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e-Front runners

FUJI ELECTRIC REVIEW

4
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Globalization of Low Voltage Switching Devices

Fuji Electric Group

e-Front runners

Fuji Electric's Twin Breaker has evolved to a new stage!

GLOBAL TWIN

Support of international standards

Certified and conforms to main regional standards throughout the world
Global frame sizes have been added

Low impact on the environment

Advanced environmental technology and energy-savings support
Adheres to the RoHS directive

G-TWIN

Compact size, high performance

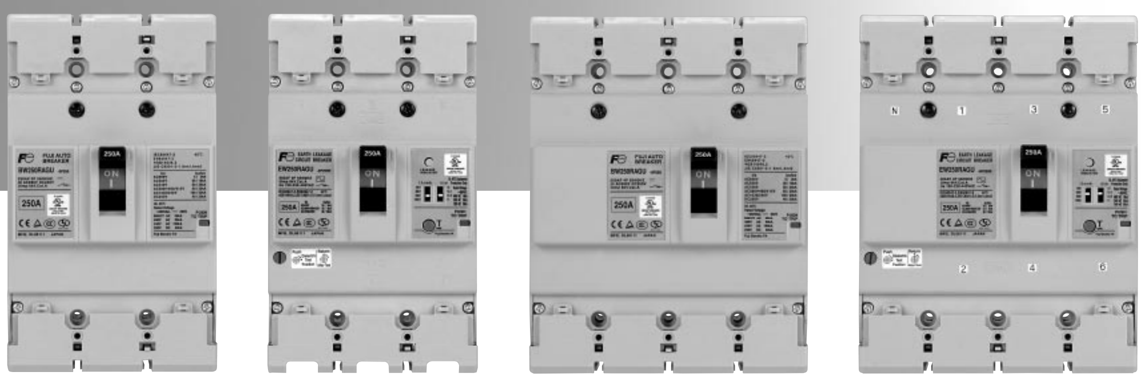
Realizes UL 489 480V and IEC 440V in a compact size of uniform dimensions

Easy to use

Built to be user friendly

Excellent safety and maintainability

Incorporates the latest IEC 60947-2 standard and features improved maintainability



Fuji Electric's molded case circuit breakers and earth leakage circuit breakers

Global Twin

Fuji Electric FA Components & Systems

FUJI ELECTRIC
REVIEW

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CONTENTS

Cover photo:

Led by the WTO (world trade organization), standards throughout the world for low voltage electrical installations and the components used therein are accelerating toward conformance with international standards (IEC standards and ISO standards). In Japan, equipment for IEC-compliant electrical installations has been recognized since 1999. Subsequently, the JIS for MCCBs and ELCBs, the main devices in low voltage electrical installations, has been revised to include the prior content and also to conform to IEC standards.

In accordance with these trends, Fuji Electric has successfully developed the G-Twin Breaker, a manual motor start (MMS), and the like.

The cover photo shows the MCCB and ELCB of the G-Twin Series and the MMS to conceptually illustrate the deployment of globalization.

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Technical Trends of Low Voltage Circuit Breakers and Fuji Electric's Efforts in This Field

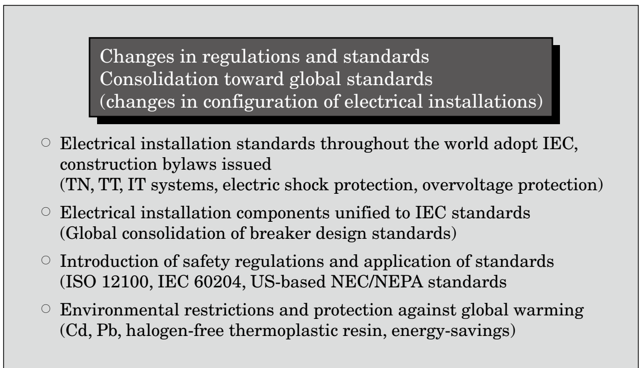
Naoshi Uchida
Akihiko Kohanawa

1. Introduction

As countries throughout the world accept the TBT (technical barriers to trade) agreement of the WTO (world trade organization), standards throughout the world for low voltage electrical installations and the components used therein are accelerating toward conformance with international standards (IEC standards and ISO standards). In 1999 in Japan, for example, article 272 "Incorporation of international standards" was added to chapter 7 "Technical standards of electrical installations" of Japanese legal requirement, and equipment that conforms to the IEC standard (IEC 60364 series) has been recognized by Japanese electrical installations. Moreover, standards relating to the electrical installations of industrial machine control gear are also moving toward harmonization with IEC 60204.

At present, as standards for distribution installations and machine control systems are accelerating toward harmonization with the international standards known as IEC standards, many electrical machine systems based on the independent electrical installation standards of an individual country coexist with electrical machine systems based on IEC standards. Based on these circumstances, this paper shall discuss the technical trends of molded case circuit breakers (MCCB) and earth leakage circuit breakers (ELCB), which are the main components used in electrical installations, as well as Fuji Electric's basic philosophy for responding to these circumstances.

Fig.1 Recent changes in low voltage electrical installations



2. Changes in Low Voltage Electrical Installations

Figure 1 shows changes in low voltage electrical installations. As described above, there are two series of electrical installations for each countries, a system unique to the particular country (if there is) and an IEC system. In Japan, the new JIS C 8201, 8210 and 8220 series that harmonize the IEC 60947 and IEC 60898 series standard with the previous JIS standard have been issued as standards for MCCBs and ELCBs. (See Fig. 2.)

Fig.2 Changes in equipment application from the perspective of low voltage circuit breakers (in the case of Japan)

Application categories according to electrical installation standard

New JIS No. system			Construction regulations	
Category	Standard number	Annex	IEC-based construction	Existing construction
Industrial use	JIS C 8201-2-1	Annex 1	○	–
		Annex 2	–	○
	JIS C 8201-2-2	Annex 1	○	–
		Annex 2	–	○
Home use	JIS C 8211	Annex 1	○	–
		Annex 2	–	○
	JIS C 8221 (without OC)	Annex 1	○	–
		Annex 2	–	○
	JIS C 8222 (with OC)	Annex 1	○	–
		Annex 2	–	○

OC : Overcurrent protector

Existing installation regulations

Japanese legal requirement for electrical installation regulations from articles 3 to 271 of the electrical installation technical standards

Mixed use not permitted

IEC-based installation regulations

Electrical installation standard of article 272 of the electrical facility technical standard
Electrical installation standard JIS C 600364 series standard.
Equivalent standards as the IEC 60364 series.

Moreover, for electrical safety, significant changes have been also made in regulations concerning the prevention of faulty touch to live portion and the protection of electric motors.

Meanwhile, to help preventing global warming, with the enactment of the Kyoto Protocol, each country has been responsible for implementing strict mandatory reductions in carbon dioxide (CO_2) emissions. As one way to reduce CO_2 emissions, each country develops its own "guidelines for the rationalization of energy usage" and vigorously promotes the expanded application of those guidelines. At present, electrical energy control is extremely important for commercial buildings and small to medium-size factories.

Consumers are also increasing their requests for an easy-to-construct means for measurement and controll of electric power energy. In response to this request, Fuji Electric is developing a series of energy management components and is also incorporating energy monitoring functions into low voltage circuit breakers, which are the main components used in electrical installations.

3. Changing Need for Low Voltage Circuit Breaker

In response to the changing circumstances surrounding the low voltage electrical installations described in section 2, the main requirements of low voltage circuit breakers are as follows.

(1) Commercialization of a low voltage circuit breaker that supports standards in various countries, in particular, IEC standards and UL standards (See Fig. 3.)

(2) Establishment of a series of circuit breakers equipped with an electric energy measuring function to enable easy monitoring and control of energy savings

(3) Establishment of a series of circuit breakers that ensure high-level safety protection against short-circuits in an electric motor circuit

(4) Development of a low voltage circuit breaker that contains no designated hazardous substances and is capable of helping to protect the global environment

These requirements can be summarized as the "realization of a unified global circuit breaker capable of supporting standards throughout the world." To satisfy such customer needs, a significant change is necessary in the concept of the present series of low voltage circuit breakers.

The basis of Fuji Electric's new concept is to realize the performance required by the IEC standard while maintaining the benefits (compact size, high quality, multiple variations) of a circuit breaker that conforms to the conventional Japanese standards. Fuji Electric's response to realize this need is described below in section 4.

4. Fuji Electric's Response to the Need for Low Voltage Circuit Breakers

Fuji Electric has developed many technologies in advance so as to be able to respond to the need for low voltage circuit breakers.

Examples of this technical development include: ① arc control technology that simultaneously satisfies the interrupting duty of both the UL 489 standard and the IEC standard, ② material technology for molding material and contact material, ③ technical advances concerning the detection of earth leakage current, and ④ structural analysis of a breaker with attached wattmeter.

Fuji Electric then applied the results of this technical development to create ① the "G-Twin Breaker," a single product capable of being used in all electrical installations throughout the world, ② the "Manual Motor Starter" (MMS), a compact-size motor breaker that realizes a new type of electric motor protection, and ③ the "FePSU Breaker," which is optimized for monitoring and controll of energy savings. The main points are summarized below.

Fig.3 Low voltage circuit breakers consolidate to 2 series worldwide

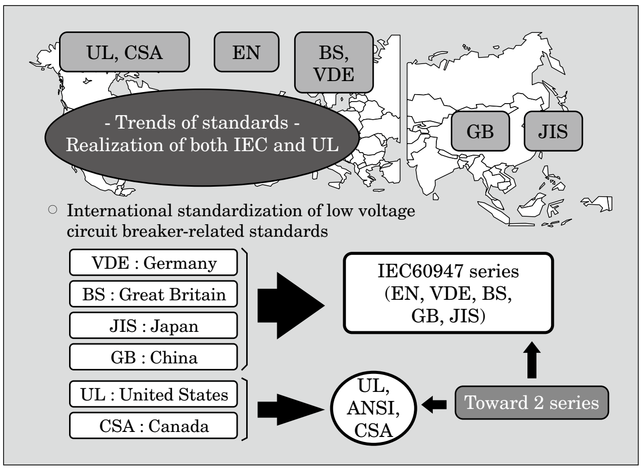


Fig.4 Scheduled internationalization of JIS

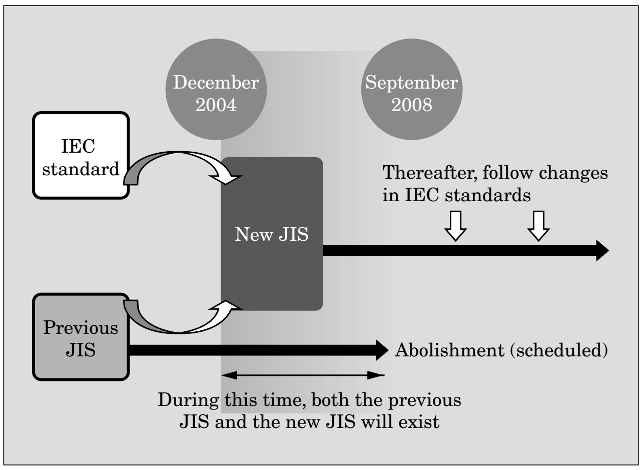


Fig.5 Concept of the new global MCCB and ELCB

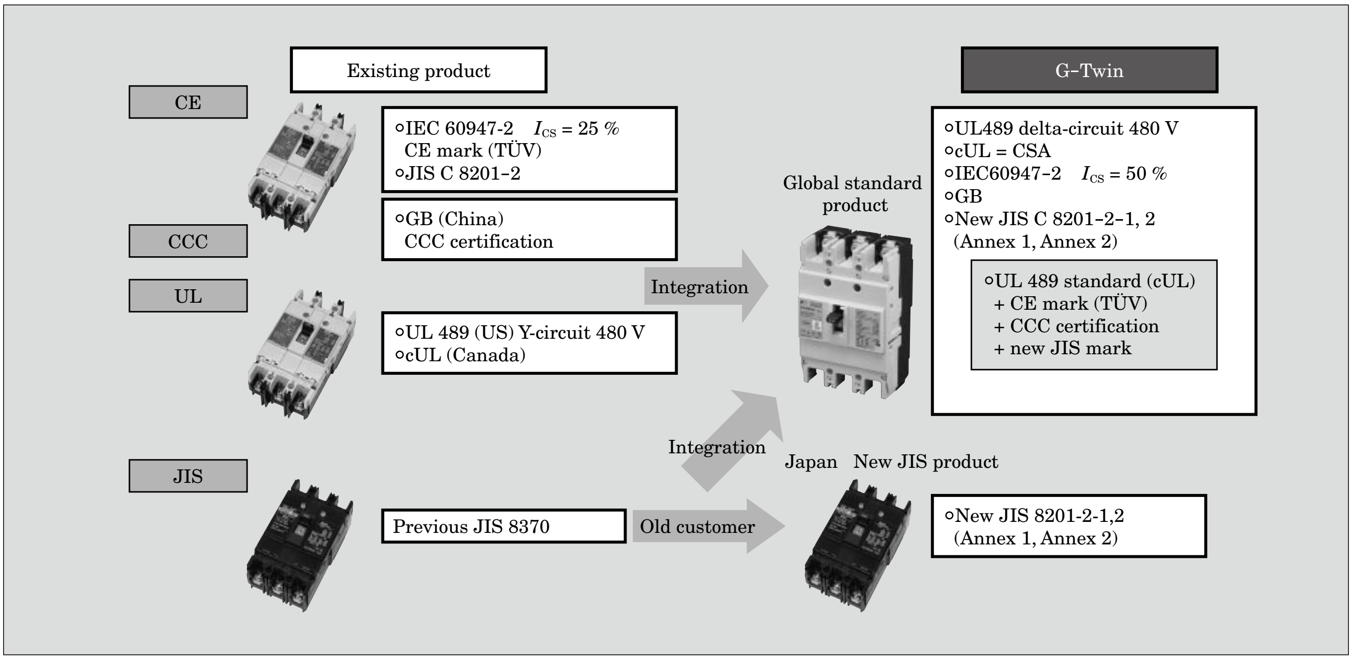
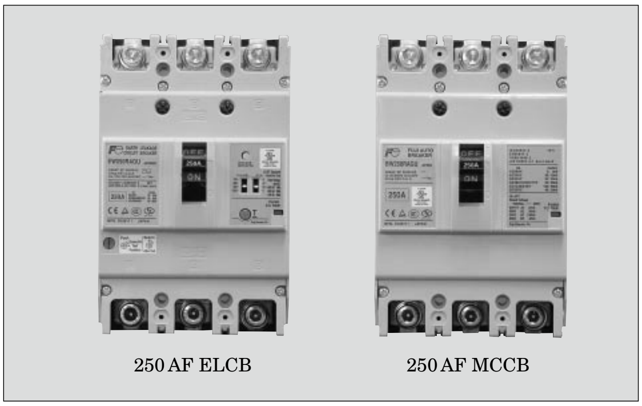


Fig.6 G-Twin low voltage circuit breakers



(1) Development of the new MCCB and ELCB series

Figure 4 shows the schedule in Japan for changing over from the previous JIS to the new JIS that conforms to IEC standards. During this transition period in Japan, low voltage circuit breakers must be used according to whether they support "existing electrical installations" or "IEC-based electrical installations." Because this problem is common to all countries throughout the world, Fuji Electric has proposed the concept of the new global "G-Twin Breaker" as a solution. (See Fig. 5.) Figure 6 shows the appearance of an implementation of this concept in 250A frame (AF).

The G-Twin Breaker is a revolutionary product that has acquired certification of IEC (Europe), new JIS (Japan), GB (China) and UL (United States) standards with a single circuit breaker unit, while maintaining the Japanese standard dimensions for circuit breakers. In particular, the capability to use this single circuit breaker unit also for 480 V delta circuits (UL) is an important advantage, as such dual use had been difficult to establish previously.

