UDC 621. 316. 3

FUJI MINI F-CLAD 24/36kV METAL-CLAD SWITCHGEAR WITH FUJI MINI F-CIRCUIT BREAKER

Katsuyuki Kubomura
Tsuneo Ohkawara
Yutaka Ishibashi

I. INTRODUCTION

Fuji Electric has been engaged in the research and development of new types of 24/36kV switchgears and recently, a highly safe and economical 24/36kV compact metal-clad "Fuji Mini F-clad" has been completed by the combination of the Fuji Mini F-circuit breaker and resin-insulated bus bars.

The circuit breakers are of the grounded tank type with which a high degree of safety can be maintained since the operators have many occasions to approach them for inspections, etc. The bus bars are not normally approached but once an arc fault occurs, it can spread widely. Therefore, the bus bars have been provided with an insulated cover to prevent arc faults and their spreading.

II. FEATURES

1) The breaker is an oilless Fuji Mini F-circuit breaker

The Fuji Mini F-circuit breaker uses SF_6 gas as an insulation and arc quenching material, so that it is oilless, surgeless and noiseless.

2) Compactness

This equipment has become much more compact through the use of the compact Fuji Mini F-circuit breakers and the newly developed resin-insulated bus-bars. *Fig.1* shows the outline of the 36kV switchgear.

3) High safety

The Mini F-circuit breakers have grounded tanks, so that there is no risk of electric shocks during maintenance or inspections. The bus bars are resin insulated so that there is no problem of bus arc faults due to the penetration of vermin, etc. into the bus compartment.

The possibility of arc faults is extremely small but if one should occur for some reason, the fault can not spread to other parts via the bus bars.

4) Attractive construction

The Mini F-circuit breaker is arranged in the front part of a metal-clad and there is no door in the front surface which assures an attractive appearance and also is very favorable for routine maintenance and inspections.

5) There is a high degree of freedom in the combination of devices

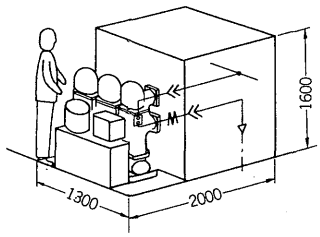

Fig. 1. Outline dimensions of the 36kV Fuji Mini F-clad

Table 1. Ratings and specifications of Mini F-clad

Rated voltage	(kV)	24	36
Rated frequency	(Hz)	50/60	
Rated current	(A)	600, 1,200 2,000	600, 1,200 2,000
Rated bus bar current	(A)	1,200, 2,000	1,200, 2,000
Breaker rated breaking current	(kA)	25	25
Rated short-time current	(kA)	25	25
Power frequency withstand voltage	(kV)	50	70
Impulse withstand voltage	(kV)	125	170
Rated operating voltage		DC 100V	
Control voltage		DC 100V	
Standards		IEC 298, JEM 1153	

It is easy to connect the resin insulated bus bars with conventional equipment such as ordinary disconnecting switches, instrument transformers, lightning arrestors and cable heads.

III. RATINGS AND SPECIFICATIONS

Table 1 shows the ratings and specifications for the Mini F-clad. The basic unit of the 24kV Mini F-clad is shown in *Fig.2.*

IV. RESIN-INSULATED BUS BARS

The resin insulated bus bars are the main structural component ensuring the features of the Mini F-clad. *Fig.3*

