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FUJI MINI F-CIRCUIT BREAKER 24/36kV 25kA SF_6 GAS CIRCUIT BREAKERS

Katsuyuki Kubomura
Kazuro Fujimiya
Chohei Tanno
Iwao Watanabe

I. INTRODUCTION

Fuji Electric is engaged in research and development work on new 24/36kV switchgears. Recently, the "Fuji Mini F-clad" 24/36kV swithgears which have a high level of compactness and are based on a combination of the Fuji Mini F-circuit breakers which are SF_6 gas circuit breakers, and cubicles with resin-insulated bus bars went into production.

The "Fuji Mini F-circuit breakers developed as the main Fuji Mini F-clad units employ the excellent technology and the long years of experience in the production of 72~300kV SF_6 gas breakers and SF_6 gas insulated metal clad switchgears. The 24/36kV single pressure grounded tank type gas circuit breakers were developed on the basis of fundamental research using models.

II. FEATURES

1) Compactness

Greater compactness has been achieved through the use of the grounded tank type breaking chamber.

2) High safety, oilless

There is no danger of electrical shocks when handling since the charged parts are covered by the grounded tank.

SF_6 gas is chemically inert and highly safe. It is harmless and odorless and it is physiologically safe. Since it is non-inflammable, there is no danger of fire.

3) Excellent braking performance and long life

The life is especially long because of the use of the puffer-type double flow system based on two new arc quenching principles: the precharge inner blast which increases the puffer pressure sufficiently before opening and the arc guide nozzle which causes the arc at the instant it is generated flow from the contacts to the nozzle. Excellent performance is also achieved for breaking under special conditions such as double earth faults and out-of-phase conditions.

4) Surgeless

Because of the electron affinity of SF_6 gas, the arc can be maintained stably to the small current region so that the overvoltage level during small inductive current breaking is low. Because of the excellent insulating characteristics of SF_6 gas, small capacitive current breaking and capacitor bank switching result in without reignition and restrike.

5) Ideal for very frequent switching

Very frequent switching is possible because of the use of simplified and long-life contact mechanisms and solenoid operating devices.

6) Maintenanc-free for long periods

Maintenance is not necessary for long periods because of the use of the single pressure sealed tank, long-life contacts and the solenoid operating device.

7) BCT can be attached

The cubicle construction can be simplified by the attachment of a BCT to the bushing part.

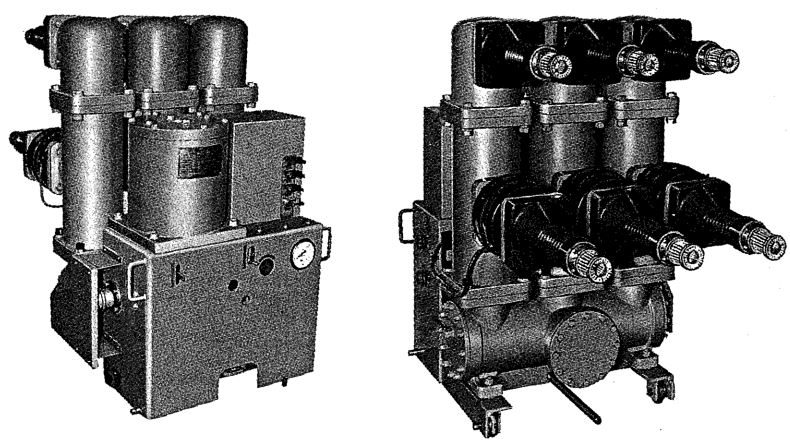


Fig. 1. Fuji Mini F-circuit breaker 36kV 25kA 1,200A with BCT

III. RATINGS AND SPECIFICATIONS

The ratings and specifications of the Mini F-circuit breakers are shown in *Table 1.*

