Development of the "SANMOTION F5"– An AC Power Input 5-Phase Stepping System

Masao Mizuguchi Shigehiro Kamada Ryuichi Yanagisawa Kouhei Yamaura Keisuke Ishizaki

Akio Miyahara Kouji Nakatake Yasushi Yoda Kazuhiro Yoda

1. Introduction

Stepping systems are capable of open-loop control, meaning control can be carried out easily in a simple system. For this reason, stepping systems are used broadly, in general industrial devices, semiconductor manufacturing equipment and so on. In recent years, customers have started to demand low heat and low power consumption, therefore a demand of stepping systems supporting such features is increasing. Furthermore, the demand for stepping systems is increasing in regards to medical equipment as well, with stepping systems that enable equipment to achieve low vibration being highly sought.

As a result, Sanyo Denki decided to develop the "SANMOTION F5", an AC power input 5-phase stepping system which achieves low loss, improved motor efficiency and significantly lower vibration in order to contribute to low heat and low power consumption. This document introduces these features.

2. Product Lineup

2.1 Driver lineup

Four types of drivers are included in the lineup with different combinations of input voltage and current output. Table 1 shows driver specifications.

There is the 100 – 120 V AC group and 200 – 240 V AC group, depending on input voltage specifications. Moreover, each product group consists of a 0.35 A/ phase output and 0.75 A/phase output, which can be used to suit motor size. Driver size, function, conforming overseas standards and so on are all common.

2.2. Motor lineup

Three types of motor lengths have been included in the lineup, with the three flange sizes of 42 mm sq., 60 mm sq. and 86 mm sq. Tables 2.1, 2.2 and 2.3 shows motor specifications. Figures 1.1, 1.2 and 1.3 show the pull-out torque characteristic for the representative motors.

Table 1: Driver specifications

Model No.		F5PAA035P100	F5PAA075P100	F5PAB035P100	F5PAB075P100
Output capacity		0.35 A/phase	0.75 A/phase	0.35 A/phase	0.75 A/phase
Conforming motors (flange size)		42 mm sq.	60 mm sq., 86 mm sq.	42 mm sq.	60 mm sq., 86 mm sq.
Input power voltage		Single phase 100-120 V AC +10%, -15% 50/60 Hz		Single phase 200-240 V AC +10%, -15% 50/60 Hz	
Size, mass		160 (H) x 40 (W) x 120 (D), 0.65 kg			
Operating ambient temperature		0 to 55°C			
Operating ambient humidity		90% RH or less (non-condensing)			
Compatible motors Option	Encoder	Incremental type 3 channel phase difference input method, 4000 P/R			
	Brake	Non-excitation actuating type (power supplied from driver)			
Input/output	Command pulse input type	Photocoupler type (terminal for line driver, terminal for open collector)			
	General-purpose input/output	Photocoupler type 4 inputs, 3 outputs			
	Encoder input	Line receiver input type			
	PC-I/F	RS485 half-duplex communication			
Functions	Operation mode	Normal mode, analysis mode			
	Command resolution option	• 1/1 - 1/256 microstep • Electronic gear			
	Monitoring function	Voltage monitoring, overcurrent monitoring, overheat protection			
Conforming regulations, etc.		UL/cUL, low voltage directive, EMC Directive, KC mark			

The motor has a maximum input voltage of 250 V AC and can be used regardless of driver power source voltage. Moreover, we have ensured the standard specifications of these models comply with overseas safety standards.

Because 5-phase stepping systems are often used with general industrial devices, Sanyo Denki had already been including motors with gear heads, motors with holding brakes and so on as standard products in our lineup. To accompany such products, we have added a motor with an encoder which can monitor for non-synchronization and analyze operations.

The developed driver has functions which flexibly support gear heads, holding brakes and encoders. These functions are explained in Chapter 4.