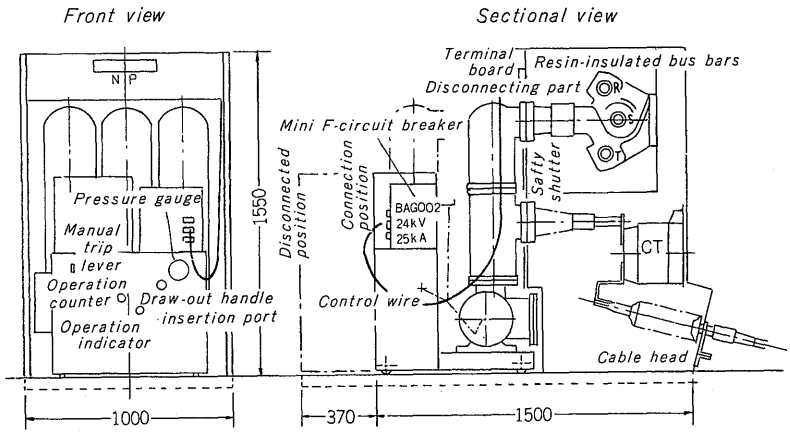

Fig. 2. Basic unit of 24kV Mini F-clad

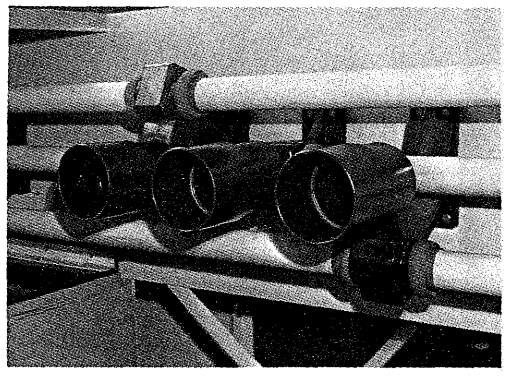

Fig. 3. Appearance of 24/36kV resin-insulated bus bar

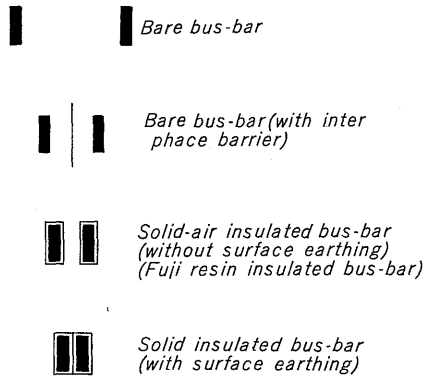

Fig. 4. Methods of bus bar insulation

shows the outer appearance of these bus bars.

1. Selection of Bus Bar Insulation System

There are various types of bus bar insulation systems from the bare bus bar to solid insulated bus bar as shown in *Fig. 4*. The main reasons for covering the bus bars with insulation were as follows: (1) preventing shocks and arc faults, (2) preventing the spread of arc faults and (3) greater compactness. To achieve these purposes, the solid-air insulation system was used for the following reaons:

1) With this system, the insulated bus bar is supported and insulated from the ground by means of a support insulator. This support insulator has been widely used and has shown high reliability.
2) Concerning the voltage distribution between the solid (resin insulation) and air, air has the main voltage distribution so that the resin insulation electrical stress (electrical field) is extremely small and there is no danger of deterioration due to strong electrical fields.
3) Even if the resin insulator should be damaged electrically, some degree of insulation can be maintained by the air gap, and short circuit or ground faults will not occur immediately.

2. Construction of Resin-insulated Bus Bars

As shown in *Fig.5*, the resin insulated bus bars consist of the pipe bus bars with insulation cover and the contact supporting insulators. As the insulation cover material,

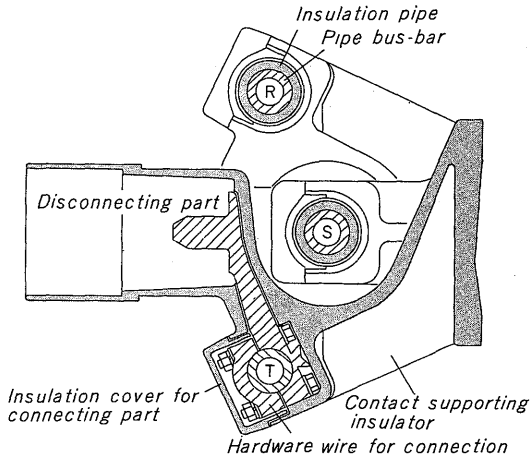

Fig. 5. Construction of resin-insulated bus bar

unsaturated polyester resin has been selected from among the thermo-setting resins because of its excellent incombustibility and arc resistance. These resins are produced in a pipe form which surrounds the copper pipe bus bars. An electrical conductor layer is provided inside the insulation pipe to prevent the partial discharges inside the insulation pipe. The copper pipe bus bars have a constant outer diameter of 50mmϕ at a rated current of 2,000A or less and the thickness changes in accordance with the rated bus current. *Table 2* shows the relation between the rated

