UDC 621. 311. 4

72.5 kV TRIPLE-POLE, COMMON-TANK TYPE SF_6 GAS INSULATED METAL-CLAD SWITCHGEARS (VMH)

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I. INTRODUCTION

In 1966, Fuji Electric focussed its attention on the SF_6-insulated metal-clad switchgear as ultra-compact switching equipment which can make possible the construction of substations to meet the rapidly increasing demands for power with the extremely high prices of land and difficulty in finding sites because of the greater urbanization and also which can meet demands for labor saving in construction work and higher reliability for substation equipment. In addition to basic research on SF_6 gas, attempts were made to develop and test SF_6-insulated equipment. As a result, 72.5~123kV metal-clad switchgear equipment (abbreviated as VMH) and 300kV SF_6 gas breaker were completed in the spring of 1969. This equipment was exhibited to the public to invite evaluations from users. From that time, Fuji Electric has been devoted to improving the performance of gas-insulated switching gears by incorporating users' requirements in accordance with the actual conditions in Japan. Since the first breaker unit was delivered in 1970, about 700 breakers with capacities ranging from 72.5~245kV have been completed and a total of 30 VMH Feeders are operating well to date including a 72.5kV device delivered to the Kimitsu Works of Nippon Steel Corporation in 1970, and a 170kV unit delivered to the Sendai Works of Azuma Steel Co., Ltd. in 1974.

To meet the expanded demands for VMH in the future, Fuji Electric is strengthening its manufacturing system by expanding dust-proof assemblly shops and altering factory layouts, while at the same time, progressing with the development of new models. To make the conventional phase-separated type VMH more compact, Fuji Electric recently developed a 72.5kV triple-pole common-tank type VMH which has been type tested in cooperation with Electric power companies. The first model was delivered to the Soen Substation of the Hokkaido Electric Power Co. in October, 1975 (*Fig. 1*). In keeping with conditions in Japan, the triple-pole common-tank type VMH should become very popular. The 72.5kV triple-pole common-tank VMH is described here.

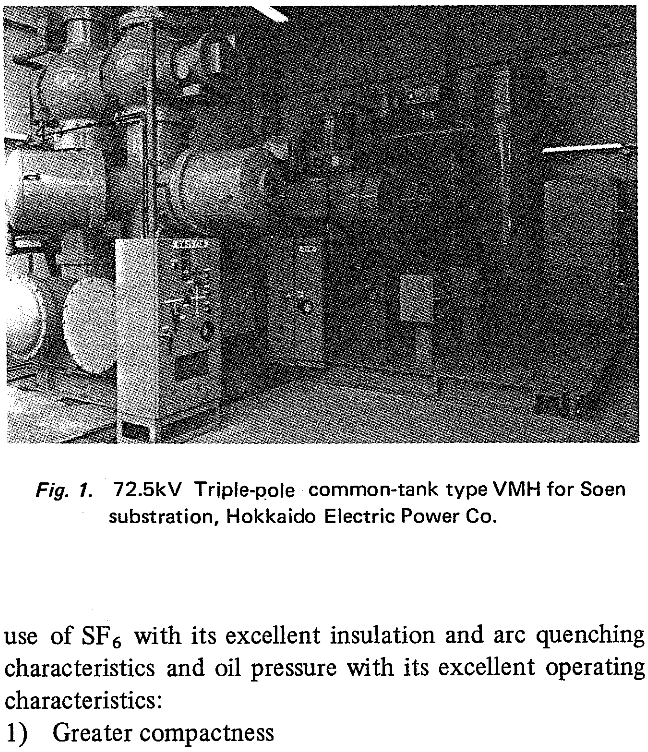


Fig. 1. 72.5kV Triple-pole common-tank type VMH for Soen substration, Hokkaido Electric Power Co.

