New Technology of the Global Twin Breaker "G-TWIN Series"

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ABSTRACT

Against the backdrop of market globalization, Fuji Electric has developed and commercialized the "G-TWIN" global breaker, and upon completing the 32 to 800 AF series in January 2009, launched a full-scale effort to expand the market. Because of the relationship of protective coordination with lower devices, a fork-type dual-contact breaking method was adopted as new technology for compact high performance current-limiting breaking. Moreover, to ensure the stability and reliability of the supply of electric power, Fuji Electric has expanded its lineup of plug-in circuit breaker models, and demand for these models is expected to increase in recent years. Fuji Electric has also developed a proprietary arc extinguishing function and expanded its lineup of breaker models for use in photovoltaic cells and the DC circuits in data centers.

1. Introduction

Molded case circuit breakers (MCCB) and earth leakage circuit breakers (ELCB) function to protect wiring, equipment and human body from electrical accidents, such as the application of an overcurrent to distribution lines and loads, or the occurrence of a short circuit, ground fault or earth leakage in a distribution circuit. These circuit breakers are installed in all types of devices, machinery and buildings that use electricity.

In 1990, Fuji Electric released its "Twin Breaker Series" that featured MCCBs and ELCBs with common external dimensions for the first time in the world, and as a result of the improved convenience due to installation interchangeability and the ability to share accessories, as well as contributions to the standardization and miniaturization of switch board equipment and systems, this series has received the support of many customers. Meanwhile, in response to recent requests from customers who are expanding their global businesses, rather than the previous implementation in which successive variations of products were certified to meet individual standards, a single series of global MCCBs/ELCBs capable of satisfying all standards is believed to be necessary, and for this purpose Fuji Electric has developed and released the "G-TWIN" breaker series that combines the concepts of "global" products with that of "twin" breakers. In January 2009, the entire series, ranging from 32 to 800 AF, was completed (see Tables 1, 2 and 3) and a full-scale marketing campaign was conducted.

The basic development concept of combining compatibility with the new JIS/IEC standard and the UL489 standard, and the development of the elemental technology have already been described in other papers[1),2)].

Using the example of the 125 AF, this paper describes high performance current-limiting breaker technology for low-rated-current products, as innovative technology for enhancing the current-limiting performance of branch circuit breakers in order to coordinate tripping with devices connected in lower level. Also introduced are products that support plug-in circuit breakers and their expanded application to DC circuits, for which demand is expected to grow in the near future from the perspective of power supply stability and reliability.

2. High Performance Current Limiting Breaker Technology for Low-Rated 125 AF Products

The breaking capacity of low voltage circuit breakers that use a molded case is primarily determined according to the tolerable limit of stress that is created by arc energy generated during a breaking operation. If the stress cannot be controlled, the sudden increase in internal pressure will damage the molded case, the dielectric strength will deteriorate due to the melting and scattering of conductive materials and insulation materials at high temperature, the operation of the switching mechanism will malfunction, and so on.

The prior series of UL-standard products were intended for the North American market, and as such, were separate from the Twin Breaker Series. Compared to the Twin Breaker Series, this prior series featured larger external dimensions and also a larger-sized breaking mechanism and main contact separating distance, and had ample tolerance against stress.

In the course of developing the G-TWIN breaker which, within the same external dimensions, satisfies both the new JIS/IEC standard and the UL standard,

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Table 1 "G-TWIN Standard Series" (wiring-use)

