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72.5~170KV THREE PHASE ENCAPSULATED SF_6 GAS INSULATED SWITCHGEAR

Takasuke Kodama
Shigemi Mitsuhashi
Hiroshi Nagao
Yujiro Yagi

1 INTRODUCTION

Since the first SF_6 gas insulated switchgear was used practically in Japan, 15 years have already elapsed. During these years, various improvements were made, the phase segregated type was developed to three phase encapsulated type, and reduction of the dimensions was achieved. Recently, space and size reductions of substations have been demanded more and more, and the need of a compact three phase encapsulated type is increasing. This paper introduces the technical points of Fuji Electric's three phase encapsulated SF_6 gas insulated switchgear.

2 FEATURES

Generally, gas insulated switchgear is outstanding at the points of reduced dimensions, harmonization with the environment, high reliability, safety and maintenance ease. In addition to these features, Fuji Electric's three phase encapsulated type SF_6 gas insulated switchgear has the following great features.

(1) Three phase encapsulation on all components

The three phase encapsulation is employed in all the components of switchgear installed in power/substations.

(2) Reduced height

The total height of the 72.5 kV three phase encapsulated SF_6 gas insulated switchgear is reduced to such a level as that it can be transported by an ordinary truck. This height is approximately same as those of 6.6 to 22 kV metal-enclosed switchgear. Further, the height of 145/170 kV class switchgear is so low that they can be transported by ordinary low bed trailer.

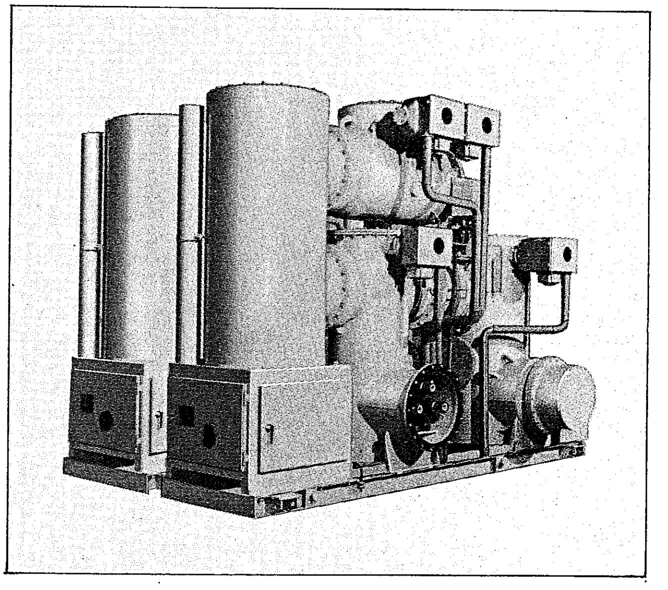
(3) Unified gas pressure

Pressure of the gas filled in the circuit breaker compartment is the same as other compartments and therefore, the maintenance is simplified.

(4) Use of a high performance circuit breaker

Puffer type single pressure gas circuit breakers which employ a high performance double flow interrupter are used. This is used uniformly also for outdoor circuit breakers and has many accomplishments.

Fig. 1 Three phase encapsulated 170 kV SF_6 gas insulated switchgear



(5) Hydraulic operating mechanism

For the circuit breaker, a compact 320 kgf/cm^2 operating mechanism (which uses the minimum number of parts) is used. With the complete block system, the mechanism is constructed to be piping-less type.

(6) Compound components

The isolator and earthing switch are combined, and busbar and isolator are combined.

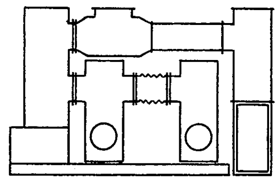
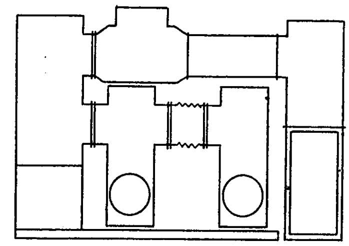
(7) Countermeasure taken against metalic dust

The three phase conductors are well arranged and electric field within the enclosure is suppressed so that metalic dust will not be floated even if metalic dust enters the enclosure.

3 RATINGS

The ratings of the SF_6 gas insulated switchgear (GIS) are shown in *Table 1.*

Table 1 Ratings

			SDF 108	SDF 120		
Model						
Rated voltage		(kV)	72.5	123	145	170
Rated normal current		(A)	1200, 2000, 3000	1200, 2000, 4000		
Rated short-time withstand current		(kA)	31.5	40		
SF_6 Gas pressure		(kgf/cm^2) (20°)	5			
Circuit Breaker	Rated voltage	(kV)	72.5	123	145	170
	Rated breaking current	(kA)	31.5	40		
	Rated break time	(cycles)	3			
	Operating mechanism		320 kgf/cm² oil hydraulic			
Isolator	Rated voltage	(kV)	72.5	123	145	170
	Operating mechanism		Motor, Motor-spring, Manual			
Earthing switch	Rated voltage	(kV)	72.5	123	145	170
	Operating mechanism		Motor, Motor-spring, Manual			
Busbar	Highest system voltage	(kV)	72.5	123	145	170
Surge arrester	Type		SF_6 Gas, ZnO			
	Rated voltage	(kV)	84	108, 120	132, 138	150, 168
	Nominal discharge current	(kA)	10			
Voltage transformer	Type		SF_6 Gas, electromagnetic			
	Rated primary voltage	(kV)	66	110	132	150
	Rated secondary voltage	(V)	110			
	Rated tertiary voltage	(V)	110/3			
	Rated output	(VA)	3 x 500			
	Acculacy class		1.0			
Current transformer	Type		SF_6 Gas insulated ring type			
	Rated primary current	(A)	As required			
	Rated secondary current	(A)	1, 5			
	Rated output	(VA)	10, 30 (Other values upon request)			
	Acculacy class		1.0, 5P, 10P (Other values upon request)			

