

Expanded Line-up of “NEO SC Series” Magnetic Contactors

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ABSTRACT

In response to market needs for magnetic contactors with smaller size and lighter weight, and a low-voltage DC control circuit with reduced inrush power consumption, Fuji Electric has developed the “SC-N5A” AC operated contactor that retains compatibility (external dimensions, mounting dimensions and terminal locations) with, but is lighter than, the previous model, and the “SC-N4/G” and “SC-N5/G” DC operated contactors which feature greatly reduced inrush power consumption of the DC control circuit, and these models, ranging from 5.5 kW to 22 kW, have been added to the “NEO SC Series.” Using a multi-objective algorithm, the power consumption and electromagnet dimensions were optimized and electromagnetic field analysis of coupled motion, large deformation analysis and thermal-hydraulic analysis were performed to develop a new electromagnet structure.

1. Introduction

Magnetic contactors switch electric circuits on and off by manipulating an electromagnet and are used for automated load switching. A magnetic contactor combined with a thermal overload relay (thermal relay) is known as a magnetic starter, and magnetic starters are used primarily for the automated operation of electric motors and are equipped with a function for protecting the electric motor in an overload state due to damage from burnout.

For more than 50 years since being introduced to the market in 1954, Fuji Electric’s magnetic contactors have continuously maintained the top market share in Japan, and a cumulative total of 270 million these devices have been manufactured. By consistently anticipating market demands and technical trends of the times, Fuji Electric has contributed to technical development through providing distinctive products to the market, and has maintained its position as a leading manufacturer in the field of electric motor control.

With the globalization of markets, internationally-compatible products and environmentally-friendly products are being requested, and in 1999 Fuji Electric rolled out the SC-N1 to SC-N16 models (motor capacity 200 Vac, 5.5 to 200 kW) of the NEO SC Series of magnetic contactors. These standard products conform to CE marking (EU standard) and UL/CSA (North American standards) standards, and with the resulting significant reduction in product power consumption, the products have been well received by customers as energy-saving global products.

Efforts to address environmental concerns, not only by improving the energy savings during product usage such as by reducing the power consumption dur-

ing operation, but also efforts to minimize the total amount of energy consumption and environmental load throughout the product lifecycle, including production, transportation, usage and disposal, are attracting attention. Similarly, for the control panel, the following environmental measures are also being advanced.

- Resource conservation by reducing the part count and shrinking the installation space
- Reduction of transport energy by making the control panel lighter weight
- Reduction of the amount of power consumed during operation

Moreover, safety standards for machinery and equipment have been established. As an inherently safe design measure for protecting against electric shocks in the control panel, the use of lower voltage DC control circuits, such as typified by the use of 24 Vdc circuits, is being advanced. In response to requests for the abovementioned environmental and safety measures, the ability to realize smaller size and lower capacity DC power supplies has become an important topic in the development and design of control panels.

In implementing the abovementioned environmental and safety measures, requests have intensified for the magnetic contactors installed inside a control panel to be made more compact in size, lighter in weight so as to be less power consuming, and for the DC operating circuits it is required to reduce the inrush input consumption.

In response to these types of changing requests, Fuji Electric has developed the “SC-N5A” AC operated magnetic contactor and the “SC-N4/G” and “SC-N5/G” DC operated magnetic contactors (motor capacity SC-N4: 18.5 kW, SC-N5A: 22 kW, 200 Vac) to expand the line-up of the NEO SC Series (see Table 1). Figure 1 shows the external appearance of the SC-N5A and SC-N5/G. An overview of these newly developed products

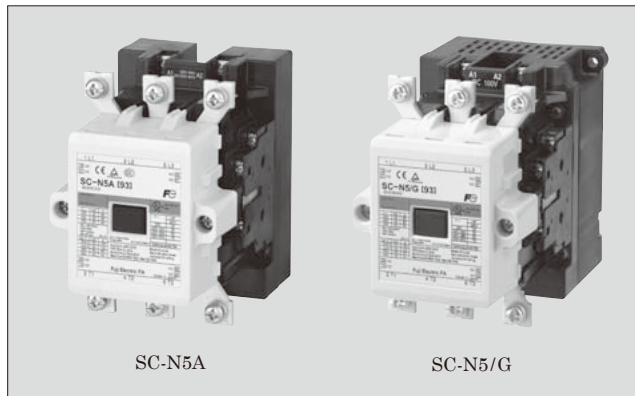
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Table 1 “NEO SC Series” line-up (22 kW and smaller)