Table 1. Ratings and specifications

Model		BAG002	BAG003
Rated voltage	(kV)	24	36
Power frequency withstand voltage	(kV)	50	70
Impulse withstand voltage	(kV)	125	170
Rated current	(A)	600, 1,200, 2,000	600, 1,200 2,000
Rated frequency	(Hz)	50/60	
Rated breaking current	(kA)	25	25
Rated recovery voltage	(kV/μs)	0.5	0.6
Rated opening time	(ms)	55	
Rated breaking time	(cycle)	5	
No-load closing time	(s)	0.55	
Rated operating squence		O–1min–CO–3min–CO CO–15sec–CO	
SF_6 gas pressure	(kg/cm^2·g)	5 (at 20°C)	
SF_6 gas weight (three-phase parts)	(kg)	4	
Weight	(kg)	690	720
Installation method		Horizontal draw-out method	
Standards		IEC56, JEC181	

IV. CONSTRUCTION AND OPERATION

1. Outline of Construction

Fig. 1 shows a photograph of the outside and *Fig. 2* shows the outline of the Mini F-circuit breakers. As can be seen in these figures, the Mini F-circuit breakers employ the grounded tank. In this type, the breaking chambers for each phase which form the grounded tank are connected on the tank bottom to form one tank. This tank is attached to a base with wheels and a built-in solenoid operating device. The main circuit has an epoxy resin bushing and can be pulled out from the rear of the circuit breaker. Attachment to the cubicle is by means of tulip-contact connectors. Therefore, by accomodating the bushing and the connector in a booth, the cubicle breaking compartment is eliminated and the Mini F-clad structure becomes possible.

The horizontal draw-out system is used for attachment to the cubicle. The draw-out equipment is of the feed screw type and interlocks such as the draw-out lock under closing conditions and the switching lock during draw-out are provided for safety.

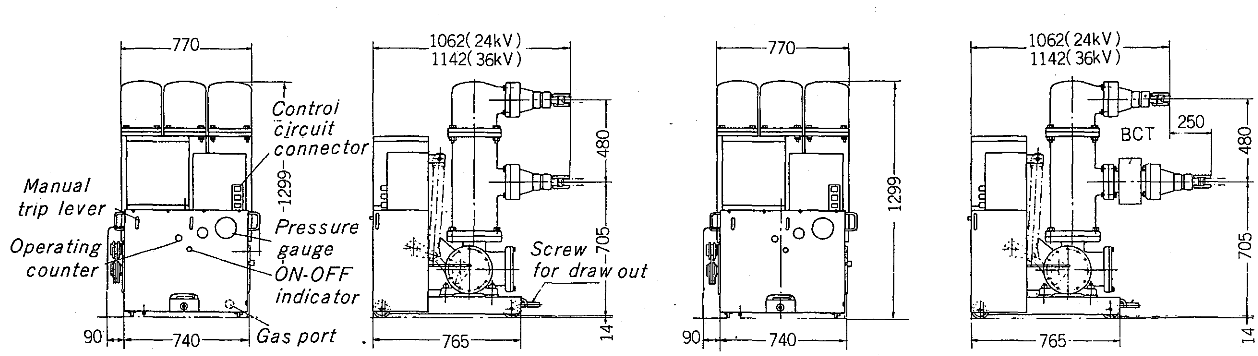
2. Arc Quenching Principles

The excellent arc quenching characteristics and long-life performance of the Mini F-circuit breakers can be explained in accordance with the two new arc quenching principles, the precharge inner blast and the arc guide nozzle. These principles are outlined in *Figs. 3* and *4*.

Both the upper and lower fixed contacts have hollow-type graphite nozzles attached to their tips and they are arranged opposite each other. The moving contacts which have arc resistant metal chips attached to their tips form a bridge with the fixed contacts.

At the time of breaking operation, the puffer piston is moved downwards, the SF_6 gas in the puffer chamber is compressed. Since the pressure has already been raised sufficiently beforehand (prehcarge), it continues from the contact opening to the flow guide opening. When the flow guide is opened, the arc formed between the contacts is instantly blown into the hollow graphite nozzle by the precharge pressure. The arc blown into the nozzle is elongated and extinguished by the SF_6 gas flow caused by the precharge pressure. This is the precharge inner blast pressure.

