“SK Series” of Miniature Contactor

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ABSTRACT

Demands for downsizing and energy saving are increasing for production facilities and machines. The miniature contactor SK Series featuring the world’s smallest size has been developed to meet these demands.

The reduction in external dimensions gives the wide scope of installation locations, while the addition of strong insulation properties make these contactors possible to be used for high voltage applications. We devised isolation mechanism and heat-resistant insulation materials in the contact structure, as well as we pursued minimization and efficiency of spring load characteristics in electromagnet structure. Fuji Electric also provides product conformance to overseas standards and rich lineup of options to meet the various demands of the customers.

1. Introduction

As magnetic contactors are used in many applications such as in the control panels and machinery of manufacturing equipment, they are essential devices for starting and stopping electric motors, opening and closing power supply circuits, and so on. Since the use of contactors to isolate the electrically charged circuit mechanically has become widespread in innovative electrical equipment and machinery, responsibility of the contactors is recently increasing importance. As part of the energy saving and ecology movement trends of recent years, downsizing and power savings have been advanced further than ever before in manufacturing equipment and machinery.

Since launching the “SJ Series” small-size, low power consumption contactor in 1986, Fuji Electric has continued to supply products that contribute to the downsizing and the reduction of power consumption of control panels. Up to the present time, marketplace trends toward miniaturization and power savings have intensified, and there have been increasing requests for a change in the main circuit power supply voltage from 200 V to 400 V so that equipment can run more efficiently, for a wider range of device options to enhance usability, for improved safety, for compliance with international standards, and so on.

The “SK Series” miniature contactor is the world’s smallest size contactor which have been developed by incorporating these market requests and the latest technology, such as three-dimensional arc drive analysis and electromagnetic analysis. This paper describes the features, structure and miniaturization technology of the SK Series

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2. Development Goals and Product Features

2.1 Development goals

Miniature contactors are mainly built into dedicated machinery such as mounting equipment and molding machines, and are used to start and stop electric equipment such as motors and to switch on and off the primary power circuits to inverters. As machinery becomes smaller, magnetic switches that combine a contactor and thermal relay must be installable in ever smaller spaces. Additionally, in consideration of the energy-saving trend of equipment, it is desirable that the control power supply for a magnetic switch consumes less amount of power. Further, in addition to the requests for controlling the main circuit, there are also various other requests concerning the number of auxiliary contacts and variations of the contacts (normally closed, normally open) so that the control circuit can be switched on and off with fewer devices.

The JIS standard for magnetic switches was unified with international standards in 1999. With the differences in specifications between Japanese domestic products and overseas products having been eliminated, the magnetic switches become the control devices used worldwide. In order to support the exportation of customer products to overseas, even Japanese domestic customers are strongly requesting a change in the main circuit voltage of their products from 200 V to 400 V. Accordingly, improved high-voltage interrupting performance is desired for small-sized contactors. Thus, as an alternate to the SJ Series, which had been designed to target use in Japan, in consideration of anticipated global applications, there has emerged a need for the development of a small contactor having high switching and interrupting capability. Fuji Electric’s SK Series complies with the international standard IEC 60947-1, as well as EN 60947-1 and JIS C 8201-

1, and has also acquired UL and CSA certification in the United States and China Compulsory Certification (CCC*1) in China.

2.2 Product features

The SK Series of miniature contactors provide world-class performance with the following features.

(1) Low-power consumption drive
- ○ This series can be driven by AC and DC power supplies, respectively
- ○ Each product has world's lowest class of power consumption (As of November 2011, based upon in-house research)
- ○ AC operation: 22 VA on closing, 4.5 VA on holding
- ○ DC operation: Standard type 2.4 W, low-power type 1.2 W

(2) Small size
- ○ Same external dimensions for both AC and DC driven products
- ○ W45×H48×D49 (mm)
- ○ World's smallest contactor having power switching capability

(3) Product line-up with wide range of options
- ○ Complementary functionality to support various customer requirements

(4) Safety and usability
- ○ Complies with safety requirements for electrical danger
- ○ Terminal cover protection with standard IP20 protection class from front direction
- ○ Compliance with IEC standard types I and II through combination of various circuit breakers and fuses
- ○ High short-circuit protection performance with protection coordination of 5 to 65 kA through combination with manual motor starter (MMS)

Moreover, as one feature that differs from overseas products, the terminal structure that supports Japan's unique wiring connections with screw terminal is also provided. In addition to having world-class level of performance, the products are also easy to use in the Japanese market.

