENKI in 2017.
Power Systems Div., Design Dept.
Works on the development and design of UPS.

Servo System Technologies Creating Monozukuri Changes

Hideaki Kodama Yasutaka Narusawa Norio Nakamura Shusaku Magotake

1. Introduction

In recent years, it has become necessary for the manufacturing industry to both improve productivity and increase flexibility toward market changes and fluctuation. As such, many manufacturers are undertaking major change by incorporating ICT technologies for robot automation, etc. and information technologies, such as IoT and AI, in an attempt to achieve advanced *monozukuri*.

This article will introduce technologies that support robot development, and servo system monitoring functions and ICT technologies as servo system technologies that create monozukuri change. This article will also provide examples of our production line initiatives which use these technologies.

2. Robot Development Support Technologies

An effective way to increase monozukuri productivity and flexibility is to use robots to automate processes that were conventionally done by humans. However, there are a number of issues involved in developing a production system that uses robots, such as training personnel to have robot expertise and prolonged development periods.

In order to solve such issues, SANYO DENKI's *SANMOTION C Controller*[1] features technologies and functions supporting robot development, and these are introduced below.

SANMOTION C features an abundance of technologies enabling the development of robot operation programs easily and quickly, namely, robot posture control, a teaching/program function, and a simulation function. Below are explanations about each technology.

2.1 Robot posture control

For *SANMOTION C*, we have prepared a mechanism setting tool, as per Fig. 1, which makes it possible to control robot posture with ease.

Robot posture can be controlled simply by setting the type of robot to be developed, arm length, and gear ratio. Posture control does not require complicated calculations, therefore the burden of program development placed on customers is reduced.

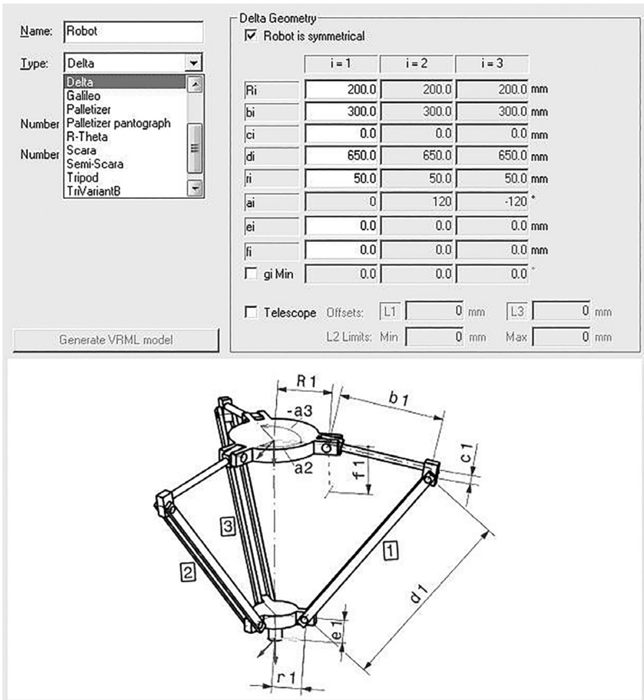


Fig. 1 Robot mechanism setting tool

2.2 Teaching/program function

As Figure 2 shows, *SANMOTION C* features a teaching pendant to easily program robot operations. Wizard-style screens such as that shown in Figure 3 simplify the process of setting complex robot hand positions. Moreover, the commands shown in Table 1 have been prepared to achieve robot operations with ease. These functions make it possible to program robot operations in a short period of time.