II. FEATURES

These VMH have the following features because of the use of SF_6 with its excellent insulation and arc quenching characteristics and oil pressure with its excellent operating characteristics:

1) Greater compactness

Compared with the atmospheric insulated types, the phase-separated type of VMH occupies 15~20% of the area and this triple-pole common-tank VMH occupies only 60% of the area of the phase-separated type (*Fig. 2*).

2) Low noise

Operating noise is low because an oil hydraulic operating system is used in the breaker and electrical operating systems are used in the disconnecting and earthing switches. The breaker noise is about 10 phons less than that of breakers with the conventional compressed air operating system and the noise frequency has been shifted mainly to the low frequency range so that the noise is hardly noticeable.

3) Excellent reliability

Since the charged parts are all metal clad, there are few effects from the outside such as damage caused by salt, dust, snow or birds and animals. Since there are no link-mechanism in the operating unit because of the triple-pole common-tank system, these also can not be affected from the exterior. Excellent reliability can be obtained because the number of parts has been reduced.

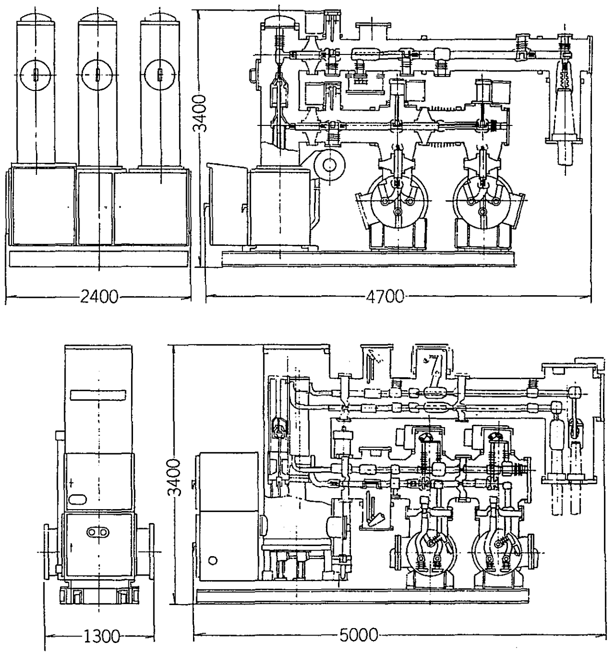


Fig. 2. Sectional view of phase-separate type and triple-pole type

4) Maintenance and inspection-free over long periods

Because the structural components are sealed in SF_6 gas and the breaker driving parts are in operating oil, there is no need to worry about contamination or oxidative deterioration. And maintenance and inspection intervals can be long.

5) Simplified site assembly

Although each feeder unit of the phase-separated type VMH had to be transported by a trailer, two feeder units of the triple-pole common-tank type can be transported by a trailer directly in the factory assembled condition and site installation work is greatly simplified.

6) Improved appearance

Even the phase-separated type VMH was more attractive than the atmospheric insulated substations because of the lack of supporting frame work, etc. which was an advantage from the standpoint of environmental harmony. In the triple-pole common-tank type, the number of metal tanks has been reduced to 1/3 and the driving link mechanism have been eliminated so that the exterior is neat and the appearance is improved.

7) Safety

These VMH are safe with no fear of electrical shocks because of the grounding of all of the structural tanks.

III. RATINGS

The standard ratings of each component are shown in *Table 1.*

IV. CONSTRUCTION

1. Outline

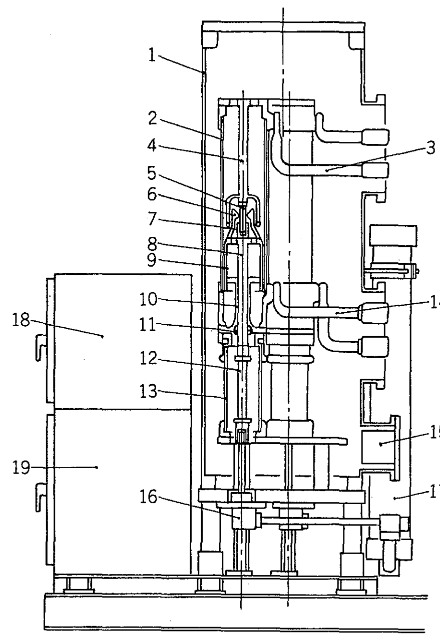
All of the charged parts are sealed in SF_6 gas and