2.3 Product lineup

The SK Series provides a sufficient product line with a rich set of options to meet the needs of all customers (see Fig. 1).

(1) Operation indicator unit

The operation indicator unit can be add-on to the contactor itself that provides notification with an indicator lamp when a coil voltage has been applied.

(2) Coil surge absorption unit

The coil surge absorber unit prevents malfunction of the electronic circuitry by absorbing surge voltages when the coil is in the off-state. The surge absorption circuit contains a varistor to cut the peak waveform of the surge voltage. DC operated coils are equipped with internal varistors as a standard feature, and a coil surge absorber unit with operation indication and a coil surge absorber unit with an operation indicator lamp are available.

(3) Auxiliary contact unit

4-pole versions with five contact configurations of 4a, 3a1b, 2a2b, 1a3b and 4b, and 2-pole versions with three configurations of 2a, 1a1b and 2b are available, and the number of auxiliary contacts can be expanded with "one-touch" operation.

(4) Small auxiliary contact unit

This low-profile small-size auxiliary contact unit is limited to a 1a1b contact configuration, and is well suited for environments that require space-saving installation.

(5) Interlock unit

By using a reversible wiring kit and an interlock unit in combination, the reversible contactor to perform forward and reverse operation and the like can be configured easily. The interlock unit mechanically prevents the simultaneous switching on of 2 contactors.

(6) Connection module

The connection module is used to combine the MMS and contactors. The combination of these devices allows a more compact configuration of the electric motor control circuit, and protects the motor more reliably from accidents due to short circuits and overcurrents in the three-phase electric motor circuit.

(7) Main circuit surge absorber unit

This unit absorbs surge voltage generated from the three-phase motor when the contactor opens and clos-

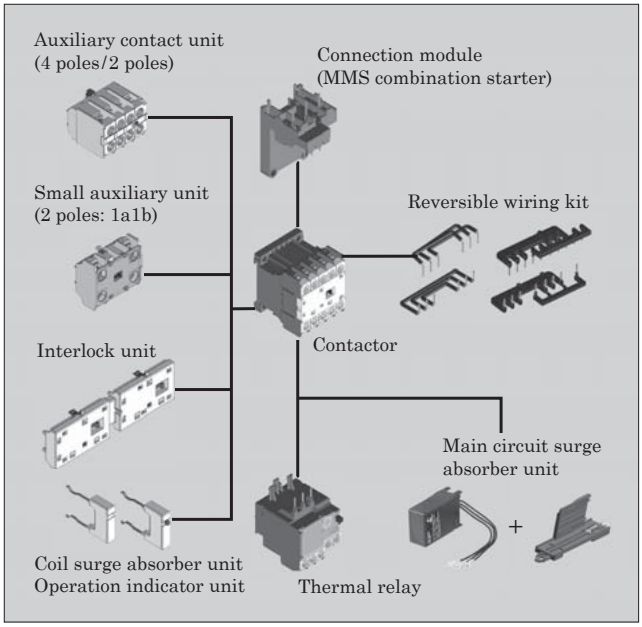

Fig.1 Set of options for the "SK Series"

*1: CCC: China Compulsory Certification (See "Supplemental explanation 2" on page 139)

es, and suppresses the influence of the surge voltage. The main circuit surge absorber unit may be mounted as a set with an adapter, separately from the contactor.