Fig. 2 External appearance of the teaching pendant

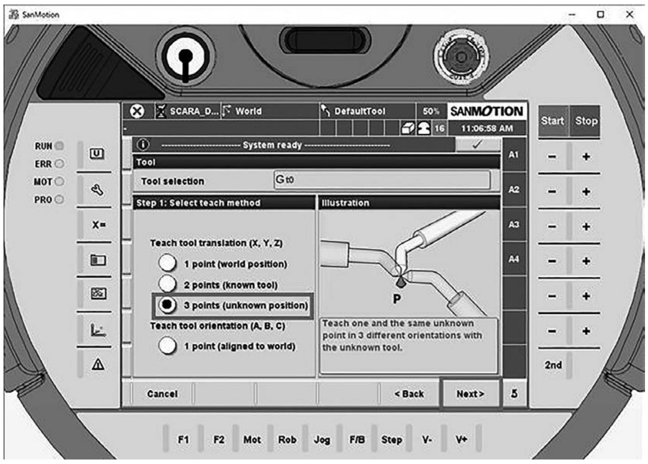


Fig. 3 Robot hand setting screen

Table 1 Examples of main robot language commands

Command name	Description
PTP	Point-to-point movement
LIN	Linear interpolation movement
CIRC	Circular interpolation movement
PTPRel	Distance-specified PTP operation
LINRel	Distance-specified linear interpolation operation
StopRobot	Robot stop
WaitFinished	Wait for robot command to process
RefRobotAxis	Homing operation
TOOL	Tool coordinates setting
Ovl	Overlap setting (Path)
Ramp	Acceleration/deceleration curve setting
WaitTime	Wait time (timer)
DIN.Wait	Wait for digital input
Dout. Set	Digital output setting (BOOL)
WHILE ... DO	Iterative control
IF ... THEN	Branch instruction

2.3 Operation simulation

SANMOTION C offers software that can simulate robot operations.

This software makes it possible to confirm whether the robot is operating efficiently and safely without using the actual robot.

As Figure 4 shows, it is possible to visually analyze each axis' operation (position, speed, acceleration) while confirming robot operations in 3D.

Even after the actual robot is installed, operations can be confirmed using simulation. Moreover, video footage can be recorded while logging motor speed, acceleration, and torque data, and this information can be utilized to analyze frequent robot stops or to improve cycle time.

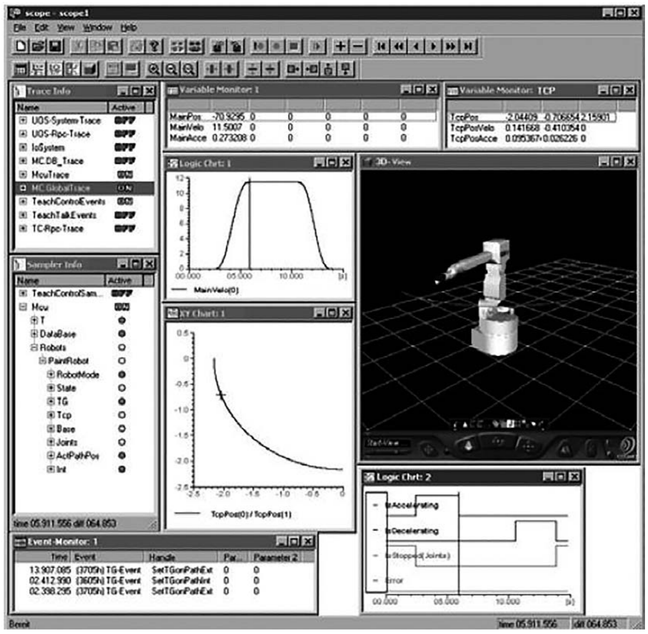


Fig. 4 Screen of 3D simulation software

In this way, even users without robot expertise can use the technologies in *SANMOTION C* to support the development of robot operation programs in a short period of time.

3. Monitoring function

With the aim of improving productivity and quality, servo systems are also required to have functions for monitoring part life, equipment operational status, operating environment, and so forth.

This section explains the monitoring functions of the *SANMOTION R 3E Model* servo amplifier.

3.1 Service life prediction function

Servo equipment such as servo motors and servo amplifiers are service life-limited components which wear and deteriorate over time. In order to use products for an extended period of time, regular part replacement is necessary. However, part life differs depending on the operating conditions and operating environment, therefore it is difficult to ascertain the appropriate replacement timing. As such, SANYO DENKI has included a function to monitor the remaining life of the motor holding brake and relays, etc. used in inrush current prevention circuits. The remaining life of these parts can be monitored through a motion network from the host controller. Moreover, as shown in Figure 5, motor setup software can be used for monitoring.