Table 1 Ratings

Component	Item	Ratings			
General		Outdoor use, indoor use			
	Rated voltage	72.5kV			
	Rated lightning impulse withstand voltage	140 (160) kV			
	Rated power frequency withstand voltage	325 (400) kV			
	Rated frequency	50/60Hz			
Circuit breaker	Type	BAK207 ML-ZWE 11			
	Rated current	1,250A, 1,600A, 2,000A			
	Rated breaking current	31.5kA			
	Rated breaking time	3 cycles			
	Drive system	Hydraulic operating system (open, close)			
	Rated driving pressure	220kg/cm^2·g			
	Rated gas pressure	6kg/cm^2·g			
Disconnecting switch	Type	Three phase common-tank type			
	Rated current	1,250A, 1,600A, 2,000A			
	Rated short time current	31.5kA			
	Drive system	Motor system			
	Rated gas pressure	2.7kg/cm^2·g			
Earthing switch	Type	Three phase common-tank type			
	Rated short time current	31.5kA			
	Drive system	Motor system			
Busbar	Type	Three phase common-tank type			
	Rated current	1,250A, 1,600A, 2,000A			
	Rated short time current	31.5kA			
	Rated gas pressure	2.7kg/cm^2·g			
Potential transformer	Type	Epoxy mold winding type			
	Rated primary voltage	$66/\sqrt{3}$kV,			
	Rated secondary voltage	$110/\sqrt{3}$V			
	Rated tertiary voltage	110/3V			
	Rated burden (2ry/3ry)	200VA/200VA			
	Accuracy class (2ry/3ry)	1.0 class/3G class			
Current transformer	Type	Pass-through type			
	Current ratio	100/5A	200/5A	400/5A	$\geq$600/5A
	Rated burden	20VA	20VA	40VA	60VA
	Accuracy class	3.0 class	1.0 class	1.0 class	1.0 class
	Over current constant	$>$10	$>$20	$>$20	$>$20
Lightning arrester	Type	SF_6 gas type			
	Nominal discharge current	10kA			
	Special duty capacity	25μF, 50μF			

Note: Figure in ( ) shows the voltage which should be tested in the case of Japanese Standard.

accomodated in grounded metal tanks. These are supported by epoxy resin insulating spacers and support insulators. The insulating spacers can also be used to partitioning the gas into compartments. Pleats are provided on the surface of the insulating spacers and support insulators and the insulation reliability has been improved.



1. Metal tank
2. Insulating pipe
3. Upper connecting conductor
4. Fixed contact support
5. Fixed contact
6. Nozzle
7. Moving contact
8. Rod
9. Moving cylinder
10. Support
11. Slide contact
12. Insulating rod
13. Insulating support
14. Lower connecting conductor
15. Moisture absorber
16. Hydraulic cylinder
17. Accumulater
18. Control box
19. Drive box

