Super Twin Breakers with Solid-State Overcurrent Relay

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1. Introduction

Recently, with the increase of intelligent buildings and the enlargement of factory scale, improvement in the reliability of low voltage power distribution systems have become strongly desired. Central monitoring systems which use computers, communication network systems which operate between devices and high level systems for preventive maintenance are under development in many fields. For these applications, small sized breakers (MCCB) with high performance and functionality are needed for low voltage distribution networks.

High level functions, such as the pre-alarm function which prevents sudden power system down and the rated current adjustment function should be able to easily adapt to the requirements of the facility.

In order to meet these needs, Fuji Electric has developed new super twin breakers with a solid-state overcurrent relay (hereby called solid-state super twin breakers) (**Fig. 1**).

A summary of the solid-state super twin breakers is introduced in this paper.

2. FAB Series

Table 1 shows a series of Fuji Auto Breakers (hereafter called FAB) with a solid-state overcurrent relay.

Fig. 1 Outline view of solid-state super twin breakers

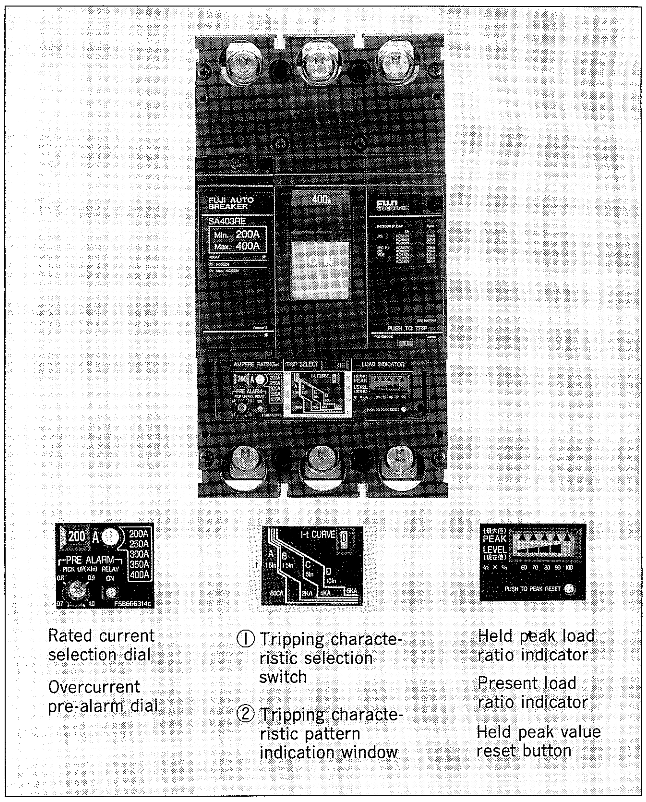


Table 1 Series of FAB with solid-state overcurrent relay

Frame size	30A	50A	100A	225A	400A	600A	800A	1,200A	1,600A	2,000A	2,500A	3,200A
Solid-state motor breaker	░	░										
Solid-state twin breaker			░	░								
Solid-state super twin breaker					▓	▓	▓					
Power breaker, etc.								░	░	░	░	░
Application	Induction motor		Distribution					Main network				

▓ : New series

Table 2 Specifications of solid-state super twin breakers

Frame [A]		400		600		800	
Type		SA400RE	H400BE	SA600RE	H600BE	SA800RE	H800BE
Rated current I_n [A]		200–400 (5 step changeable)		300–600 (5 step changeable)		400–800 (5 step changeable)	
Rated insulation voltage U_i [V]		660 (460: With earth leakage alarm)					
Rated interrupting capacity [kA]	AC550V	35	42	35	42	35	42
	AC460V	50	65	50	65	50	65
	AC220V	85	125	85	125	85	125
Tripping characteristic		4 pattern changeable					