Frame		N1	N2	N2S	N3	N4	N5
Rating	Motor capacity 200 V _{ac}	5.5 kW 26 A	7.5 kW 35 A	11 kW 50 A	15 kW 65 A	18.5 kW 80 A	22 kW 93 A
Operating method	AC/DC operated type (with super magnet attached)	N1/SE	N2/SE	N2S/SE	N3/SE	N4/SE	N5
	AC operated type	N1	N2	N2S	N3	N4	N5A
	DC operated type	N1/G	N2/G	N2S/G	N3/G	N4/G	N5/G

□ : New product

Fig.1 External appearance of “SC-N5A” and “SC-N5/G”



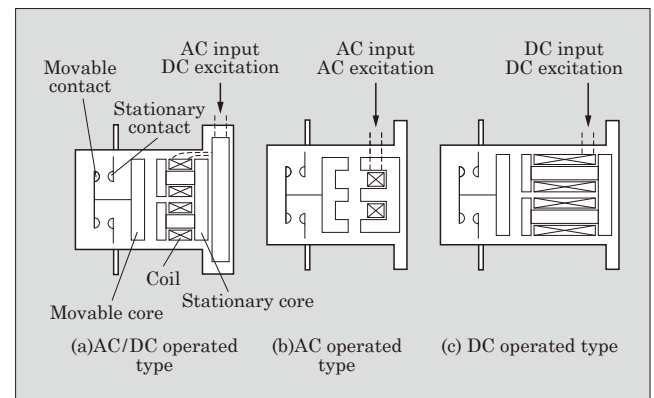
is presented below.

2. Development Goals

There are three ways in which the electromagnet of a magnetic contactor can be manipulated, AC/DC operation, AC operation or DC operation (see Fig. 2).

The SC-N5 to SC-N16 (motor capacity 55 to 200 kW, 200 V_{ac}) large magnetic contactors of the NEO SC Series use an AC/DC operated “super magnet⁽¹⁾.” In the case of a super magnet, an AC input is rectified into a DC signal and the electromagnet is driven with DC excitation, and a characteristic feature is that the operating circuit is equipped with a voltage detection circuit and a power switching circuit. When the coil voltage is applied to the operating circuit of a super magnet, the voltage detection circuit verifies the magnitude of the applied voltage, and only if it has been determined that there are no obstructions to the closing operation, a closing signal is generated and the coil is excited. After completion of the closing operation, the signal changes to a sealing signal, and the power switching circuit suppresses the coil excitation current to reduce the power consumption. The magnet operation will remain in a sealed state even voltage fluctuations or the like cause the coil voltage drop to below a certain level. If the case of a significant drop in the coil voltage, before the voltage drops to a level at which chattering among the contacts would occur, the voltage detection circuit operates to determine the necessity for opening, and if necessary, terminates the sealing signal and opens the contacts. The voltage

Fig.2 Methods for manipulating electromagnet of magnetic contactor



detection circuit constantly monitors the coil voltage, and in doing so, ensures stable operation without chattering even in the case of such conditions as voltage fluctuations, instantaneous sag or when the applied voltage is in the low voltage region, which would cause unstable voltage with other operating methods.

An AC/DC operated magnetic contactor having these types of characteristics is suitable for use in environments susceptible to large voltage fluctuations and in applications for which there is a desire to lower power costs.

On the other hand, the AC operated method is provided with an AC-input AC-excitation AC electromagnet. With an AC electromagnet, in the open state, the reluctance is small. Therefore, the inductance decreases, and when closing the contact, a large coil current flows. After application of the attractive force, the inductance increases and the coil current decreases. Therefore with a compact-size and simple electromagnetic structure, an AC operated electromagnet provides the advantage of a relatively large attractive force when closing.