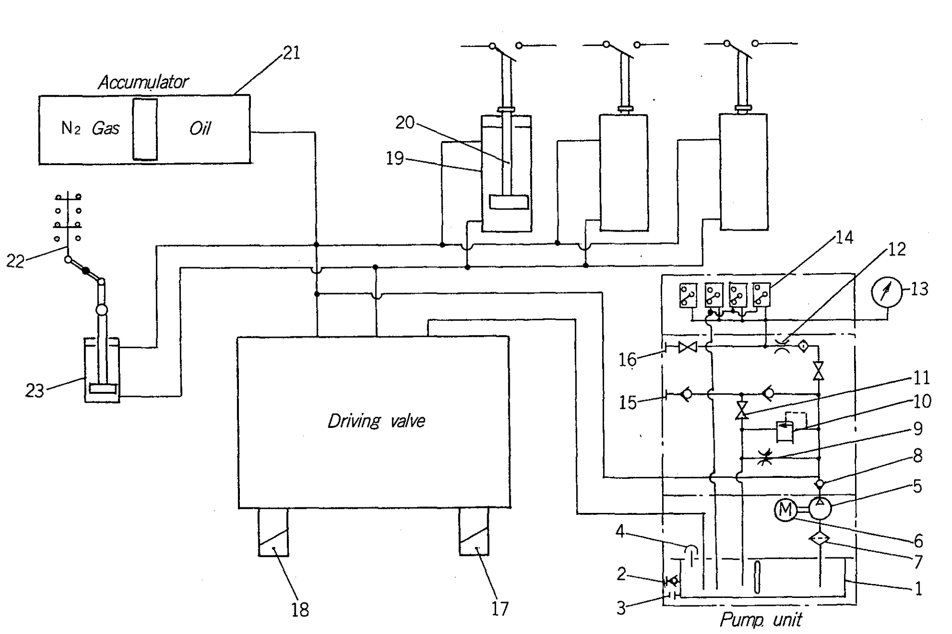
Fig. 3. **Sectional view of circuit breaker**

2. Circuit Breaker

Fig. 3 shows a sectional view of the circuit breaker. The breaker parts are in the sealed tanks at ground potential containing the sealed SF_6 gas. The three phase breaker parts are individually wrapped in insulating pipes to prevent the occurrence of inter-phase short circuits due to the effects of breaking arcs. The arc quenching system is based on the single pressure type (so-called puffer type) so that the same fixed and moving contacts, nozzle, moving cylinder, etc used in the BAP2 series of oil hydraulic driving type single pressure gas breakers developed previously can be employed. The current conducting parts consist of the upper connecting conductors, fixed contact supports, fixed contacts, moving contacts, rods, slide contracts, supports and the lower connecting conductors. There is a hydraulic cylinder in the lower part of the sealed tank and it is directly connected to the insulated operating rod in the SF_6 gas. The accumulators which serves as the oil hydraulic pressure source are attached to sealed tank and the drive box on the front contains the SF_6 gas system of the breaker, the oil operating valve and the oil pump unit. This oil drive unit is exactly the same as the BAP2 series, just as in the breaking parts. The oil system is shown in *Fig. 4.* The details are omitted here since they have already been reported.

3. Disconnecting Switch

There are the linear type disconnecting switch (*Fig. 5*) used in linear current circuits and the right-angle type disconnecting switch (*Fig. 6*) used in parts where the current path bends at right angles. Switching operation is performed by driving the moving contact in the axial direction by turning the sealed driving shaft via an insulating lever in the linear type and an insulating rod in the right-angle type. In both the linear and right angle types, operation is by means of a motor driven operating unit



1. Oil tank
2. Connector for DC pump
3. Plug for drain
4. Air breather
5. Hydraulic pump
6. Motor
7. Moisture absorber
8. Check valve
9. Stop valve
10. Safety valve
11. Stop valve
12. Restrictor
13. Pressure gauge
14. Pressure switch
15. Connector for DC pump
16. Connector for pressure gauge
17. Closing solenoid valve
18. Tripping solenoid valve
19. Hydraulic cylinder
20. Piston rod
21. Accumulator
22. Auxiliary switch
23. Auxiliary hydraulic cylinder

