UDC 621. 316. 545 : 621. 315. 622. 8

DEVELOPMENT OF GENERAL USE V TYPE DISCONNECTING SWITCHES WITH FLAT TYPE EPOXY RESIN INSULATOR

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I. INTRODUCTION

A large number of epoxy resin insulators, hollow porcelains and bushings are used in electrical equipment in Japan, Europe and America.

The use of epoxy resin insulators and hollow porcelains instead of ceramic insulators and hollow porcelains is especially evident in indoor electrical equipment. Epoxy resin insulators were presented as a new theme within the insulator section at the 19th CIGRE Conference in 1962. A plan for the uniform specification of the performances and dimensions of indoor epoxy resin insulators has been under study by the IEC Technical Committee 36 for the past several years and the 1st draft plan was submitted last year.

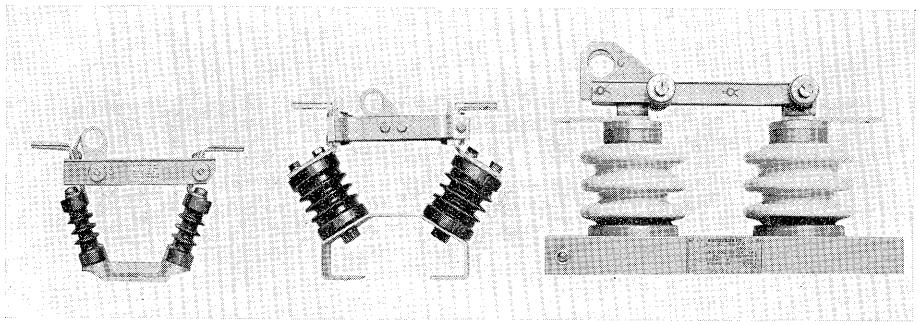
Fuji Electric, the first manufacturer in this field in Japan commenced research and trial manufacture on hollow porcelains in 1960 and has since manufactured a large number of epoxy resin insulators, hollow porcelains and bushings for use in indoor electrical equipment.

The size of the disconnecting switch was considerably reduced as shown in *Fig. 1* through the use of flat epoxy resin insulators and by modifying the disconnecting switch base.

The features of the disconnecting switch are presented here. The flat type epoxy resin insulator is a Fuji Electric utility model (Reg No. 812413) and posseses many features.

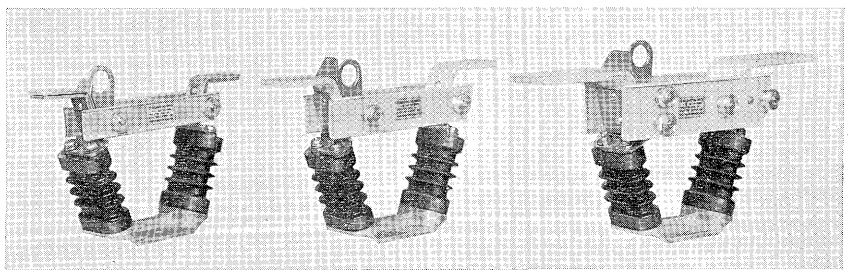
Table 1 **Ratings of V type disconnecting switches**

Type	Rating			Weight (kg)
	Voltage (kV)	Current (A)	Rated short time current (kA)	
V- 2	3.6/7.2	200	14	1.2
V- 4		400	14	1.2
V- 6		600	27	1.7
V-12		1,200	32	2.8