Table 2.1: 42 mm sq. motor specifications

Motor model	Single-ended spindle	SM5421-3240	SM5422-3240	SM5423-3240
	Dual-ended spindle	SM5421-3210	SM5422-3210	SM5423-3210
Motor length (as a single unit)		35 mm	41 mm	49 mm
Conforming driver model no.		F5PAA035P100/F5PAB035P100		
Motor	Drive voltage	250 V AC or less		
	Holding torque (N·m)	0.13	0.185	0.245
	Rotor inertia (x10^{-4}kg·m^2)	0.028	0.045	0.056
	Rated current (A/phase)	0.35		
	Motor mass (kg)	0.24	0.31	0.38
With low-backlash gear		Yes	-	-
With harmonic gear		Yes	-	-
Brake	Power voltage	24 V ±5%		
	Static friction torque	0.3 N·m MIN.		
Encoder	Power voltage	5 V DC ±5%		
	Basic partition no.	4000		
	No. of channels	3		
	Output method	Line driver		
Conforming regulation, etc.		UL, CE marking (Low Voltage Directive)		

Table 2.2: 60 mm sq. motor specifications

Motor model	Single-ended spindle	SM5601-7240	SM5602-7240	SM5603-7240
	Dual-ended spindle	SM5601-7210	SM5602-7210	SM5603-7210
Motor length (as a single unit)		49 mm	60 mm	89 mm
Conforming driver model no.		F5PAA075P100/F5PAB075P100		
Motor	Drive voltage	250 V AC or less		
	Holding torque (N-m)	0.57	0.9	1.7
	Rotor inertia (x10^{-4}kg·m^2)	0.2	0.31	0.6
	Rated current (A/phase)	0.75		
	Motor mass (kg)	0.62	0.8	1.27
With low-backlash gear		Yes	-	-
With harmonic gear		Yes	-	-
Brake	Power voltage	24 V ±5%		
	Static friction torque	0.8 N·m MIN.		
encoder	Power voltage	5 V DC ±5%		
	Basic partition no.	4000		
	No. of channels	3		
	Output method	Line driver		
Conforming regulation, etc.		UL, cUL, CE marking (Low Voltage Directive)		

Table 2.3: 86 mm sq. motor specifications

Motor model	Single-ended spindle	SM5861-7240	SM5862-7240	SM5863-7240
	Dual-ended spindle	SM5861-7210	SM5862-7210	SM5863-7210
Motor length (as a single unit)		66 mm	96.5 mm	127 mm
Conforming driver model no.		F5PAA075P100/F5PAB075P100		
Motor	Drive voltage	250 V AC or less		
	Holding torque (N-m)	2.3	4.4	6.8
	Rotor inertia ($x10^{-4}kg{\cdot}m^2$)	1.48	3	4.5
	Rated current (A/phase)	0.75		
	Motor mass (kg)	1.75	2.9	4
With low-backlash gear		Yes	-	-
With harmonic gear		Yes	-	-
Brake	Power voltage	24 V ±10%		
	Static friction torque	5 N·m MIN.		
Encoder	Power voltage	5 V DC ±5%		
	Basic partition no.	4000		
	No. of channels	3		
	Output method	Line driver		
Conforming regulation, etc.		UL, cUL, CE marking (Low Voltage Directive)		