Fig.7 Appearance of MMS

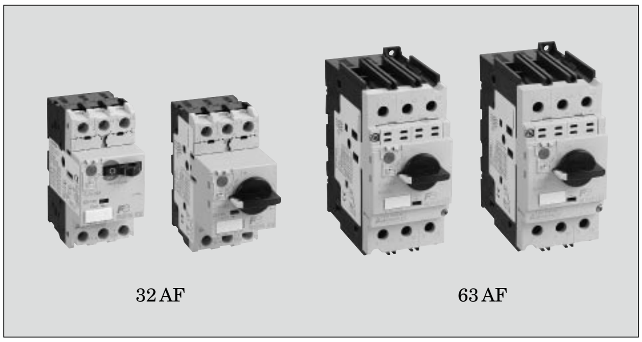
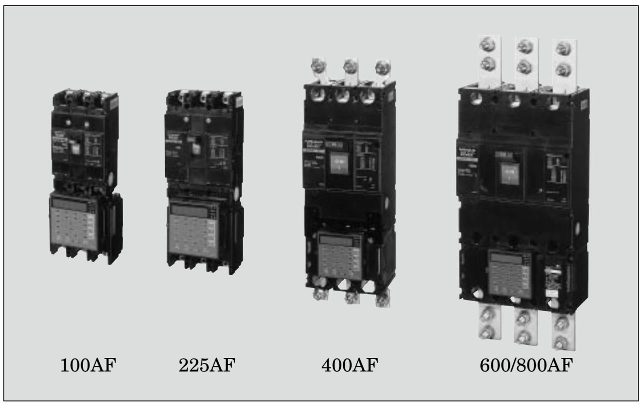


Fig.8 Appearance of FePSU Breakers

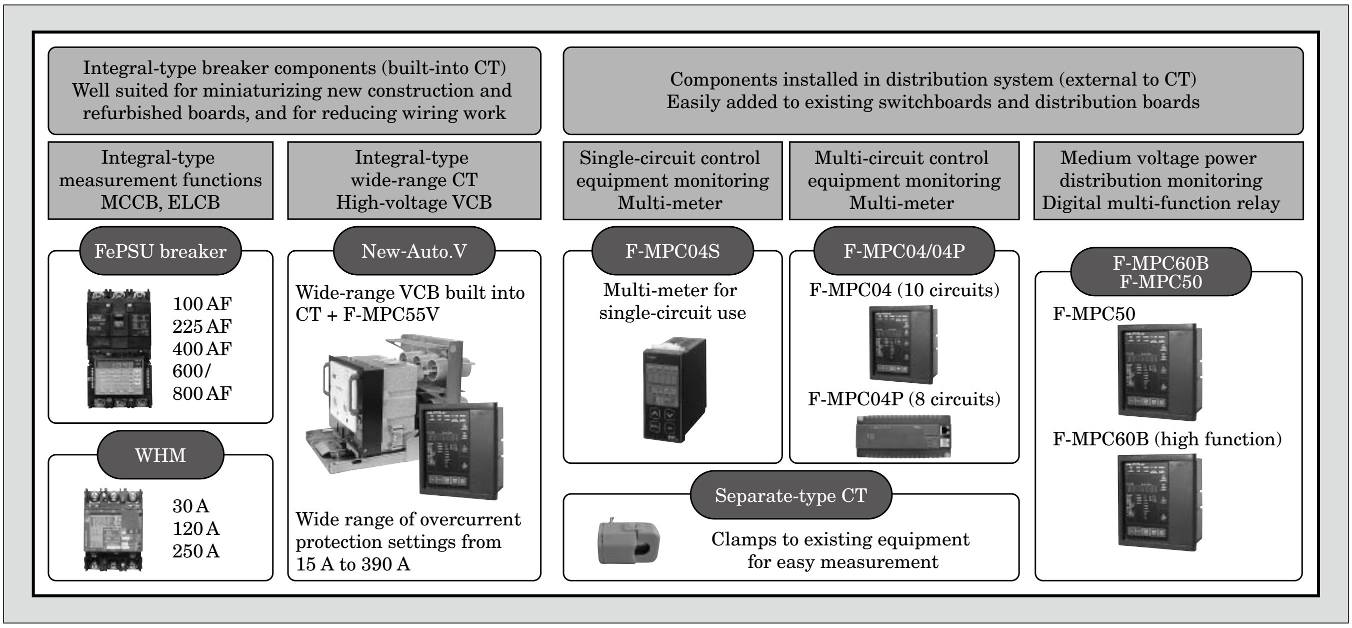


For further details, please refer to the separate article "New Global MCCB/ELCB G-Twin Breaker Series" in this special issue.

(2) MMS that achieves a new type of electric motor protection

IEC standards for the protection of electric motors

Fig.9 Product line of power distribution monitoring system components



in electrical installations contain many safety related items. The newly developed MMS is a compact-size motor breaker that realizes overcurrent protection for each motor branch circuit. The smallest frame size is 32AF, having a width of 45 mm in accordance with the new dimensional standards selected for compactness. Furthermore, the MMS also features a high interrupting capacity rating of 50 kA (400 V AC) and current-limiting performance similar to that of a fuse. (See Fig. 7.) The use of this product enables improved backup protection for downstream series-connected devices, such as a magnetic contactor, and wire protectors. Moreover, the MMS has obtained UL508 type E certification as stipulated in UL 508A for "industrial control gear," therefore, it is suitable for use in branch circuit protectors in the United States.

For further details, please refer to the separate article "Fuji Electric's New Global Motor Control Series" in this special issue.

(3) "FePSU Breaker Series" equipped with wattmeter

Users want to measure the amount of electricity used, and efforts to reduce the consumption of energy not only for compliance with energy-saving standards, but also as an increased awareness for reducing the energy consumed to lower the cost of production. Based on this need, Fuji Electric has developed and is supplying the "F-MPC Series," which is suitable for the monitoring and control of electric power in low voltage installations and has received favorable reviews. We have also developed a product series of wattmeter-equipped "FePSU Breakers" that are suitable for new installations. Accordingly, the components to network low voltage power distribution system and to support energy conservation constitute the product lineup shown in Fig. 9 from which products can be selected corresponding to the diverse needs of the energy monitoring and control field.

5. Conclusion

This paper has presented an overview of the changing circumstances for low voltage circuit breakers, then has analyzed the associated customer needs and described examples of Fuji Electric's response to those needs. Low voltage circuit breakers are the model most influenced by the harmonization with IEC standards as a result of the TBT agreement of the WTO. As actual application progress, Fuji Electric intends to continue to provide solutions to customer problems arising during commercial operation. The authors hope that this paper will be beneficial for the globalization of low voltage electric installations.

New Global MCCB/ELCB G-Twin Breaker Series

Katsunori Kuboyama
Akihiko Kohanawa

1. Introduction

In 1990, Fuji Electric began selling the "Twin Breaker," the world's first series of molded case circuit breakers (MCCB) and earth leakage circuit breakers (ELCB) that have common external dimensions. The Twin Breaker was well received and supported, thus this concept has become the de facto standard in the industry.

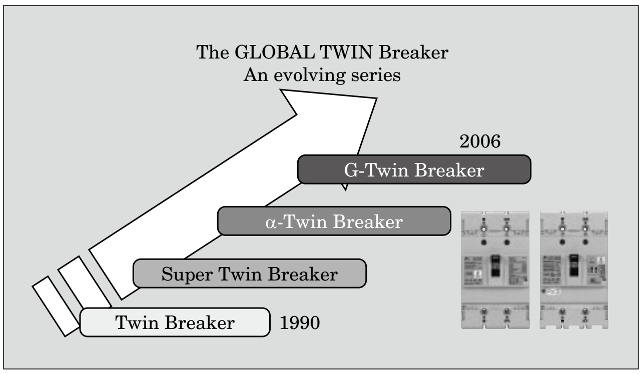
Then, in 1992 Fuji Electric introduced the "Super Twin Breaker" which, for the first time in Japan, enabled user installation of internal accessories, and in 1995 introduced the "Super 60 Series" that further advanced the concept of modularization.

Constantly anticipating changes in the market, in 2001, Fuji Electric began selling the "α-Twin Series" that achieved even smaller modularization of the 100A Frame (AF) class or lower. It was marketed as a multi-standard product that supports all standards worldwide.

Recently, the trend of market globalization has been accelerating at an increasing rate. Each country's standards for low voltage electric installations are moving toward conformance with the IEC standards, and the trend toward globalization is evident in the electrical devices used in such installations. Fuji Electric has responded to the needs of the market by acquiring certification of various standards to satisfy global customers, and by expanding its variety of products based on the Twin Breaker Series. On the other hand, as more product variety leads to more cumbersome selection and procurement of equipment, users are requesting its improvement. Under these circumstances, Fuji Electric has moved ahead with innovative technical development for low voltage circuit breakers, and has developed a 125 to 400 AF "G-Twin Series" as a global MCCB/ELCB series. (See Fig. 1.)

This paper describes the features, specifications and configuration of the G-Twin Series.

Fig.1 History of Fuji Electric's Twin Breaker Series



2. Background and Goals of G-Twin MCCB/ELCB Development

2.1 Background of development

Due to Japan's policy of harmonizing with IEC standards, as shown in Fig. 2, the JIS for low voltage circuit breakers is harmonized with the IEC standard. As a result, Japan has adopted unified new JIS series standard for low voltage circuit breakers. Main different points are described below.

(1) The three standards for conventional molded case circuit breakers, earth leakage circuit breakers, and low voltage circuit breakers are separated and

Fig.2 Technical harmonization with IEC standards in Japan, New JIS system for MCCB/ELCB

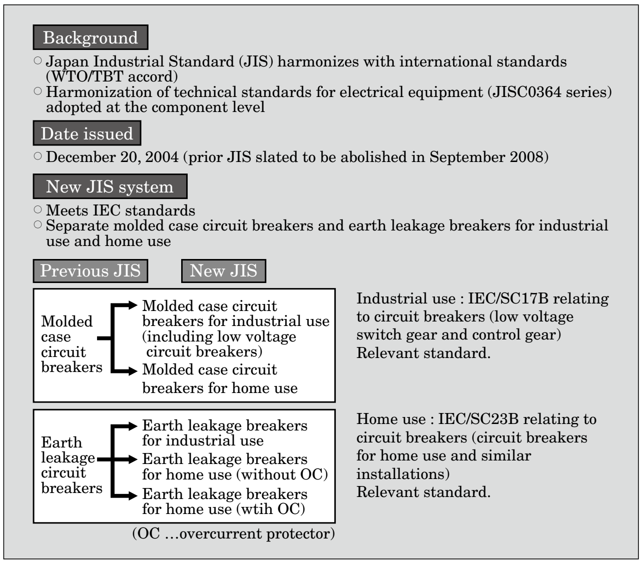


Fig.3 IEC harmonization in Japan, New JIS classifications

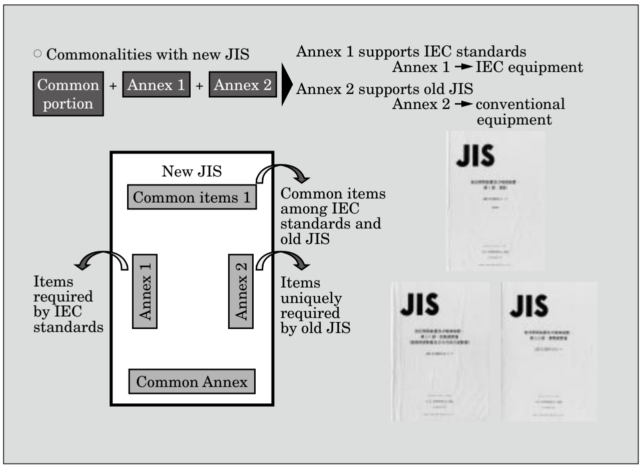
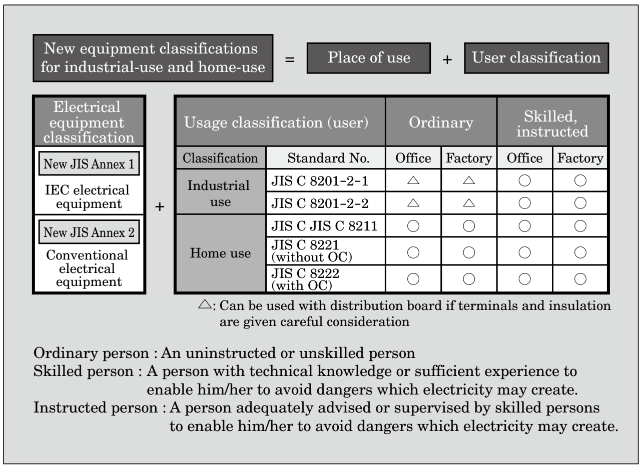


Fig.4 IEC harmonization in Japan, application categories of low voltage circuit breakers



reconfigured as a Common Standard, and two volumes for Circuit Breakers and three volumes for Earth Leakage Circuit Breakers. (See Fig. 3.)

(2) In the five volumes listed above, circuit breakers are classified according to either the Japanese conventional electric installations of Annex 2 or the IEC installations of Annex 1.

(3) Applications are separated into industrial-use circuit breakers to be used by persons skilled in electricity, and home-use circuit breakers to be used by ordinary persons. (See Fig. 4.)

(4) Industrial-use ELCBs are prescribed by Annex B of IEC 60947-2, and are prescribed by the new JIS with the independent standard JIS C 8201-2-2. (See Fig. 4.)

(5) The new JIS for ELCBs additionally incorporates IEC 60947-2 Edition III (operation during open phase). (See Fig. 5.)

Thus, with the issuance of the new JIS in Japan, low voltage circuit breakers will have to meet standards for the installation. Furthermore, markings indicating the circuit breaker model and the like must also be categorized. Harmonization with IEC standards is

Fig.5 IEC 60947-2 Ed. III, ELCB compatibility with 3-phase power supply

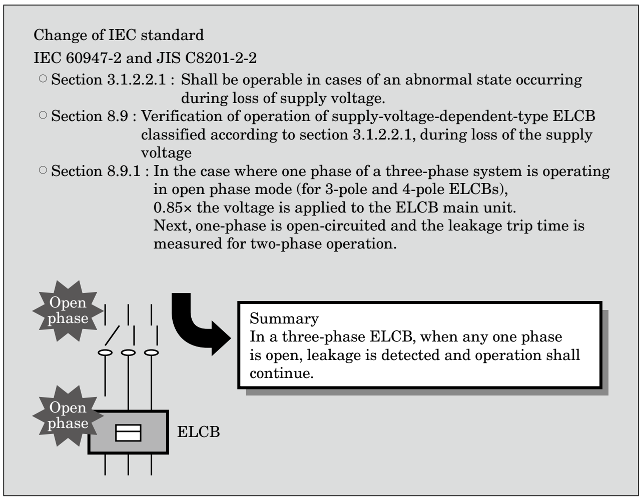
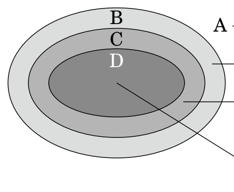


Table 1 G-Twin MCCB/ECLB customer applications

Series	G-Twin (global standard)	G-Twin (multi-standard)	α-Twin
Indication of standards	UL/CE/CCC/ New JIS	CE/CCC/ New JIS	New JIS
Model series	Fuji gray-color  Terminal cover standard installation	Fuji gray-color 	Fuji black-color  Japan-use only product
Category	A B C (D)	A (B) C (D)	D
Customer selection	 A: Overseas customer; B: Global customer; C: Customer that exports from Japan; D: Japan-use only customer		

advancing rapidly in Asian countries, and Japan is no exception.

2.2 Development goals

Based on an analysis of the changing circumstances surrounding low voltage circuit breakers, and in order to anticipate the customer needs of the future, Fuji Electric determined that it was necessary to develop a novel-concept MCCB and ELCB, and moved ahead with technical development to commercialize the "G-Twin" Global Breaker. (See Table 1.) The development goals of the G-Twin are summarized below.

(1) Compatibility with global standards for low voltage circuit breakers

To realize a single model certified for all standards, thus it is more efficient than former products that were issued in various configurations to comply individually with various international standards

(2) Technical support synchronized to revisions of IEC standards

To reconsider and catch-up basic circuit breaking functions corresponding to the latest IEC standards

(3) Conformance with the European Union's RoHS standards and domestic environmental standards

To remove designated hazardous metals, reconsider lower-cost materials, and reconsider the method of production

(4) Unification of new JIS, IEC, and UL 489 compatible circuit breaker

To realize a single product series that unifies both a UL 489 certified 480 V product and an IEC 60947-2 certified 400 V product, while maintaining the present compact size.

(5) Easily distributable circuit breaker and accessary system throughout the world.

To realize unified circuit breaker accessories that are configured so as to permit user installation.

As various countries adhere to IEC standards, circuit breakers that realize the abovementioned goals are anticipated to become the global standard of the future.

3. G-Twin Features

Figure 6 shows the appearance of G-Twin Breakers. The molded cover is colored "Fuji gray" (light gray) and projects a new global image. On the other hand, the black cover of the α-Twin Breakers matches the existing equipment in Japan, and this color scheme is maintained in consideration of those customers who are presently using the α-Twin Series. Therefore Fuji Electric provides two series of breakers to conform to standards throughout the world. The G-Twin Series consists of the following two product lines, one of which displays the UL 489 standard. (See Table 1.)

① A universal MCCB/ELCB G-Twin Series that can be used in all installations throughout the world (including Japan)

② MCCB/ELCB α-Twin Series used mainly with electrical installations in Japan

The five major features of the G-Twin are described below.

(1) A multi-standard product that maintains Japanese standard dimensions

Figure 7 shows the concept of a unified G-Twin Series. For the first time in the world, while maintaining Japanese standard dimensions, a single product has obtained IEC, new JIS, GB, and UL (480 V delta system) certification and can be used in any country in the world. In eliminating the previously required task of selecting a particular circuit breaker from among models having the same functionality for use in a particular country, this new product is extremely convenient.