4 CONSTRUCTION

4.1 Series

To improve advanges on the maintenance realized by using common parts and reliability realized by a mass production of same parts, the series is simplified. Toward the entire range from 72.5 kV to 170 kV, the GIS is grouped into two types. Fig. 2 shows the series.

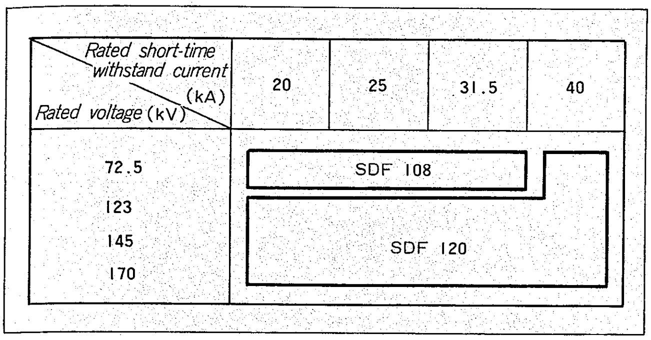
4.2 Components

The components which are most frequently adjacent mutually are busbar and bus isolator, and isolator and earthing switch. To compactly compose the system, the busbar and bus isolator are combined, and the isolator and earthing switch are combined.

4.3 Gas section

Fault disconnection is primarily accomplished by the circuit breaker. Therefore, the circuit breaker is handled as an independent gas section, and the other parts of the switchgear are arranged to be separate gas sections. With this arrangement, the monitoring can be simplified and each section can be separated when a fault occurs. Accordingly,

Fig. 2 Series



the gas section within one circuit unit can be normally segregated to the circuit breaker compartment and other compartments, or when a fault occurs, it can be segregated to the line side, circuit breaker and busbar side by operating the stopping valve. *Fig. 3* shows the gas system.

4.4 Overall construction

Fig. 4 shows the cross-sectional view of the standard double busbar cable feeder unit. Under the basic arrangement, the busbar is laid horizontally on the ground and the circuit breaker is arranged vertically on the front face. The busbar is combined with the bus isolator to be a single unit, and they are segregated by each feeder unit. In case of a double busbar system, a plug-in coupling with bellows is installed in between the busbars so that one busbar can be removed without moving the other busbar.

4.5 Construction of each component

(1) Circuit breaker

The circuit breaker enclosure is located on the control box, and three phase arc-quenching chamber is standing by itself. For the interrupter, the double flow type arc-quenching chamber which has the breaking performance of 40 kA at 245 kV per unit break is used for all 72.5 kV to 170 kV GIS. The moving contact and puffer cylinder are connected to the insulated operating rod. The earth side of the insulated operating rod is totally connected with a link plate for all three phases and connected to an oil hydraulic cylinder. With this construction, all three phases are mechanically driven. When a single phase release is requested, the insulated operating rod is connected to the hydraulic actuator by each phase without using the link plate so that each phase can be operated independently. *Fig. 5* shows the cross-sectional view of the circuit breaker.

(2) Isolator and earthing switch

There are two types of isolator and earthing switch, namely linear type and right-angled type. The linear type is provided on a linear current passage, and right-angled type is provided on a passage branched in right angle. For both the isolator contact and earthing switch contact, the three phases are arranged in parallel, and the operating lever and operating rod are operated simultaneously with a single driving shaft. Thus, the operating link mechanism has been greatly simplified. The isolator with switching capability of loop current disconnecting switch can be constructed simply by installing Fuji Electric's special grid type arc quenching chamber in the stationary contact unit, and all