The DC operated method is provided with a DC-input DC-excitation DC electromagnet. With a DC electromagnet, there is no change in the excitation current when opening or closing. Therefore, the number of ampere-turns must be increased in order to maintain a sufficient attractive force when closed. Although the volume of the coil windings will increase, the capability to reduce the inrush power consumption is an advantage of this method.

Table 2 Comparison of specifications of newly developed products (AC-operated and DC-operated types) to prior models

		AC/DC-operated type (with super magnet)		AC-operated type	DC-operated type	
Motor capacity 200 V		18.5 kW	22 kW	22 kW	18.5 kW	22 kW
Model		SC-N4/SE	SC-N5	SC-N5A	SC-N4/G	SC-N5/G
External appearance						
Coil power consumption 200 V, 50 Hz	Pick-up (VA)	100	80	250	20	
	Seal (VA)	2.8	4	18.4	20	
External dimensions (mm)	H×W×D	127×88×132		127×88×132	127×88×159	
Weight (kg)		1.8		1.5	2.3	

 : New product

Table 3 Characteristics of each operating method

	AC/DC-operated type	AC-operated type	DC-operated type
Compact size	◎	◎	○
Light weight	○	◎	○
Energy savings (sealed power consumption)	◎	○	○
Smaller DC power supply (inrush power consumption)	△	—	◎
Voltage fluctuation immunity (SEMI sag immunity)	◎	×	◎

◎ : Optimal, ○ : Suitable, △ : Less suitable,  : New product
 × : Unsuitable, — : Not applicable

Considering the characteristics of each operating method and the needs of control panels, the SC-N5A AC-operated magnetic contactor is compact in size and light weight, and is well suited for use in a control panel environment. The SC-N4/G and SC-N5/G DC-operated magnetic controllers reduce the inrush power consumption, which helps to realize more compact and lower capacity DC power supplies, and are well suited for safety-related applications.

Accordingly, this enhanced line-up of the NEO SC Series enables Fuji Electric to provide various magnetic contactors well suited to a diversity of customer applications.

3. Characteristics

The main characteristics of Fuji Electric's newly developed AC-operated magnetic contactors and DC-operated magnetic contactors are described below.

3.1 AC-operated magnetic contactor

The specifications of the SC-N5A and the SC-N5 prior model (AC/DC operated type) are compared in Table 2. Utilizing a small and lightweight AC electromagnet, the SC-N5A maintains compatibility (in regard to external dimensions, installation dimensions and pin locations) with the prior model while realizing lighter weight, and as a result, helps to realize lighter weight and resource conservation in control panels.

3.2 DC-operated magnetic contactors

Specifications of the SC-N4/G and SC-N5/G are also compared with those of the SC-N5 prior model (AC/DC operated type) in Table 2. The SC-N4/G and SC-N5/G realize the world's lowest power consumption and smallest external dimensions. In particular, their inrush power consumption is reduced to 1/5th that of the AC/DC operated type, enabling the DC power supply installed in a control panel to be made smaller in size and capacity, and helping to realize smaller size, resource conservation and lower costs for control panels.

Characteristics of each operating method are shown in Table 3. The magnetic contactor best suited for a particular application can be selected.

4. Technology to Achieve Smaller Size and Lighter Weight

4.1 AC-operated magnetic contactor

The structure of the SC-N5A AC-operated magnetic contactor is shown in Fig. 3. The electromagnet consists of a movable core, a stationary core and a coil, and the movable core is coupled to a part that houses a movable contact known as a movable contact carrier. Also, a contact spring is attached to the movable contact so as to apply contact pressure toward the stationary contact when the contactor closes. When an excitation current flows in the coil, the movable core

Fig.3 Structure of “SC-N5A”