Frame (A)	Rated breaking capacity *I*cu (kA)		MCCB	ELCB
	230 Vac	440 Vac		
32	2.5	–		EW32AAG
	2.5	1.5	BW32AAG	EW32EAG
	5	2.5	BW32SAG	EW32SAG
50	2.5	1.5	BW50AAG	EW50AAG
	5	2.5	BW50EAG	EW50EAG
	10	7.5	BW50SAG	EW50SAG
	25	10	BW50RAG	EW50RAG
	125	65	BW50HAG	EW50HAG
63	5	2.5	BW63EAG	EW63EAG
	10	7.5	BW63SAG	EW63SAG
	25	10	BW63RAG	EW63RAG
100	5	1.5	BW100AAG	EW100AAG
	25	10	BW100EAG	EW100EAG
125	50	30	BW125JAG	EW125JAG
	100	50	BW125RAG	EW125RAG
	125	65	BW125HAG	EW125HAG
250	36	18	BW250EAG	EW250EAG
	50	30	BW250JAG	EW250JAG
	100	50	BW250RAG	EW250RAG
	125	65	BW250HAG	EW250HAG
400	50	30	BW400EAG	EW400EAG
	85	36	BW400SAG	EW400SAG
	100	50	BW400RAG	EW400RAG
	125	70	BW400HAG	EW400HAG
630	50	36	BW630EAG	EW630EAG
	100	50	BW630RAG	EW630RAG
	125	70	BW630HAG	EW630HAG
800	50	36	BW800EAG	EW800EAG
	100	50	BW800RAG	EW800RAG
	125	70	BW800HAG	EW800HAG

Table 2 "G-TWIN Global Series" (wiring-use)

Frame (A)	Rated breaking capacity *I*cu (kA)		MCCB	ELCB
	230 Vac	440 Vac		
50	25	10	BW50RAGU	EW50RAGU
100	25	10	BW100EAGU	EW100EAGU
125	50	30	BW125JAGU	EW125JAGU
	100	50	BW125RAGU	EW125RAGU
250	36	18	BW250EAGU	
	50	30	BW250JAGU	EW250JAGU
	100	50	BW250RAGU	EW250RAGU
400	50	30	BW400EAGU	
	85	36	BW400SAGU	EW400SAGU
	100	50	BW400RAGU	EW400RAGU
	125	70	BW400HAGU	EW400HAGU
630	50	36	BW630EAGU	
	100	50	BW630RAGU	EW630RAGU
	125	70	BW630HAGU	
800	50	36	BW800EAGU	
	100	50	BW800RAGU	
	125	70	BW800HAGU	

Table 3 Variant usage of the "G-TWIN Standard Series"

Frame (A)	For electric motor protection	For use with primary-side of transformer	Instantaneous tripping	Non-auto switch	With leakage alarm	For use with resistance welder	4-pole product	DC-only product
32	○	○	○	○				○
50	○	○	○	○	○			○
63	○		○	○				○
100	○	○		○	○			○
125	○	○	○	○	○		○	○
250	○	○	○	○	○	○	○	○
400		○	○	○	○	○	○	○
630		○	○	○	○		○	○
800			○	○	○		○	○

the development of a new breaking mechanism with increased current-limiting effect was needed.

To increase the breaking capacity, the most effective method is to increase the arc voltage by separating the contacts at high-speed beginning at the time when a short circuit occurs, and to limit the current to a coolable current value. With the G-TWIN Breaker, to improve the current-limiting performance of the low-rated-current region, in addition to techniques used with high-rated-current products, a forked dual-contact breaking method was newly developed to realize technology for further improving the current-limiting effect. Such techniques were utilized from high-rated-current products as enhancing the ablation effect with the narrow slit resin, optimally arranging the magnetic yoke for promoting arc driving, and reducing the emission of ionized gas on the load side by adopting an isolated construction of the molded casing.

Characteristics of the breaking mechanisms of high-rated-current products and low-rated-current products are shown in Figs. 1 and 2, and a sketch of the breaking mechanism for low-rated-current products is shown in Fig. 3.