Table 2. Pipe bus-bar size and rated bus current

Material	Pipe bus bar dimensions outer dia. x thickness (mm)	Rated bus current (A)
Cu	50 x 3	1,200
	50 x 5	1,600
	50 x 10	2,000
Al	50 (rod)	2,000

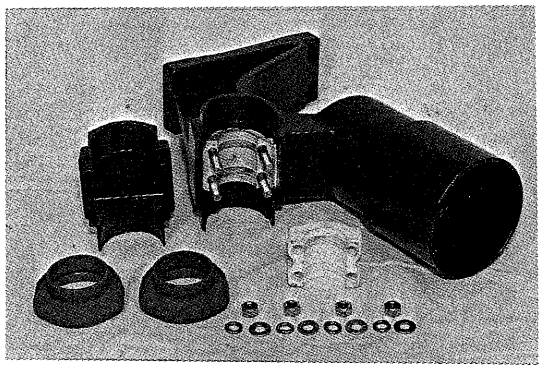

Fig. 6. Components of R/T phase contact supporting insulator

current and pipe size.

The contact supporting insulators are special support insulators with three functions: straight and branching connections of the bus bars and fixed contact of the draw-out type disconnecting switch of the circuit breaker. It is a unique form based on the full application of the synthetic resin features. The contact insulator is made of epoxy resin and is embedded with a copper insert to form a single unit. The pipe bus bars are fixed in position with four bolts via their connection fittings so that connections can be made. *Fig.6* shows the components of the R/T phase contact supporting insulator.

V. CONSTRUCTION OF MINI F-CLAD

1. Outline of Construction

The basic Mini F-clad unit, as shown in *Fig.2*, has the Mini F-circuit breaker in the front part and the metal enclosed bus bar compartment, the current transformer and the cable head compartment in the rear.

2. Construction Around Mini F-circuit Breaker

Since the Mini F-circuit breaker has a grounded tank, there is no breaker compartment cover. Therefore, the mechanical operation indicator, pressure gauge, operation counter, etc. in the breaker operating device box can be seen from the exterior. Mini F-circuit breaker is the draw-out type provided with self coupling type disconnecting switch and manually coupling type control circuit disconnecting switch. Complete interlocks are also provided. When the Mini F-circuit breakers are drawn-out to the disconnected position, the opening of the disconnecting parts is automatically covered with a grounded metal safety shutter.

3. Bus Compartment

The resin-insulated bus bars are accommodated in the bus compartment.

4. Current Transformer and Cable Head Compartment

In addition to the wound type current transformer as shown in *Fig.2,* the divided pass-through type attached to the Mini F-circuit breaker bushing can also be used.

5. Mounting of Instruments and Relays

In principle, the instruments and relays are attached to separate panels. When the instruments and relays are attached, a relay panel is provided in the upper part of the bus bar compartment.

VI. TEST RESULTS

To confirm the safety and reliability of Fuji Mini F-clad with resin-insulated bus bars, ordinary tests and various types of functional tests considering the various conditions of use and locations have been performed.

This section describes test results for a 36kV switchgear.

1. Temperature Rise Test

Table 3 shows the results of temperature rise tests for a combination with a 36kV, 1,200A Mini F-circuit breaker. *Fig.7* shows the measurement locations.