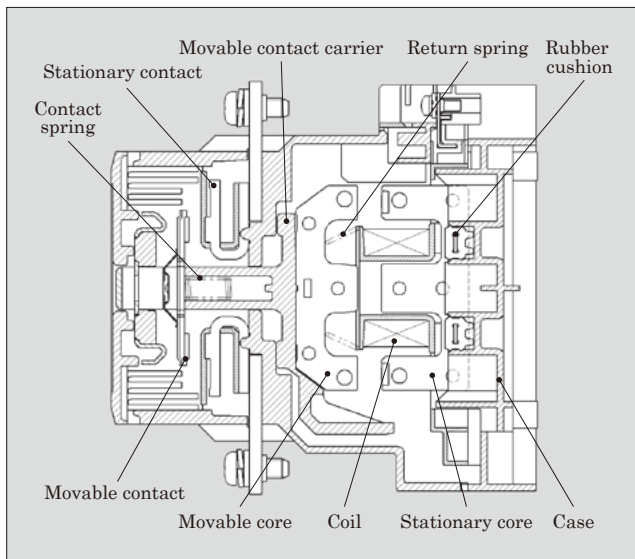
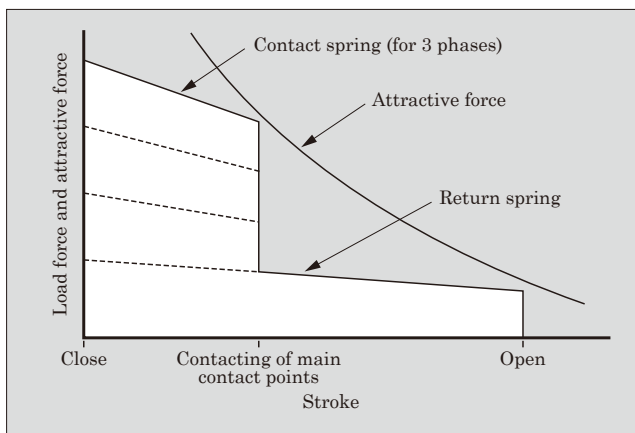


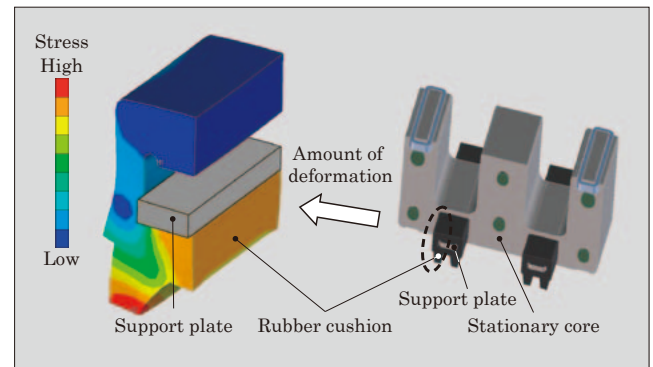
Fig.4 Load force of electromagnet and attractive force generated by electromagnet



is attracted toward the stationary core, the movable contact and movable core move toward the stationary core, and as a result of this series of actions the contact closes. When the contact closes, the movable core ultimately collides with the stationary core. To absorb the impact at the time of this collision, a rubber cushion is placed between the stationary core and the case.

For the SC-N5A to realize compact size and light weight, a small AC electromagnet having the same dimensions as that of the SC-N4 lower frame is used as the electromagnet load. As shown in Fig. 4, the load force becomes the combined total load force of the moving return spring and contact spring. Therefore, the electromagnet must generate an attractive force that is larger than this load force. Since the carrying capacity and the making capacity determine the load force of the contact spring (i.e., the contact force), a large spring load force is needed to ensure the carrying capacity and the making capacity of the SC-N5A. The higher the carrying current, the greater the heat generation and larger the electromagnetic repulsive force

Fig.5 Example analysis of stress distribution and deformation of rubber cushion (1/2 model)



of the contacts. As a result, a stronger spring load force is needed.

However, the kinetic energy of the moving parts increases when an attractive force comparable to the load force is applied. Therefore, ensuring the mechanical durability by cushioning the impact at the time of the collision of the electromagnet core presented a challenge during development of the SC-N5A.

To overcome this challenge, the design of the rubber cushion was optimized to realize a small and lightweight electromagnet structure that features a powerful attractive force and strong durability. At the time when the core collides, if the cushioning of the impact is inadequate, the core and the movable contact carrier will be damaged. To ensure sufficient mechanical durability, the rubber cushion must be designed with sufficient shock-absorbing functionality and a large compressive deformation capability. However, if the amount of compressive deformation capability is increased, the stress caused from repeated deformation will damage the rubber cushion, and the shock-absorbing functionality will deteriorate.