Fig. 4. **Schematic diagram of oil system**

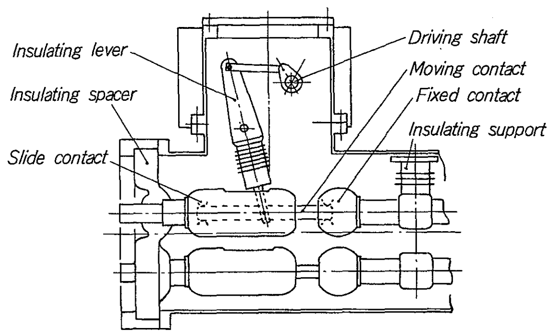


Fig. 5. Linear type disconnecting switch

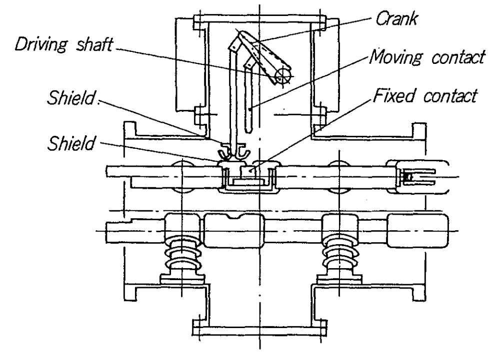


Fig. 7. Linear type earthing switch

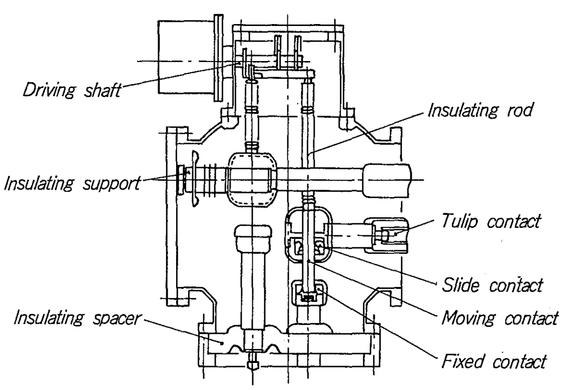


Fig. 6. Right-angle type disconnencting switch

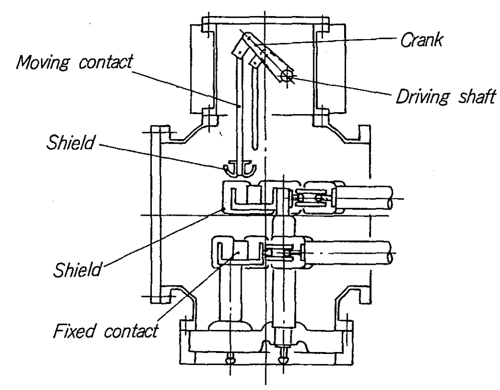


Fig. 8. Right-angle type earthing switch

attached to the outside of the disconnecting switch unit, but operation is also possible by a manual handle. The switching position is indicated mechanically by an indicator attached to the air end of the driving shaft and electrically in the control panel via an auxiliary switch in the motor driven operating unit.

4. Earthing Switch

There are also linear (*Fig. 7*) and right-angle (*Fig. 8*) earthing switches but they are completely the same in their contact and operating structures and differ only in one part of the conductors and the sealed tanks accomodating them. This is very convenient with respect to the overall construction of the VMH. The moving contact is operated linearly by rotation of the driving shaft via cranks which differ in length depending on the phases. The fixed contact is located in the current path and covered by a electrical shield. The operating system is the same motor driven type as in the disconnecting switches and the possibility of manual operation and switching position indication are also the same as in the disconnecting switches.

It is also possible to provide a megger link in the earthing switches for megger measurements of the completely sealed VMH charged parts and measurement of the breaker switching characteristics.

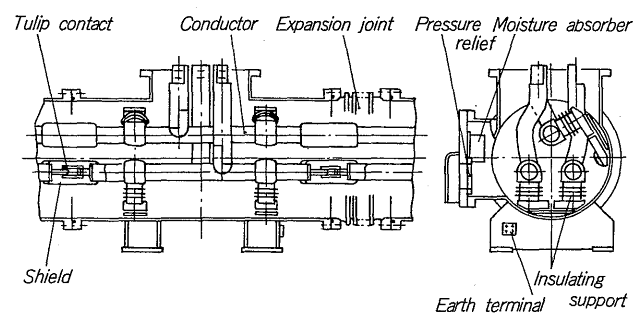


Fig. 9. Bus

5. Bus Bar

Fig. 9 shows a cross section of the busbar. The three-phase conductors are supported by insulating supports in a cylindrical metal tank. The connections between feeder conductors are by means of a tulip contact. There are flange connections among the sealed tanks via gaskets but stainless steel expansion joints can be provided to correct dimensional errors and compensate for thermal expansion. There is also a earth terminal at the support foot of the busbar tank.