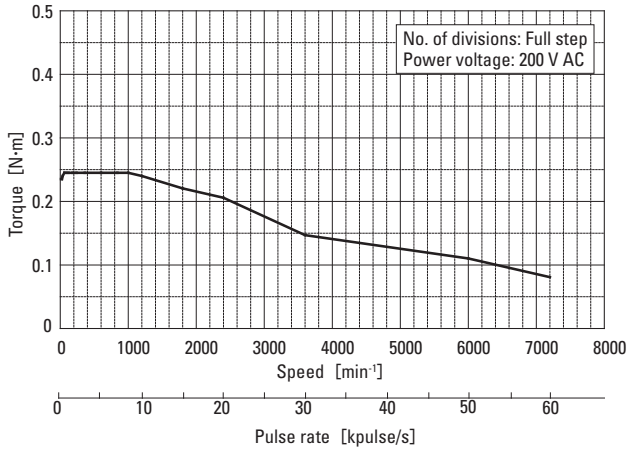


Fig. 1.1: SM5422-3240 pull-out torque characteristic

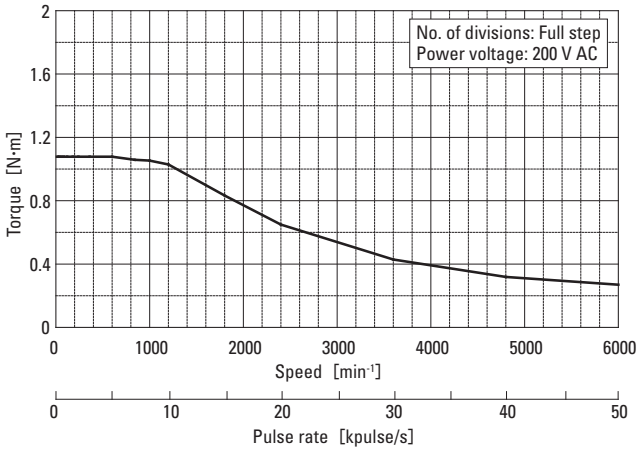


Fig. 1.2: SM5602-7240 pull-out torque characteristic

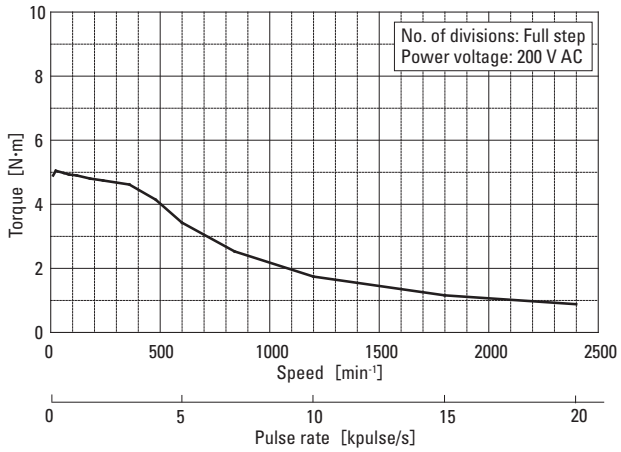


Fig. 1.3: SM5862-7240 pull-out torque characteristic

3. Features

3.1 Low-vibration

In the case of stepping motors, speed fluctuation caused by torque pulsation is a factor effecting equipment vibration however on the new model, speed fluctuation has been reduced by an average of around 30% compared to conventional models. By implementing feedback control of all 5 phases' winding current, the current balance of each phase is optimized and torque pulsation is minimized. Moreover, by implementing digital control through a special-purpose ASIC of command pulse input to current control, the interference with command pulse and sampling cycle is minimized even when command resolution is poor, thus enabling stable operations.

Moreover, the engagement dimensions and protruding sections of the stator core, flange and end cap have been revised, increasing motor stiffness and reducing speed fluctuation. Fig. 2 shows a comparison of speed fluctuation between the new model and the conventional model.

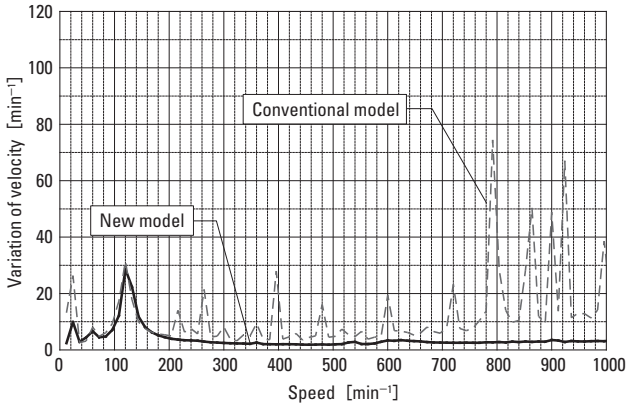


Fig. 2: Comparison of speed variation with a conventional model

3.2 High efficiency, high torque

In order to reduce motor loss and improve efficiency, iron loss bas been reduced by optimizing the design of the stator and rotor core's magnetic path and changing the electromagnetic steel plate material. Moreover, the space factor has been improved and copper loss reduced by increasing winding space and winding alignment.