Therefore, large deformation analysis was carried out to analyze materials capable of large amounts of deformation. By computing the deformation amount and stress of the rubber cushion, and optimizing the materials, shape and support structure design, a cushion structure that combines both shock-cushioning functionality and strength was developed. Rubber cushions are positioned on both sides of the stationary core, support plates inserted through a hole formed in each part are coupled together and the assembly is housed inside the case. Figure 5 shows an example of this analysis.

4.2 DC-operated magnetic contactor

The structure of the SC-N5/G, a DC-operated magnetic contactor, is shown in Fig. 6. The structure of the arc extinguishing part and the contact part is the same as for the SC-N5 AC/DC-operated type. By increasing the efficiency of the electromagnet part, the world's smallest power consumption and external dimensions in a DC-operated magnetic contactor were realized.

Fig.6 Structure of “SC-N5/G”

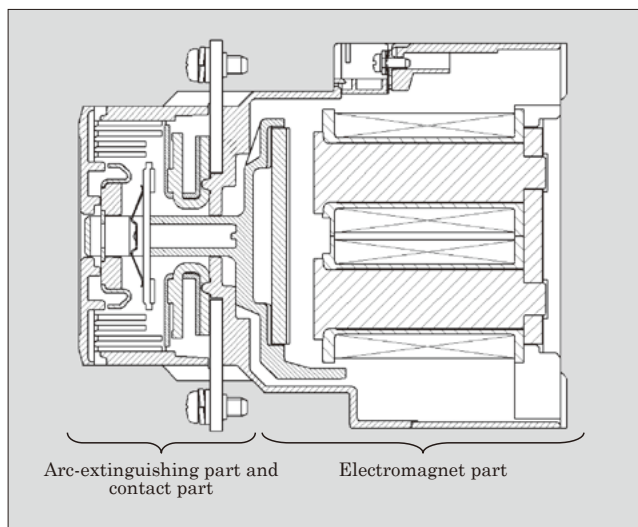
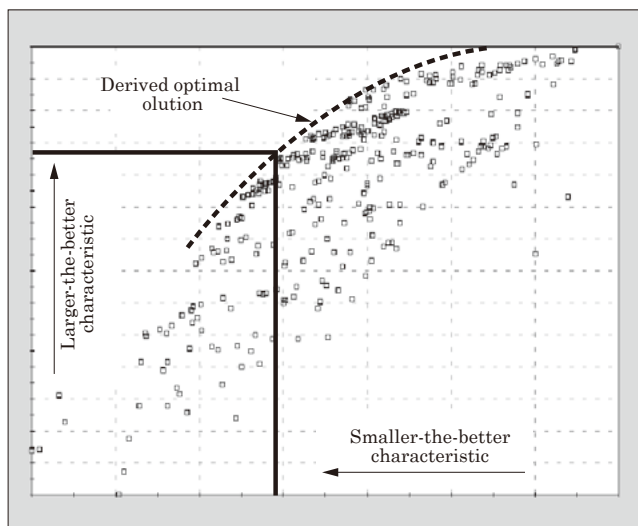


Fig.7 Results derived from optimal solution using “MOGA”



The basic structure of the SC-N4/G is the same as that of the SC-N5/G, only the contacts are different.

(1) Application of an optimization method

In a DC electromagnet, for a given number of ampere-turns, a so-called tradeoff relation exists between the power consumption and size of the coil windings (electromagnet dimensions). Attempting to reduce the power consumption will result in an increase in the number and size of the coil windings. On the other hand, attempting to reduce the size of the coil windings will result in an increase in current to compensate for fewer number of coil windings, and the power consumption will increase. In the development of the new

*1: MOGA: Multi-objective genetic algorithm that uses stochastic search techniques (genetic algorithms) that model genetics and biological evolution to calculate by simulation an optimal solution (multi-objective optimization) for multiple functions that involve trade-off relations