The principles of electromotive force generation with the forked dual-contact breaking method are shown in Fig. 4. The primary-side fixed contact connected to the line-side terminal is folded into a U-shape, and joined to a contact tip. The opposed movable contact is folded into a C-shape in the width direction of the breaker, and via a secondary-side contact,

Fig.1 Features of large current rated (40 to 125 A) breaker structures

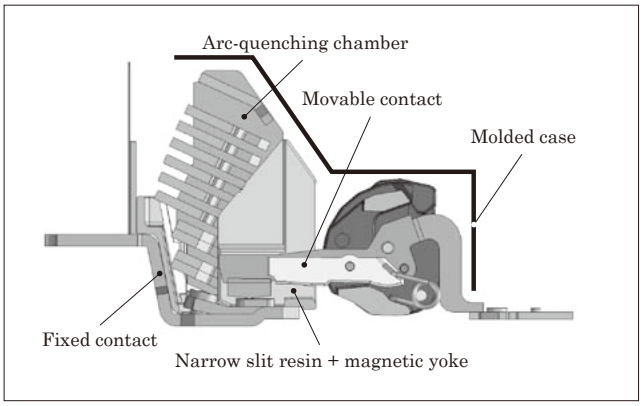


Fig.2 Features of small current rated (15 to 30 A) breaker structures

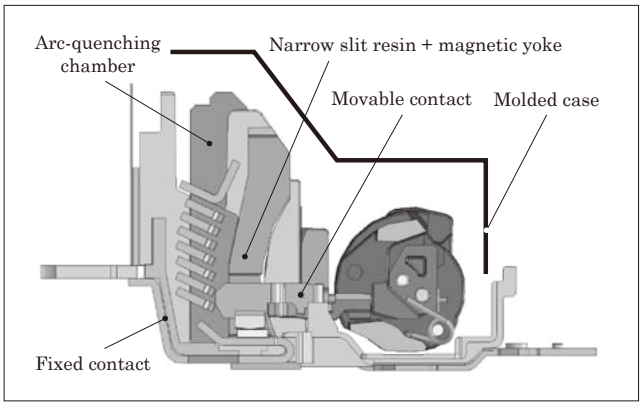
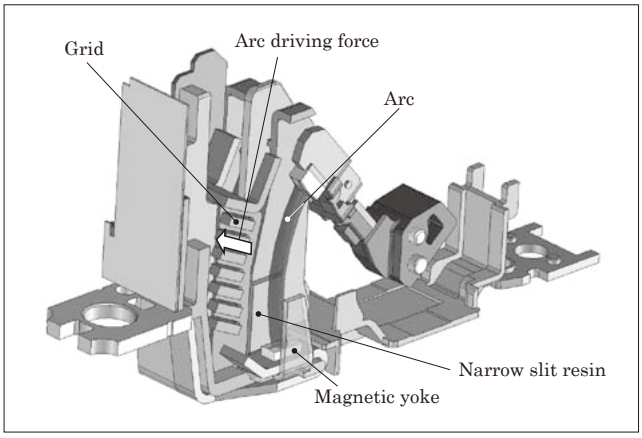


Fig.3 Breaker structure of small current rated device



opposes the fixed contact. The secondary-side fixed contact extends outward in a straight line and is connected to an overcurrent release. When a short-circuit current occurs, an electromotive force is generated between each of the respective primary-side and secondary-side fixed and movable contacts, and with the added effect of a magnetic yoke, the two contacts separate simultaneously at high-speed. The arc generated between the contacts is generated in series at the primary and secondary sides. Therefore, the rate of rise