Fig.6 Appearance of G-Twin MCCB/ELCB

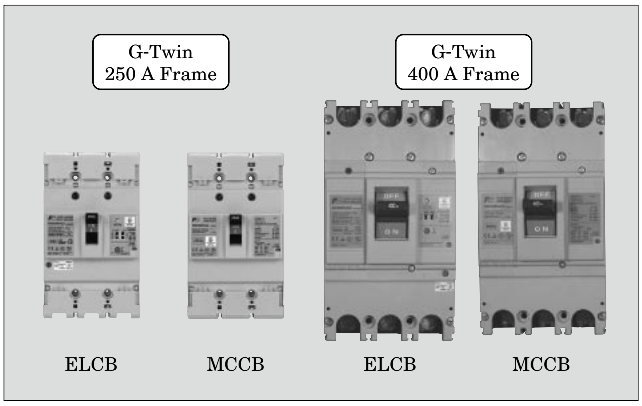
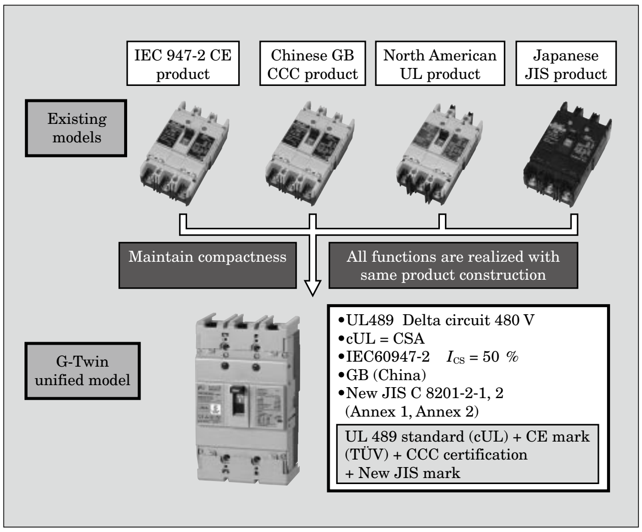


Fig.7 Concept of unified G-Twin Series



(2) Incorporation of IEC 60947-2 Ed. III and improved maintainability

A CE*1 mark must be affixed to export to the EU community. A circuit breaker to which a CE mark is affixed must satisfy the latest technical requirements of IEC 60947-2. In particular, with an ELCB, due to differences in distribution voltages or grounded systems, it is necessary to be careful about whether IEC 60947-2 technical requirements are being satisfied. The G-Twin completely conforms to IEC 60947-2, supports CE marking, and improves the ease of maintenance. Examples of the improvements are listed below.

① The detection circuit power supply of the ELCB is changed to a three-phase input to realize reliable operation during open-phase operation. (See Fig. 5.)

② A dielectric test switch is provided to enable the easy implementation of an insulation-to-earth resistance test of the wiring or equipment on the load-side of the ELCB. (See Fig. 8.)

(3) Conformance with the US-based UL 489 480 V AC

*1: CE mark is a marking certifying that a product complies with Europe's safety requirements.

Fig.8 Equipping with maintenance-use dielectric test switch

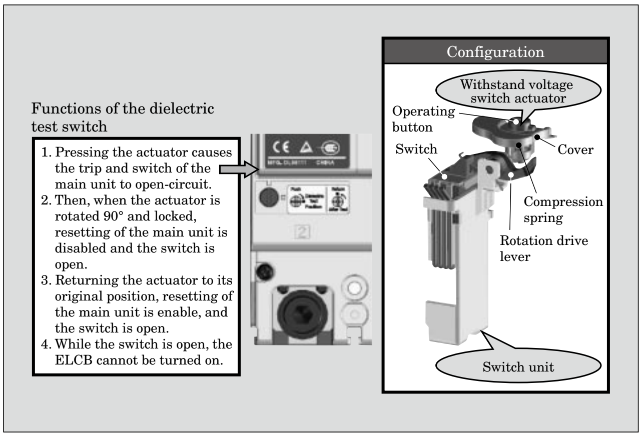
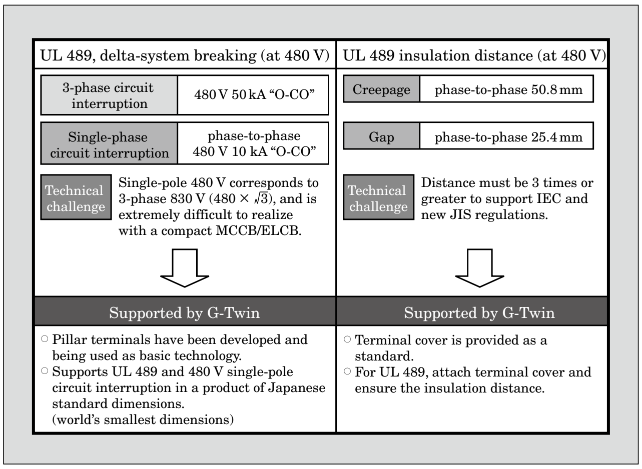


Fig.9 Breaking duty and insulation distance of UL 489 delta-system



delta connection system

The greatest technical challenge for the globalization of low voltage circuit breakers is with keeping Japanese standard compact size is making it possible to satisfy the duty of a UL 489 480 V AC delta connection. The G-Twin Breakers maintain the Twin Breaker principle of common dimensions for the MCCB and ELCB, and they are the world's first MCCB and ELCB to have met this challenge. (See Fig. 9.)

(4) User-friendly configuration

125 AF and 250 AF frame sizes were selected as these are the global standard for circuit breaker frames. Also, the number of connection terminals was increased for 400 AF frames to enhance compatibility with distribution switch gear. (See Fig. 10.) Internal accessories (auxiliary, warning switch, voltage trip coil, etc.) for installation inside the circuit breaker are streamlined into two series of common accessories for 125 AF to 250 AF and for 400 AF and larger sizes, thus improving the ease of user installation.

(5) Industry's highest level environmental protection and energy savings

The G-Twin Breaker, including the main unit and accessories, completely conforms to the EU's environmental standard known as the RoHS directive.

Fig.10 400 AF terminal variation

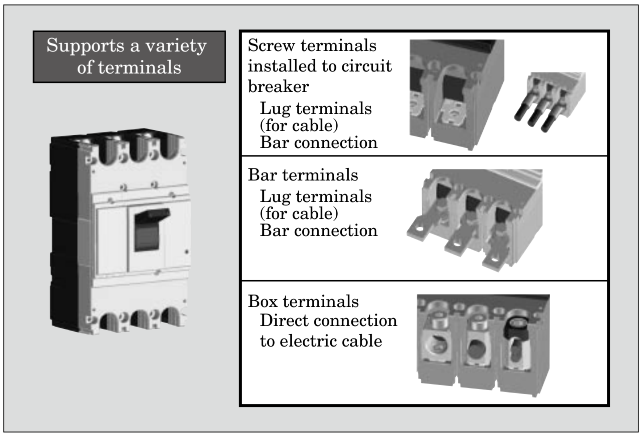


Fig.11 G-Twin FePSU Breaker equipped with power monitoring function

A model variation, the G-Twin FePSU Breaker, having a function for monitoring electric energy at the branch circuit and a function for transmitting its data, was added to the lineup of this breaker series. Therefore Fuji Electric's series of energy-savings support devices was expanded. (See Fig. 11.)

4. Summary of G-Twin Ratings and Specifications

With the completion of the G-Twin MCCB/ELCB, Fuji Electric's twin breaker series is configured as shown in Fig. 12. In other words, the G-Twin product line consists of the following two series.

(1) High-end series: Highest-level "global breaker" series capable of supporting all standards worldwide in the same model

(2) Middle-class series: "Multi-standard breaker" series that supports Japanese and IEC standards.

Customers who use either series (1) or (2) above in accordance with their percentage of MCCB/ELCB usage for each standard (IEC standard, UL standard, new JIS, GB standard) will be free of the task of choosing series of MCCBs and ELCBs according the application, and therefore, the tasks of designing and stocking equipment will become more streamlined.

Fig.12 MCCB/ELCB series

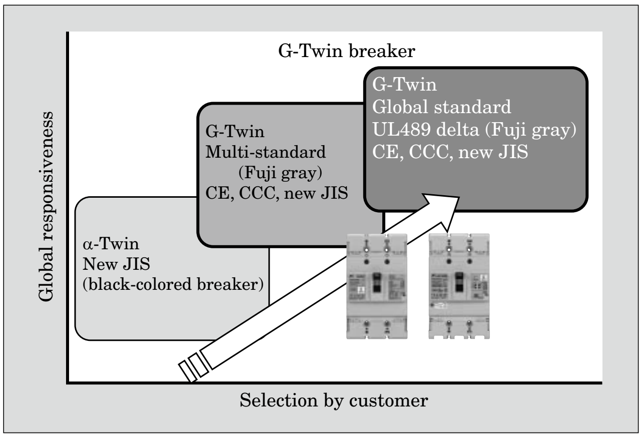


Table 2 lists the main specifications of the global twin breaker, and Fig. 13 shows the main nameplate.

5. G-Twin Breaker Structure and Technology

The basic structure of the G-Twin was determined according to the primary goal to realize the maximum level of performance while maintaining the Twin Breaker concept, i.e. maintaining the same external dimensions with the ELCB and MCCB.

As shown in Fig. 14, an improved product was successfully realized by applying a new arc-extinguishing principle utilizing ablation technology, technological advances developed through a full reassessment of

Table 2 G-Twin MCCB and ELCB specifications

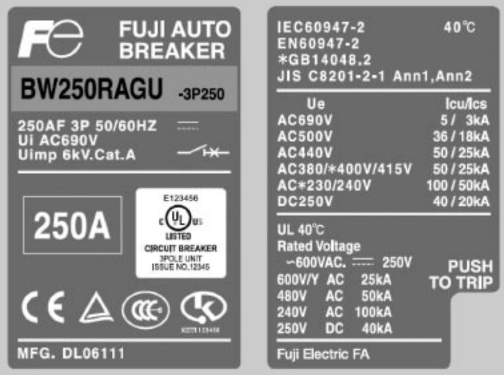
(a) MCCB

Frame			125 AF		250 AF		400 AF		
Number of poles			2, 3 ,4		(2), 3, 4		(2), 3, 4		
Rated current (A)			15, 20, 30, 40, 50, 60, 75, 100, 125		100, 125, 150, 175, 200, 225, 250		250, 300, 350, 400		
Model number			BW125JAGU	BW125RAGU	BW250JAGU	BW250RAGU	BW400SAGU	BW400RAGU	BW400HAGU
Rated insulation voltage (V)			690		690		690		
External dimensions (mm)		2 poles	W : 60, H : 155, D : 68	W : 90, H : 155, D : 68	W : 105, H : 165, D : 68		W : 140, H : 257, D : 103		
		3 poles	W : 90, H : 155, D : 68		W : 105, H : 165, D : 68		W : 140, H : 257, D : 103		
		4 poles	W : 120, H : 155, D : 68		W : 140, H : 165, D : 68		W : 185, H : 257, D : 103		
Breaker capacity (kA)	JIS C 8201-2-1 Annex 1, Annex 2 IEC60947-2 GB14084.2 I_{cu} / I_{cs}	690 V	–	5/3	–	5/3	10/5	15/8	20/10
		440 V	30/15	50/25	30/15	50/25	36/18	50/25	70/35
		400 V	30/15	50/25	30/15	50/25	36/18	50/25	70/35
		240 V	50/25	100/50	50/25	100/50	85/43	100/50	125/63
	UL489 delta-system cUL	480 V	25	50	30	50	35	50	65
		240 V	50	100	50	100	85	100	125

(b) ELCB

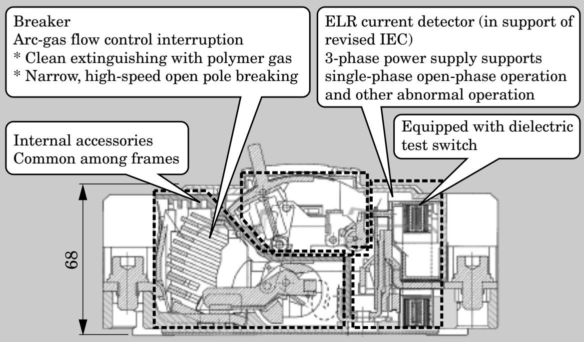
Frame			125 AF		250 AF		400 AF		
Number of poles			3, 4		3, 4		3, 4		
Rated current			15, 20, 30, 40, 50, 60, 75, 100, 125		100, 125, 150, 175, 200, 225, 250		250, 300, 350, 400		
Model number			EW125JAGU	EW125RAGU	EW250JAGU	EW250RAGU	EW400SAGU	EW400RAGU	EW400HAGU
Rated voltage AC (V)			100-230-440		100-230-440		100-230-440		
Rated sensitive current (mA)			30, 100/200/500		30, 100/200/500		30, 100/200/500		
Tripping time (s) at/delta n			0.1		0.1		0.1		
External dimensions (mm)		3 poles	W : 90, H : 155, D : 68		W : 105, H : 165, D : 68		W : 140, H : 257, D : 103		
		4 poles	W : 120, H : 155, D : 68		W : 140, H : 165, D : 68		W : 185, H : 257, D : 103		
Breaker capacity (kA)	JIS C 8201-2-2 Annex 1, Annex 2 IEC60947-2 GB14084.2 I_{cu} / I_{cs}	440 V	30/15	50/25	30/15	50/25	36/18	50/25	70/35
		400 V	30/15	50/25	30/15	50/25	36/18	50/25	70/35
		240 V	50/25	100/50	50/25	100/50	85/43	100/50	125/63
	UL489 delta-system +UL1053 cUL	480 V	25	50	30	50	35	50	65
		240 V	50	100	50	100	85	100	125

Fig.13 Main nameplate of the G-Twin MCCB



Example of nameplate for 250 A frame

Fig.14 G-Twin ELCB structural cross-section and development technology



the earth leakage trip unit, and technological breakthroughs in environmental technology and the like achieved in the development of new materials. Items of significance are described below.

5.1 Realization of both IEC-standard interrupting duty and UL-standard 480 V delta-system interrupting duty

(1) Difficulty of compatibility with both IEC 60947-2 and UL 489

Table 3 lists the differences between the IEC standard/new JIS and the UL standard. From this table, it can be seen that UL 489 has stricter requirements. As previous UL-listed products were larger in size than IEC-standard products, it was distributed as a separate series for the North American market.

In particular, a large obstacle to product design was keeping the single-pole interrupting duty assuming a single-line ground fault in a delta-connection 480 V grounded system, and ensuring the insulation distance.

(2) Realization of both IEC and UL interrupting duty with ablation-based interrupting technology

In order to increase the initial open acceleration of the movable contact, a magnetic yoke and a stationary contact are positioned in combination, and a three-dimensional simulator was used heavily to determine the optimal positioning. Moreover, the ablation gas effect is added to the arc plate, to cool the arc, thus achieving a dramatic improvement in the current-limiting performance, and 70 % reduction of let-through energy (I^2t) during an IEC standard 440 V AC/50 kA interruption compared to the conventional 225 AF.

In addition to the improvement in current-limiting performance, the flow of exhaust gas from the arc plate to the load-side of the breaker is controlled by the structure of the case and cover so that the arc meets the current zero-point reliably on the plate. As a result of this effect, the UL standard for 480 V single-pole interruption duty is kept. (See Fig. 15.)

Table 3 Differences between UL 489 and IEC 60947-2 requirements

Main requirements			UL 489	IEC 60947-2, new JIS
Rated voltage			Requirements of 480 V, delta-connection to ground system	Requirements of 400 V, Y-connection to ground system
Structure	Creepage insulation distance	Phase to phase	50.8 mm	10 mm
		To ground	25.4 mm	10 mm
	Creepage insulation clearance	Phase to phase	25.4 mm	5.5 mm
		To ground	12.7 mm	5.5 mm
	Double insulation		Not required	Necessary
	Isolation		Not required	Necessary
Electrical	Impulse withstand voltage		Not required	6 kV
	Electrical durability (250 A)		4,000 cycles at I_n (4,000) mechanical	1,000 cycles at I_n (7,000) mechanical
	Overload switch		50 cycles at 6 I_n	12 cycles at 6 I_n
	Temp. rise of terminal		50 deg. or less	70 deg. or less
Short-circuit breaking	Limiting interruption (I_{cu})		"O" to "CO" at 480 V (twice)	"O" to "CO" at 400 V (twice)
	Service interruption (I_{cs})		Not required	"O" to "CO" to "CO" at 400 V (three times)
	One-phase ground fault interruption		"O" to "CO" at 480 V for each phase	Not required (manufacturer's value)
	Withstand voltage after interruption		960 V, 1 minute	1,380 V, 1 minute

5.2 Technical advances of the earth leakage trip unit

(1) Realization of an earth leakage trip unit that conforms to IEC 60947-2 Ed. III

When a certain earth leakage current occurs, the earth leakage trip unit outputs a signal to the detection circuit to make the trip coil operate to trip the connection of the main unit. In IEC 60947-2 Ed. III, assuming the use of a fuse or the like as an overcurrent protector, an internal power supply circuit is required so that earth leakage current can be detected and the

Fig.15 Configuration of breaker unit in G-Twin Breaker

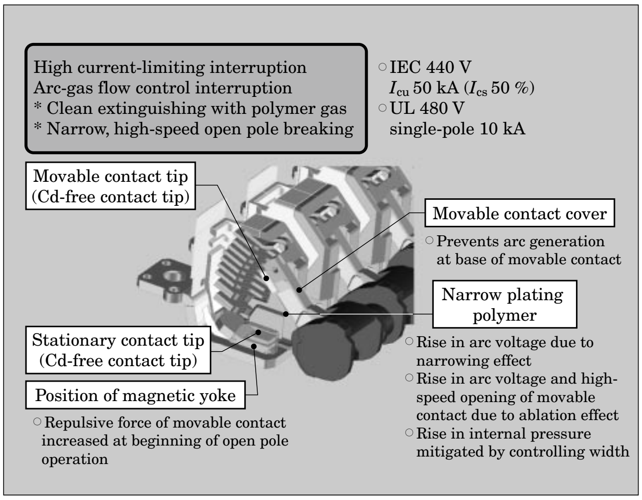
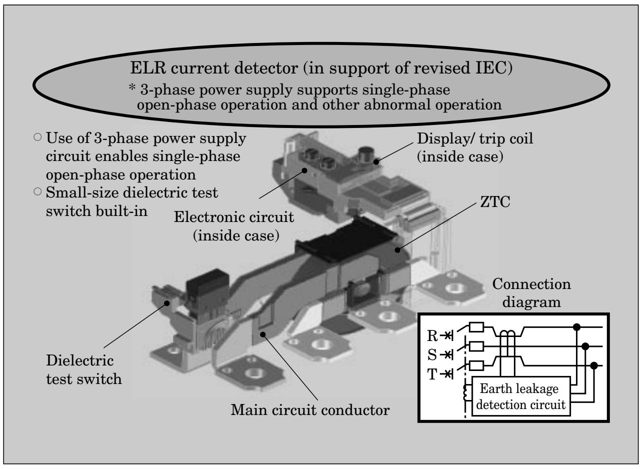


Fig.16 Configuration of G-Twin's internal earth leakage relay

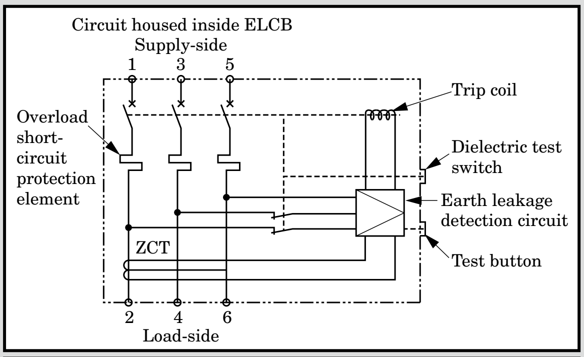


circuit tripped even in cases where one of the three phases is an open-phase. To support this requirement, a new small-size power supply circuit was developed and applied. In addition, ultra-miniaturization of the trip coil and modularization of mechanical parts that transfer motion enabled the successful development of a small-size earth leakage trip unit. (See Fig. 16.) As a result, the product was commercialized without having to modify the external dimensions of conventional products.