2. Withstand Voltage Test

No abnormalities were found when a test voltage corresponding to power frequency 70kV, impulse ±170kV

Table 3. Results of temperature rise tests

Measurement position		Temperature rise value (deg)	Rated temperature rise value (deg)
Breaker bushing S-phase	1	35.0	50*
Breaker tank surface S-phase	2	20.5	–
Air in breaker compartment	3	12.0	–
Disconnecting part (Upper) S-phase	4	51.5	65
Bus bar conductor branching part R-phase	5	44.0	65
Bus bar conductor branching part S-phase	6	49.5	65
Bus bar R-phase	7	46.0	65
Bus bar insulating cover R-phase	8	38.5	65*
Air in bus bar compartment	9	17.0	–
Disconnecting part (Lower) S-phase	10	44.5	65
Air in cable compartment	11	11.5	–
Ambient temperature	12	17.0	–

(Asterisk (*) indicates company control value)

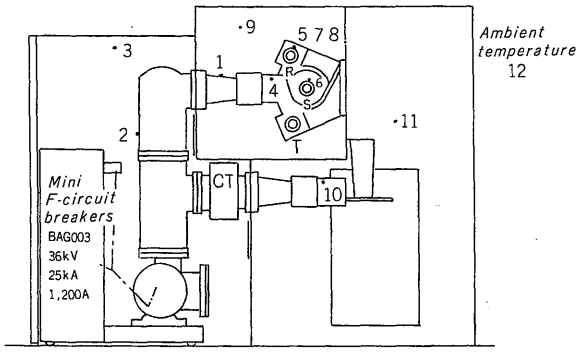

Fig. 7. Temperature rise measuring points

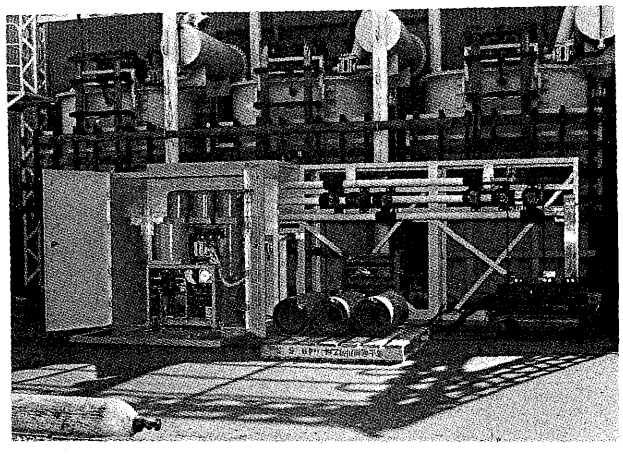

Fig. 8. 36kV Mini F-clad switchgear during short-time current test

was applied between live parts and ground, and between phases.

3. Short-time Current Tests

To verify the short-time current capacity and the mechanical resistance to electromagnetic force under the short circuit condition, a 3-phase short time current test was performed combined with a 36kV, 1,200A Mini F-circuit breaker. The current used had a first peak value of 70.2kA and an effective value of 25.7kA and it flowed for 2.14 seconds, all of which are above rated conditions, but there were no abnormalities found. *Fig.8* shows a 36kV Mini F-clad during short-time current test.

4. Tests to Show Applicability of Resin-insulated Bus Bars

1) Partial discharge test

This test was performed to confirm that no partial discharges occur under normal conditions of use. In Fuji Electric, the voltage was first increased to 1.7 times the normal phase to earth coltage and after 10 seconds, it was decreased to 1.1 times the normal phase to earth voltage. It was confirmed that there were no partial discharges of over 10 PC at these voltages.

2) Cooling/heating test

The contact supporting insulator, insulating pipes, etc. were subjected a cooling/heating cycle using a thermostatic oven of the variable temeprature type repeated five times as follows:

$20°C \rightarrow 90°C \rightarrow 20°C \rightarrow -20°C \rightarrow$ return to original temperature

2h 1h 2h 1h 2h 1h 2h

After the heating/cooling cycle, an external investigation, power frequency withstand voltage test and partial discharge test were performed but no abnormalities were found.

3) Long-time charging test

The long-time charging test is an accelerated deterioration test which simulates electric field deterioration occurring when the insulation is used at a high electrical field strength. There is almost no risk of field deterioration in the case of the resin-insulated bus bars since the electrical field strength of the insulation cover is very low. However, this test was performed for unitial confirmation.

The deterioration is accelerated by means of a combination of voltage and frequency acceleration.

VII. CONCLUSION

The Mini F-clads are metal clad switchgears which balance safety, size, practicability, maintenance and economy as was described above. They have a wide range of applications and should play a role in the rationalization of substation design.