The arc guide nozzle principle is explained in accordance with *Fig. 4. Fig. 4*(a) shows the bridge contact closed conditions and *Fig. 4*(b) shows the conditions just after opening. The contact surfaces move in accordance with the movement of the moving contact and when the contacts are



(a) Standard (b) With BCT

Fig. 2. Outline of Mini F-circuit breaker

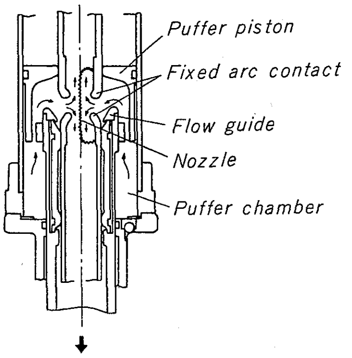
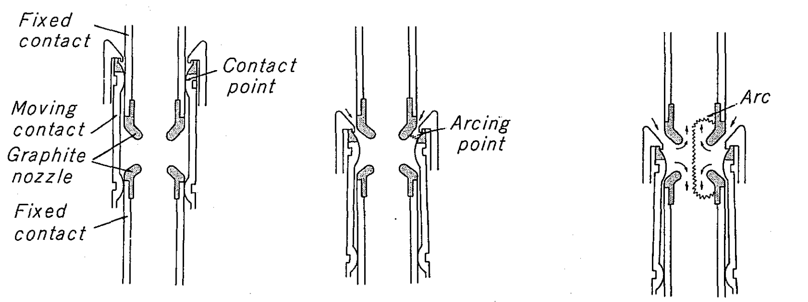
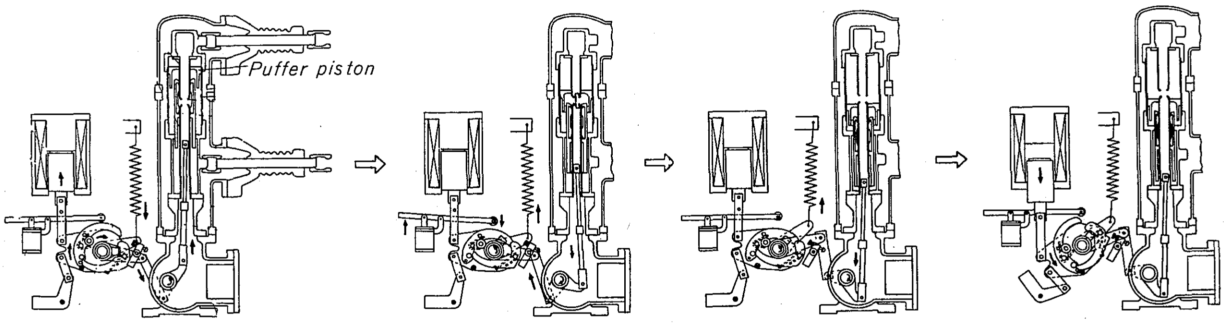


Fig. 3. Arc quenching mechanism



(a) Closed condition (b) Just after pole opening (c) During arc quenching

Fig. 4. Contact operation mechanism



Arrows indicate the closing operation direction

(a) Closed condition (b) Opening condition (c) Trip-free condition (d) Open condition

Fig. 5. Operation mechanism

open, an arc is formed between the graphite nozzle and the arc resistant metal on the moving contact. In other words, although the moving and fixed contacts are both the same contacts, the current conducting surface and the arc generation point are separate. The arc from between the contacts is blasted into the hollow graphite nozzle immediately after it occurs by the precharge pressure described previously under the conditions shown in *Fig. 4*(c). As is evident from the figure, the arc is turned from the contacts into the graphite nozzle and the hollow nozzle acts as an arc guide. Because of the separation of the current conducting surface and the arc generation point and the action of the nozzle arc guide, there is little contact wear and frequent switching becomes possible. In this case, the graphite used in the nozzle has an extremely high melting point of 4,000°C compared with about 1,100°C for copper. Therefore, there is almost no wear caused by the arc and a very small amount of metallic vapor is produced by the arc. The use of the graphite nozzle in connection with both of the above principles improves the arc quenching characteristics and lengthens the life.