(2) Installation of dielectric test switch for maintenance use

The power supply circuit for the earth leakage trip unit is connected to the main circuit inside the ELCB. Therefore, during dielectric testing of the electrical connections, the high voltage that is applied between phases may cause damage to the circuit elements. For this reason, previous ELCBs were provided with warnings not to perform a phase-to-phase dielectric test, and to remove the ELCB wiring when performing a dielectric test. To eliminate such inconvenience, the G-Twin ELCB is equipped with a switch that provides voltage withstand performance between the earth leakage trip unit and the internal main circuit conductor. This dielectric test switch is provided as a standard feature in 125AF and higher G-Twin ELCBs. (See Fig. 17.) By operating this switch during dielectric testing, maintenance inspections can be performed with dramatically improved ease.

Fig.17 Dielectric test switch circuit and specifications



Specifications

- ○Rated voltage 100 to 480 V
- ○Rated current 1 to 30 mA
- ○Contact resistance 100 mΩ or less
- ○Withstand voltage 2,500 V AC
- ○Insulation resistance 100 MΩ or higher
- ○Lightening impulse withstand voltage U_{imp} 6 kV
- ○Electrical durability 100 cycles
- ○Mechanical durability 1,000 cycles

Operation

- ○Press button and turn switch off during test of main circuit withstand voltage
- ○Self-holding mechanically
- ○Mechanically interlocks with breaker

6. Conclusion

The development, features and specifications of the G-Twin have been presented above. The use of global products in electrical installations worldwide will become increasingly important for realizing more efficient equipment design and production. The G-Twin Series anticipates these needs and we are confident that the G-Twin will be able to satisfy a diverse array of customer requirements. In addition, we believe that our low-voltage circuit breakers which incorporate this concept will become the de facto standard for the next generation of products. Fuji Electric will continue to seek advice from customers, and will strive to develop an even broader product line in the future.

Technical Development for New Global MCCB and ELCB

Masaaki Nakano
Toshiyuki Onchi
Shuichi Sugiyama

1. Introduction

Molded case circuit breakers (MCCB) and earth leakage circuit breakers (ELCB) function to protect wiring, equipment and people from overcurrent and ground faults, and are used throughout the world and are installed in virtually all devices, machines, equipment and buildings that use electricity. The performance of MCCB and ELCB is provided for by the standard by the country on the region. However, the content also has a different part by the difference and the historical background of the idea by the composition of the electrical system.

At present, there is a movement to unify the different standards. However, actually, various standards such as IEC (Europe, Asia), UL (United States), GB (China, essentially the same as IEC), JIS (Japan, some content is essentially the same as IEC and some content is specific to Japan) exist throughout the world, and product lines that conform to these standards, i.e., IEC standards, UL standards, JIS standard, etc., are being developed and supplied. Thus the new global MCCB and ELCB aim to realize a truly global product line, and were developed with the goal of providing a single model that conforms to all these various standards.

This paper describes the basic technology for realizing products that satisfy various global standards simultaneously maintaining the existing dimensions of JIS-compliant products.

Fig.1 Appearance of the new MCCB/ELCB

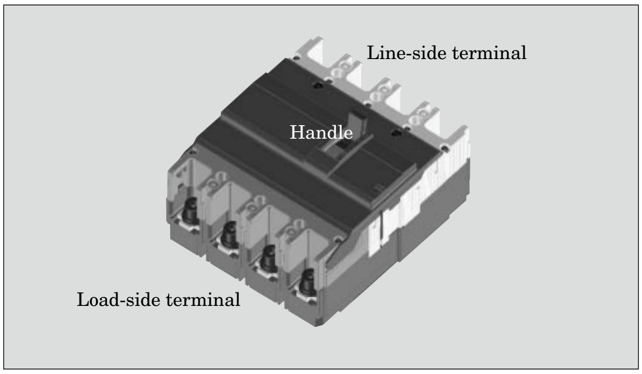
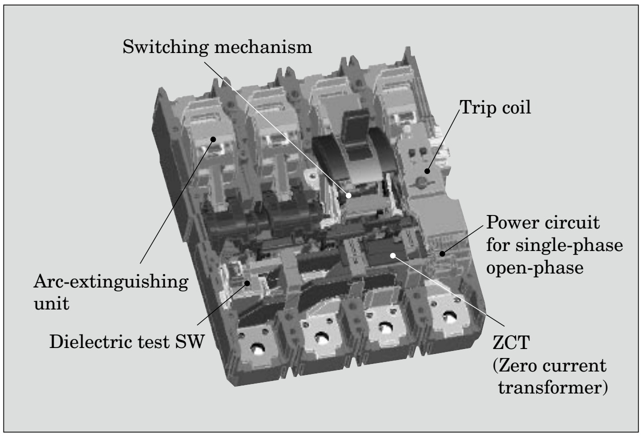


Fig.2 Structure of the new ELCB



2. Structure of the Newly Developed MCCB and ELCB

The newly developed MCCB and ELCB are the same size as well as "Twin Breakers" of an existing product. Figure 1 shows the externals.

Figure 2 shows the structure of the new ELCB. In conformance with IEC 60947-2, Annex B, 3rd Edition, the earth leakage detector circuit is equipped with a newly developed power circuit for supplying electric power from each phase so that earth leakage protection can be implemented even if one of the three phases is operating as an open-phase. Moreover, abnormalities in the equipment or wiring are usual verified by measuring the withstand voltage of the circuit, but the voltage applied in this case is excessive for the internal circuit elements of the ELCB, and will result in device failure. To prevent such failure, Fuji Electric equips the ELCB with a newly developed dielectric test switch that is isolated from the portions of the circuit in order to conduct current during inspection.

The MCCB shares the same case, circuit breaker, switchgear, and has the same construction as the ELCB, with the exception of those ELCB modules involved in the operation or in the detection of leakage current.

3. Technical Development for the New MCCB and ELCB

This paper presents examples of the technology used in developing the high-capacity current breaking performance, the earth leakage protection operation that is compatible with single-phase open-phase operation, and the high-strength case structure.

3.1 High capacity breaking performance

The breaking duty of a low voltage breaker is prescribed in the IEC standard according to the I_{CS} duty (O-CO-CO*[1]), and is prescribed in the UL standard according to a single-phase ground fault test in which a large recovery voltage is applied between phases. A single model that supports these various duty cycles would require large external dimensions and thus would be difficult to satisfy customer requirements. In the search for a solution, advances in circuit breaking technology will play a crucial role. The optimization of gas flow control during circuit breaking and of sidewall structure is discussed below.

3.1.1 Gas flow control

In the past, when breaking a large current such as a short-line fault current, a magnetic field is applied to the arc via an arc plate and a magnetic body such as a magnetic yoke installed at the periphery of stationary and movable contacts. The electromagnetic force generated by interaction with the current that flows in the arc acts to drive and cool off the arc, pushing inward on the arc plate and interrupting the current flow. At this time, the arc causes the breaking unit to be at a high temperature and high pressure, and gas flows toward low-pressure regions. This time's development work aims to achieve even higher capacity breaking performance by utilizing this gas flow, in addition to the electromagnetic force described above. Figure 3 shows the gas flow at this time. As can be seen in the figure, the gas flow is divided into a portion flowing through the arc plate and toward the line-side, and a portion flowing oppositely through the switchgear and the overcurrent/earth leakage detector and toward the load-side. By increasing the gas flow toward the line-side, the arc can be driven toward the arc plate.

Figure 4 shows examples of the measurement of various arc plate potentials for the purpose of verifying whether the arc is being pushed inward. The verification is carried out under conditions of single-phase circuit interruption with a rated voltage of 480 V per delta connection as specified by the strict regulations of the high recovery voltage of UL 489. From the measured results, it is determined that the arc is being pushed toward several arc plates due to the potential of each arc plate. The results shown in Fig. 5 illustrate the relationship to the success or failure of the current breaking. As can be seen in this figure, the ratio of the flow rates of gas exhausted to the line-side and load-side must be greater than a certain value, and by optimizing the shape of the exhaust to the line-side and to the load-side, and by controlling the flow of gas blown to the arc, there is an increase in the number of arc plates pushed inward by the arc, thereby enabling circuit breaking.

*1: O-CO-CO is Off - Cut off - Cut off.

Fig.3 Schematic of current breaking operation

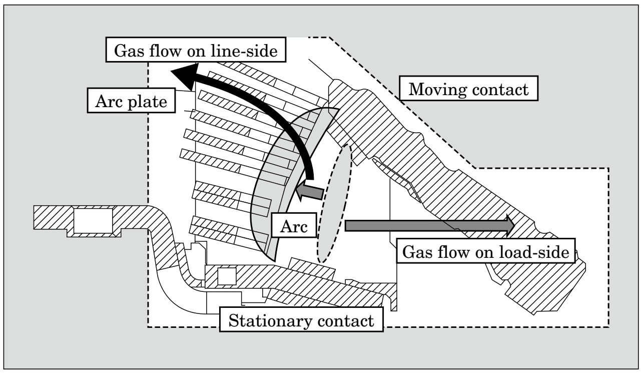


Fig.4 Example of arc plate measurement

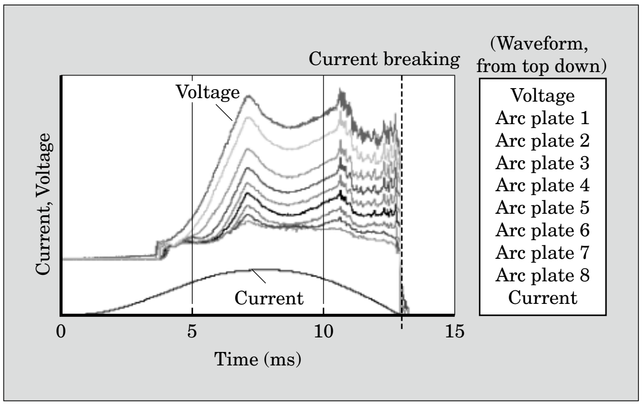
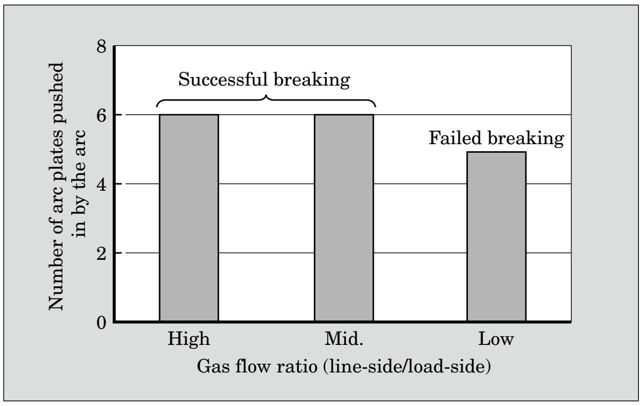


Fig.5 Number of arc plates pushed in by the arc and breaking performance



3.1.2 Sidewall structure of the circuit breaker

At the circuit breaker, a plastic resin sidewall is used to surround the arc, and the arc is cooled by the ablation effect of the resin. To improve the current limiting performance and realize higher capacity breaking performance, the distance between the resin and the arc must be reduced to enhance the ablation effect. However, due to the increased quantity of gas vaporization from the resin and the increase arc voltage due to cooling, the internal pressure increases and may cause damage to the case. With Fuji Electric's new developments, the sidewall structure is optimized so that the increase in internal pressure is suppressed while high-capacity breaking performance is realized.

From an oscillogram captured at the time of short-circuit current breaking, it can be seen that the current first reaches a peak value, and then after some time, both the arc voltage and internal pressure either rise at approximately the same time and reach peak values, or the internal pressure will reaches its peak value after a slight delay. In Fuji Electric's new developments, attention focused on this time delay, and at the beginning of the breaking operation, or in other words, when the movable contact is within a short distance of the stationary contact and the sidewall gap is narrower, ablation enhances the current-limiting performance so that the peak value of the current is limited, and at the end of the current breaking operation, or in other words, when the movable contact is a distance away from the stationary contact and the sidewall gap is increased, the increase in generated ablation gas and in arc voltage are suppressed, thereby enabling the rise in internal pressure to be mitigated.

Figure 6 shows the shape of the sidewall gap and Fig. 7 shows the results of verification testing. From these figures, it can be seen that the sidewall becomes narrower in the vicinity of the stationary contact and

Fig.6 Shape of resin sidewalls

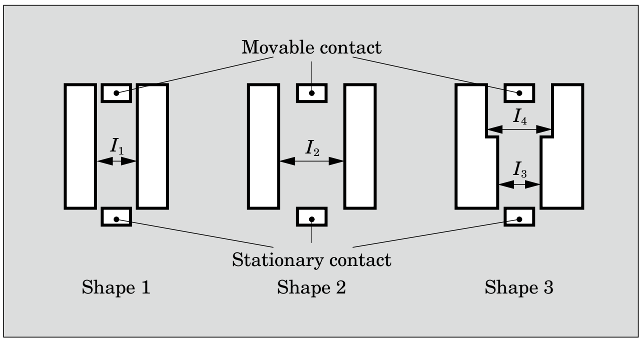
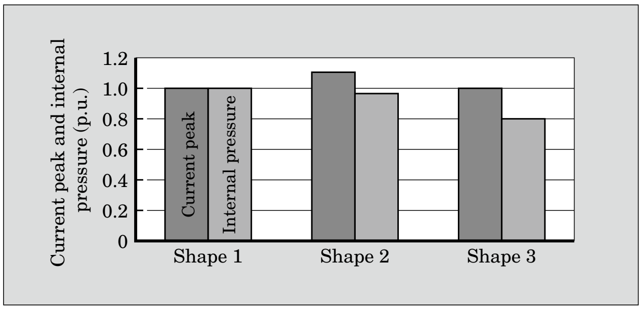


Fig.7 Effect of sidewall shape on current and rise in internal pressure



becomes wider at a distance from the stationary contact, and as a result, the current peak is suppressed to the same extent as when the sidewall is narrow (shape 1), and a rise in internal pressure is mitigated.

The above discussion concerned optimization of the gas flow control and sidewall shape, but by also using simulations to optimize the shape of the stationary contract, movable contact, arc plate, magnetic yoke and the like of the circuit breaker to achieve high-capacity breaking performance, in addition to conformance with IEC and JIS standards, is also possible to interrupt current with a single model that supports the rated voltage of 480 V per delta connection as specified in UL 489, which had been difficult to support in the past.

3.2. Single-phase open-phase operation for earth leakage protection

IEC 60947 requires the capability to implement earth leakage protection even when one of the three phases is operating in an open-phase mode. Moreover, the same category of regulations has also been added to JIS C 8201.

Technical developments for a power circuit that supplies power to an earth leakage relay part and for a trip coil are described below.

3.2.1 Power circuit

So that power can be supplied to the trip coil of an earth leakage relay during single-phase open-phase operation, the power supplied to the detector and relay circuits must be changed from two to three phases. This is because, with the two-phase method, power cannot be supplied if one phase operates as an open-phase, but with the three-phase method, even if one phase operates as an open-phase, power can still be supplied by the remaining two phases. With the three-phase method, the supply voltage during single-phase open-phase operation is lower than usual. Because it is necessary, even in this case, to supply power stably to the trip coil, a two-stage transistor method is employed that combines two types of transistors, a high-breakdown voltage transistor for changing a high voltage to a low voltage and a low-breakdown voltage transistor for making the load current a constant current.