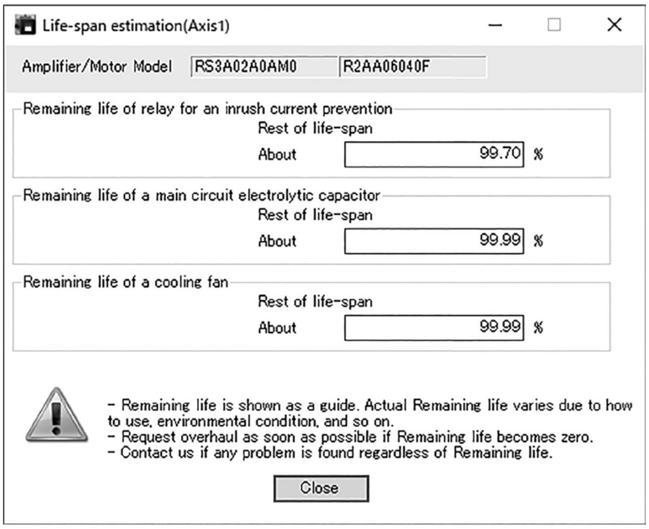


Fig. 5 Service life prediction screen in the motor setup software

Knowing a part's remaining life makes it possible to schedule maintenance before breakdowns on servo equipment and machinery actually occur.

For details on the service life prediction function, please refer to "New Product Introduction: *SANMOTION R 3E Model* 400 VAC Input Servo Amplifier (150 A, 300 A)"[2] of this Technical Report.

3.2 Operational status monitoring function

The *SANMOTION R 3E Model* servo amplifier is equipped with numerous functions to monitor the equipment operational status.

For example, it is possible to easily monitor motor and amplifier power consumption with a power consumption monitoring function that calculates the power consumption based on the rotational speed and electric current of the servo motor. By monitoring power consumption, it is possible to ascertain the energy usage status of machinery and production equipment. This helps to reduce the factory's overall energy costs and promote energy-saving.

The *SANMOTION R 3E Model* servo amplifier is also equipped with a communication error monitoring function which monitors communication quality. By quantitatively monitoring communication quality, it is possible to prevent communication trouble caused by changes in equipment over time and operating environment changes. Moreover, when a problem does arise, it is possible to swiftly perform troubleshooting.

4. Information and Communication Technology

As mentioned above, a lot of information can be obtained from the servo system, such as remaining part life and machine operating status. As shown in Figure 6, this information can be collected and accumulated in host production management systems, data servers, etc. via devices on each level and a network.

In order to effectively utilize this information, there is a need for ICT technology to easily transfer data from the servo equipment to the host device or data server. This section explains the ICT technologies SANYO DENKI is working on for servo systems.

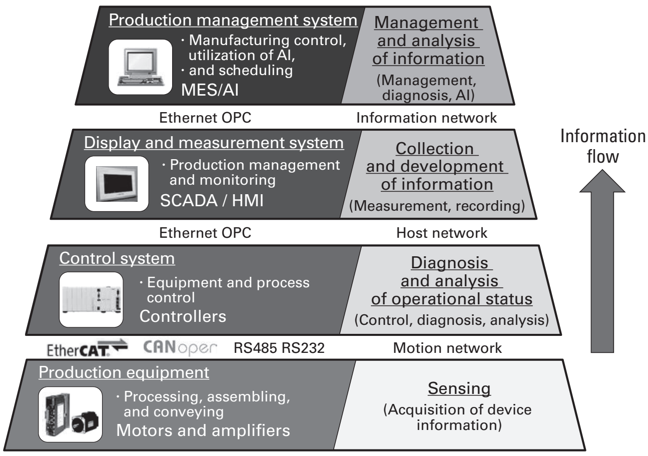


Fig. 6 Flow of production equipment information

4.1 Motion network communication technology

In order to acquire a high volume of information from a servo system, there is a need for a high-speed, large-capacity motion network.

The *SANMOTION R 3E Model* EtherCAT servo amplifier[3], which is compatible with high-speed motion networks, is the optimal product for utilizing ICT technology on the production line.

This servo amplifier achieves a minimal communication cycle of 62.5 μs, meaning that the maximum data transfer amount in one communication cycle is approximately 1.6 times greater than the conventional model. It is possible to send information to the host controller in real-time, including not only commands and feedback information required for servo motor control, but also monitoring information such as remaining part life and equipment operating environment.

By utilizing these features, naturally the performance of machinery is improved, but so too is the reliability of failure detection, preventive maintenance, etc.

4.2 Network connection technology

SANYO DENKI's *SANMOTION C* motion controller can easily establish communication between devices through an OPC server and network library. Figure 7 shows an example of network connection between devices.