Fig. 4 Cross-sectional view of double busbar cable feeder unit

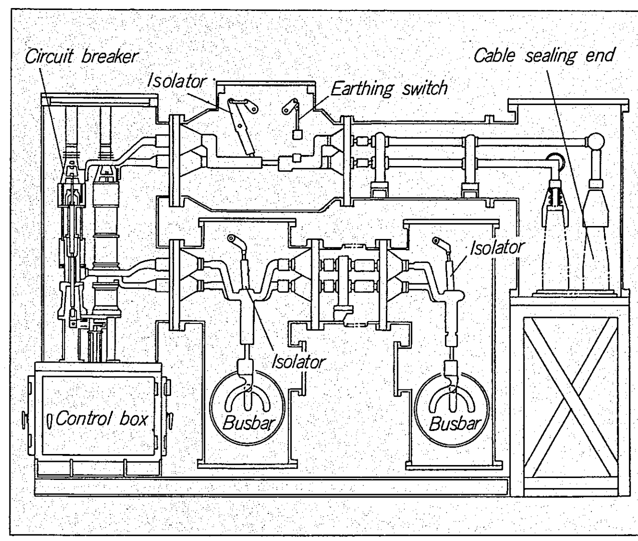


Fig. 3 Gas system

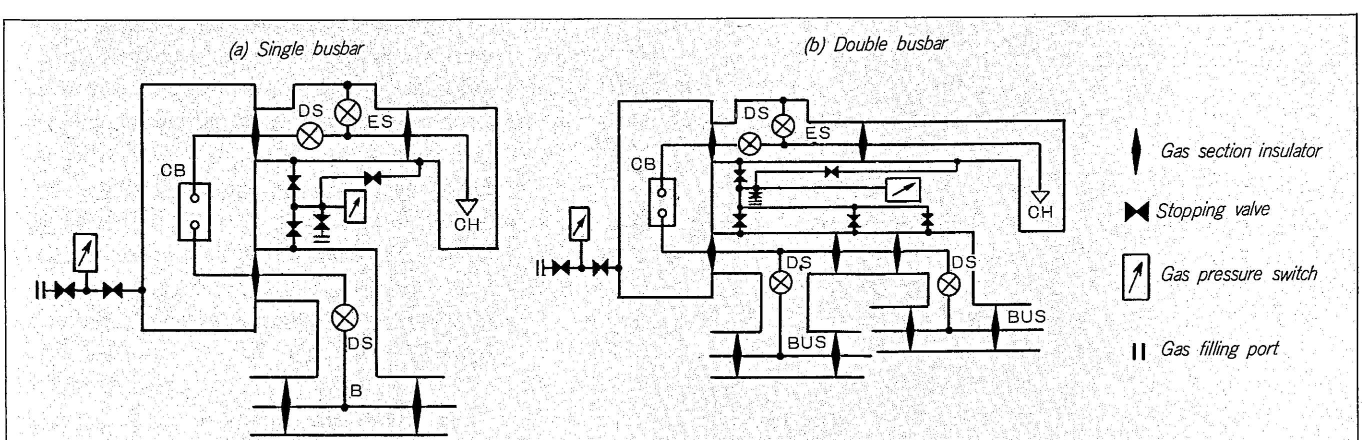


Fig. 5 Cross-sectional view of circuit breaker

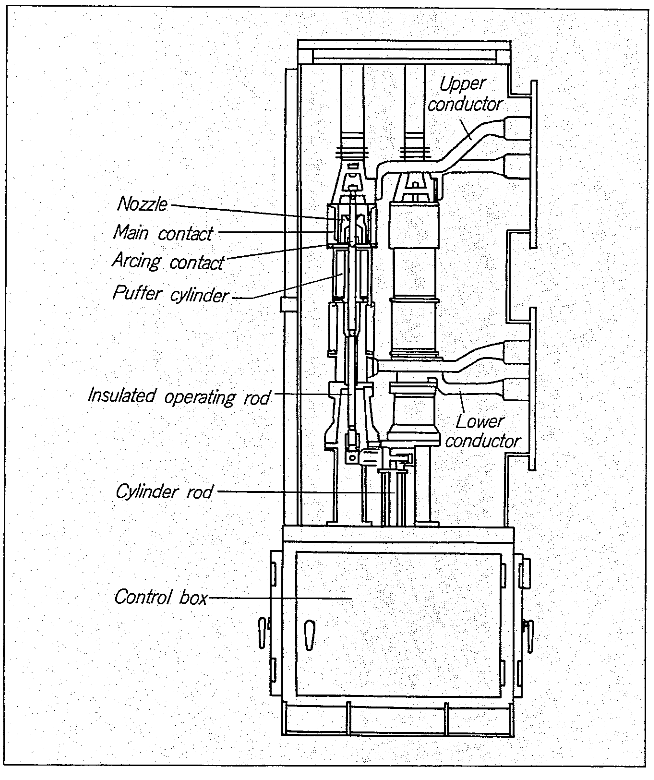
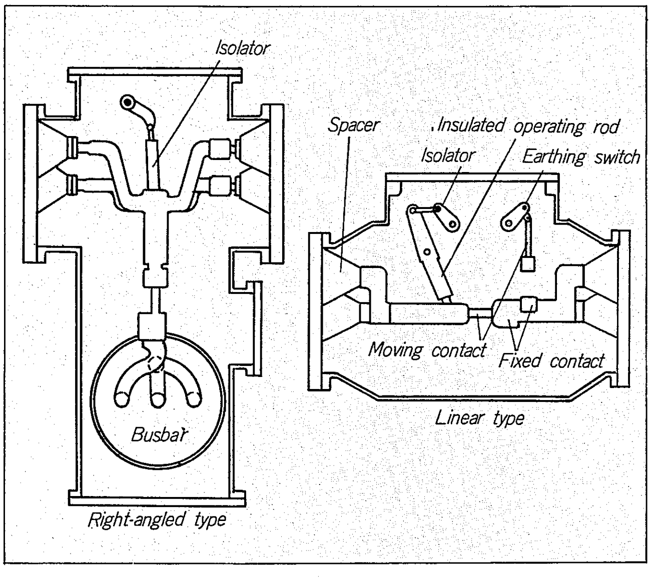


Fig. 6 Cross-sectional views of isolator and earthing switch



other portions are the same as general purpose isolator. When compared to an arc-quenching chamber with a puffer piston, the grid type arc-quenching chamber has such an advantages as that the driving energy is less. *Fig. 6* shows the cross-sectional view of the isolator and earthing switch.