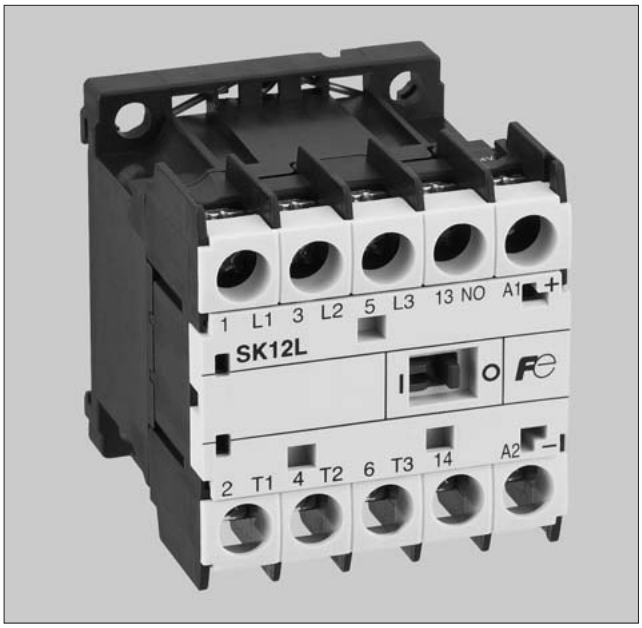

Fig.2 "SK Series"

2.4 Specifications and ratings

(1) Contactor specifications

Figure 2 shows the external appearance of a SK Series contactor, and Table 1 lists the contact configuration and durability specifications of this series. The lineup of class AC-3 rated contactors include 6 A, 9 A and 12 A products that have a 3-pole main circuit and a single pole auxiliary circuit configuration.

Table 2 lists the contactor product lineup and the main circuit ratings.

(2) Auxiliary relay specifications

Table 1 Contact configuration and durability specifications of contactors

		6 A product	9 A product	12 A product
Contact configuration	Main circuit	3a		
	Auxiliary circuit	1a or 1b		
Durability	Electrically (AC-3)	1 million times		
	Mechanically	10 million times		

Table 2 Contactor product lineup and main circuit ratings

			6 A product	9 A product	12 A product
Type		AC driven product	SK06A	SK09A	SK12A
		DC driven product (2.4 W)	SK06G	SK09G	SK12G
		DC driven product (1.2 W)	SK06L	SK09L	SK12L
Rated capacity (kW)	3-phase squirrel-cage motor (AC-3)	200 to 240 V	0.75	1.5	2.2
		380 to 440 V	2.2	3.7	5.5
		500 to 550 V	2.7	3.7	5.5
Rated operating current (A)	3-phase squirrel-cage motor (AC-3)	200 to 240 V	6	9	12
		380 to 440 V	6	9	12
		500 to 550 V	5	7	9
	Resistive load (AC-1)	200 to 240 V	12	16	20
		380 to 440 V	12	16	20
Open thermal current (A)			20	20	20

Table 3 Auxiliary relay product lineup and ratings

		Standard (high reliability product)			High capacity product		
		AC coil	DC coil (2.4 W product)	DC coil (1.2 W product)	AC coil	DC coil (2.4 W product)	DC coil (1.2 W product)
Type		SKH4 A	SKH4 G	SKH4L	SKH4 AH	SKH4 GH	SKH4LH
Additional auxiliary contact unit		4 poles or 2 poles		2 poles	4 poles or 2 poles		2 poles
Open thermal current		10 A			Same as on the left		
Contact configuration		4 A, 3a1b, 2a2b (1a3b and 4b not available)			Same as on the left		
Rated operating current AC-15 (coil load)	AC100 to 120 V	3 A			6 A		
	AC200 to 240 V	3 A			6 A		
	AC400 to 440 V	1 A			6 A		
	AC500 to 600 V	0.5 A			3 A		
Minimum operating voltage and current		DC5 V, 3 mA			DC24 V, 10 mA		

Table 4 List of compliant standards

Model	Type	Compliant standards			Certified standards			EC directive	Certifying authority
		JIS	IEC	EN	UL	CSA	GB (CCC)	CE mark	TÜV
		Japan	International	Europe	US	Canada	China	Europe	Germany
Contactor	SK***A SK***G SK***L	○	○	○	○ *	○ *	○	○	○

* : Certified by cULus

The SK Series includes a lineup of auxiliary relays which are optimal for low-load switching because their four contacts are all configured with auxiliary contacts (see Table 3).