V-2 VD-6/200 Porcelain insulator

Fig. 1 Comparison of 7.2 kV 200 A disconnecting switch size



V-4 V-6 V-12

Fig. 2 View of V type disconnecting switches

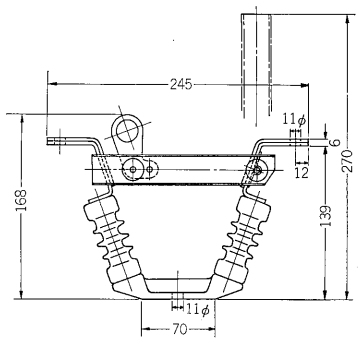


Fig. 3 (a) Outline dimensions of V-2, V-4

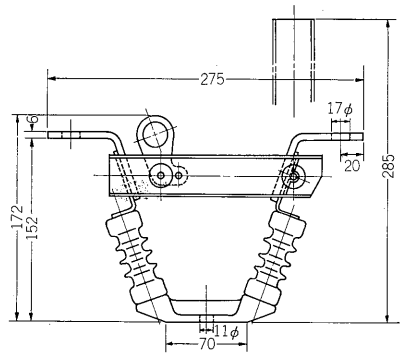


Fig. 3 (b) Outline dimensions of V-6

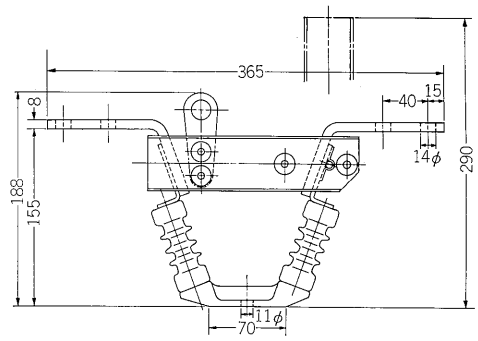


Fig. 3 (c) Outline dimensions of V-12

Table 2 **Comparison of disconnecting switch volume**

Insulator	Type of disconnecting switch	Rating	Outline dimensions (mm)	Comparison of volume (%)	Weight (kg)
Porcelain insulator	RF240[1]/6/200	Voltage: 7.2 kV	140×255×365	100	13
Round type epoxy resin	VD-6/200	Current: 200 A	60×205×220	21	3
Flat type epoxy resin	V-2		60×170×245	19	1.2

II. RATINGS AND FEATURES OF THE GENERAL USE V TYPE DISCONNECTING SWITCH

The ratings of the V type disconnecting switch employing flat epoxy resin insulators are given in *Table 1*. External views of the V-2, V-4, V-6 and V-12 are showm in *Fig. 2* and outline dimensions in *Fig. 3*. The general use V type disconnecting switch employing flat epoxy resin insulators has the following features.

(1) Small and lightweight

As showm the "Volume comparison" column of *Table 2*, weight and dimensions of the new disconnecting switch are considerably smaller than those of conventional switches.

(2) Back connection possible

Since the two flat epoxy resin insulators are in the form of a V, the connecting conductor can be connected by merely bending it thus eliminating the bushing required conventional switches.

(3) Easy installation to cubicles

Since only one angle ($5 \times 40 \times 40$) is required to install the disconnecting switch, savings in installation material cost and work are possible.

(4) Blade is not opened by electromagnetic force

The disconnecting switch is constructed to eliminate the safety latch. Since the direction of the electromagnetic force applied to the blade toward the left as shown in *Fig. 4*. Automatic opening of the blade during short circuits does not occur.

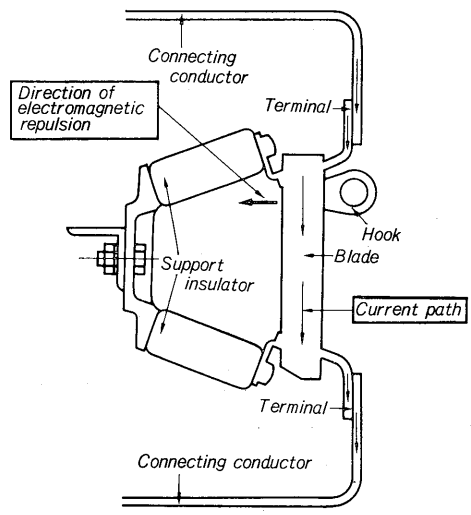


Fig. 4 Direction of electromagmetic force that acts on the blade

III. FEATURES OF FLAT TYPE EPOXY RESIN INSULATORS

The many electrical and mechanical features of the epoxy resin insulator as compared to porcelain insulators are well known. The flat epoxy resin insulator has been made to have an oval cross section by taking advantage of the special characteristics of epoxy resin which permit is moulding into complex shape.

Porcelain insulators can be made to have a round in cross section due to material properties and the manufacturing process. The resin insulator, however, can be freely made in any shape. The flat shape is designed to coincide the direction of action of the electromagnetic force due to short circuit current with the long diameter direction of the insulator, thus providing to specified mechanical strength as well as economy by minimizing the epoxy resin volume.

The outline dimensions of the flat type epoxy resin insulator are shown in *Fig. 5*. Its ratings are given in *Table 3*.