Fig.4 Principle of electromotive force generation according to contact shape

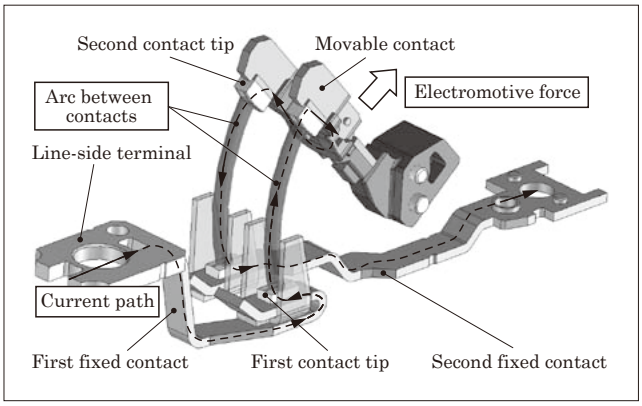
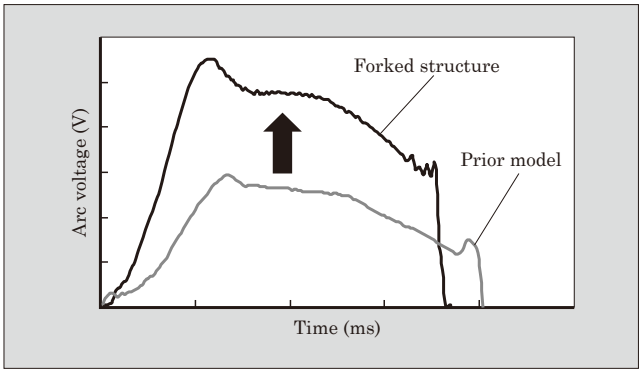


Fig.5 Comparison of arc voltages



of the arc voltage (dV/dt) is approximately twice that of a single contact. Moreover, by ensuring twice the contact separation distance with the same arc-quenching chamber space as for a single contact, a peak value of arc voltage that is approximately twice as large can be realized, and the current-limiting effect is enhanced significantly. The arc voltages for the forked structure and prior structure are compared in Fig. 5.

By applying these techniques, an approximate 15 % reduction in I^2t was realized in comparison to the prior series of breakers, and at the same time, performance that satisfies the UL489 standard was realized in a Japanese standard-size breaker shape. Moreover, the Twin Breaker concept of uniform dimensions for the MCCB and ELCB is maintained and parts for the make-and-break mechanisms in 40 A and higher rated products can also be shared.

3. High Reliability and High Efficiency Power Supply system technology

3.1 Plug-in type circuit breakers

In recent years, from the perspective of simplifying and reducing the amount of labor involved in the installation of equipment, improving the stability and maintainability of the electric power supply, and reducing the environmental load, plug-in type circuit breakers have attracted attention and have begun to

Table 4 Variations of “G-TWIN” plug-in circuit breakers

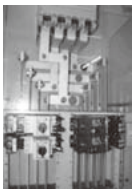
Name	Plug-in circuit breakers			
Main use	Switch board	Distribution board		
Applicable AF	125, 250, 400, 630	32, 50, 100, 125, 250	32 (MMS)	50 (MCCB-2P)
			Branched breaking capacity 200V/100 kA 	Branched breaking capacity 200V/2.5 to 25 kA
Mounting pitch	15 mm	15 mm	50 mm	
Installation height	125 mm	91 mm	94 mm	
Busbar layout	Vertical	Vertical	Vertical	
Busbar thickness	10 mm	4 mm	3 mm	
Busbar pitch	70 mm	45 mm	30 mm	
Features	○ Plug-in verification indicator ○ Can be equipped with power monitoring breaker, leakage alarm, etc. ○ High breaking capacity	○ Shutter mechanism for energized parts ○ Plug-in verification indicator ○ High and medium breaking capacity	○ Super-high breaking capacity ○ Selective trip coordination ○ Space-saving	○ Medium breaking capacity ○ Space-saving