6. External Connection Part

Three external connection method are provided: the transformer direct coupling type, gas bushing connection type to overhead lines and the underground cable connection system. *Fig. 10* shows the structure of the cable head.

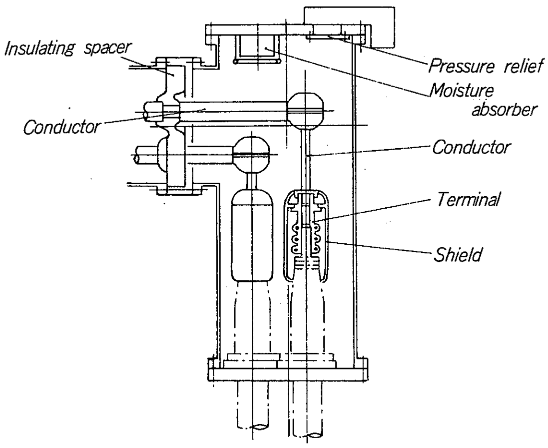


Fig. 10. Cable head

7. Potential Transformer

There has already been a report on the potential transformer. The single-phase type epoxy resin molded potential transformer used with good results in phase separated VMH is also used in the triple-pole common-tank type (*Fig. 11*).

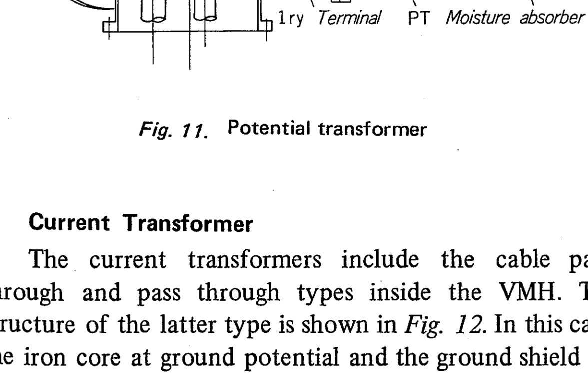


Fig. 11. Potential transformer

8. Current Transformer

The current transformers include the cable pass-through and pass through types inside the VMH. The structure of the latter type is shown in *Fig. 12*. In this case, the iron core at ground potential and the ground shield are accomodated in three-phase metal tanks so that the outer diameter of the metal tanks is greater than that of the metal tanks of other busbar parts.

9. Voltage Checker

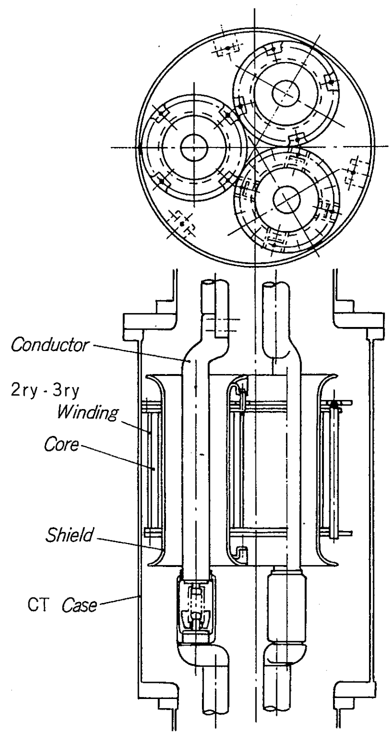


Fig. 12. Current transformer

Since the charged parts are completely sealed when the cables are led in, it is necessary to provide a voltage checker utilizing the static capacity of the insulating support to detect any voltage inside the triple-pole common-tank VMH just as in the phase separated VMH.