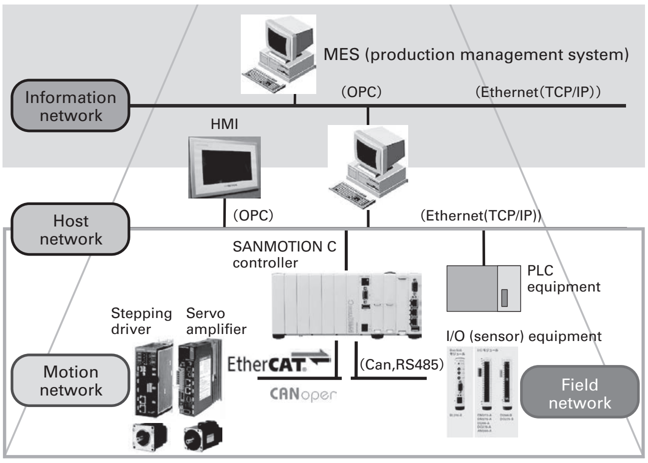


Fig. 7 Network connection between devices

Users who develop communication programs only need to set parameters through GUI for the controller to automatically establish communication between devices, thus enabling a network to be built in a short period of time.

5. Examples of use on SANYO DENKI's production line

This section introduces examples of how we have applied technologies that support the development of robots, servo system monitoring functions, and ICT technologies to SANYO DENKI's monozukuri.

5.1 Example of use for robot development support technologies

Previously, the part insertion process for servo amplifier's printed circuit board heavily depended on manual work and was known as a bottleneck process of the production line. To alleviate this bottleneck, we built a production system utilizing robots. Figure 8 shows the external appearance of a dual-arm robot developed in-house by SANYO DENKI.

This in-house robot loads and unloads printed circuit boards to and from the in-circuit tester then transfers PCBs to the downstream process.

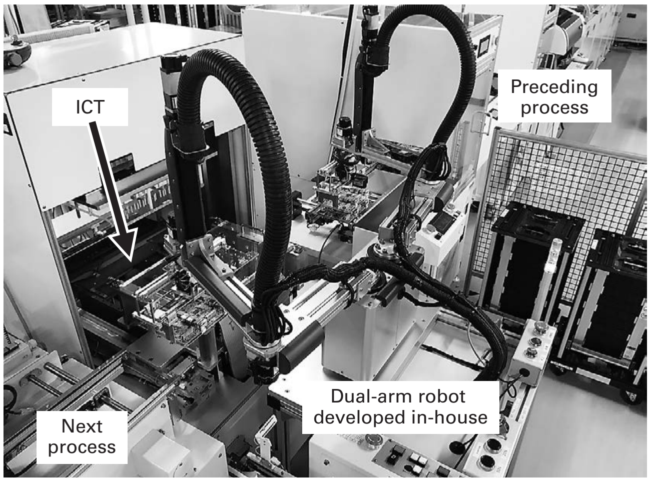


Fig. 8 External appearance of an in-house developed dual-arm robot

By using the robot development support technologies of *SANMOTION C*, we were able to develop this robot in one-third of the time typically required, and minimize installation costs. The newly built part insertion process achieves four times greater productivity and two-thirds shorter lead time compared to the conventional process. Moreover, it is possible to produce several different varieties of PCBs on the same production line, therefore productivity and flexibility have been dramatically improved.

5.2 Examples of use for monitoring functions and ICT technology

Robots and automation equipment using SANYO DENKI's SANMOTION products have also been introduced to the servo motor production line. We have begun initiatives to increase productivity and stabilize quality by utilizing the various types of information that can be obtained from the servo motors, encoders, and servo amplifiers using such equipment.

As one example, this article will introduce how we have used ICT technology on the rotor assembly line for compact servo motors.

This assembly line performs everything from attaching the magnet to the motor shaft to rotor inspection. As shown in Figure 9, the control system comprises of the *SANMOTION R 3E Model* EtherCAT servo amplifier and the *SANMOTION C* controller.

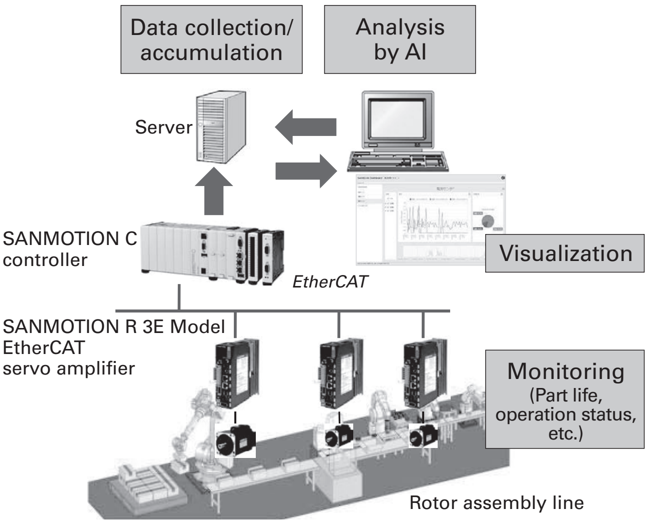


Fig. 9 Example use of ICT technology on a rotor assembly line

A large volume of information monitored by the servo system, such as part life and power consumption, is sent to the *SANMOTION C* controller in real-time by utilizing the high-speed performance and efficient data transfer of EtherCAT. Moreover, information acquired by the controller is accumulated in the data server.