Fig.6 External view of plug-in type circuit breaker

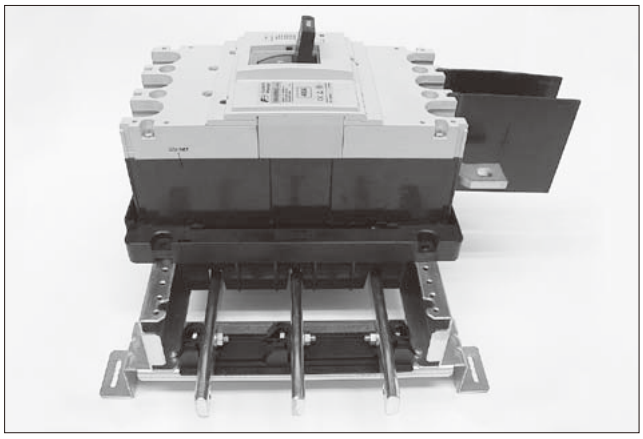
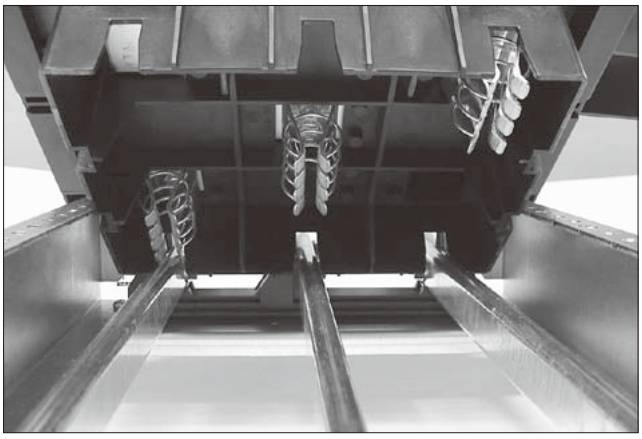


Fig.7 Structure of plug-in part connecting busbar



be used widely in facilities such as data centers and public utilities where a highly reliable supply of electric power is required.

Instead of using stud-type terminals such as in the previous insertion-type configuration, a plug-in circuit breaker (Fig. 6) is provided with clip-shaped contacts at the power supply-side terminal, and these contacts directly connect to and hold copper busbars provided at the board-side (Fig. 7). Since the wiring on the power-supply side of this structure can be realized without using electrical cable, the following benefits are provided.

(a) Space savings and resource savings of the switch board and distribution board
(b) Shorter assembly and delivery times
(c) Easier to change capacity, and shorter time required for replacement tasks
(d) Prevents work omissions and misconnections

Fuji Electric has prepared a wide variety of products that can be selected according to the usage and protection goals (Table 4).

For switch board applications, the circuit breakers used for branched circuits can be equipped with MCCBs and ELCBs ranging from 125 to 630 AF, and the maximum value of the busbar conduction current is 2,100 A. Moreover, in addition to MCCBs and ELCBs for general wiring applications, a breaker equipped with a leakage alarm, the “FePSU Breaker” equipped with a power monitoring function and the like are provided, and breakers can be freely selected for a particular application.

For power distribution board and lighting distribution board applications, plug-in circuit breakers have

Fig.8 Current waveforms of AC and DC circuits

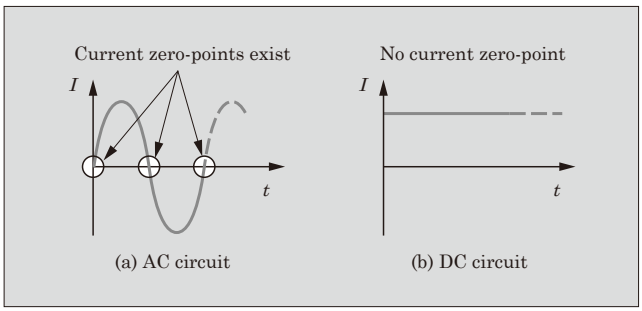
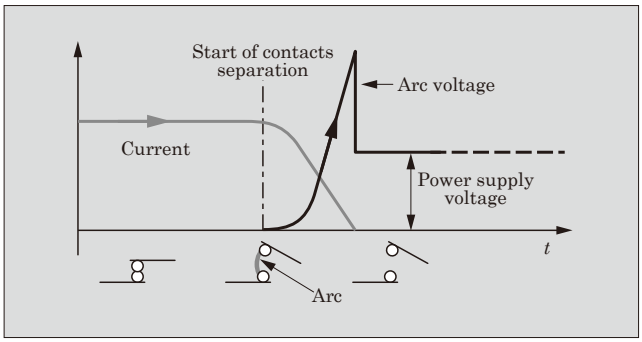


Fig.9 DC circuit current breaking waveform



been prepared in two varieties, with 32 to 250 AF or 32 to 50 AF, which enable further reductions in the size of switch boards. Also, "manual motor starter (MMS)" installation is also possible, and as a result of the super-high current-limiting breaking performance of an MMS, selective trip coordination with an upper-level circuit breaker can be implemented, thereby contributing to the realization of a reliable supply of electric power. Moreover, except for a few models, safety-related options, such as a safety shutter function that closes off the busbar when the breaker has been removed or a gauge function that verifies the plug-in status are also available.