Fig.8 Example of coil excitation current based on electro-magnetic field analysis of coupled motion

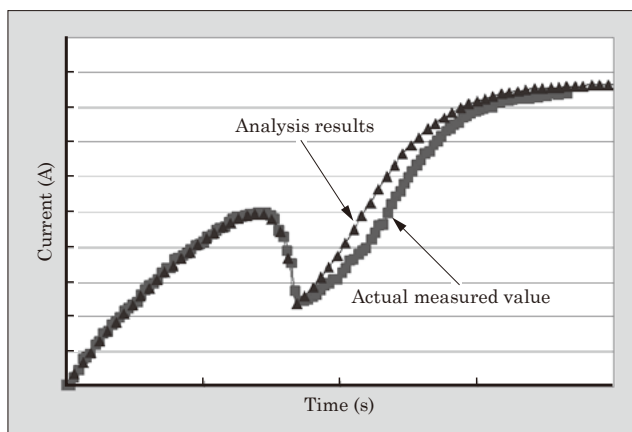
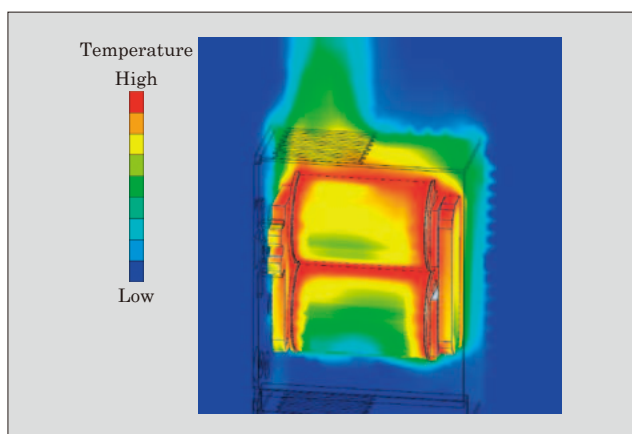


Fig.9 Example of thermal-hydraulic analysis inside DC electro-magnet and case



DC electromagnet, an optimization method known as a multi-objective genetic algorithm (MOGA*¹) was used to derive an optimal solution for the tradeoff relation between power consumption and electromagnet dimensions, and the designs of the electromagnet shape and winding specifications were optimized. Figure 7 shows an example of the optimal solution results derived from the MOGA.

(2) Detailed development of DC electromagnet

So that the magnetic contactor can perform a closing operation, an attractive force sufficient to drive the movable core must be ensured. Because the attractive force is generated according to the number of ampere-turns, i.e., the product of the number of coil windings and the amount of the coil excitation current, the coil excitation current must be calculated with a high level of accuracy in order to implement a detailed design of a DC electromagnet. When the movable core is displaced, the magnetic flux fluctuates and the inductance increases. Therefore the coil excitation current decreases temporarily at the time of a closing operation. This transient phenomenon cannot be calculated using static electromagnetic analysis techniques. Coupled analysis of the electromagnetic field and motion was

performed to calculate the transient coil excitation current and attractive force, and a high precision design of a new DC electromagnet was implemented. Figure 8 shows an example of the coil excitation waveform at the time of a closing operation according to an electromagnetic field analysis of coupled motion.

When designing an electromagnet, in order to ensure the thermal endurance of the coil windings, it is essential that any rise in coil temperature remains within the specifications. Thermal-hydraulic analysis that considers the flow of air was used to optimize the location and size of heat dissipation holes and to optimize the coil temperature rise. An example of thermal-hydraulic analysis is shown in Fig. 9. As a result, in conformance with the external dimension and power consumption constraints, a case was designed that effi-

ciently disperses heat generated in the coils so that the rise in coil temperature can be minimized.

5. Postscript

Fuji Electric has expanded its lineup of models in the NEO SC Series which are capable of quickly responding to market needs such as for environmental and safety measures. Fuji Electric intends actively to continue to improve products so as provide precise support for the changing market needs of the future.

References

- (1) Kogawa, Kuniyuki et al. NEO SC Series New Large-Size Magnetic Contactors. Fuji Electric Journal. 1999, vol.72, no.7, p.370-376.





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