Through this loss reduction, the 86 mm sq. motor has achieved the following compared with conventional models;

- Loss is reduced by approx. 24% and maximum efficiency is 85.1%
- Temperature rise: Reduced by up to 46%
- Holding torque: Improved 24% to 8.07 N·m

Pull-out torque was improved by 5 to 20%. Fig. 3 shows a comparison of pull-out torque between a conventional model and the new model.

Moreover, on the new model with a 100 V AC input type driver, the applied voltage to the motor internally has increased to an equivalent of 200 V AC. Not only has torque been significantly increased compared with the conventional 100 V AC input stepping system, but also the properties of the 100 V AC and 200 V AC input types have been made identical, therefore the user does not need to change the motor in line with power specification changes, meaning that the labor required for mechanical design and motor replacement is unnecessary.

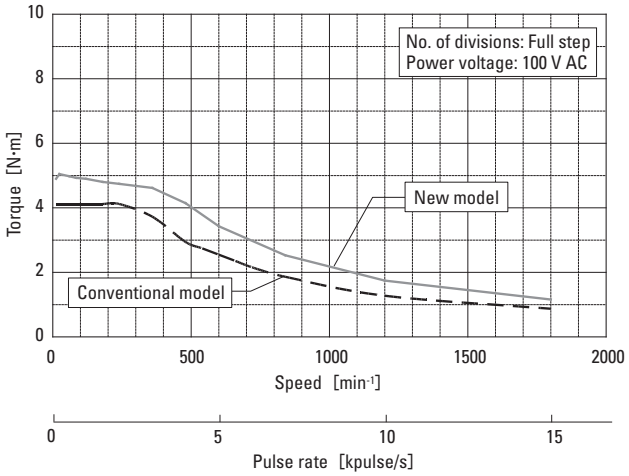


Fig. 3: Comparison of pull-out torque with a conventional model

3.3 Driver size and weight reduction

The driver of the new model has 29% less volume and 19% less mass compared with conventional models. The height is the same as Sanyo Denki's servo amplifier and 2-phase stepping driver (160 mm), thus maintaining uniformity if locating the new model alongside a switchboard.

3.4 Conforming to overseas standards

Both the driver and motor of the new model conform to UL certification and CE marking, making the certification of user equipment easy.

4. Improved Driver Functions

4.1 Supporting deceleration rate change

Most equipment that use motors use a deceleration mechanism in the power transmission process to convert rotational movement to linear movement and increase

output torque. As one option to achieve a compact deceleration mechanism, Sanyo Denki offers a motor with a gear head. Motors with gear heads have various deceleration rates however if it becomes necessary to change the deceleration rate of a piece of equipment that has been developed it is also necessary to change the command pulse number and related frequency to be inputted in the driver, therefore placing a significant burden on the user in order to change the command of the host controller.

The newly developed driver is equipped with an electronic gear function therefore it is only necessary to change the electronic gear rate in relation to the change in the deceleration rate, thus significantly alleviating the burden on the user.

4.2 Supporting motors with a holding brake

The 5-phase stepping system can be differentiated from the 2 and 3-phase stepping systems by the fact it does not easily trigger resonant vibration with machines and in many cases adopts a vertical drive shaft which utilizes a ball-screw, etc. In such cases, motors with holding brakes are used for load fall-prevention however, on conventional products it was common to have users prepare an external power source for the brakes.

This is not necessary with the new model, as it features a power source for the holding brake built into the driver. The holding brake wiring is included in the motor power connector, therefore only one power cable is necessary between the driver and motor, thus reducing the cost of an external power source and man-hours required for wiring work.

Moreover, the holding and releasing of the brake creates a mechanical delay, therefore controlling timing is essential in order to achieve stable operation in the shortest time possible suitable to the motor excitation status. On the new model, the driver monitors the motor excitation status and the timing of brake hold/release operation is controlled automatically. The burden on the user in regards to timing design can be alleviated merely by commanding the motor excitation status to achieve continuous brake operation, automatic hold in emergencies such as during alarms, and so forth. The holding brake of the new model also features a forced release function for equipment maintenance purposes.

4.3 Encoder-based monitoring and analysis function

The driver is standardly equipped with a connector for encoder signal input. The following functions will be enabled when a motor with an encoder is used and the operation mode of the driver is set to “analysis mode”.