By utilizing the data stored in the server, it is possible to achieve visualization of remaining part life, equipment operating status, amplifier operating status, and so on. As such, users can expect many benefits from the support functions that enable scheduled maintenance and enhanced productivity of servo equipment. Moreover, by utilizing machine learning such as AI, the large quantity of data that is collected can be analyzed and used to verify symptom detection for equipment failures and faults.

6. Conclusion

This article introduced robot development support technologies, and the monitoring functions and ICT technologies of servo systems as servo system technologies creating monozukuri change. This article also provided examples of SANYO DENKI's monozukuri using these technologies.

We will continue enhancing support technologies for the introduction and utilization of robots in order to further improve productivity and flexibility. Moreover, SANYO DENKI wishes to incorporate the know-how relating to ICT technology verified on our production lines into developing technologies and products creating new values for our customers, as well as creating change.

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(3) Ito, Machida and others: Development of the SANMOTION R 3E Model EtherCAT Servo Amplifier
SANYO DENKI Technical Report No. 44 (2017-11)

Hideaki Kodama
Joined SANYO DENKI in 1991.
Servo Systems Div., Design Dept. 2
Works on the design and development of controllers.

Yasutaka Narusawa
Joined SANYO DENKI in 1991.
Servo Systems Div., Design Dept. 2
Works on the design and development of servo amplifiers.

Norio Nakamura
Joined SANYO DENKI in 2007.
Servo Systems Div., Production Engineering Dept.
Works on the production technology of servo motors.

Shusaku Magotake
Joined SANYO DENKI in 1996.
Servo Systems Div., Production Engineering Dept.
Works on the production technology of controllers and servo motors.

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

Haruhiko Chino Hiroaki Koike Haruhiko Kamijyou

Yasuhiro Wakui Masaki Miyashita Satoshi Hiramitsu

1. Introduction

The *SANMOTION R 3E Model* 200 VAC input servo amplifier developed in 2014 features a wide range of products able to drive motors with outputs of up to 30 kW, and is being used by customers in a variety of machinery. With the globalization of industry, a high demand for 400 VAC input servo amplifiers is emerging primarily in Europe and Asia, therefore SANYO DENKI has enhanced the lineup with new 400 VAC input models capable of driving motors with the same outputs as the 200 VAC models.

This article will introduce the two new models added to the *SANMOTION R 3E Model* 400 VAC input servo amplifier lineup:150 A and 300 A.

First, an overview of the new models will be provided. Next, the main performance, functions and development points will be introduced.

2. Product Overview

2.1 Appearance and dimensions

Figure 1 shows the appearance of the *SANMOTION R 3E Model* 400 VAC input servo amplifiers with 150 A and 300 A capacities (hereinafter 150 A and 300 A models), while Figures 2 and 3 show their dimensions.

In order to maintain compatibility with existing products, the new models were given the same width and height dimensions as the current models.

2.2 Main specifications

Table 1 shows the main specifications of the 150 A and 300 A amplifiers. The interface supports analog and pulse train inputs, as well as EtherCAT. We have also added a functional safety model to the lineup, allowing customers to choose the right one for their equipment's application.

Compatible motors are the R1 and R2 series 400 V input motors with 5.5 to 30 kW outputs.

Compatible encoders are our absolute encoders and wire-saving incremental encoders. Moreover, these models also support encoders manufactured by HEIDENHAIN (EnDat2.2 interface) for use with linear motors or fully closed-loop control systems.

The new models also comply with international standards such as Europe's Low Voltage Directive, the EMC Directive, Functional Safety, UL/cUL (US), and KC mark (Korea).