Two product lines are offered: standard type that support electronic devices with twin contacts to increase the contact reliability and high capacity type that feature significantly larger contact capacity.

The auxiliary relays comply with EN60941-5 and have a linked contact function that conforms to EN60204-1, which is a requirement of the Machinery Directive of the EC. The linked contact function enables the configuration of a safety circuit with monitoring the welded contacts of the auxiliary relay.

2.5 Compliant standards

Table 4 shows the standard certification and acquisition status of the SK Series. The SK Series complies with the world's major standards, and has also obtained various certifications.

3. Miniaturization Technology

3.1 Aim of miniaturization

Recently, the control panels in machine tools, lifts and the like have been made smaller and thinner, and requests for the miniaturization of electric distribution and control devices are also intensifying.

For small electric distribution and control devices, as in the case of the MMS and contactor shown in Fig. 3, the de facto standard width for products is 45 mm. In order to combine peripheral devices within a control panel of limited space, a high level of space utilization is required, and therefore the realization of a dense layout and the use of a general-purpose wiring member (busbar) that corresponds to the interval of 45 mm are essential.

Additionally, as a result of the prevalent usage of distributed control, demand is increasing for small-size control panels to be installed in each machine and equipment terminal. In case where installation space is limited, a reduction in the product depth direction is strongly requested in order to accommodate a thin control panel in addition to the conventional installation footprint reduction.

In support of these industry standards and changes in the size of the installed control panel, Fuji Electric aims to miniaturize product dimensions in order to expand the scope of customer applications.

Fig.3 Combination of MMS and contactor

3.2 Structure of the contact part

(1) Insulation enhancing structure

In the contactor, the contact part is responsible for the basic function of switching the current. For miniaturization, it is essential that a rated insulation voltage of 690 V, which is the highest-class insulation performance, can be realized within a small space.

Insulating performance is necessary between phases, and the ability to control the flow of arc gas and to limit the drop in insulation resistance is important issues at the time of current interruption.

(2) Interphase insulation structure

Miniature contactors also achieve lower power consumption of the electromagnet (to be described later). In consideration of the limited motion space of the electromagnet and moving contact due to miniaturization, and of the efficiency of the electromagnetic attractive force, a horizontal drive method in the interphase direction was adopted for driving the contactor. Additionally, a multi-structure that allows both "a" and "b" contacts in each phase was incorporated, thus enabling changeover to an auxiliary relay or the like. With a conventional structure in which an inter-phase barrier is disposed between fixed contacts, the inability to ensure motion space around the contacts was a problem.

As shown in Fig. 4, by positioning the main inter-

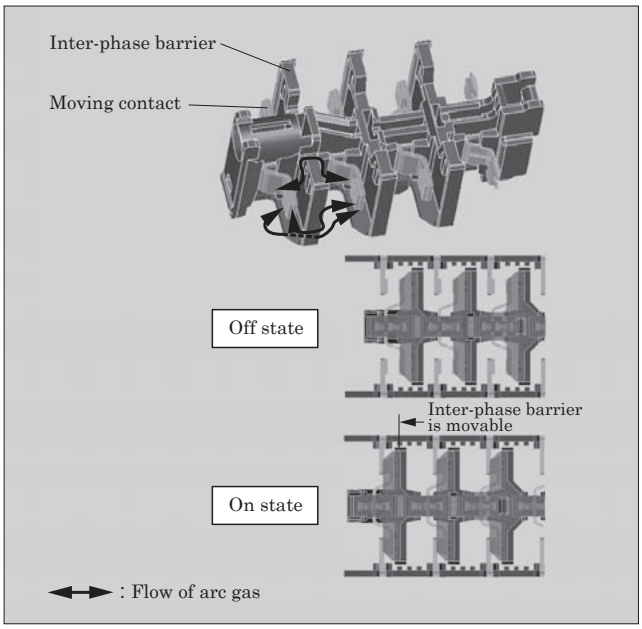

Fig.4 Barrier structure of movable parts of contact

phase barrier at the contact support, which is a movable part, to ensure motion space, and by coupling the inter-phase barrier movement with the switching operation, the interruption space in the vicinity of open contacts can be expanded, thus leading to stabilization of the interruption performance, such as by cooling of the arc gas. Further, by providing a rib structure that retains the passing arc gas on the inter-phase path connected to the arc generation point of the contact, inflows to adjacent phases can be suppressed temporarily and the insulation performance improved.