Since the graphite surface remains smooth even after frequent switching, the withstand pressure maintained in the gap between the nozzles by the high insulation withstand of the SF_6 gas is not affected by breaking. Fig. 5 shows the braking process including the operating mechanism.

3. Operating Device

The Mini F-circuit breakers employ and solenoid operating device. The trip-free mechanism of this operating device is attached to the driving shaft of the operating device. The basic members are three: the driver, ratchet lever and release lever. These members are arranged compactly centering on the drive shaft with no change in quality. In addition, wear is minimized by use of rollers in connecting parts, the required trip force is lowered by the use of light alloys and the skilfull combining of the members, and the centers of gravity of each of the members are arranged appropriately so that there is no misoperation due to inertia during closing. The operating principle including operation of the breaking part is shown in *Fig. 5.* As can be seen from this figure, the mechanism is extremely simple.

V. TESTS

1. Short Circuit, Double Earth Fault Breaking and Out-of-phase Switching Tests

The rated breaking current for both the 24kV and 36kV breakers is 25kA and the only difference between the 24kV and 36kV breakers is the bushing length. Therefore, each of the breaking tests were performed on a 36kV breaker and the 24kV ratings were covered simultaneously. However, the 100% I (25kA) short circuit test was performed on a 24kV breaker using a 3-phase direct test. For the 36kV breaker, a Weil test was used but in this case, a recovery voltage under double earth fault conditions and the double earth fault breaking characteristics were also examined. These test results are summarized in *Table 2* and typical oscillograms are given in *Figs. 6* and *7*. To prove the long life of the contacts as described in the arc quenching principles, breaking tests at 36kV and 25kA were con-

Table 2. Schedule of 36kV (24kV) breaking test results

Breaking test		Operating sequence	No. of times	Test method		Test SF_6 gas pressure	Specified value					Test result								Remarks
									Transient recovery voltage					Breaking current		Arcing time	Transient recovery voltage			
Fault	Breaking current			Type	Single phase / 3 phase	(kg/cm²·g)	Test voltage (kA)	Breaking current (kA)	Uc (kV)	t_3 (μs)	U_c/t_3 (kV/μs)	Test voltage (kV)	Recovery voltage (%)	Current (kA)	DC component (%)	(~)	Uc (kA)	t_3 (μs)	U_c/t_3 (kV/μs)	
Short circuit (BTF)	10% I	1min. 3min. O – O – O	1	Direct	Single phase	4.0	31.2	2.5	62	52	1.2	31.5	100	2.7	0	0.19~ 0.40	69	98	0.70	
	30% I	1 min. 3min. O – O – O	1	Direct	Single phase	4.0	31.2	7.5	62	52	1.2	33.9	100	7.06	0	0.63~ 0.85	69	72.5	0.95	
	60% I	1min. 3min. O – O – O	1	Weil	Single phase	4.0	31.2	15	62	52	1.2	36	115	16.4	9.4~ 18.3	0.34~ 0.61	71.4	54.2	1.32	
	100%I	1min. 3min O – O – O	1	Weil	Single phase	4.0	31.2	25	62	103	0.6	38	122	26.5~ 26.6	16.0~ 29.0	0.60~ 0.70	75.5	114	0.66	Also used for double earth fault test
	100%I*	1min. 3 min O – CO – CO	1	Direct	3 phase	4.0	24	25	62	103	0.6	24	92	25.1~ 26.3	0~ 7.6	0.62~ 0.97	41.0	59	0.70	Making current (Specified value: 63kA, Actual test value: 68.6kA)
Double earth fault	87%I	3min. O – O	1	Weil	Single phase	4.0	36	21.2	71.5	119	0.6	38	106	26.5~ 26.6	16.0~ 29.0	0.60~ 0.70	75.5	114	0.66	
Out-of-phase switching	25%I	3min. O – O	1	Weil	Single phase	4.0	52	6.25	92	218	0.42	53.7	103	6.6	0~ 23	0.40~ 0.50	95.0	216	0.44	
Small capacitive current	30%Ic	O	12	Direct	Single phase	4.0	27	(A) 15	–	–	–	48	178	(A) 16	–	0.07~ 0.46	–	–	–	Without reignition and restrike
	100%Ic	O	12	Direct	Single phase	4.0	27	(A) 50	–	–	–	48	178	(A) 50	–	0.07~ 0.48	–	–	–	
	Capacitor current	O	12	S & S	Single phase	4.0	27	(A) 600	–	–	–	48	178	(A) 605	–	0.05~ 0.45	–	–	–	Without reignition and restrike
		O	12	S & S	Single phase	4.0	27	(A) 2000	–	–	–	48	178	(A) 2100	–	0.10~ 0.50	–	–	–	
Small inductive current	$30\%I_L$	O	12	Direct	Single phase	5.3	31.2	(A) 6	–	–	–	31.2	100	(A) 5.5	–	0.10~ 0.42	–	–	–	Overvoltage multiple 1.85 or less
	$100\%I_L$	O	12	Direct	Single phase	5.3	31.2	(A) 20	–	–	–	31.2	100	(A) 19.1	–	0.13~ 0.50	–	–	–	Overvoltage multiple 1.58 or less