(3) Busbar

The internal surface electric field strength on the bottom of the enclosure is greatly reduced by arranging the three phase conductors in the upper half of the enclosure.

Fig. 7 Cross-sectional view of busbar

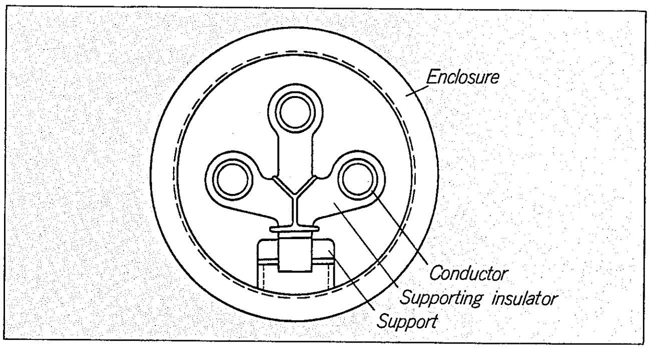
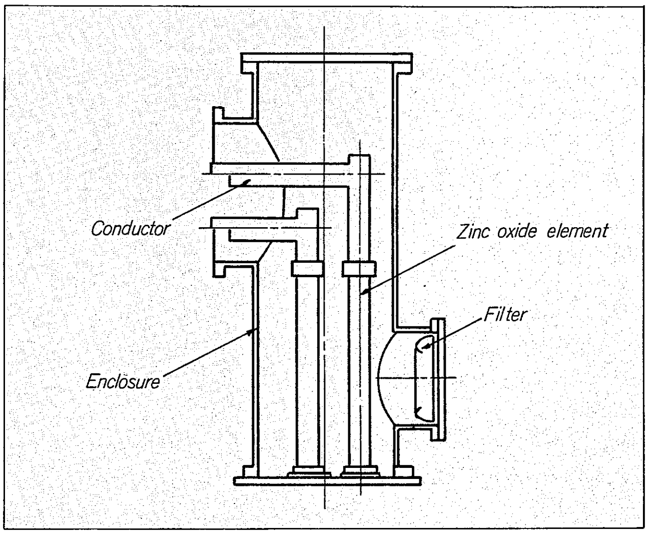


Fig. 8 Cross-sectional view of surge arrester



Because of this construction, the enclosure diameter has been successfully reduced without installing a special dust trap. Further, the insulator is provided with ribs, improving the insulating reliability. The three phase conductors are supported and fixed with a three phase cone type insulator and three phase branched complex post type insulator. Therefore, unbalance of distance between phases of the three phase conductors is eliminated, improving insulation between phases. *Fig. 7* shows the cross-section of the busbar.

(4) Surge arrester

The surge arrester uses a zinc oxide element, the residual voltage characteristics of which are excellent, and all three phases are accommodated in the enclosure. *Fig 8* shows the cross-sectional view of surge arrester.

(5) Voltage transformer

The electromagnetic voltage transformers for all three phases, the windings of which are mutually insulated with plastic foil, are accommodated in the enclosure. In case of a single phase measurement which requires a secondary burden, single phase electromagnetic voltage transformers of the same operating principle can be installed. When secondary burden is not required, voltage detectors with an amplifier which use electrostatic capacity of SF_6 gas can be installed. *Figs 9* and *10* respectively indicate the cross-

Fig. 9 Cross-sectional view of voltage transformer

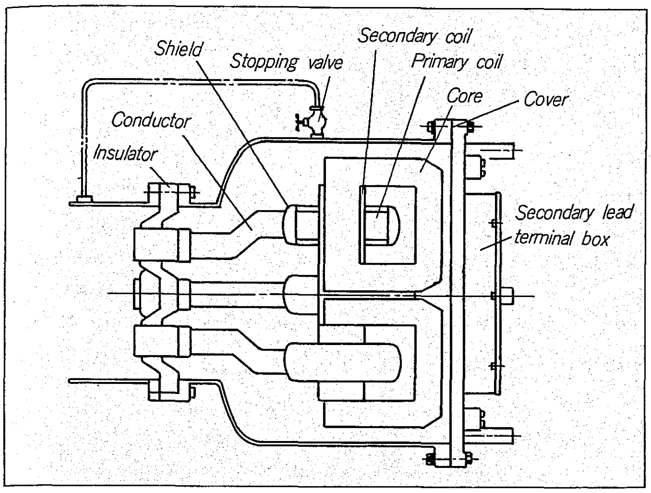
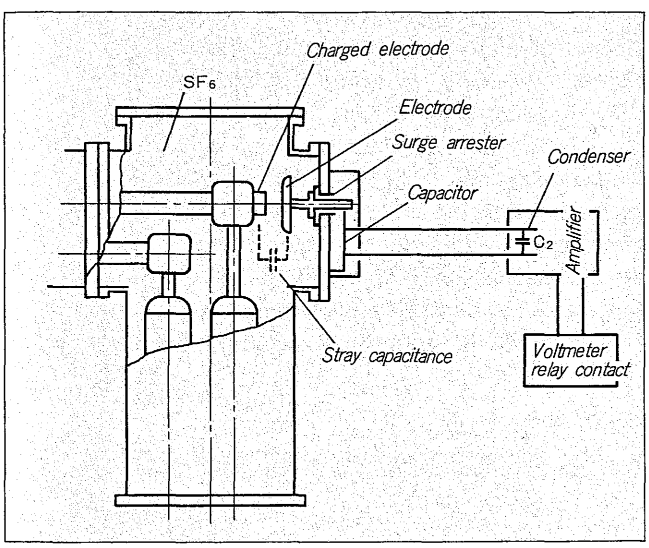


Fig. 10 Operating principle of voltage detector with an amplifier



sectional view of the three phase encapsulated voltage transformer and operating principle of the voltage detector with an amplifier.