Tripping pattern	A	B	C	D
Short time delay pickup current	$1.5 \times I_n$	$1.5 \times I_n$	$5 \times I_n$	$10 \times I_n$
Instantanious pickup current	$2 \times I_f$	$5 \times I_f$	$10 \times I_f$	400AF: 6kA 600AF: 7.6kA 800AF: 8.4kA
	(I_n: Rated current, I_f: Frame ampere)			

Load ratio indications	Held peak load ratio indicator	0.6/0.7/0.8/0.9/1.0 (5 step changeable)
	Present load ratio indicator	0.6/0.7/0.8/0.9/1.0 (5 step changeable)
Overcurrent pre-alarm		○

FAB with a solid-state overcurrent relay are classified into four groups according to the application. The series of solid-state super twin breakers have 400 to 800 ampere-frames as the upstream breaker for middle sized distribution panels. There is a complete series of breakers with solid-state overcurrent relay of 30 to 3,200 ampere frames.

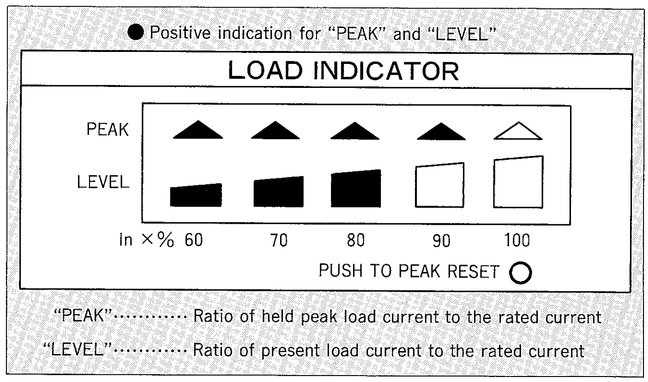
Table 2 shows the specifications of the solid-state super twin breakers.

The frame size of the breakers are 400, 600 and 800 ampere-frames. For each of these sizes, standard models and models with a higher interrupting capacity are available.

3. Features and Functions

The solid-state overcurrent trip consists of a current transformer, a solid-state relay and a trip coil. When the current transformer detects an overcurrent, the solid-state relay determines the required operation and the trip coil activates the moving contact. The solid-state relay controls the actual tripping operation. Hence, FAB with a solid-state overcurrent relay can have advanced functions that cannot be achieved with bimetallic and magnetic elements. For example, rated currents and overcurrent tripping characteristics can be adjusted over a wide range and functions may be added for quick overcurrent tripping characteristic selection and load ratio display.

Fig. 2 Load ratio display



3.1 Load ratio display

Load ratio display indicates the ratio of both the present load current and peak current to the rated current in five steps on LCD (LCD is liquid crystal display) (**Fig. 2**). By comparing these two load current values with each other, an operator can easily evaluate the current allowance and decide whether more loads can be safely connected to a branch circuit.

Table 3 shows the current allowance.

The horizontal scale of **Table 3** shows the ratio of the breaker current to the present rated current. The present level and the peak value are indicated by lamps at 60, 70, 80, 90 and 100% (with an accuracy of 5%). For example, when the present load lamp at 60% lights up, the breaker

Table 3 Load ratio display and allowance of current

	Current (Ratio of rated current): 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%	Overcurrent
Range of pickup indication	60% Indication / 70% Indication / 80% Indication / 90% Indication / 100% Indication	
60% Indicating	Range of current	Allowance of current is approx. 40%
70% Indicating	Range of current	Approx. 30%
80% Indicating	Range of current	Approx. 20%
90% Indicating	Range of current	Approx. 10%
100% Indicating	Range of current	

current is within this range and the allowance is about 40%. In the same way, when the 70% lamp is lit, the allowance is about 30%, and when 80% lamp lights up, the allowance is about 20%.

3.2 Quick selection of tripping characteristics

MCCBs with solid-state overcurrent relay have a wide range of adjustable overcurrent tripping characteristics, however, they also have many dials and are difficult to operate. In contrast, the newly developed overcurrent tripping characteristic selection switch is easy to use. The purpose of changing time-current curve is to ensure protective coordination with other protective devices or loads. The solid-state super twin breakers have four sets of time-current curve that ensure protective coordination with almost all devices connected devices. Suitable characteristics can be selected easily with the selection switch (**Fig. 3**).