The flat type epoxy resin insulator boasts the following features,

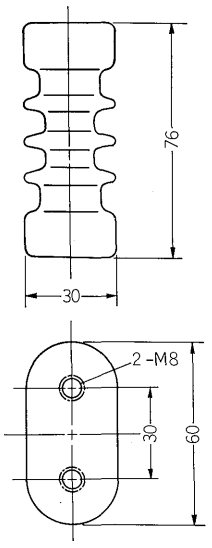


Fig. 5 Outline dimensions flat type epoxy resin insulator

Table 3 **Dimensions of flat type epoxy resin insulator**

Nominal voltage	(kV)	6.6
Power frequency withstand voltage	(kV)	22
Impulse withstand voltage	(kV)	60
Dry flashover voltage	(kV)	50
50% impulse flashover voltage	(kV)	80
Bending breaking load		
Long diameter direction	(kg)	250
Short diameter direction	(kg)	100
Tensile breaking load	(kg)	300
Surface leakage distance	(mm)	110
Weight	(kg)	0.22

(1) Since it is small and lightweight compared with conventional insulators, the size of the equipment and cubicle can be considerably reduced.
(2) Metal flanges can be embedded, thus reducing the total height of the equipment.
(3) Cost is considerably lower than that of round type insulators.
(4) Long leakage distance and superb pollution characteristics.
(5) Optimumly suitable for JIS cubicle type unit substations.
(6) Arc resistance is excellent.

IV. TEST RESULTS OF V TYPE DISCONNECTING SWITCH AND FLAT TYPE EPOXY RESIN INSULATOR

1. V Type Disconnecting Switch

1) The V type disconnecting switch was tested under normal installation conditions. The switch was continuously opened and closed and 1000 times.

Table 4 **Temperature rise of each part of disconnecting switch**

Type	Applied current (A)	Temperature rise (℃)			
		①	②	③	④
V- 2	200	14.5	17	15	22
V- 4	400	48	49.5	48.5	28
V- 6	600	23	21.5	23.5	20.5
V-12	1,200	36	33.5	35.5	20
Specified temperature rise (℃)		65	65	55	—

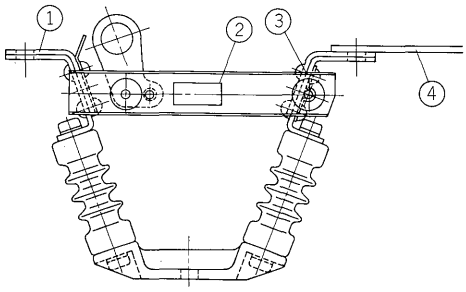


Table 5 **Results of short time current test**

Type	Effective current value (kA)	Peak value (kA)	Period current applied (s)
V- 2	13.8	34.9	1.05
V- 4	14.2	34.2	1.05
V- 6	27.7	72.2	2.08
V-12	32.4	83.5	2.12

Contact resistance measurement and temperature tests were conducted before and after the opening and closing operation test at the 0th, 500th and 1,000th times, The differences were negligible.

2) Temperature test

The temperature rise of each section of the four types of switches, the V-2, 4, 6 and 12 was measured while continuously applying the rated current. The measured satisfactorily met the JEC 165 temperature rise values in the disconnecting switch standard.

3) Short time current test

As shown in *Table 5*, the rated values of 14 kA was satisfied and also 27 kA at 600 A and 32 kA at 1,200 A respectively. An oscillogram of the short time current test carrying 32 kA is given in *Fig. 6*.

4) Withstand voltage test

Commercial power frequency withstand voltage and impulse withstand voltage tests were performed and a " No. 6 A " dielectric strength satisfied guaranteed.

2. Flat Type Epoxy Resin Insulator

Electrical and mechanical tests were conducted with respect to the following items in accordance with JIS C3801 " Insulator Test."

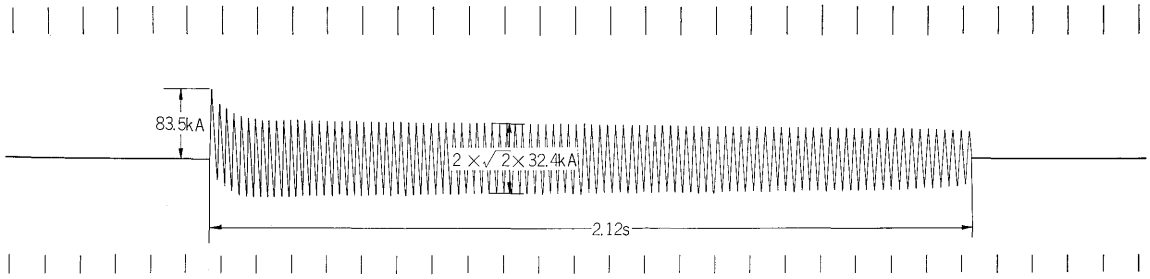


Fig. 6 Oscillogram of short time current test carrying 32 kA

1) Electrical test
(1) Dry flashover test
(2) Impulse frequency flashover voltage test (50% impulse test)
(3) Power frequency withstand voltage test
(4) Impulse withstand voltage test
The above tests, proved that the insulator satisfied "No. 6 A" standard values.
2) Mechanical load test
(1) Load withstand test
i) Tensile load withstand test
ii) Bending load withstand test
(2) Breaking load test
i) Tensile breaking load test
ii) Bending breaking load test
(3) Thermal shock test

The mechanical load test proved that the insulator satisfied standard values. Ratings considerably above the standard values were obtained in the breaking load test.