(6) Current transformer

Ring type gas insulated current transformers for all three phases which use the high voltage conductor placed in gas as the primary winding are accommodated in the enclosure. Current transformers of this type are used when arranging the current transformer in the busbar side of the circuit breaker and bus coupler unit. *Fig. 11* shows the cross section of current transformer.

When the current transformer is installed in the line side of the circuit breaker, it is economical to use cable through ring or bushing type current transformer because reliability of SF_6 gas insulated switchgear is high. Especially, in case of a Fuji Electric's SF_6 gas insulated switchgear, the bushing type current transformer which is exactly same as dead tank type gas insulated circuit breaker can be used because the pressure of gas filled in the bushing is same as that of the circuit breaker.

Fig. 11 Cross-ectional view of the current transformer

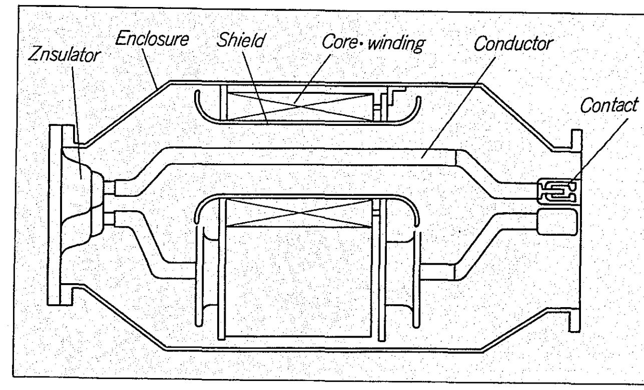


Table 2 Gas pressure

Rated gas pressure (kgf/cm²)	5.0
Alarm gas pressure (kgf/cm²)	4.5

5 DESIGN CONCEPT OF FUJI THREE PHASE ENCAPSULTED SF_6 GAS INSULATED SWITCHGEAR

5.1 Rated gas pressure

According to the careful examination for the rated gas pressure of 72.5 to 170 kV GIS, it is most advantageous to increase gas pressure as much as possible and to minimize enclosure diameter by fully utilizing the outstanding insulation characteristics of SF_6 gas because tank diameter is decided not by temperature rise but insulation at 170 kV 4000A or below. For this reason, with the liquified point taken into considerations, the rated gas pressure is selected to be 5.0 kgf/cm^2.

5.2 Countermeasure taken against metalic dust

When filled gas pressure is raised and enclosure diameter is reduced, influence of metalic dust is anticipated. To cope with the metalic dust in enclosure, generally, a dust trap is provided. However, metalic dust in the enclosure will not be floated when the lower electric field of the enclosure interior is suppressed to a certain level or below. Therefore, in the Fuji's SF_6 gas insulated switchgear, the lower electric field on the enclosure interior is reduced by properly arranging three phase conductors. As the results, the surface electric field within the enclosure of Fuji's SF_6 gas insulated switchgear is extremely low and essentially the switchgear is not affected by metalic dust. The test results are introduced on papers under a separate cover.

Further, as it has been conventionally reported, the ribs on the cast resin insulators placed in SF_6 gas are effective in preventing contamination of the insulator surface with metalic dust, and therefore, all the cast resin insulators placed in SF_6 gas of the Fuji SF_6 gas insulated

Fig. 12 Appearance of cone insulator

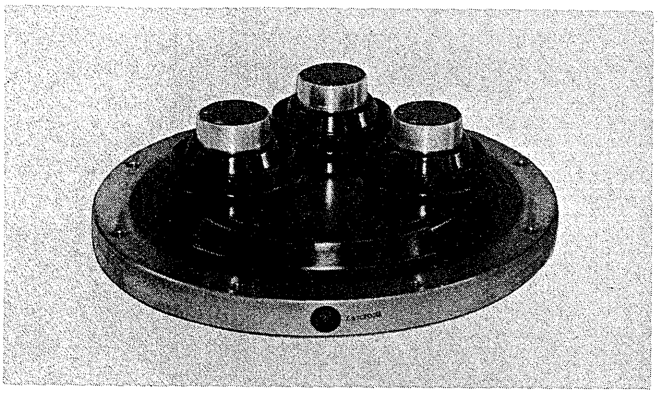
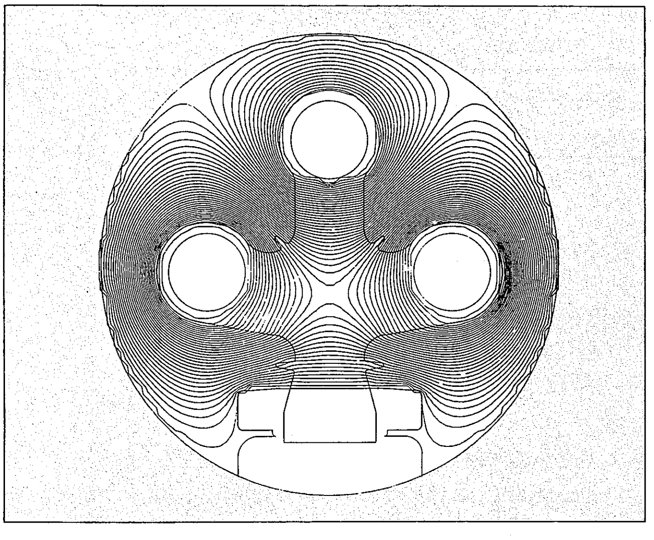