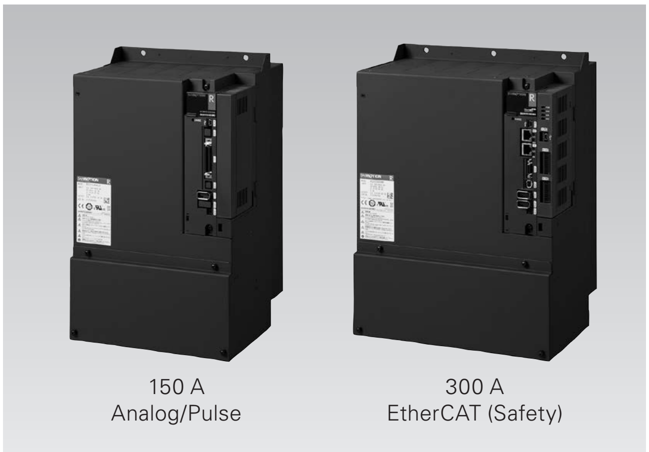


Fig. 1 Appearance

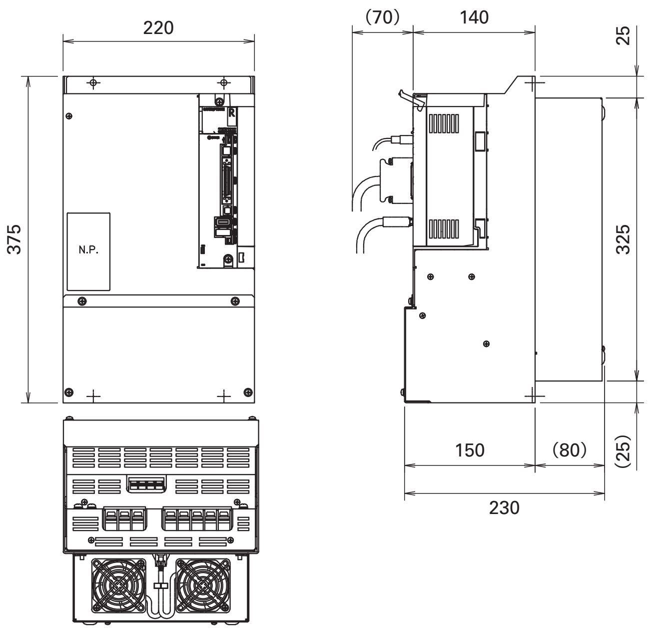


Fig. 2 Dimensions (150 A)

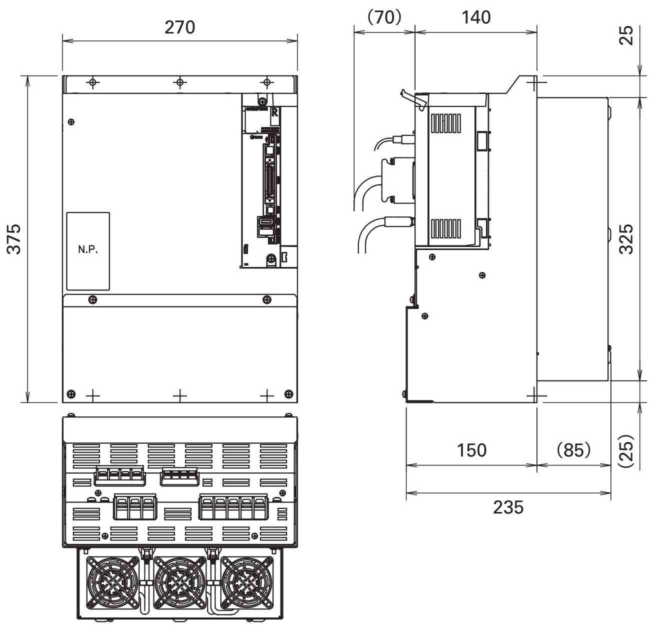


Fig. 3 Dimensions (300 A)