Figure 8 shows a comparison of the circuit configurations in the conventional method and the newly developed method, and Fig. 9 shows a comparison of the current versus voltage characteristics of the same circuits. As can be seen in these figures, the constant current characteristics have been greatly improved. Moreover, the mounting area has been decreased by 71 % and the power consumption decreased by 43 % compared to the conventional method.

3.2.2 Trip coil for earth leakage relay

Figure 10 shows the structure of the trip coil. When an earth leakage has been detected, the trip coil receives an output signal from the detection circuit and causes the plunger to move. Releasing the latch of a switchgear (not shown in the figure) causes the ELCB to trip. Usually, the attractive force of a permanent magnet compresses a spring and holds the plunger at a lower position. When an earth leakage occurs, current flows in the coil, generating a magnetic flux having an orientation opposite that of the permanent magnet, and the repulsive force of the spring causes the plunger to move upward and the ELCB to trip.

With the reduction in internal space as the result of internally housing the abovementioned power supply circuit capable of open-phase operation, Fuji Electric developed a simulator for analyzing the operation of the trip coil and optimized the trip coil. As a result, volume has been reduced by approximately 50 % compared to the previous size.

The trip coil is required to operate for short time durations on the order of milliseconds. However, because parameters of the magnetic circuit and electrical circuit vary widely and have a mutual dependence that is influenced by the plunger location, computation of those parameters must be performed with precision, and use of the general analytic technique of finite element analysis to analyze trip coil operation is impractical because of the large amount of labor and analysis time that would be required. Thus, Fuji Electric devised mathematical formulations of the magnetic circuit system, the electric circuit system and the mechanical system, and coupled these formulations to develop a simulator for analyzing operation of the trip coil.

Figure 11 shows an example analysis of the trip coil operation. Having a maximum analysis error of approximately 10 %, this simulation confirms the absence of any practical problems and was used when examining the robustness achieved through quality engineering techniques, and resulted in an optimal shape of the trip coil and an optimized control power circuit as shown in Fig. 8.

3.3 Stronger case structure

As discussed in section 3.1.2, with Fuji Electric's

Fig.8 Comparison of power circuits

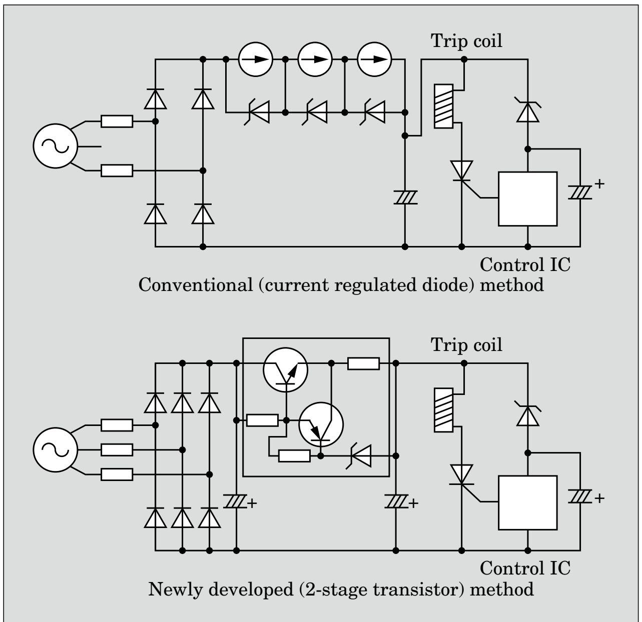


Fig.9 Comparison of power circuit characteristics

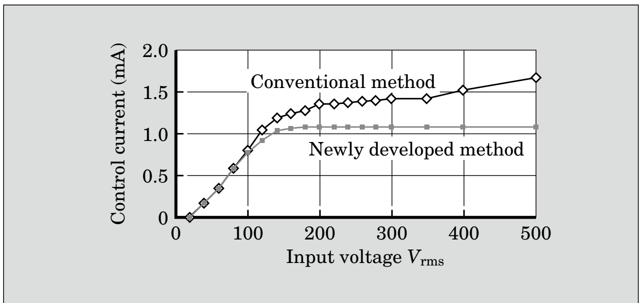


Fig.10 Trip coil structure

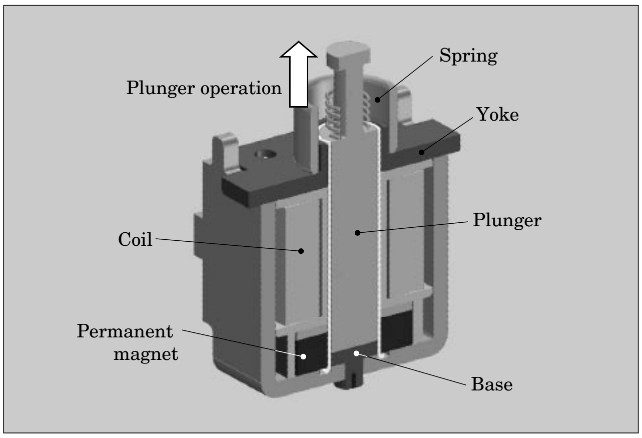


Fig.11 Example analysis of trip coil operation

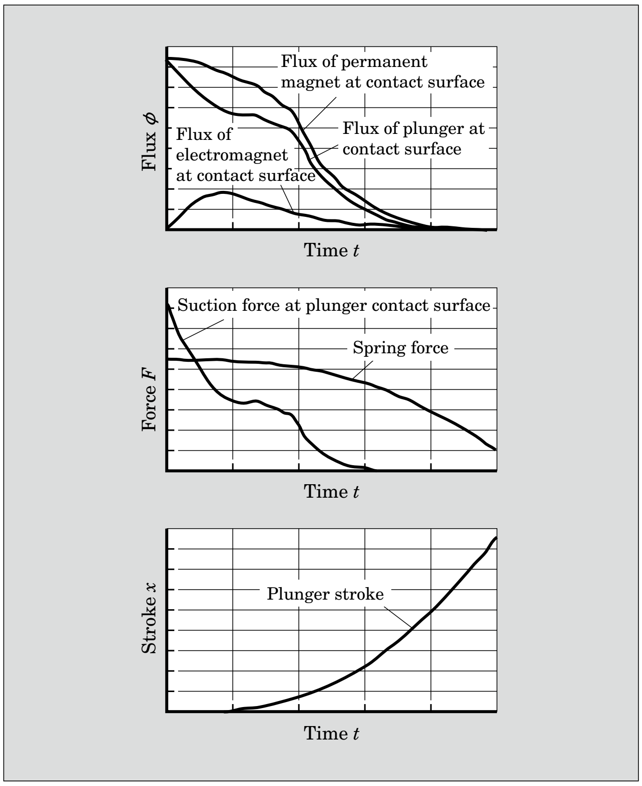
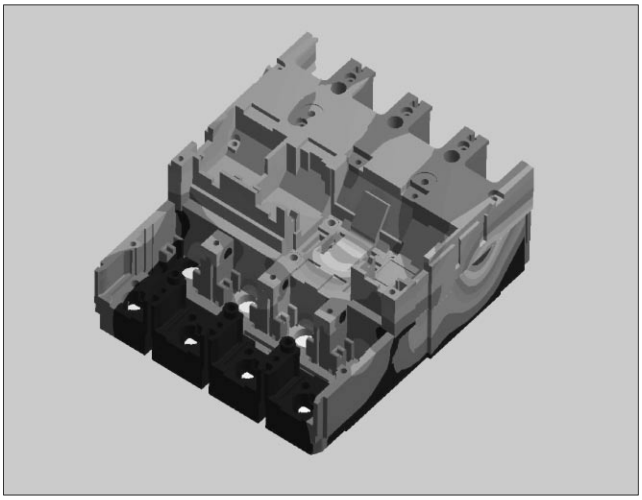


Fig.12 Example analysis of strain on case



new development, the sidewall shape of the arc plate was optimized to mitigate the rise in pressure inside the case. Further, as will be discussed below, the strength of the case was analyzed and its structure optimized to prevent damage due to a rise in pressure.

The simulator-based analysis was used in advance verification testing into which the case interior pressure distribution parameters, obtained from the analysis results, were input, and was also used to perform an integral analysis that took into consideration the screws used to fasten together the separate portions of the case. Figure 12 shows an example of the strain analysis during short-circuit current breaking.

Based on the results, the simulated data was compared to actual test results of short-circuit current breaking, verification testing performed, and the case structure was strengthened.

4. Conclusion

The development of a low-pressure circuit breaker depends upon how well other related phenomena (characteristics or performance) are controlled. For example, the factors having the greatest impact on the structure during short-circuit current breaking are temperature and pressure, which both of which rise within an extremely short time interval of several milliseconds to 10 milliseconds. The temperature rises to 10,000 K at the center of the arc, and the pressure rises from atmospheric pressure to several MPa, and the rising temperature and pressure mutually affect each other, and ultimately determine whether the circuit is interrupted. In the past, phenomena that were directly related to performance, such as current and voltage, were measured at the outer face of the circuit breaker, but to realize further improvement in performance, it is necessary to assess and control gas flow, temperature, pressure distribution and other phenomena that occur inside the breaker. Numerical calculation is a powerful tool for that task, and collecting the supporting data is of great importance. For that purpose, technology must be developed for the precise measurement of phenomena occurring within a short time under conditions of extraordinarily high temperature and pressure.

Fuji Electric's new technical developments are only a first step, and we humbly request continued guidance and support from all concerned parties.

Environmentally Responsive Technology for New Global MCCB and ELCB

Katsuro Shiozaki

1. Introduction

The directive on the restriction of certain hazardous substances (RoHS) was put into effect on February 13, 2003 and was published in the Official Journal of the European Union (EU). The RoHS directive prohibited the usage of six types of substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE)) by July 1, 2006.

The impact of this RoHS directive extends beyond the EU, and countries such as China and South Korea are moving toward enacting similar restrictions. In Japan, a law concerning the "Marking of the Presence of Certain Chemical Substances in Electrical and Electronic Equipment" was enacted as JIS C 0950.

The new global MCCB and ELCB (earth leakage circuit breaker) were developed in consideration of the individual environmental regulations of each county.

In the development of new products, the materials used play an increasingly important role. This paper describes, from the perspective of materials used, several environmentally responsive technologies used in the development of the new global MCCB and ELCB.

2. Trends of Regulating Environmental Responsiveness

2.1 Main environmental regulations of the EU

The RoHS directive directly regulates electric and electronic devices, and therefore this regulation attracts most attention from manufacturers of electrical machinery. However, several other regulations concerning electric and electronic devices have been put into effect in the EU, or are slated to be put into effect. Table 1 lists the main environmental regulations. The packaging directive and the ELV directive have already been put into effect, and the EuP directive was

Table 1 Main environmental regulations of the EU

Environmental regulation	Through 2003	2004	2005	2006	2007 and beyond
(1) Packaging directive (package waste directive)	As of July 1, 2001, the total (1) lead, (2) mercury, (3) cadmium, and (4) hexavalent chrome shall not exceed 100 ppm.				
	Recovery rate of 60% and recycling rate of 55 to 80% to be achieved by December 31, 2008.				
(2) ELV directive (end-of-life-vehicles directive)	Use was decided on May 22, 2002	As of July 1, 2003, usage of (1) lead, (2) mercury, (3) cadmium, and (4) hexavalent chrome shall be prohibited in cars for sale.			
	However, batteries are exempt. The start of the regulations may be delayed for some components.				
(3) WEEE directive (waste electrical and electronic equipment directive)	Construction of recovery and recycling system			Label shall be compliant by Aug. 13, 2005. Recycling costs to be borne.	
	Achieved regeneration rate and recycling rate			Dec. 31, 2006	
	Targets nearly all electrical and electronic equipment				
(4) RoHS directive (restriction of certain hazardous substances directive)	Content of 6 types of substances is prohibited. (1) lead, (2) mercury, (3) cadmium, (4) hexavalent chrome, (5) PBB, and (6) PBDE			Application to products for sale as of July 1, 2006	
	Medical equipment, monitoring and control equipment are not targeted ⇨				
(5) REACH proposal (proposed rule for chemical substances)	▼ July, Internet consultation deadline		Enforcement⇨registration deadline: 2008 to 2016		
	Make the registering, evaluation and authorization of chemical substances (including risk evaluation) mandatory.				
(6) EuP directive (eco-design directive)	▼ June, public announcement	Final adoption	July 22, 2005, published in EU Official Journal		
	Eco-design requested for devices that use energy. First directive having a new approach in the environment field.				

published in the Official Journal of the EU on July 22, 2005.

Representative environmental regulations of the EU are described below.

(1) Packaging directive (packaging and package waste directive)

This directive applies to all packaging placed on the market within the EU community. Member countries are requested to phase out usage of lead, mercury, cadmium, and hexavalent chromium in packaging materials, and after beginning on July 1, 2001, the total content of those substances is not to exceed 100 ppm.

(2) ELV directive (end-of-life-vehicles directive)

This directive obligates automobile manufacturers to dismantle end-of-life vehicles and to bear the cost of recycling. An important aspect for manufacturers of electrical machinery is that the use of lead, mercury, cadmium, and hexavalent chromium is prohibited in automobiles sold as of July 1, 2003. The threshold levels for these substances are 1,000 ppm for lead, mercury, and hexavalent chromium, and 100 ppm for cadmium.

(3) RoHS directive (restriction of certain hazardous substances directive)

This directive targets products in the categories of: ① large-size household appliances, ② small-size household appliances, ③ IT and communications devices, ④ AV related equipment, ⑤ lighting equipment, ⑥ electric tools, ⑦ toys, ⑧ medical equipment, ⑨ monitoring and control equipment, and ⑩ automated vending machines.

At present, the EU committee excludes ⑧ medical equipment and ⑨ monitoring and control equipment, however, is moving ahead with a reassessment of this directive.

In the RoHS directive, usage of the abovementioned six substances was prohibited, and the threshold levels of those substances were 1,000 ppm for lead, mercury, hexavalent chromium, PBB and PBDE, and 100 ppm for cadmium.

2.2 Main environmental regulations of Japan

In Japan, regulations concerning the emission of volatile organic compounds (VOC) have been strengthened with the “Act for Revising a Portion of the Building Standards Law and the like,” in addition to the “Order for Enforcement of the Occupational Health and Safety Law” and the “Law Concerning Examination and Regulation of Manufacture and Handling of Chemical Substances.”

Furthermore, with the enactment of the abovementioned law concerning the “Marking of the Presence of Certain Chemical Substances in Electrical and Electronic Equipment,” the presence of certain chemical substances must be indicated with markings when that content exceeds a reference level in seven products, including PCs.

Meanwhile, leading global companies are exhibiting increased consideration of the environmental, and are acting independently to enact green procurement standards. These standards are enacted in consideration of the RoHS directive described in section 2.1, thus demonstrating that the EU directives are functioning as global standards.

3. Environmental Responsiveness in Low Voltage Equipment

3.1 Basic principals of responsiveness

Based on the global conditions as described above, Fuji Electric is developing low voltage equipment, such as the new global MCCB and ELCB, based on the following basic principles.

- ○ Compliance with each country’s laws and regulations
- ○ Development based on product design assessment (reduction of volume, reuse of resources, environmental protection, safety, easier processing, more efficient packaging)
- ○ Construction of a system for managing environmental controlled substances

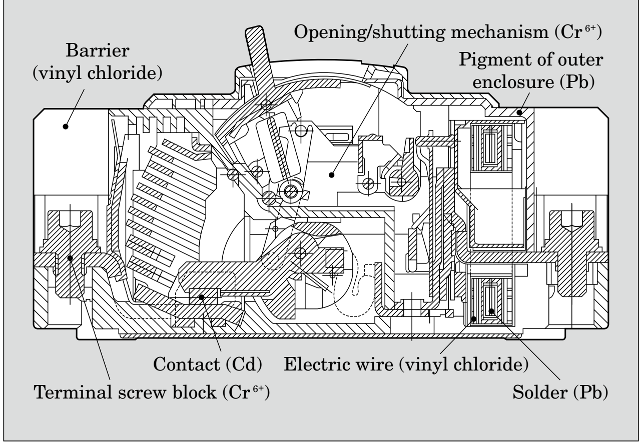
3.2 Targeted environmental controlled substances and its applied parts

Various types of environmental controlled substances have previously been used in MCCBs and ELCBs, as shown in Fig. 1.

- ○ Cadmium (Cd): Electrical contacts, pigment in various resin materials
- ○ Lead (Pb): Soldered joints, pigment, various additives
- ○ Hexavalent chromium (Cr^{6+}): Zinc-plated chromate processing
- ○ Vinyl chloride: Various electric wires, flexible resin

The environmental controlled substances listed above are extremely useful in industrial applications, and alternative substances require new types of ap-

Fig.1 Example of usage of environment control substances in conventional MCCB and ELCB



plied technologies. Several of the individual material technologies that support environmental responsiveness are introduced below.