(3) Structure for insulation resistance suppression

The arc gas resulting from current interruption forms a carbonization layer on the inter-phase insulating barrier and other surfaces, thereby degrading the insulation performance. The positioning of the inter-phase insulating barrier at the movable part, as was described in the preceding paragraph, resulted in a problem with ensuring the insulating performance because the frame that holds the fixed contacts cannot possess a significant barrier.

Therefore, in order to improve the insulation performance of the frame, the rib structure shown in Fig. 5 is provided between fixed contacts so that arc gas flowing in the gaps between the fixed contacts and inter-phase insulating barrier of the movable part can be retained. Additionally, the formation of a surface carbonization layer due to the arc gas can be kept partially, thus, leading to suppress insulation resistance decline along the creepage surface. The groove that can be formed between these ribs has a width of about 0.88 mm (height of 0.7 mm). According to the compliant standards, the inner wall creep surface portion of the groove is not valid as a creep distance, but there is a substantial effect against a decrease in insulation resistance, and this is one miniaturization technology used to ensure performance.

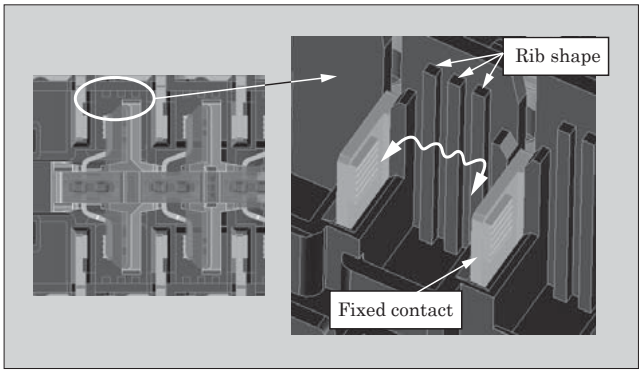

Fig.5 Frame rib shape

3.3 Use of heat-resistant insulating material

Because both "a" and "b" contacts can be accommodated in each phase, installation space must be ensured for the contact spring that outputs the contact pressure of the moving contacts. A contact spring must be housed inside the contact support that holds the moving contact (see Fig. 6). Previously, thermosetting resin having high heat resistance was used for the contact supports that touched moving contacts in the conducting parts, and thin-walled molding was difficult to accomplish. However, the use of cross-linked nylon based on a thermoplastic resin for the contact supports enables thin-walled molding and, as a result, a structure that is both heat resistant and able to house the spring.

In addition, the previous contact support consisting of a single component has been divided into two components, and an fitting structure has been adopted. As a result, assembling the contact spring to be housed and the moving contact is improved significantly, thus enabling automated assembly.

3.4 Structure of the electromagnet

(1) Minimization of spring load

The challenges in miniaturizing an electromagnet involve minimizing the spring load, such as contact pressure, and increasing the efficiency of the electro-