3) Contamination test

JIS Japan Industrial Standard does not provide any standards for the indoor support insulator contamination have become a problem because grounding accidents due to contamination occur in equipment housed in cubicles installed in dusty areas or near the seashore.

Thus contamination loss must be considered even with indoor use insulator. A comparison of contamination and flashover voltage of the flat epoxy resin insulator and porcelain insulator is given in *Table 6*.

Table 6 **Pollution test results of insulator**

Accumulated salt density (mg/cm²)	5% flashover voltage (kV)		
	Vertical flat type epoxy resin insulator	Horizontal flat type epoxy resin insulator	Porcelain insulator
	ES-6	ES-6	CD-6
0.01	17.2	16.5	10.8
0.02	11.0	10.6	8.7
0.03	10.3	9.8	7.8
0.06	8.7	8.5	6.7
0.10	7.3	7.6	6.3
0.12	7.1	7.5	6.1

The epoxy resin insulator has a higher flashover voltage than a porcelain insulator having the same ratings. The reasons for this are consider to be;

(1) Since the mechanical strength of the epoxy resin insulator is greater than that of the porcelain insulator the diameter of the body can be reduced.

The contamination flashover voltage of the insulator is thought to have a theoretical relationship with the resistance R across the upper and lower electrodes of the insulator. Assuming that the entire surface of the insulator is uniformly contaminated, resistance R across the upper and lower electrodes of a round insulator can be given by the following equation.

$$R=\rho\int_0^l \frac{dl}{\pi D}$$

D: Insulator outer diameter
l: Surface leakage distance
ρ: Surface specific resistance

The smaller outer circumference of the insulator, the higher the resistance R with respect to the same surface leakage distance and the higher the flashover voltage.

(2) In the case of the epoxy resin insulator, the shape of the fins can be freely selected. Therefore, the fins can be designed for optimun contamination characteristics. The fins can also be made at shaper angle to provides the longest leakage distance.

V. FLAT TYPE EPOXY RESIN INSULATOR APPLICATIONS

As previously described, V type disconnecting switch has been made smaller than conventional types through the use of the flat type epoxy resin insulators.

This insulator is used for single equipment and also to support cables in cubicles, thus making it possible to save installation work and cost. When the flat epoxy resin insulator is used as a cable support, it is installed to coincide the direction of electromagnetic force exerted on the insulator with the long diameter of the insulator.

The load vector when used as a cable support is very small except in the direction relative to the

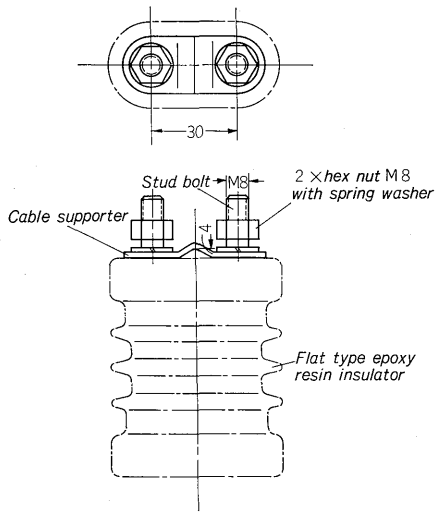


Fig. 7 Cable supporter

Table 7 **Application list of resin insulator**

Flat type epoxy resin insulator application	Disconnecting switch support insulator
	Fuse holder support insulator
	Load switch support insulator
	Cable support for cubicle type unit substation

direction of action of electromagnetic force. The flat type epoxy resin insulator is said to be the most rationally designed cable support available.

Moreover, installation time can be reduced by using the cable support accessory mounting hardware shown in *Fig. 7*.

Flat type epoxy resin insulator applications are listed in *Table 7*.

VI. CONCLUSION

The development of the 6 kV class flat type epoxy resin insulator, characteristics of the insulator and V type disconnecting switch employing the insulator were described above.

The demand for this type of epoxy resin insulator will be rapidly increase in the future with the prevalence of JIS cubicle type unit substations.

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