3.3 Cadmium-free electrical contacts

A balance between temperature, wear and adhesion resistance is important for electrical contacts. Because of their excellent balance, cadmium silver oxide (AgCdO) contacts are used for a wide range of electrical currents. However, cadmium is a chronic poison that causes kidney and liver disorders and softening of bone, and is a prohibited substance according to the RoHS directive.

For this reason, several silver alloys such as AgWC, AgSn and AgC are being developed as alternative contact materials. Here, measures to prevent wear, mostly AgWC contacts, are described.

AgWC contacts exhibit somewhat more wear during current breaking than AgCdO contacts. As a countermeasure, the AgWC particle size was redesigned and distributed uniformly to increase the contact strength. Figure 2 is a photograph showing an AgWC contact that uses improved material. On the other hand, contact wear during current breaking is closely related to the structure of the arc-extinguishing chamber of the MCCB and ELCB. Thus, the arc-extinguishing chamber was devised so to reduce the length of time that the arc stagnates on the contact. Consequently, as shown in Fig. 3, the amount of wear is limited to approximately the same amount as for an AgCdO contact, thereby realizing an alternative to AgCdO contacts.

Fig.2 Photo showing texture of an AgWC contact

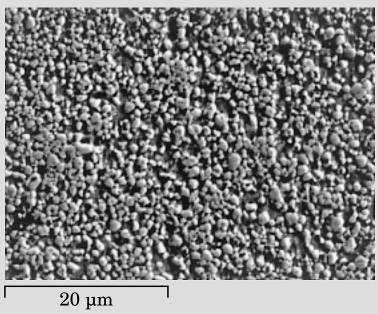
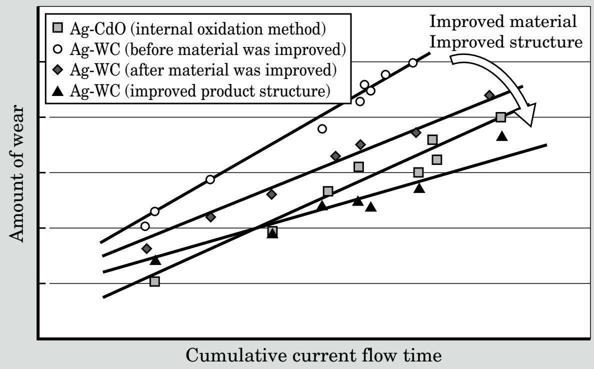


Fig.3 Improvement to lessen contact wear during short-circuit current breaking



3.4 Hexavalent chromium-free chromate process

Various surface treatments are being applied in order to improve the corrosion resistance of metal material. The occurrence of white rust is suppressed by depositing a passivation film above the zinc plating, and then treating the surface with a chromate containing self-repairing hexavalent chromium.

However, long-term exposure of the skin to hexavalent chromium causes irritation of the skin and ulcers, and therefore hexavalent chromium is a prohibited substance according to the RoHS directive.

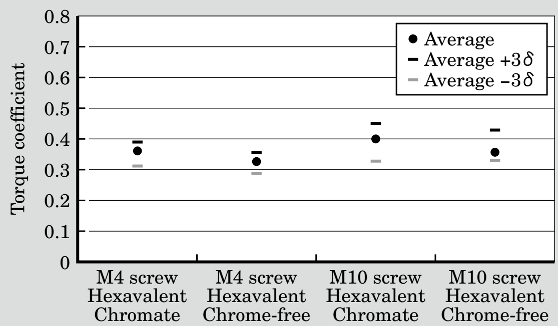
Fuji Electric is forging ahead with technological cooperation with manufacturers of plating solutions, and has used hexavalent chromium-free plating solution that exhibits an equivalent level of rust prevention strength. Figure 4 shows a sample having been subjected to a 72-hour salt spray test method. The sample exhibits the same level of resistance to corrosion.

With metal materials, a change in the plating solution affects not only the resistance to corrosion, but also screw torque characteristics, which have an important function. However, as shown in Fig. 5, no significant difference was observed at the component level. Moreover, various product evaluations that investigate the tightening strength of the terminals, wire pull-out strength, as well as vibration tests and mechanical

Fig.4 Comparison of corrosion resistance (after being sprayed with salt for 72 hours)

(a) Hexavalent chrome-free process (b) Hexavalent chrome process

Fig.5 Comparison of torque characteristics



impact test were implemented, and no problems were observed, thus realizing the hexavalent chromium-free plating solution as a viable alternative.

3.5 Development of vinyl chloride-free flexible material

Vinyl chloride is inexpensive and easily moldable, but its generation of dioxins is reported when combusted inappropriately. Moreover, lead compounds are sometimes mixed-in when used as a stabilizer. In electrical instruments, this material is being used in various types of electric wires and in barriers that require flexibility.

Vinyl chloride is not a prohibited substance, but in order to reduce its usage in the new global MCCB and ELCB, Fuji Electric is cooperating with materials manufacturers to begin developing alternative materials.

In the development of resin material, there is a tradeoff relationship between flexibility and flame resistance, but by incorporating innovative alloy components, a material that exhibits both properties has been developed and used as an alternative to vinyl chloride.

As can be seen in Table 2, which shows the physical properties of the newly developed material and the conventional product (vinyl chloride), the newly developed material is halogen-free, lead-free and realizes UL 94V-1.

Table 2 Comparison of physical properties of newly developed flexible material and vinyl chloride

Item	Newly developed material	Conventional material (vinyl chloride)
Flame class	V-1	HB
Flame retardant	Non-halogen	–
Flexibility	Passed	Passed
Moldability	Good	Good
Volatile organic compounds	No problems	No problems
Comparative tracking index	175 V or above	175 V or above

Table 3 Physical properties of newly developed polyester premixed molding compound

Item		Newly developed material	Conventional material
Flame class		V-1	HB
Relative temperature index (RTI)	Electrically	105°C	105°C
	Mechanically	130°C	130°C
Hot wire ignition		120 s or above	60 s or above
High current arc resistance to ignition		120 times or above	120 s or above
Comparative tracking index		600 V or above	600 V or above
Glow wire flammability index		960°C	960°C
Flexural strength (p.u.)		1.15	1.0
Charpy impact strength (p.u.)		1.35	1.0

3.6 Development of self-extinguishing and high-strength polyester premixed molding compound

The chassis of medium- and large-sized MCCBs and ELCBs often contains thermosetting material that stabilizes the shape during overheating or the like. With the trend toward increased globalization, self-extinguishing performance of the thermosetting material is an extremely important property and is being required for better safety. Moreover, for the integration of JIS and IEC standards, glow wire performance and the comparative tracking index have become especially important performance characteristics. On the other hand, since a large internal pressure is applied to the MCCB and ELCB chassis while breaking a short-circuit current, high mechanical strength is also required.

As the result of different types of packing material, redesigned particle size, more appropriate material mixing viscosity and the like for the new global MCCB and ELCB, a polyester premixed molding compound was developed having excellent thermal properties of a UL 94V-1 rating, a comparative tracking performance of 600 V or above, a glow wire flammability index of 960°C, and having 1.35 times the Charpy impact strength of the conventional product. Table 3 lists the physical properties of the new developed material. This material was used in the chassis, and short-circuit current breaking tests and the like were performed to evaluate various products. We confirmed that there

Fig.6 Component impact strength test conditions

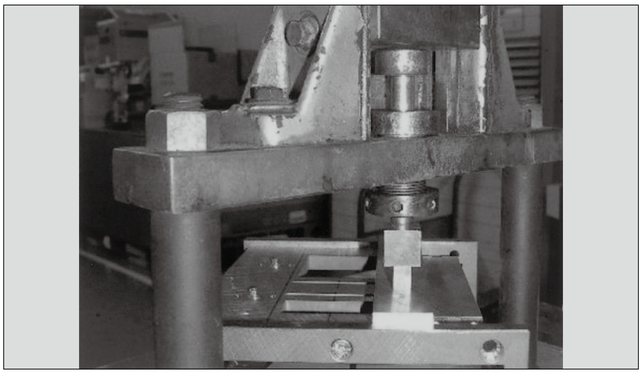
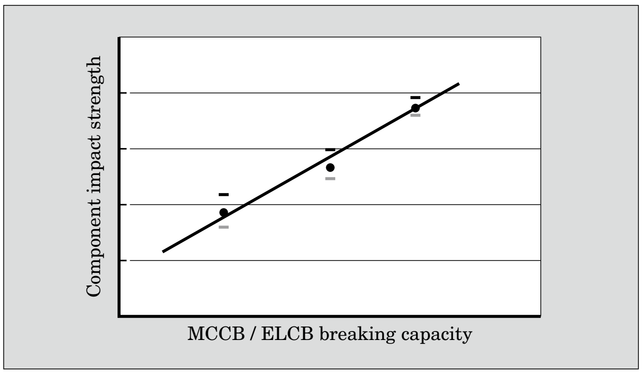


Fig.7 Relationship between MCCB / ELCB breaking capacity and component impact strength



were no problems with this newly developed material.

3.7 Application of copolymer-type polycarbonate material

Recent MCCBs and ELCBs are equipped with an attached top cover (cosmetic cover), and gray-color covers are commonly used in addition to the conventional black-color covers. The external appearance and dimensional stability are extremely important properties of the material used in the top cover. Moreover, since a portion of the internal pressure generated during breaking of a short-circuit current is applied to the top cover, the capability to withstand mechanical impact is also strongly required.

A copolymer-type polycarbonate material having excellent dimensional stability and chemical resistance has been used in the new global MCCBs and ELCBs.

As shown in Fig. 6 and in Fig. 7, we performed falling weight impact testing and assessed the relationship with breaking capacity, then we are using this data to speed up development and in daily components control.

4. Control System for Environmental Controlled Substances

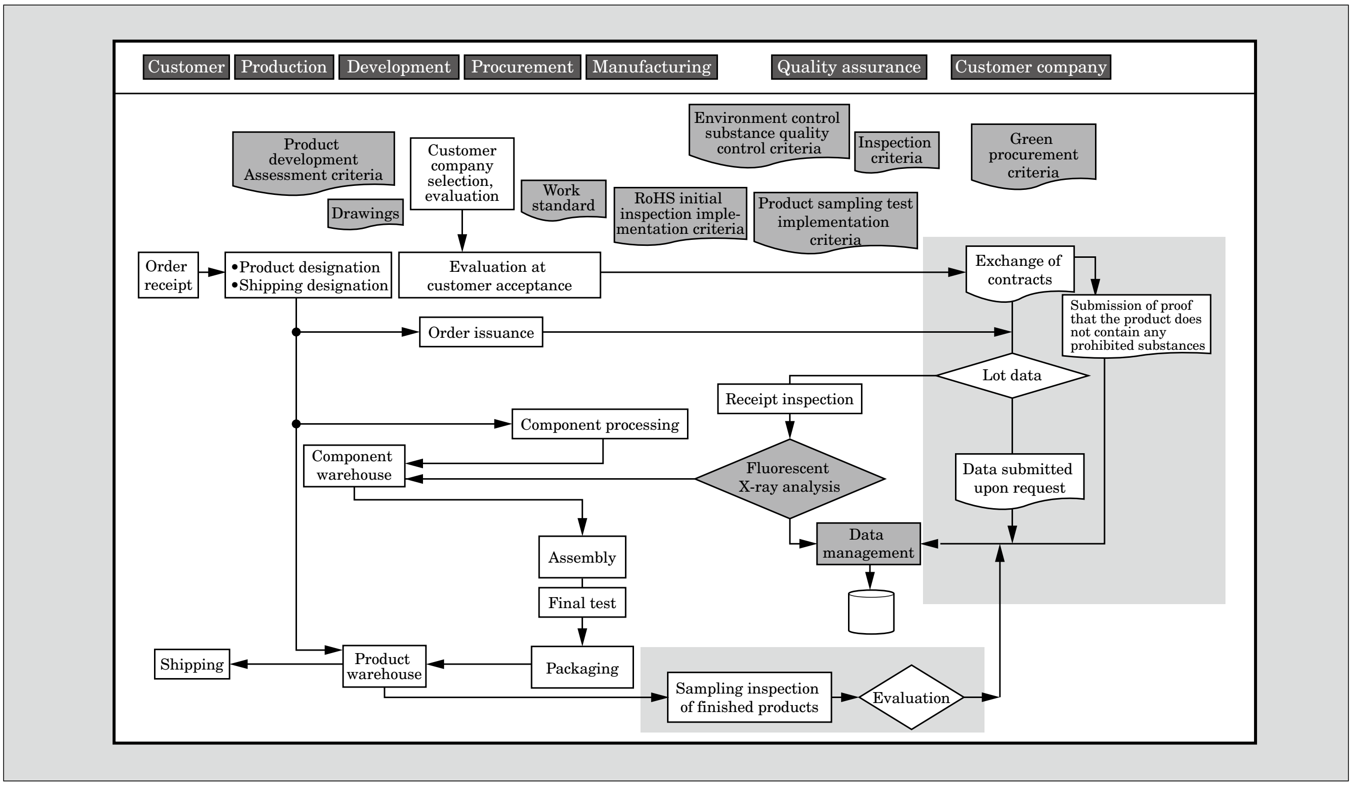
Environmentally responsive technologies in development process have been described in the above sections. This section describes a system for configuring and maintaining technology in development process.

The Fuji Electric Group established a second edition of the "Fuji Electric Group Green Procurement Guidelines" in October 2005. These guidelines designate RoHS prohibited substances, substances prohibited for manufacture according to domestic Japanese law, and persistent substances as prohibited substances, and were revised in conformance with JIG (joint industry guidelines). In accordance with the green procurement guidelines, customer companies require proof that the product does not contain any prohibited substances, and also require data of the content of controlled substances.

Moreover, we have strengthened the in-house inspection system — from order receipt to product shipment — and are using a fluorescent X-ray analyzer as

Fig.9 Example analyzer (ICP-AES) for environmental control substances

Fig.8 Control flowchart for environmental control substances



a screening device. Items treated as being in the "gray zone" with a fluorescent X-ray analyzer are judged by a highly sensitive analyzer such as an inductively coupled plasma atomic emission spectrometer (ICP-AES).

Furthermore, these data are managed in a database, and are also used to correct abnormal conditions and for corrective actions. Figure 8 shows a control flowchart for environmental control substances, and Fig. 9 shows an example of an in-house analyzer.

As described above, Fuji Electric implements a reliable system to ensure that products containing prohibited substances do not flow to sales routes.

5. Conclusion

Several materials technologies that support the environmental responsiveness of the new global MCCB and ELCB, and a control system have been introduced above. Fuji Electric is confident that these new products will help to expand further the global market. By cooperating with and receiving guidance from all concerned parties, Fuji Electric intends to improve environmentally compatible technology.

Fuji Electric's New Global Motor Control Series

Isamu Nagahiro

1. Introduction

In recent years, market globalization has caused large changes in the business environment of the motor control field. The following issues have an especially large impact on customer's equipment design and purchases.

① Conformity with JIS and IEC standards
② Adoption of global specifications for electrical equipment
③ Simplification of equipment maintenance

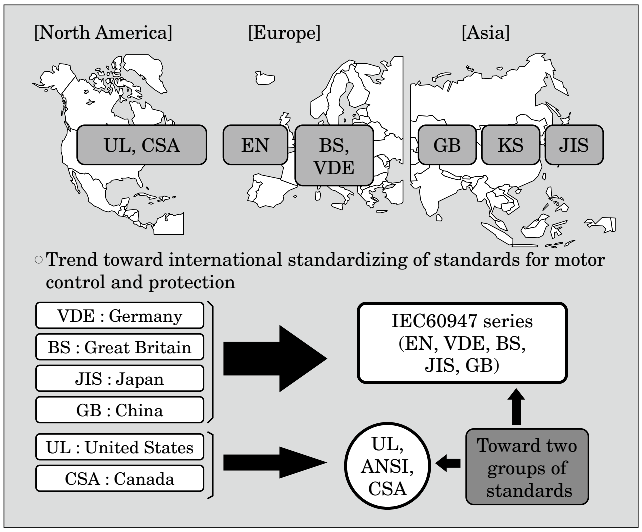
In this article we present the manual motor starter (MMS) and combination starter (combination of an MMS and a magnetic contactor (MC)), as a new motor control series that has adapted to these globalization requirements.

2. Evolution of Standards and Motor Control Methods

Throughout the world, many domestic standards for components used in electrical equipment have been adjusted to conform to IEC standards. Japan is no exception. For example, a standard that complies with the IEC60947 series has been established as JIS C 8201 for magnetic starters and motor circuit breakers. These changes affected not only equipment for industrial machines, but also equipment for ship vessels, and NK (Nippon Kaiji Kyoukai), for example, supports the new JIS C 8201-2-1 instead of the previous JIS C 8370 for circuit breakers. As we have mentioned before, the trend towards compliance with IEC standards is not limited to Japan, but exists throughout the world (Fig. 1). We are not just speaking of the European countries but also near countries in Asia. For instance, China's GB standard and South Korea's "Electric Appliance Safety Control Law" also comply with the IEC60947 series. As you can see, most of countries of the world, except UL in North America, presently have standards that comply with the IEC. This means that the globe has diverged into two systems of standards, IEC and UL.

As a result of the consistency between JIS and IEC, the method for motor control has changed (Fig. 2).