3.3 Detection of effective values

The effective value detection method is used to improve tripping characteristics of deformed current waveforms, caused by the recent increase of solid-state devices.

The effective value detection circuit performs the following effective value conversion equation through analog circuitry:

$$V_{\mathrm{rms}} = \left\{ \left(\int_0^T i^2 dt \right) \Big/ T \right\}^{1/2}$$

The square and square root signal operations are achieved with logarithm and inverse logarithm conversion circuitry, using the non-linear characteristics of the transistors. The integrating operation is achieved with an integrating circuit, using capacitor and resistance.

4. Application of Solid-State Super Twin Breakers

Figure 4 shows the selective trip coordination between MCCBs. Selective trip coordination implies that, if a short circuit occurs as shown in **Fig. 4**, only MCCB2 will trip and the power supply for the MCCB3 branch will remain constant, unaffected by the short circuit. For selective trip coordination, each set of MCCB characteristics must be determined accordingly.

To perform selective trip coordination, the time-current curves of MCCB1 and MCCB2 must be related as shown in **Fig. 4**. If the MCCB1 time-current curve is located to the right of the MCCB2 curve, MCCB2 will trip before MCCB1, achieving selective trip coordination.

Fig. 3 Quick relection of tripping characteristics (Comparison of setting part)

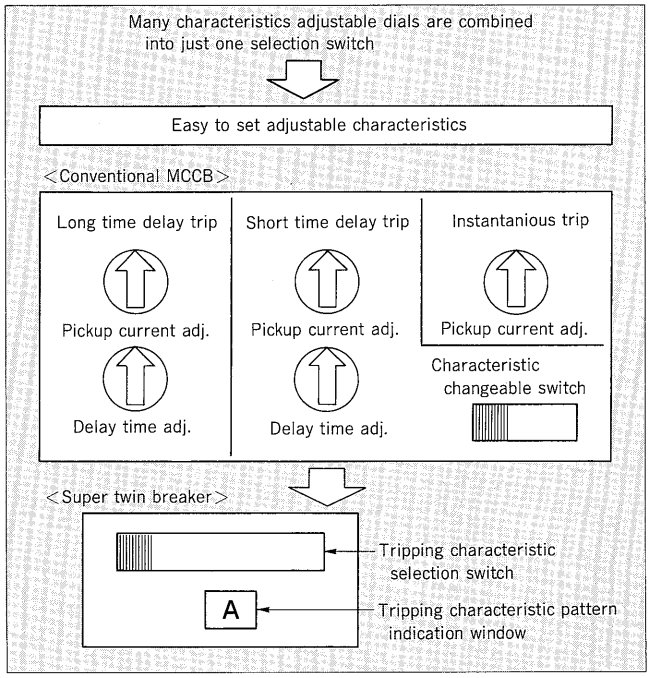


Fig. 4 Selective trip coordination between MCCBs

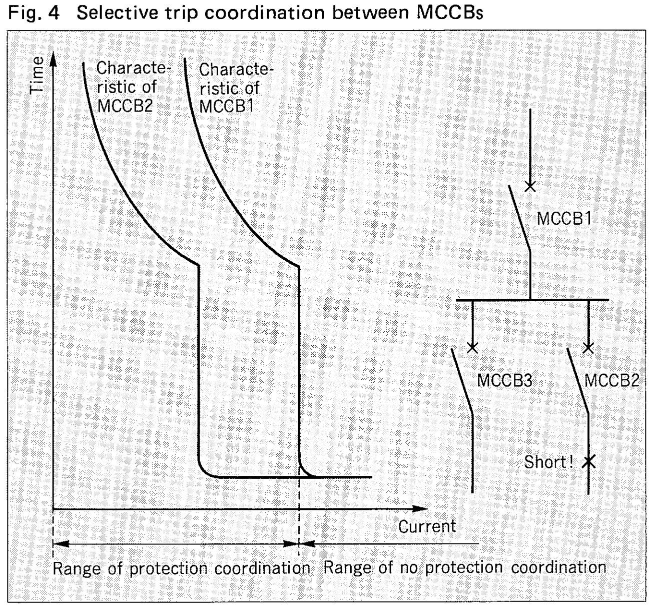


Table 4 Characteristic pattern of protective and load devices

Charac-teristic pattern	Relation of each devices	Range of voltage	Protective and load devices	Characteristic curve –: Super twin ...: Devices
A	Up stream devices	High voltage	• Power fuse	t (Time) (Current)
B	Up stream devices	High voltage	• Overcurrent protector • Auto-V	t (Time) (Current)
C	Up stream devices / Down stream devices	Low voltage	• ACB • MCCB	t (Time) (Current)
D	Down stream devices	Load devices	• Transformer • Capacitor • Motor	t (Time) (Current)

4.1 Selection of characteristic mode

Table 4 classifies into four groups the time-current curves of protective or load devices connected up- or down-stream of a breaker.

Group-A devices, such as power fuses, have a smooth characteristic curve with a steep slope.