Table 1 Main specifications

Amplifier capacity		150 A	300 A
Control power supply voltage range		24 VDC ±10%	
Main circuit power supply voltage range		380 to 480 VAC +10%, -15%	
Dimensions		220 W × 375 H × 230 D	270 W × 375 H × 235 D
Continuous output current		34.0 Arms	66.0 Arms
Peak current		83.0 Arms	157.0 Arms
Compatible motor		5.5 to 15 kW	20 to 30 kW
Compatible encoder		· Absolute encoder (battery back-up, battery-less, single turn) · Wire-saving incremental encoder · HEIDENHAIN EnDat2.2 encoder	
Function	**Control function**	· Tandem operation control · Dual positioning feedback control	
	Mechanical vibration/ resonance suppression	· FF vibration suppression control (2-Step) · CP vibration suppression control · Adaptive notch filter	
	Servo tuning	· Auto tuning response 40 levels · Servo tuning support function	
	Start-up, monitoring, diagnosis	· Virtual motor operation · Power consumption monitoring · Drive recorder · Encoder temperature monitoring · Amplifier temperature monitoring · Service life diagnosis of holding brake · Monitoring of power consumption of regenerative resistor · Monitoring of encoder communication quality · Relay clicking counter	
Safety standards	**UL**	UL 61800-5-1	
	CSA	C22.2 No.274-13	
	Low Voltage Directive	EN 61800-5-1	
	EMC Directive	EN 61800-3, EN 61326-3-1	
	Functional safety	ISO 13849-1 PL=e, EN 61508 SIL3, EN 62061 SILCL3	
	KC mark	KN 61000-6-2, KN 61000-6-4	

3. Performance and Functions

The new models offer four new functions while maintaining the same performance and functions as the *SANMOTION R 3E Model* 200 VAC input servo amplifiers.

These functions acquire and analyze data relating to servo motors and servo amplifiers to improve the maintainability of equipment through preventive maintenance and environmental diagnosis. The details of each function are provided below.

3.1 Holding brake remaining life

A servo motor with a holding brake is a service life-limited component as repetitive braking causes wear, which in turn causes the gap to widen and, ultimately, prevents normal operation.

This function counts the number of the holding brake's braking rotation to estimate brake wear and monitor the remaining life of the holding brake. This enables customers to appropriately judge the timing of servo motor replacement and prevent equipment breakdown.

3.2 Monitoring of power consumption of regenerative resistor

We have added a function to monitor power consumption of regenerative resistor.

If the input voltage rises and the capacity of the electrolytic capacitor decreases, the regenerative power increases. By monitoring power consumption, it is possible to detect changes in the power source environment and device failures. Moreover, it also enables us to check the margin in relation to maximum absorbed power, therefore customers can choose the suitable regenerative resistor.

3.3 Monitoring of encoder communication quality

A function has been added to the new models to monitor communication error rate (bit error rate) and quantitatively check the quality of communication between the servo amplifier and encoder.

The error rate varies significantly if there is a problem with the servo amplifier-servo motor connection, grounding connection, or a problem with the shielded cables. With this monitoring function, you can perform the correct wiring, grounding, etc. at the device start-up, improving the device's noise resistance. Moreover, monitoring variations in the error rate during device operation helps in checking and improving communication quality.

3.4 Relay click counter

This function enables you to monitor the remaining life of components by counting the number of relay clicks produced in the inrush current limiting circuit, dynamic brake circuit, and holding brake output circuit. This enables systematic maintenance and prevents equipment breakdown.

4. Key Points of Development

4.1 Business continuity planning (BCP) initiatives

Our suppliers suffered extensive damage in the Great East Japan Earthquake in 2011 and Kumamoto Earthquake in 2016, which made our part procurement difficult, affecting our customers' production. For example, we failed in procuring intelligent power modules (IPM) that we used as the power module for servo amplifier inverters. We could not find an alternative to it due to the lack of compatibility of the package and functions which differ by manufacturer, and however, depending on the manufacturer, and a drastic design change was required.

So, for the new 300 A servo amplifier, we selected an IGBT module which is compatible with multiple manufacturer packages. An IPM has many built-in functions such as overload protection, over-heat protection, protection against control circuit low voltage, and software isolation in the case of overloads, while the IGBT module does not offer these functions.

As such, we newly designed a common circuit as a periphery protection function of the IGBT module, achieving the same safety level as the IPM. By establishing these technologies, it became possible to purchase core parts from multiple suppliers without changing the printed circuit board and continue production even in unforeseen circumstances by minimizing damage.

This achieves one element of business continuity planning (BCP) strategy, enabling us to stably deliver our products to customers.

4.2 Reduction of servo amplifier heat generation

In order to reduce internal heat generation, we optimized the electrolytic capacitor of the main circuit. By performing FFT analysis on the ripple current derived through circuit simulation then calculating the heat generation amount from the electric current value of each frequency band, we selected the optimal specifications for the electrolytic capacitor.

Table 2 shows a comparison of the new and current models' main circuit electrolytic capacitors. By increasing the main circuit electrolytic capacitor's allowable ripple current by 35.8% compared to our conventional model (SANYO DENKI's RS1 series), temperature rise has decreased by 38.1%, thereby reducing heat generation.