Fig. 13 Example of electric field analysis of post insulator



switchgear are provided with ribs. The effect of ribs on the insulator remarkably appears in a long duration dielectric endurance test for insulators sticked with metalic dust. If the insulator is not provided with ribs, flashover occurs within a short time.

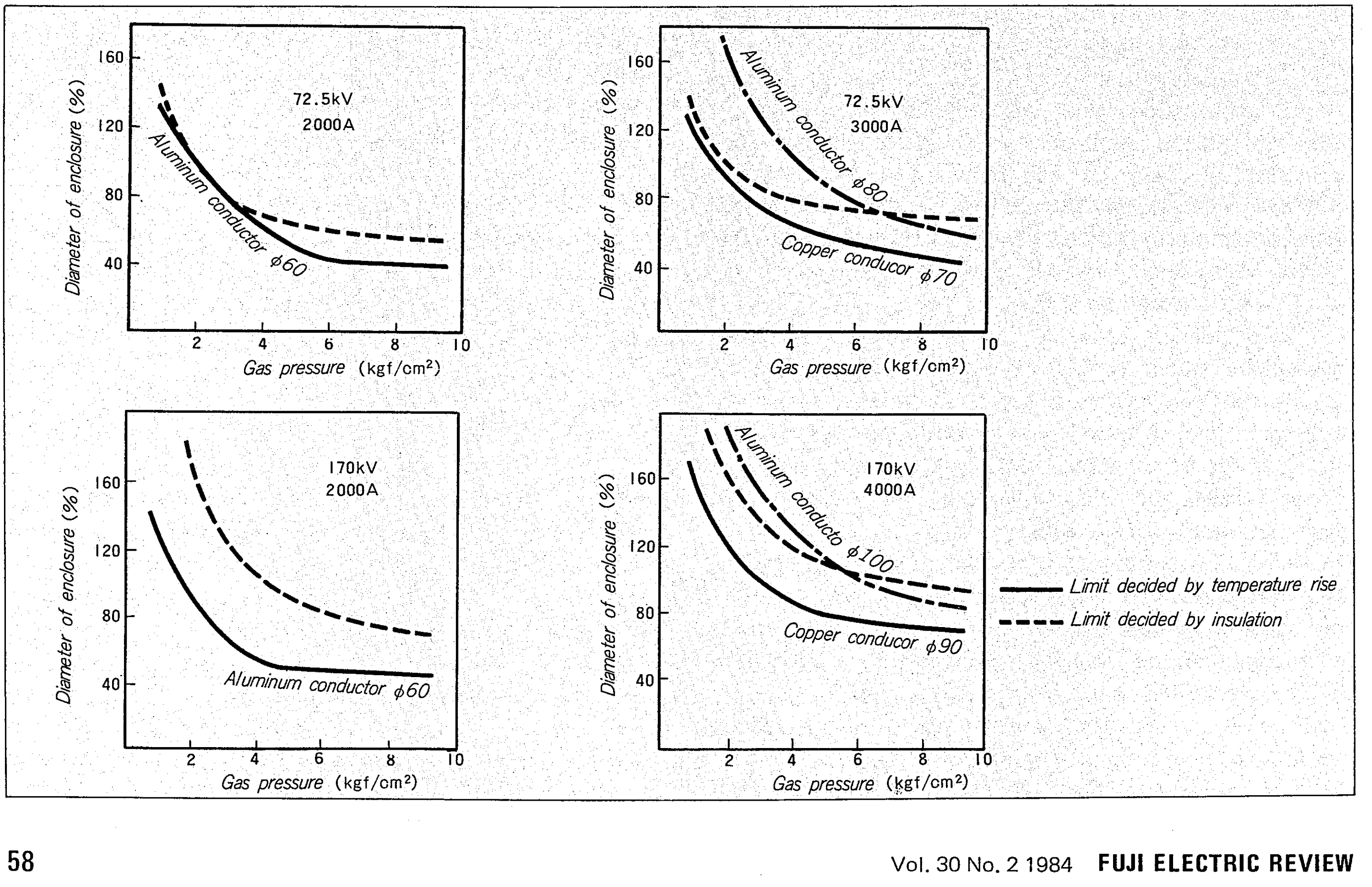
There are two types of insulator, namely three phase cone type and three phase branched complex post type. The cone type is used when gas section is required. The cone insulator is shown in *Fig. 12*. The three phase branched complex post type insulator features that it maintains conductor distance (between phases and against the ground) correctly. For insulators, design of electric field is sufficiently suppressed.