Fig.1 Trends of standards for low-voltage switches (toward two groups of standards: IEC and UL)



IEC60204-1 that relates to "Safety of machinery – Electrical equipment of machines" was established as JIS B 9960 and requires an overcurrent protective device on the line-side of a motor circuit. This means that, in Fig. 2, method B or C, in which an overcurrent protection device is provided in each motor circuit will be required instead of the previous method A.

For these new motor control methods, Fuji Electric's MMS and combination starter are ideal products that can "save space", "save wiring work", and "achieve high-level short-circuit coordination." In the following, we present the features and structure of the MMS.

3. Features of MMS and Combination Starter

The MMS is provided with the short-circuit protection function of a circuit breaker and the overload protection function of a thermal overload relay (TOR), integrated into a single compact body (Fig. 3).

Table 1 lists the main specifications of the MMS. The MMS has an AC-3 (15 kW 230 V AC, 30 kW 400 V AC) rating as a controller so it can be used for across-the-line direct motor starting. Remote switching or high frequency switching operation can be achieved by

Fig.2 Motor control method comparison

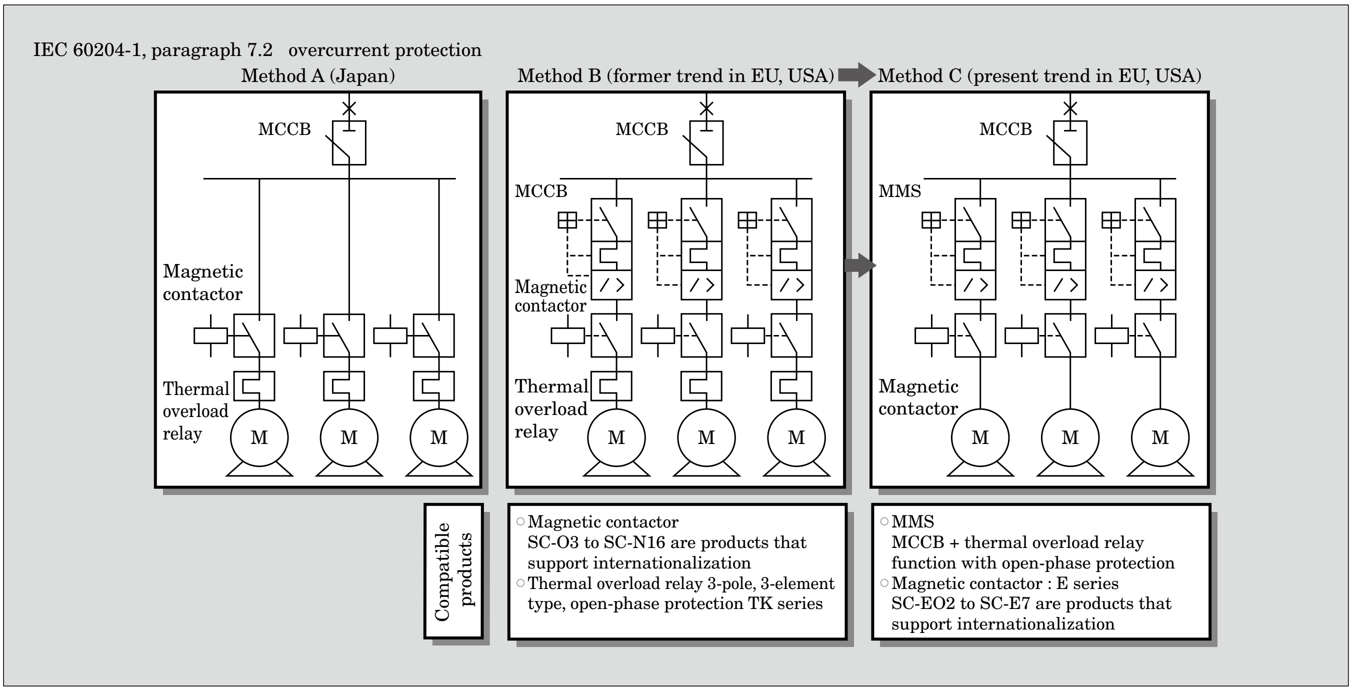
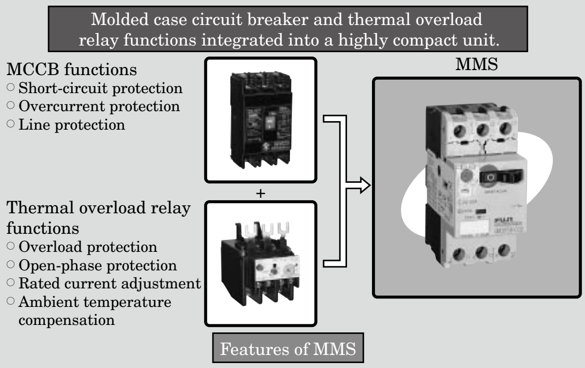
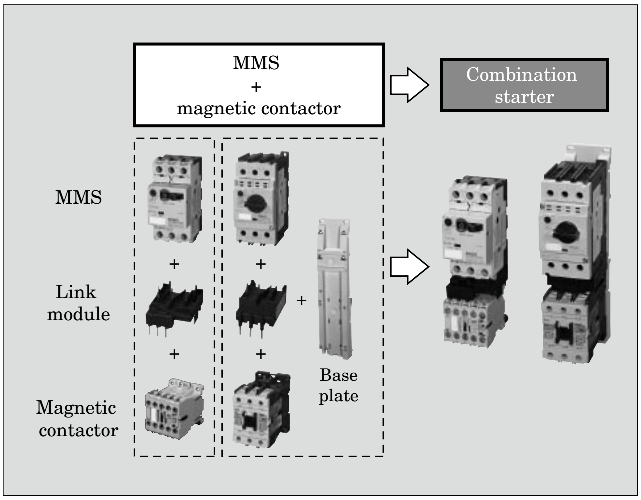


Fig.3 Configuration and features of MMS



Compact size	57 % reduction in required mounting space compared to MCCB + thermal overload relay
Large breaking capacity	400 V AC (32 A rating) 25 kA (standard model) 50 kA (high performance model)
Short-circuit protective coordination	IEC 60947-4-1 type 1, 2
Reduction in wiring work	50 % reduction in required wiring work for MMS + magnetic contactor instead of MCCB + magnetic contactor + thermal overload relay
Standards	Japanese standards : JIS C 8201-1, JIS C 8201-2-1, JIS C 8201-4-1, Electrical appliance and material safety law Overseas standards : IEC60947-1, IEC60947-2, IEC60947-4-1, UL508, CSA C22.2 No.14, China GB

Fig.4 Appearance of combination starter



combining the MMS with a magnetic contactor to make a combination starter. Figure 4 shows the external appearance of the combination starter. The combination starter is provided with many functions, such as short-circuit protection, overload protection and switching, and can therefore be easily applied to electrical equipment having motor circuits that require IEC60204-1 or JIS B 9960 conformance.

One of the most important features of the MMS and combination starter is that they provide excellent current limiting performance during a short-circuit. This current limiting characteristic has made the MMS capable of reaching short-circuit breaking levels as high as 230 V AC 100 kA and 415 V AC 50 kA (type BM3RH). In the following, we will describe the basic structure of the MMS short-circuit interrupting section.

4. Short-circuit Interrupting

The main feature of the short-circuit interrupting section is the 2-point contact opening structure (double-break mechanism), shown in Fig. 5, that reduces the

Table 1 MMS specifications

<table>
<tr><td colspan="2">Frame A</td><td colspan="8">32</td><td colspan="4">63</td></tr>
<tr><td colspan="2">Type</td><td colspan="4">BM3RSB (standard model)
BM3RSR (standard model)</td><td colspan="4">BM3RHB (high performance model)
BM3RHR (high performance model)</td><td colspan="4">BM3VHB
(high performance model)</td></tr>
<tr><td colspan="2">Number of poles</td><td colspan="4">3</td><td colspan="4">3</td><td colspan="4">3</td></tr>
<tr><td colspan="2">Handle type</td><td colspan="4">Rocker</td><td colspan="4">Rotating handle</td><td colspan="4">Rotating handle</td></tr>
<tr><td colspan="2">Rated current (A)</td><td colspan="4">0.16 to 32</td><td colspan="4">0.16 to 32</td><td colspan="4">10 to 63</td></tr>
<tr><td colspan="2">Rated insulation voltage U_i (V) /
Rated impulse withstand voltage U_{imp} (kV)</td><td colspan="4">AC690/6</td><td colspan="4">AC690/6</td><td colspan="4">AC1,000/8</td></tr>
<tr><td rowspan="2">Utilization category</td><td>IEC60947-2,
JIS C 8201-2</td><td colspan="4">Cat.A</td><td colspan="4">Cat.A</td><td colspan="4">Cat.A</td></tr>
<tr><td>IEC60947-4-1,
JIS C 8201-4-1</td><td colspan="4">AC-3</td><td colspan="4">AC-3</td><td colspan="4">AC-3</td></tr>
<tr><td>UL standard category</td><td>UL508, UL508E</td><td colspan="4">Suitable for Group Installation</td><td colspan="4">Suitable for Group Installation</td><td colspan="4">Suitable for Group Installation</td></tr>
<tr><td colspan="2">Overload protection,
open-phase protection</td><td colspan="4">Yes</td><td colspan="4">Yes</td><td colspan="4">Yes</td></tr>
<tr><td colspan="2">Instantaneous tripping characteristic</td><td colspan="4">13 × I_E max.</td><td colspan="4">13 × I_E max.</td><td colspan="4">13 × I_E max.</td></tr>
<tr><td rowspan="2">Durability</td><td>Mechanical durability
(No. of cycles)</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">50,000</td></tr>
<tr><td>Electrical durability
(No. of cycles)</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">25,000</td></tr>
<tr><td rowspan="14">Rated breaking capacity
I_{cu}(kA)
IEC60947-2
JIS C 8201-2</td><td>Rated current I_e (A)</td><td>240 V</td><td>415 V</td><td>460 V</td><td>690 V</td><td>240 V</td><td>415 V</td><td>460 V</td><td>690 V</td><td>240 V</td><td>415 V</td><td>460 V</td><td>690 V</td></tr>
<tr><td>Less than 1.6</td><td rowspan="7">100</td><td rowspan="5">100</td><td rowspan="3">100</td><td>100</td><td rowspan="10">100</td><td rowspan="6">100</td><td rowspan="4">100</td><td>100</td><td colspan="4" rowspan="4">—</td></tr>
<tr><td>1.6 to 2.5</td><td rowspan="9">3</td><td rowspan="2">8</td></tr>
<tr><td>2.5 to 4.0</td></tr>
<tr><td>4.0 to 6.3</td><td>50</td><td rowspan="3">6</td></tr>
<tr><td>6.3 to 10</td><td>15</td><td rowspan="2">50</td><td rowspan="9">100</td><td rowspan="2">100</td><td rowspan="4">50</td><td rowspan="2">6</td></tr>
<tr><td>9 to 13</td><td>50</td><td rowspan="5">10</td></tr>
<tr><td>11 to 16</td><td rowspan="4">25</td><td rowspan="4">50</td><td rowspan="4">35</td><td rowspan="4">4</td><td rowspan="7">50</td><td rowspan="7">5</td></tr>
<tr><td>14 to 20</td><td rowspan="3">50</td></tr>
<tr><td>19 to 25</td><td rowspan="5">35</td></tr>
<tr><td>24 to 32</td></tr>
<tr><td>28 to 40</td><td colspan="4" rowspan="3">—</td><td colspan="4" rowspan="3">—</td></tr>
<tr><td>35 to 50</td></tr>
<tr><td>45 to 63</td></tr>
<tr><td>External dimensions (mm)</td><td>W × H × D</td><td colspan="4">45 × 90 × 68</td><td colspan="4">45 × 90 × 79</td><td colspan="4">55 × 110 × 96</td></tr>
</table>

amount of let-through energy during the breaking of a short-circuit current. This is a result of joint development using the switching technology of an MC and the breaking technology of an MCCB. The double-break mechanism has a very efficient structure for driving the electrical arc, and enables a reduction in contact wear and also minimizes the short-circuit let-through I^2t. Below, we will present the basic principles of MMS short-circuit current breaking.

When there is a short-circuit current, the moving conductor will receive an electromagnetic repulsive force due to the parallel currents flowing in opposite directions in the fixed conductor and the moving conductor. The moving conductor is accelerated further by the magnetic field of the magnetic yoke mounted on the arc moving plate, which leads to instantaneous opening of the contacts. After the contacts have fully opened, a driving force will be applied by the magnetic force generated at the fixed contact and the current flowing through the electrical arc. Because of this force, the arc will be driven into the arc plates and extinguished immediately.

During the driving and extinguishing process it is very important to maintain a stable contact distance between the fixed and moving contacts. The MMS has a pushbar located directly above the moving contact that transmits the movement of the plunger placed in the instantaneous tripping coil. This plunger activates as soon as it detects a short-circuit current that will force the opening of the contacts via the pushbar. The advantage of this mechanism is that it can detect and also open the contacts at the same time, and thus helps to break the short-circuit current before the current rises. Furthermore, this mechanism can forcibly keep

Fig.5 Internal structure of MMS

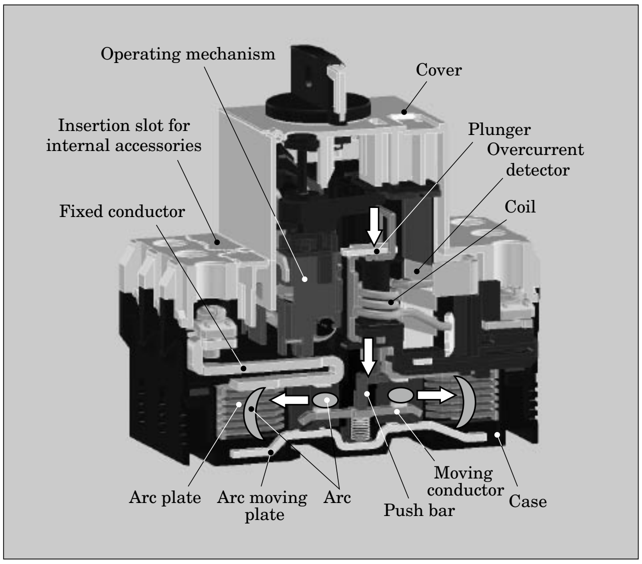
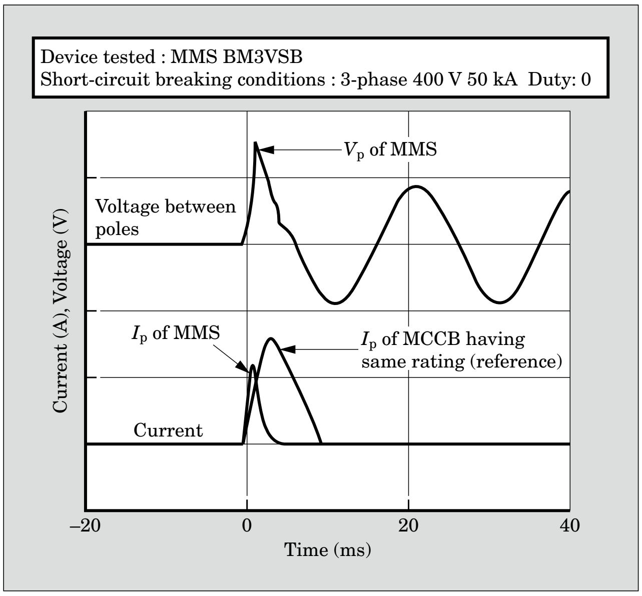


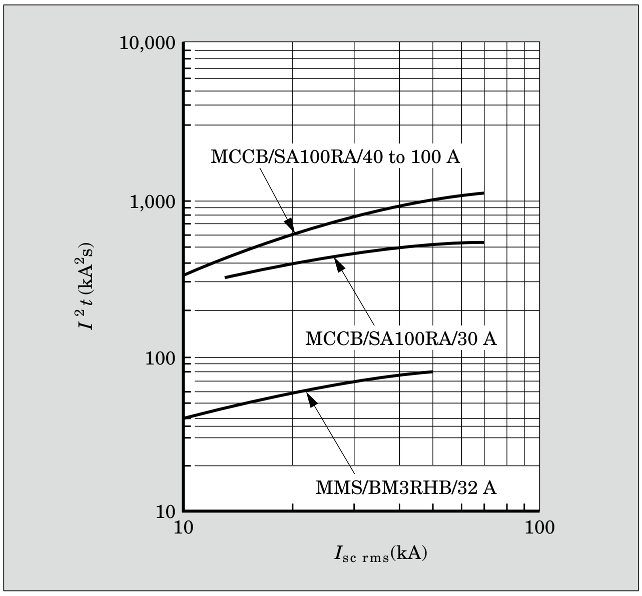
Fig.6 Oscillogram of short-circuit breaking



open the contacts as long as there is a short-circuit current. This feature will maintain the moving contact at a stable position during the current breaking process.

Because of the high current limiting performance, the MMS can break a short-circuit much more quickly than an MCCB. Figure 6 is an oscillogram at 400 V/50 kA, comparing an MMS and MCCB during the breaking of an arc. The overall breaking time with an MMS is only 3 ms (compared to 10 ms with an MCCB) and the current peak (I_p) is limited to 75 % (12 kA). Due to this short breaking time and the small peak value of current, the short-circuit let-through energy (I^2t) during a short-circuit will also be very small. This means that the impact of heat energy on load-side components (such as the MC) of the MMS is also limited to a small value. Figure 7 compares the I^2t values of Fuji Electric's MMS and MCCB. The I^2t of the MMS

Fig.7 Short-circuit let-through I^2t (compared to MCCB)



is less than 1/5th that of the MCCB.