Group-B devices have a smooth characteristic curve with a gentle slope. Typical devices are overcurrent protectors with solid-state relays, or the Fuji Auto-V which consists of a vacuum circuit breaker and an overcurrent relay.

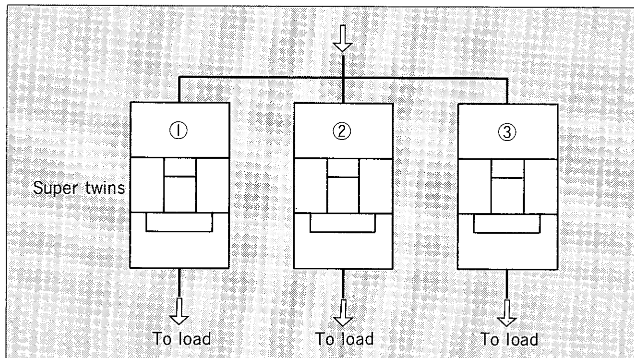
Group-C devices, such as ACB and MCCB, have a characteristic curve with the same slope as the characteristic curve for wire.

Group-D devices, such as transformers and motors, initially draw a large current.

Each solid-state super twin breaker has four sets of time-current curves, one for devices from each of these four groups.

To perform selective tripping effectively, an MCCB's operating characteristics must be determined so that its characteristic curve does not intersect the characteristic curve of the object device. That is, the characteristic curve of the object device should have the same slope as that of the MCCB. Four characteristic curves are possible with the solid-state super twin breakers.

Fig. 5 How to use the load ratio display



Load ratio indications	Super twin ①	Super twin ②	Super twin ③
LEVEL	60%	70%	60%
PEAK	90%	80%	70%
Allowance current	Approx. 10%	Approx. 20%	Approx. 30%

※ Additional load should connect to MCCB ③

The Type-A curve has a steep slope. The Type-B curve has a gentle slope. The Type-C curve has the same slope as standard MCCBs. The Type-D curve is relatively insensitive to overcurrent.

4.2 Addition of load

Figure 5 shows solid-state super twin breakers connected to three circuit branches. When the present levels and peak load currents are as shown here, the currents in the three branches are almost the same, and the load of each branch can be increased.

However, the peak load current display shows that previously a current of 90% was flowing in breaker ①. If the load of breaker ① is increased, an overcurrent may occur. The additional load should, therefore, be connected to breaker ③.

5. Conclusion

In addition to the features explained above, the solid-state super twin breakers have a warning feature, which outputs an alarm before tripping the overcurrent. An optional earth leakage alarm is also available.

There are many customer benefits to using solid-state super twin breakers such as selectable time-current curve to allow easy ordering, increased number of applications, simplified maintenance and a reliable supply of power.