5.4 Consideration for enclosure diameter

For the factors which decide enclosure diameter, there are the size decided by insulation characteristics and the size to secure the enclosure surface area required in suppressing temperature rise. Within the range of 72.5~170 kV, 1200~4000A, the limit decided by insulation is larger than that decided by temperature rise as shown in *Fig. 14*. Therefore, enclosure diameter is so decided that the required insulation characteristics are satisfied.

For temperature rise, both enclosure and conductor temperatures must be examined simultaneously. The enclosure diameter and conductor diameter at which both the enclosure and conductor temperatures reach the limits simultaneously appear to be the curves shown in *Fig. 15*, and with these curves, conductor diameter and material can be decided. Based on the analyzing result like this, Fuji SF_6

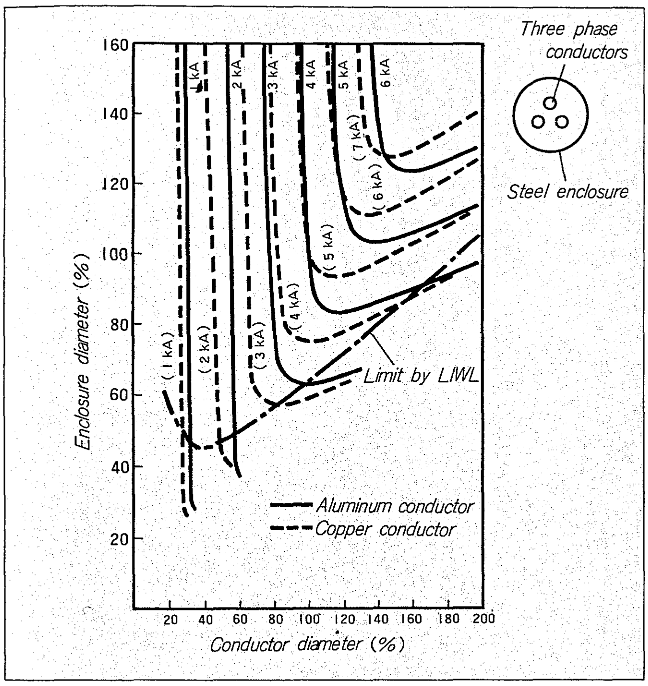
Fig. 14 Enclosure dimensions limited by temperature rise and insulation characteristics



GIS is made available in series of 1200 to 4000A using steel enclosures. Materials of the enclosure and conductor are shown in *Table 3*.

5.5 Arc-quenching chamber and oil hydraulic operating mechanism of circuit breaker

Fig. 15 Relationship between enclosue diameter and conductor diameter



The SF_6 gas insulated switchgear uses puffer type circuit breakers. The arc-quenching chamber is of a double

Table 3 Materials of enclosure and conductor

	Current (A)	72.5 kV	123/145/170 kV
Enclosure	1200	Steel	Steel
	2000		
	3000		
	4000		
Conductor	1200	Steel	Steel
	2000		
	3000	Copper	Copper
	4000		