(Note) (1) The small capacitive current test is performed at a voltage corresponding to a 60Hz one-line ground fault.
(2) In the Weil test, the current gradient of the superimposed current matches a 60Hz current gradient.
(3) The asterisk (*) indicates a 24kV 3-phase direct short circuit test.

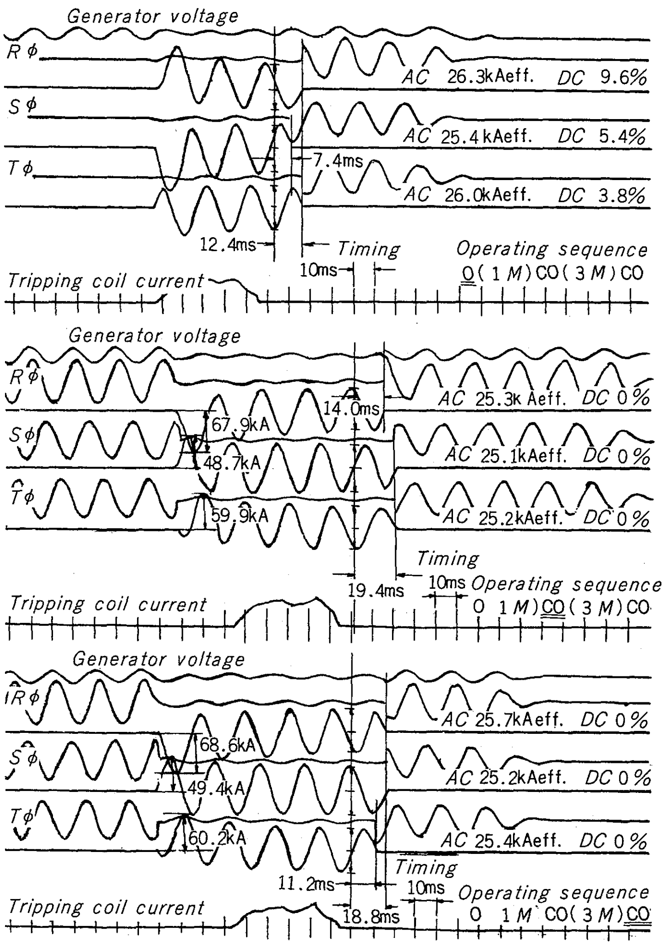


Fig. 6. Oscillograms of 24kV 25kA three-phase short-circuit breaking test

ducted for 30 times consecutively but the wear to the contacts after the tests was very little as can be seen from the photo in Fig. 8 and further breaking was possible.