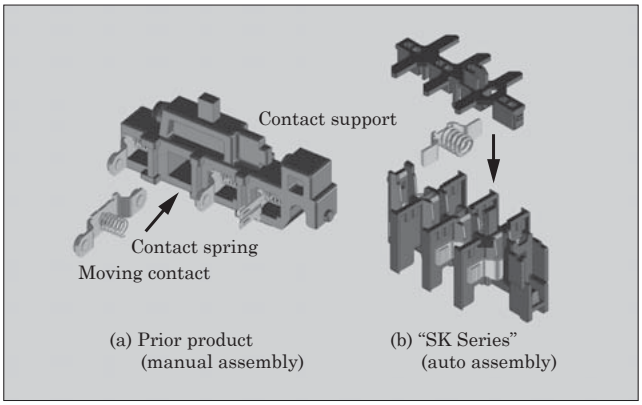

Fig.6 Contact support assembly

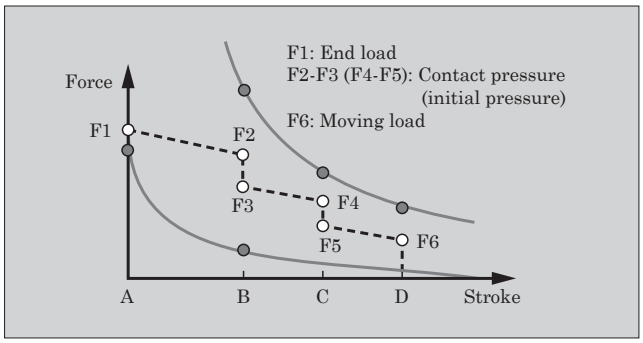

Fig.7 Spring load

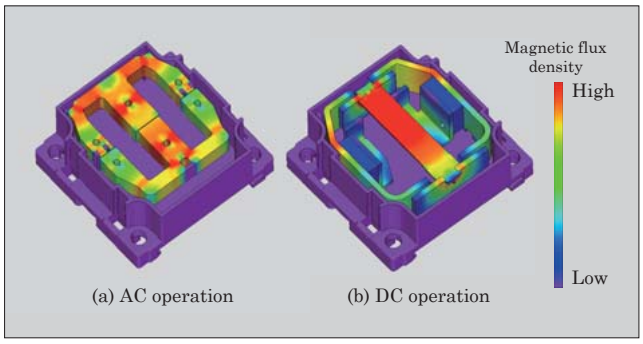

Fig.8 Magnetic field analysis

magnet, and the main determinant factors are listed below.

(a) Contact pressure (initial pressure)

Reduce mass of moving parts and contact bounce

(b) Moving load

Resistance to malfunction by mechanical shock of "b" contact in off-state

(c) End load

Determinant factor of no-load voltage (Attractive force at time of no-load < end load)

To establish each of these determinant factors, a two-pronged approach was adopted of pursuing critical performance through kinematic analysis and experimentation, and of adjusting for the attractive force

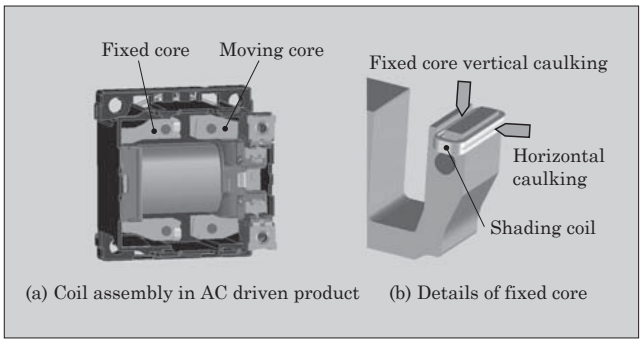

Fig.9 Fixed core horizontal caulking method

characteristics in the electromagnet design to realize a reduction in spring load (see Fig. 7).

(2) Pursuit of higher efficiency

By efficiently producing the attractive force of the electromagnet within a limited space as in the case of the contact parts, and optimizing the magnetic path through electromagnetic analysis shown in Fig. 8, and so on, the following low-power consumption products were realized.

○ AC driven product: 4.5 VA (60 Hz : 1.3 W)
○ DC driven product (standard type): 2.4 W
○ DC driven product (low power type): 1.2 W

Additionally, in the fixed core of the AC driven product, horizontal caulking from the one side (see Fig. 9) was adopted for the first time as the method for caulking the shading coil, and as a result, the pole contact area was maximized and the space utilization was improved.

4. Postscript

The miniature contactor "SK Series" was developed based upon Fuji Electric's many year experience and accumulated technology, and is a product series that will certainly meet the needs of the market. So as to continue to be responsive to diversifying needs in the future, Fuji Electric intends to enhance this series further.