- Non-synchronization monitoring and recording of status when non-synchronization occurs
- Confirmation of motor operation waveform in accordance with actual position and actual speed

The new model can offer an encoder-based function to monitor non-synchronization on equipment which requires high reliability. If, in the rare event, that non-synchronization does occur on equipment in mid-operation, this function uses an alarm signal to alert the host controller of an abnormality and automatically perform brake holding, thereby stopping the system in a safe manner. Moreover, if set in advance, it is possible to record the status of the equipment within the driver when a non-synchronization alarm occurs. This information can be called up at a later stage in order to identify the cause.

The encoder option is effective as a support function for equipment start-up. By connecting “SANMOTION Motor Setup Software”, software for PCs, it is possible to confirm the operation waveform to observe how the motor is actually behaving in relation to an inputted command. The driver is also equipped with a function for trial operations, therefore even if the host controller has not been completed, it is possible to design the optimal drive profile at an early stage by confirming the waveform of motor movements while commanding simple positioning and continuous rotation operations from a PC. It is possible to achieve the optimal operation at a low cost when mass producing equipment by eliminating the encoder and using the driver in “normal mode”.

4.4 Digital operator

The new model is equipped with a digital operator function which has a well-established reputation on Sanyo Denki’s closed loop stepping system PB series. Simple parameter settings, trial operation and so on can be performed by operating switches on the digital operator, therefore PC connection is not required and convenience is improved. Table 3 shows the functions provided by the digital operator.

Table 3: Digital operator function

Modes	Functions
0	Driver status display Displays excitation status, pulse input status, etc.
4	Selection of stopping current Set the excitation current when motor is stopped
5	Step partition no. mode setting Able to switch to resolution compatible with 2-phase motors
6	2nd resolution setting Set the resolution used when performing resolution switching via I/O signal
7	Excitation phase preservation setting Set the excitation phase when power is turned on
8	Jog operation speed setting Mode 9 speed setting
9	Jog operations Continuous rotation when button is pressed
A	Alarm code display Displays alarm code during an alarm
B	Settling parameter setting Function for reducing overshoot at acceleration/ deceleration

5. Conclusion

This document has introduced the features and functions of the "SANMOTION F5" – an AC power input 5-phase stepping system.

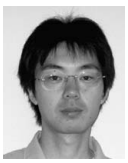
On the new model, both the driver and motor have been renewed, and system properties (speed fluctuation, torque and efficiency) have been significantly improved. Moreover, at the same time as increasing motor options, the new model is equipped with functions to flexibly support the respective motors and conforms to overseas standards in an attempt to expand its application on equipment across an even broader range of fields. The new model is also equipped with an abundance of functions to support users' equipment development and troubleshooting functions, thus offering better convenience.

Even from an environmental perspective, the new model has lower power consumption, reduced shipment cost due to its reduced size and weight, etc., thus we believe it contributes to energy conservation.

Sanyo Denki shall continue our efforts to further improve performance and increase functions in order to develop products with more benefits for our users.

Masao Mizuguchi
Joined Sanyo Denki in 1998.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of stepping drivers.

Shigehiro Kamada
Joined Sanyo Denki in 1986.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of stepping drivers.



Ryuuichi Yanagisawa
Joined Sanyo Denki in 1996.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of stepping drivers.

Kouhei Yamaura
Joined Sanyo Denki in 2007.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of stepping drivers.

Keisuke Ishizaki
Joined Sanyo Denki in 2008.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.

Akio Miyahara
Joined Sanyo Denki in 1991.
Servo Systems Division, 1st Design Dept.
Worked on the development and design of stepping motors.

Kouji Nakatake
Joined Sanyo Denki in 2001.
Servo Systems Division, 1st Design Dept.
Worked on the development and design of stepping motors.

Yasushi Yoda
Joined Sanyo Denki in 2002.
Servo Systems Division, 1st Design Dept.
Worked on the development and design of stepping motors.

Kazuhiro Yoda
Joined Sanyo Denki in 2008.
Servo Systems Division, 1st Design Dept.
Worked on the development and design of stepping motors.