2. Small Current Breaking Tests

When the charging current is interrupted under double earth fault conditions on the load or power source sides, $2\sqrt{3}$ times the maximum phase voltage is applied between the breaker poles. Under such severe conditions, the small capacitive current was changed between 16A and 53A equivalent to single-phase 36kV, 60Hz with 12 breakings at each value. To test the capacitor bank switching characteristics, 12 breakings were also performed each at single phase 36kV 605A and 2,000A capacitor currents by a synthetic test (S & S method) but there were no cases of reignition and restrike of arcs.

In the small inductive current breaking tests, 12 breakings each were also performed at single phase 31.2kV 5.5A and 19.1A. The maximum value of the overvoltage multiple was 1.85 and the excellent characteristics of the SF_6 gas were confirmed. Table 2 summarizes the results of these tests.

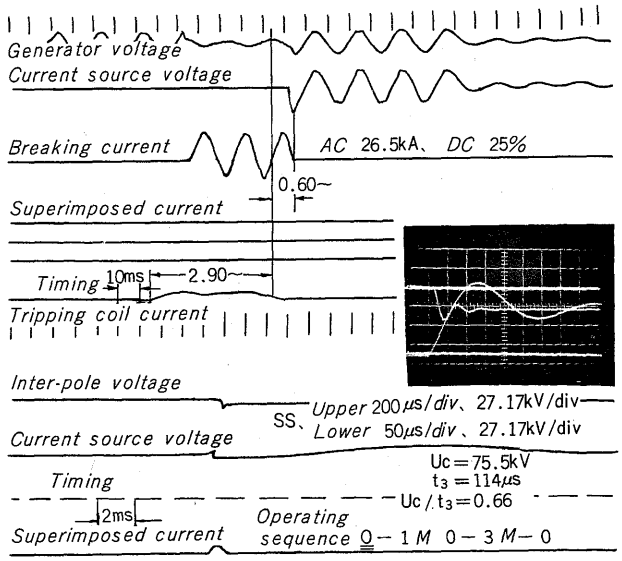


Fig. 7. Oscillograms of 36kV 25kA synthetic test

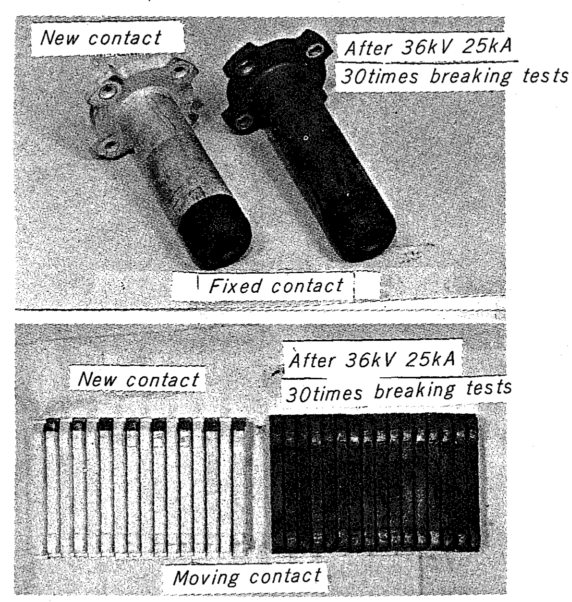


Fig. 8. Fixed and moving contacts after 36kV 25kA 30-times breaking test

VI. CONCLUSION

This article introduces Mini F-circuit breakers consisting of 24/36kV gas types which are Mini F-clad breakers combining compactness, safety and economy by the use of a rational arrangement of components and resin-insulated bus bars as a new type of 24/36kV switchgear designed for substations which are more compact, rational and in harmony with the environment.

As was explained previously, these Mini F-circuit breakers are suitable for a wide range of applications as oilless breakers with an extremely good balance of safety, size, practicability and maintenance. It can be expected that these applications will spread in forming oilless equipment by combinations with molded transformers, etc.