3.2 "G-TWIN" DC breaker series

In recent years, with the increased popularity of green energy such as solar power and also with the widespread prevalence of data centers, requests for a more highly reliable and efficient supply of power have intensified, and there is growing demand to changeover from conventional AC power transmission and distribution to DC power transmission and distribution. Especially for data centers, decreasing the amount of AC-DC conversion is said to enable a reduction in power transmission loss of up to 10 or 20%, and the energy saving effect would be large. Additionally, higher voltage transmission and distribution technology has also been requested in recent years in order to reduce transmission loss.

In an AC circuit, a current zero-point generally occurs periodically, and at a zero-point, if the insulation can be maintained, the current can easily be interrupted (see Fig. 8). But in a DC circuit, because there is no zero point, a technique for boosting the arc voltage generated between contacts to a level greater than the power supply voltage is needed in the breaker to interrupted the current (create a zero point) (see Fig. 9). Additionally, as the power supply voltage increases,

Table 5 "G-TWIN DC Series" lineup

Rated DC voltage (V)	Basic model	No. of poles	Rated current (A)	Breaking capacity *I*cu (kA)				
				EAG	JAG	SAG	RAG	HAG
250	BW32 □*	2-pole	3 to 32	–	–	2.5	–	–
	BW50 □ BW63 □		5 to 63	2.5	–	5	5	–
	BW100 □		50 to 100	5	–	–	–	–
	BW125 □		15 to 125	–	15	–	40	–
	BW250 □		125 to 250	10	20	–	30	–
	BW400 □		250 to 400	20	–	20	40	40
	BW630 □ BW800 □		500 to 800	20	–	–	40	40
400	BW32 □	3-pole	3 to 32	–	–	2.5	–	–
	BW50 □ BW63 □		5 to 63	–	–	5	–	–
	BW100 □		50 to 100	5	–	–	–	–
500	BW50 □	3-pole	5 to 50	–	–	2.5	–	–
	BW100 □		50 to 100	2.5	–	–	–	–
	BW125 □		15 to 125	–	10	–	20	–
	BW250 □		125 to 250	–	10	–	20	–
	BW400 □		250 to 400	20	–	20	40	40
	BW630 □ BW800 □		500 to 800	20	–	–	40	40
600	BW125 □	4-pole	15 to 125	–	–	–	25	–
	BW250 □		125 to 250	–	25	–	40	–
	BW400 □		250 to 400	–	–	–	40	40
	BW630 □ BW800 □		500 to 800	–	–	–	40	40

* : □ indicates the breaker capacity type

Table 6 "G-TWIN" specifications of 2 or 3 parallel phases energizing breakers

Model	AF	No. of poles	Rated current (max.)	Rated breaking capacity (Icu)	
				60 V dc	125 V dc
BW32	32	2P	40 A	7.5 kA	5 kA
		3P	60 A		
BW50	50	2P	75 A	20 kA	10 kA
		3P	100 A		
BW63	63	2P	90 A	20 kA	10 kA
		3P	125 A		
BW100	100	2P	150 A	15 kA	10 kA
		3P	225 A		
BW125	125	2P	175 A	30 kA	20 kA
		3P	250 A	60 kA	40 kA
BW250	250	3P	550 A	60 kA	40 kA
BW400	400	3P	950 A	80 kA	60 kA
BW630	630	3P	1,400 A	80 kA	60 kA
BW800	800	3P	1,900 A	80 kA	60 kA

device miniaturization becomes more difficult as the arc-quenching mechanism must be made larger in size and the distance between contacts increased.