From the above we can say that the combination starter is an ideal component for large short-circuit breaking applications such as motor control centers.

5. Short Circuit Co-ordination Between MMS and MC

With globalization, the electrical equipment of a domestic customer may be installed in various countries throughout the world, and the demand for simplified maintenance is increasing. For example, there is a demand for electrical equipment that is able to quickly restore the power supply of manufacturing facilities for minimum stoppage time following a short-circuit accident. To fulfill this requirement, motor control components must comply with the IEC60947-4-1 standard for "type 2" short-circuit co-ordination.

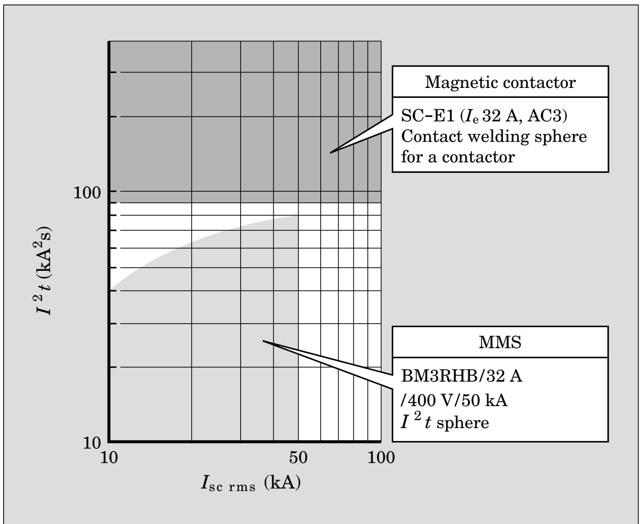
In the IEC60947-4-1 standard, there are two types of protection levels defined as "type 1" and "type 2" for the short-circuit co-ordination between short-circuit protective devices (fuses or MCCB) and the MC. "Type 1" protection level allows the MC to sustain damage and require partial or complete replacement for further service (contacts are allowed to be welded), after a short-circuit accident. On the other hand, "type 2" protection level must provide continuous service, without requiring replacement or sustaining damage except for light welding of the MC contacts.

Fuji Electric's combination starter series is capable of "type 2" performance up to 400 V 18.5 kW. (See Table 2.) Previously, it had been difficult to achieve "type 2" performance using an MCCB, because the short-circuit let-through I^2t was quite large during a short-circuit. But because the MMS has a very small short-circuit let-through I^2t, the combination starter can achieve short-circuit co-ordination even with a 50 kA (400 V)

Table 2 Combination starter series

AC400 V	BM3R + SC-M	BM3R + SC-E02 to E05	BM3R + SC-E1	BM3V + SC-E1, E2, E2S
External appearance				
Type 1	0.06 to 4 kW 0.23 to 9 A	0.06 to 11 kW 0.23 to 22 A	15 kW 30 A	18.5 to 22 kW 37 to 48 A
Type 2	0.06 to 1.1 kW 0.23 to 2.5 A	0.06 to 7.5 kW 0.23 to 16 A	11 kW 22 A	15 to 18.5 kW 30 to 37 A

Fig.8 Relation between MMS I^2t performance and the contact-welding sphere of a magnetic contactor



circuit. Figure 8 shows a comparison of the short-circuit let-through I^2t of the MMS and the contact-welding sphere of the MC at 400 V 50 kA. The maximum I^2t of the MMS is about 80 kA^{2}s, and is smaller than the limit value of 90 kA^{2}s of the MC. This performance is the result of applying Fuji Electric's unique breaking technology presented in section 4. This excellent performance can be used to contribute to improved maintenance capability in global equipment.

Previously, "type 2" performance was a requirement of the IEC standard but was not included in the old JIS standard. This requirement has been introduced, however, for the new JIS C 8021-4-1 standard that is mostly compatible with the IEC. As a result, the demand for "type 2" performance is increasing. We can say that Fuji Electric's combination starters are a product series that has anticipated important needs in advance.

Fig.9 Combination starter system

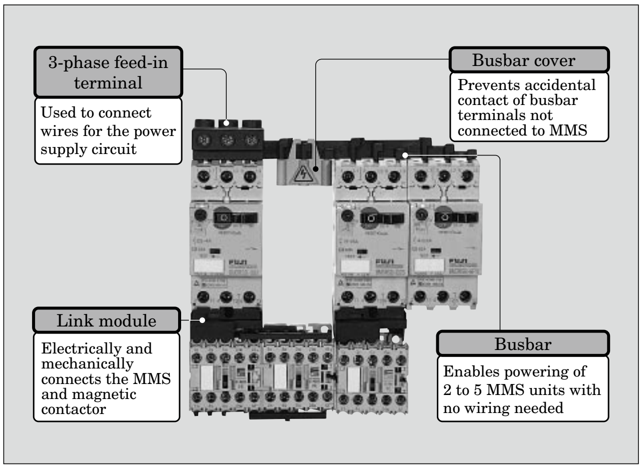
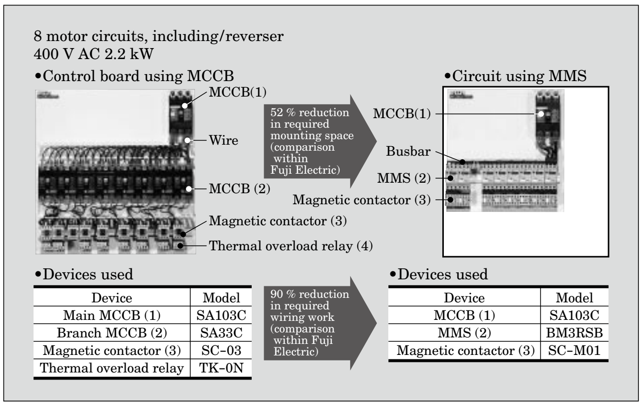


Fig.10 Comparison between MMS and MCCB



6. Greater Efficiency Using a Combination Starter

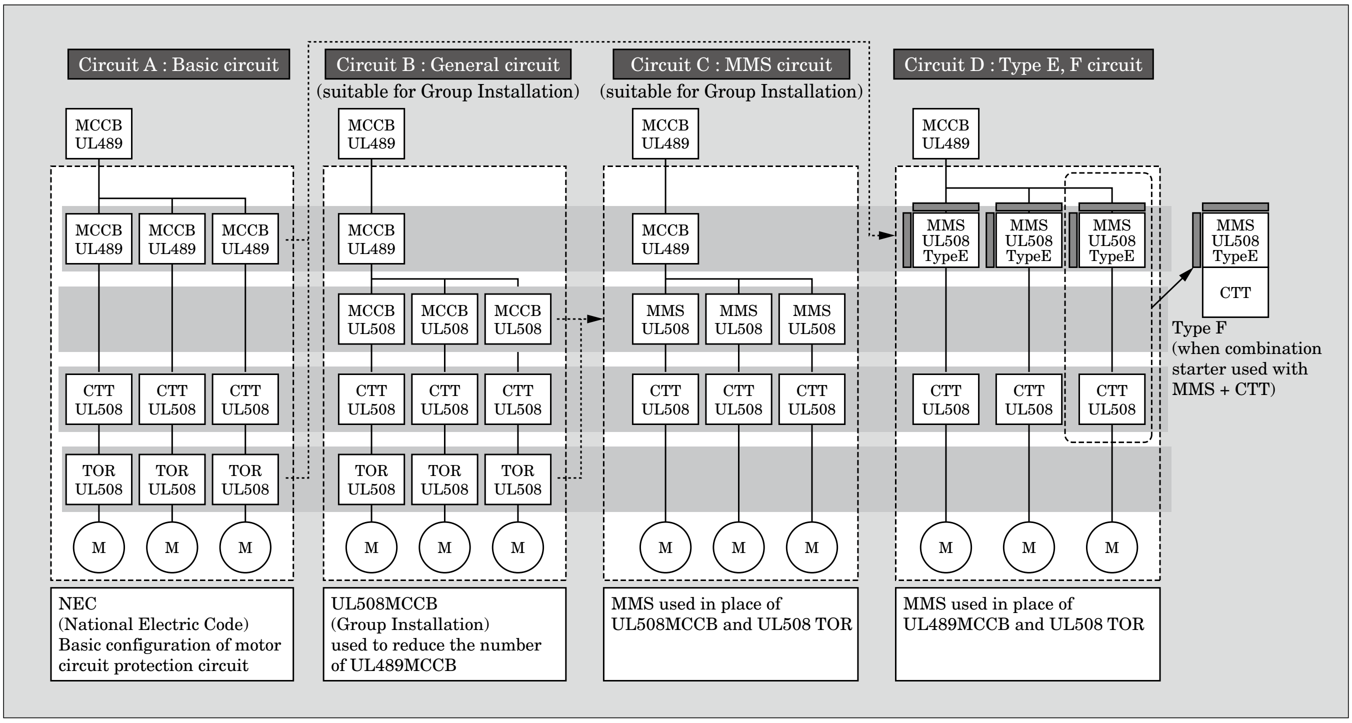
Figure 9 shows an example of a combination starter system. The system is constructed by wiring such parts as 3-phase feed-in terminals, busbars, and link modules, and is used to reduce the wiring work necessary when constructing the system. A specific comparison is made in Fig. 10. The circuit consists of eight 400 V AC 2.2 kW motors, one of which being reversible. Use of the combination starter instead of the conventional style enables a space savings of 52 % in the installation area and a 90 % reduction in wiring work. From this, we can see that the combination starter system is very effective for increasing the efficiency of motor circuits.

7. Applications in North America

MMS is UL-listed as a "manual motor controller," conforming to the UL508 standard for Industrial Control Equipment, which is the same standard for MCs, TORs, and push button switches.

According to the basic regulations of NFPA70, a fuse or a UL489-listed circuit breaker must be used for individual short-circuit protection of each branch

Fig.11 North American motor circuit example



circuit. There are some exceptions to this rule, one of them is when the conductor length and size satisfy the required values, and at the same time, the UL508 component is listed as "suitable for group installation."

Figure 11 is an example, showing several branch circuits taped from a UL489 circuit breaker when the abovementioned conditions are satisfied. Circuit A is an example of the most basic rule, which is to apply one UL489 circuit breaker to each motor load. Circuits B and C are more efficient circuits, composed from "suitable for group installation" components. C is an example using MMS, and because it has an overload protection function and is "suitable for group installation," the TORs in circuit B can be omitted. This saves cost and space on the control panel as mentioned in section 6.

There are two categories of "group installation." One is the ordinary "suitable for group installation" and the other is "suitable for tap conductor protection in group installation." The difference between the two is that the branch circuit conductor cross section can be 1/10th (when the length is shorter than 3 m) of the main circuit, compared to the ordinary group installation component that has a conductor size limit of 1/3rd of the main circuit (when the length is shorter than 7.6 m). This means that for a line-side UL489 circuit breaker of the same rating, a component that is "suitable for tap conductor protection in group installation" enables more loads to be connected, which makes the circuit more efficient. To obtain certification of this tap conductor protection, the component has to pass a very demanding short-circuit breaking test. But thanks to its high current limiting performance, the MMS has achieved this "suitable for tap conductor protection in group installation".

In North America, there are special conditions that allow use of the MMS instead of a UL489 circuit breaker for branch circuit protection of a motor circuit. This is when the component has been UL-certified as UL508 "type E" or "type F." Circuit D shows an example of a circuit constructed by using "type E" and "type F" components. When a MMS that is listed as "type E" is used, the component will be eligible to be used as a branch circuit short-circuit protective device, which means that the UL489 can be omitted to make the circuit more efficient. Figure 12 shows the external appearance of a UL508 "type E" MMS. In order to comply with the required insulation distances and indication of the cause of tripping, a terminal cover and a short-circuit alarm contact block are applied to the standard MMS. The advantages of "type E" are (1) the number of components for protection can be minimized, and (2) the components can be selected easily (because you can select the component based on the horsepower rating of the motor, instead of a complicated calculation of wire length, size, and short-circuit co-ordination required for group installation applications).

As can be seen, the use of MMS as components "suitable for group installation" and as "type E," means that the customer does not have to select different components according to whichever standard is used, IEC or UL. This means that the MMS and combination starter are totally global products that can contribute to the global unification of control panels.

Fig.12 Appearance of UL508 type E

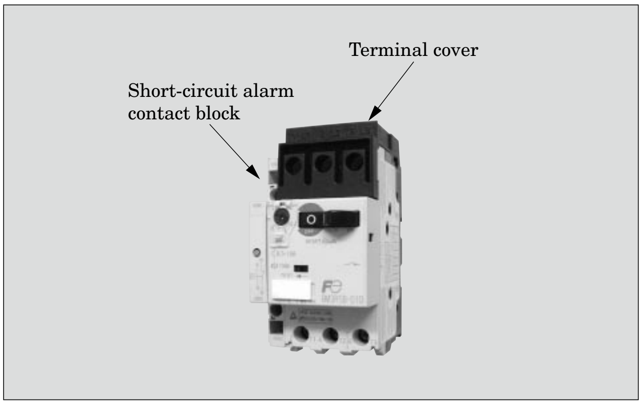
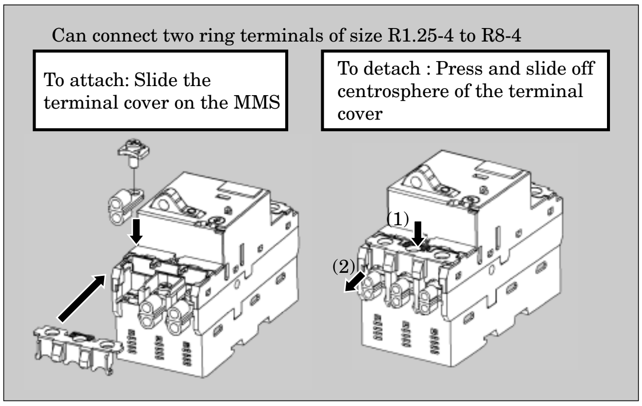


Fig.13 Ring terminal connecting-type MMS



8. Offers to Local Needs

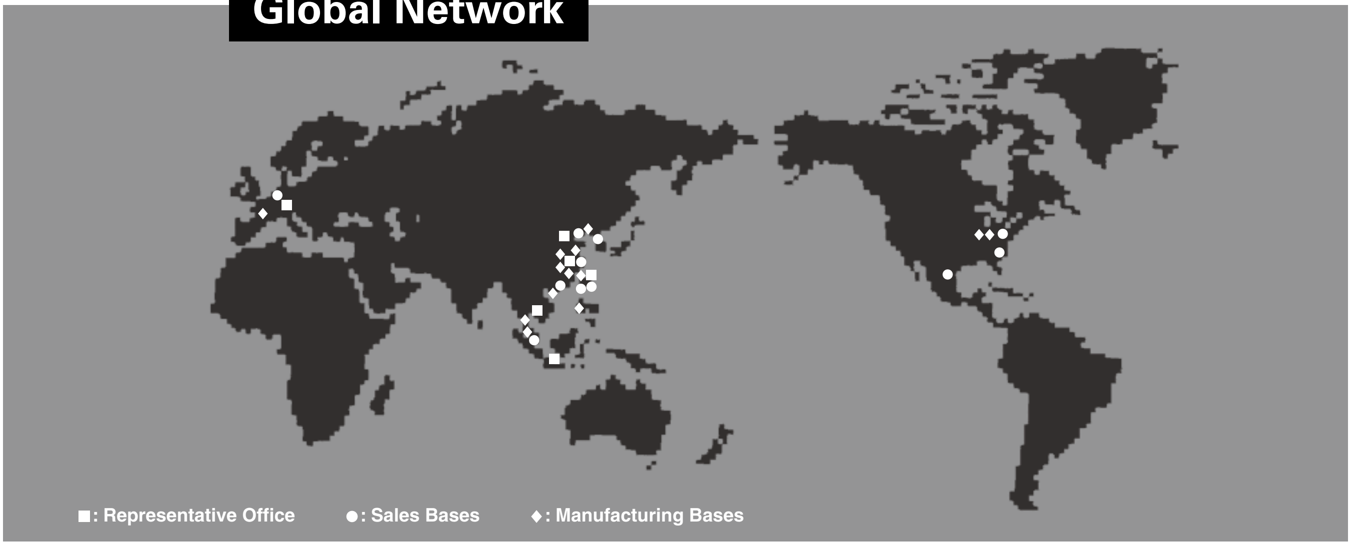
As presented in section 7, the MMS and combination starter are truly global products conforming to worldwide standards. However, even a global product must meet the needs of local customers. The ring terminal connecting-type MMS and combination starter series are provided as special products for the Japanese wiring market.

This series (BM3R□R) is applicable up to 400 V 15 kW, and one of its main features is that the terminal cover is designed to slide off for easy wiring (Fig. 13). As with this series, Fuji Electric intends to continue to support local needs.

9. Conclusion

In this article, we have presented an overview of the changes in motor control caused by the globalization of electrical equipment and such components as the MMS and combination starter that adequately support these changes. Fuji Electric intends to continue to leverage its diverse experience and accumulated technology to offer products that match customers' values.

Global Network



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