Fig. 16 Loop current breaking test result

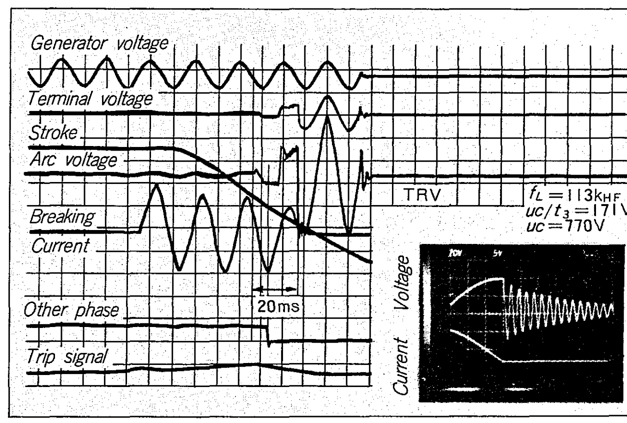


Fig. 17 Typical arrangement

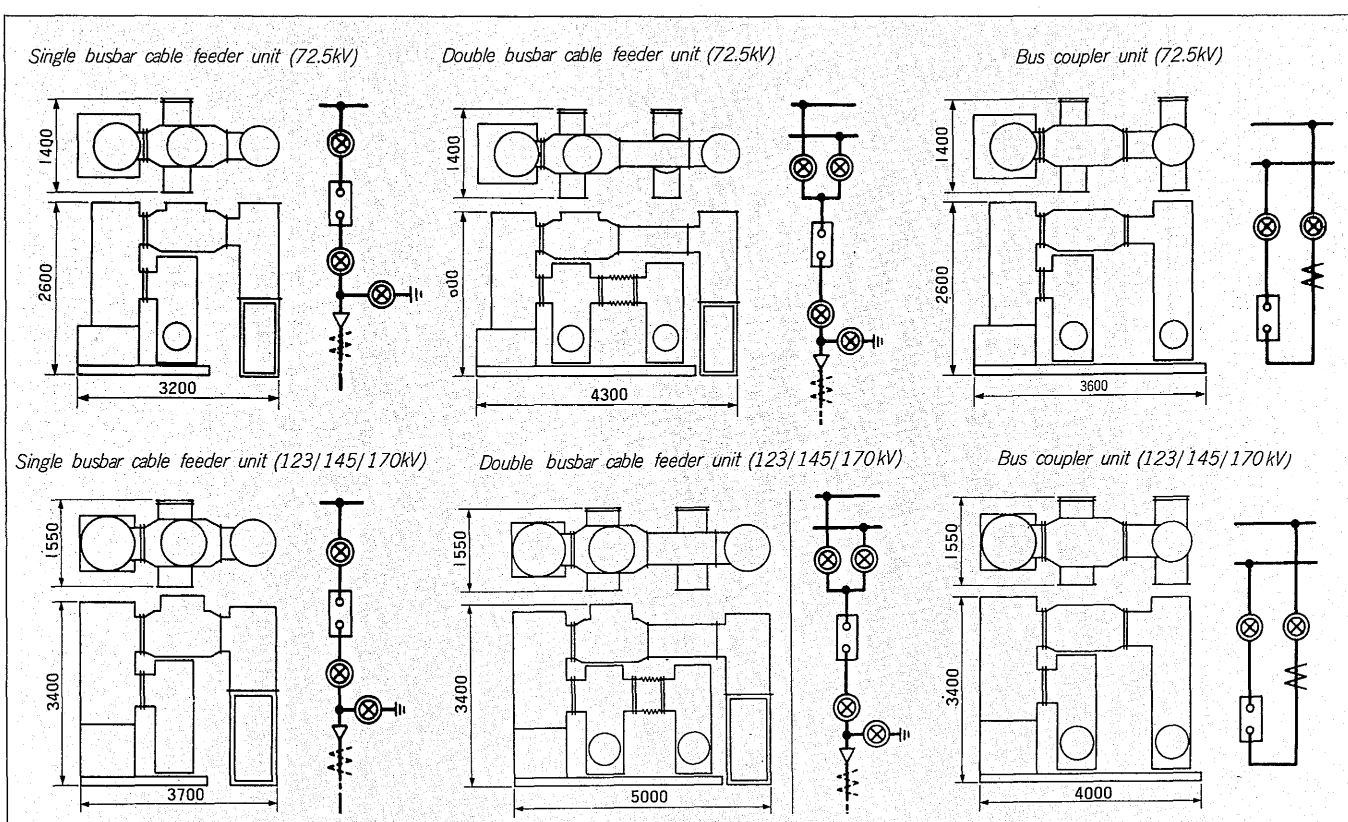
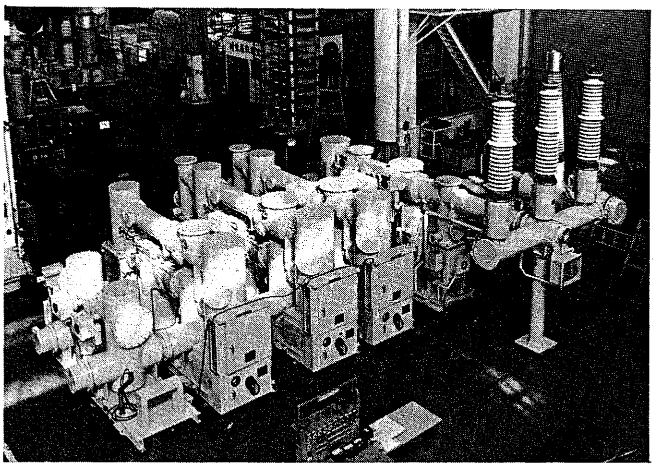


Fig. 18 72.5 kV GIS with double busbar system under shop test



flow type to which the self-arc-quenching effect is added. The operating mechanism is operated by 320 kgf/cm^2 hydraulic oil. As the complete block system is adapted, no piping is required.

5.6 Isolator and earthing switch for current switching

During recent years, it has been requested more and more to provide the isolator and earthing switch, which are primarily used for non-voltage switchings, with a current switching performance. Especially, loop current switching required for bus isolator of a double busbar system or isolator in a distribution substation are very severe because the breaking current is high in the former and voltage is high in the latter. For this reason, on the isolator used for loop current switching, a high performance grid type acr-quenching chamber is installed. To be more specific, grids which are made of ferromagnetic substance are laminated and built in the stationary contact of the isolator. The arc generated when breaking loop current is extinguished while the moving contact passes through the grid arc-quenching chamber. Consequently, arc never comes out into the space between the disconnecting poles, and the safety is extremely high. In addition, the energy required in operating the mechanism could be reduced to about 25% of that of a isolator with puffer chamber. *Fig. 16* shows oscillogram of the loop current breaking test using the grid type arc-quenching chamber.

6 SF_6 GAS INSULATED SWITCHGEAR APPLICATION EXAMPLES.

The basic compositions of Fuji SF_6 gas insulated switchgear are shown in *Fig. 17* by single busbar unit, double busbar unit and bus coupler unit. *Fig. 18* shows a 72.5 kV GIS with double busbar system under shop test.

7 POST SCRIPT

Through the reduction of enclosure diameter realized by raising SF_6 gas pressure endorsed by the countermeasure against metalic dust and temperature rise, reduction of dimensions of circuit breaker realized by using improved type arc-quenching chamber and oil hydraulic operating mechanism, reduction of dimensions of isolator for current switching realized by the use of grid type arc-quenching chamber, compound components, etc., the Fuji three phase encapsulated GIS is one grade more compact as described in this paper. This GIS improves the reliability as number of used parts is greatly reduced. We are intending to make every efforts in improving the products further, and taking this opportunity, we should like ask those concerned for continuous cooperation and advice.