By developing a proprietary arc-quenching mechanism for DC applications, Fuji Electric has established efficient breaking technology. Further, by wiring 3-pole or 4-pole circuit breakers in series and maintaining the contact separation distance, these circuit breakers can be applied to block even higher voltages. As a result, compared to the applicable range of up to DC250 V with a standard breaker, the "G-TWIN DC Series" can be applied to voltage circuits of 400 to 500 V for 3-pole circuit breaker or up to 600 V for 4-pole breakers (125 to 800 AF), and with its wide range of AF specifications, the G-TWIN Series offers a product lineup suitable for a wide range of needs (see Table 5). Additionally, switches (non-auto SW) that do not contain overcurrent protection elements have also been developed into a product series, and the selectable range of models is expanding.

3.3 DC breakers variations

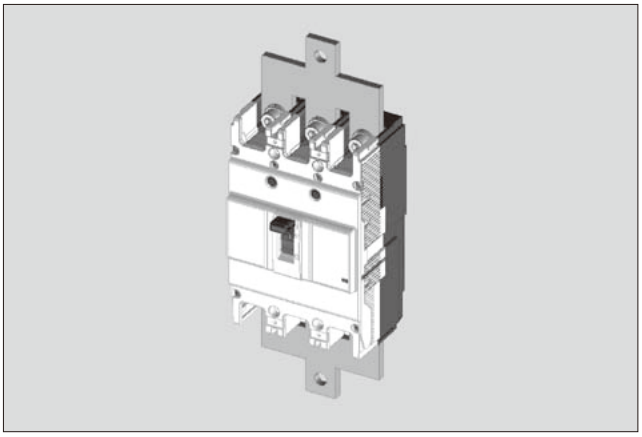
(1) 2 or 3 parallel phase energizing breakers

Specifications for parallel phase energizing breakers for low-voltage DC circuit applications have recently been added to the lineup of the G-TWIN DC Series (see Table 6).

These breakers are mainly used in applications involving DC power supply equipment for mobile base stations and the like (see Fig. 10), and since the current flow is divided into 2 or 3 phases, the current flow per phase is small, and the ability to realize conduction in excess of the previous maximum rating for each AF contributes to the miniaturization of devices and switch boards.

(2) Compact disconnecting switch for solar power applications

Fig.10 2 or 3 parallel phases energizing breaker



In the field of solar power, which has become widely popular, the installation of a disconnecting switch is required by the JIS C60364-5-55 standard in order to permit the maintenance and inspection of solar inverters. Also, aiming to raise the power generating efficiency of solar cells, the trend towards higher voltages is being advanced. In response, Fuji Electric has developed a compact arc-quenching mechanism that adds a permanent magnet to the conventional arc-quenching mechanism, and has also developed a compact disconnecting switch that is optimally suited for solar power generation. Designed to have the same size as an AC output-side ELCB, this breaker model contributes to the standardization of switch board design and the miniaturization of solar cell equipment.

4. Postscript

The elemental technologies of the G-TWIN Breaker Series and the various models introduced to the market have been described above. In the future, with advances in the reliability, safety and efficiency of electrical equipment both in Japan and overseas, a product lineup suited to the market needs, such as for selective trip coordination and DC distribution, and the improvement of product quality are expected to become increasingly important. By accurately assessing the requirements of its customers, Fuji Electric intends to continue to expand its offering of products, such as the G-TWIN Breakers, that are responsive to the needs of the market, and to broaden the lineup of its product series.

References

(1) Kuboyama, K. et al., New Global MCCB/ELCB G-Twin Series. Fuji Electric Journal. 2006, vol.79, no.2, p.160-166.

(2) Takahashi, Y. et al, Expanded Product Lineup of the G-Twin Series and Accessories to Enhance Functionality. Fuji Electric Journal. 2008, vol.81, no.3, p.237-241.