Moreover, by providing feedback of evaluation results and considering the worst conditions for product specifications and parts in the design phase, we have developed a product that offers greater safety, greater security and higher quality.

Table 2 Comparison of main circuit electrolytic capacitors

Item	Current model (RS1) 150 A	New models 150 A	Difference with current model
Temperature rise	13.9 K	8.6 K	-38.1%
Static electricity capacity	2,000 μF	2,180 μF	9.0%
Allowable ripple	9.0 Arms	12.3 Arms	35.8%
Volume	628,319 mm^3	461,814 mm^3	-26.5%
Surface area	7,854 mm^3	7,697 mm^3	-2.0%

4.3 Downsizing

As Figure 4 shows, the new models are installed within the control panel on the front side, and inside the duct on the back side. Table 3 gives a comparison of depth dimensions with current models. For the current models, the front side depth dimension (which previously differed depending on amplifier capacity) has been standardized to 150 mm, and the overall size has been reduced by up to 10%. Moreover, the safety function expansion board can be completely built into the main unit, therefore it is possible to switch to the *SANMOTION R 3E Model Safety*, which complies with functional safety standards, without changing amplifier mounting positions within the control panel, or increasing space occupancy.

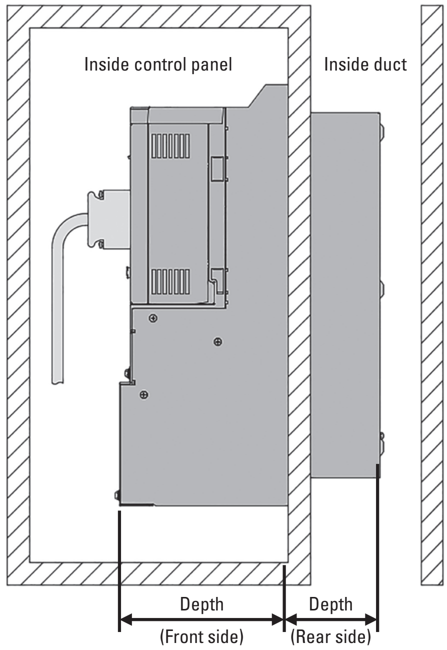


Fig. 4 Amplifier depth

Table 3 Comparison of depth and volume with current model

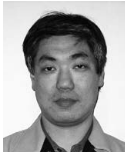
Capacity	Model number	Depth (Front side)	Depth (Duct side)	Volume Reduction rate
150 A	RS3C15 (New model)	150 mm	80 mm	-2%
	RS1C15 (Current model)	155 mm	80 mm	
300 A	RS3C30 (New model)	150 mm	85 mm	-10%
	RS1D30 (Current model)	160 mm	100 mm	

5. Conclusion

This article has introduced the main performance, functions, and development points of the new models added to the *SANMOTION R 3E Model* 400 VAC input servo amplifier lineup: the 150 A amplifier and the 300 A amplifier.

With the addition of these new models it is now possible to combine supporting motors of up to 30 kW outputs, which is equivalent to the *SANMOTION R 3E Model* 200 VAC input servo amplifiers. Furthermore, through newly added IoT functions, these models contribute to improved equipment maintainability, failure prediction, and preventive maintenance.

Moving forward, amidst market change and fluctuation, SANYO DENKI will continue to constantly assess the servo system requirements of our customers and develop products which create new value. Moreover, so that our customers may use our products safely and securely, we will further our efforts to improve design quality.



Haruhiko Chino
Joined SANYO DENKI in 1983.
Servo Systems Div., Design Dept. 2
Works on the design and development of system products.

Hiroaki Koike
Joined SANYO DENKI in 1988.
Servo Systems Div., Design Dept. 2
Works on the design and development of system products.

Haruhiko Kamijyou
Joined SANYO DENKI in 2005.
Servo Systems Div., Design Dept. 2
Works on the design and development of system products.

Yasuhiro Wakui
Joined SANYO DENKI in 2012.
Servo Systems Div., Design Dept. 2
Works on the design and development of system products.

Masaki Miyashita
Joined SANYO DENKI in 2013.
Servo Systems Div., Design Dept. 2
Works on the design and development of system products.

Satoshi Hiramitsu
Joined SANYO DENKI in 2017.
Servo Systems Div., Design Dept. 2
Works on the design and development of system products.

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