10. Control Panel

There are separate control panels on the front and rear of the breaker. The control panel on the front of the breaker contains the electrical interlocking switches among the breaker, disconnecting switches and earthing switches, the VMH general fault indicator, a mimic skeleton, operating switches of the various switches, etc. The control panel on the rear of the breaker contains all of the input control cable terminals for the VMH, the SF_6 gas circuit parts except the breaker, etc. out of consideration for cases when the breaker is pulled out toward the front.

V. GAS SYSTEM

1. Gas Compartments

The gas for the structural components is divided into compartments by means of insulating spacers to prevent the spread of internal defects and facilitate maintenance and inspection. Moisture absorber is inserted in each compartment and the amount of moisture in the gas is kept to a minimum. *Fig. 13* shows a sample of gas system with single busbar and cable connections.

2. Gas Density Monitoring and Protection

Each gas compartment contains a pressure switch with a temperature compensation. An alarm is given when the

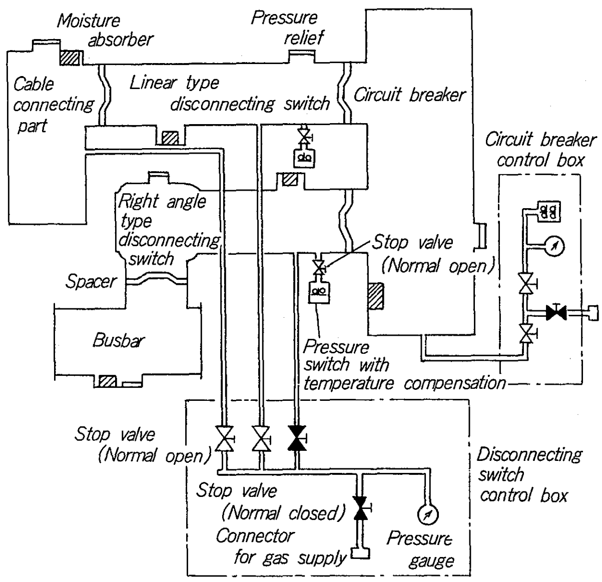


Fig. 13. Sample of gas system diagram

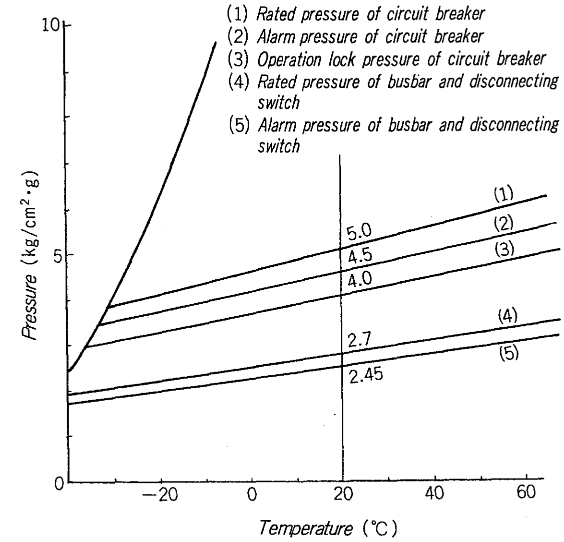


Fig. 14. Gas pressure diagram

gas density drops below a set value. This gas pressure system is illustrated in *Fig. 14.*

The system is designed so that the insulation of the various components is resistant to test voltages at the alarm pressure (density) and it is able to withstand normal operating voltage even when the gas pressure drops and becomes equal to the atmospheric pressure. If the gas pressure should exceed the normal value, breakage of the tank is prevented by the release of gas by means of pressure relief device.

VI. TESTING

Various deliberate considerations have been given to the manufacturing process including the selection of suitable materials, special processing of the flange joint surfaces, and assembly in dust-proof shops to prevent the incorporation of moisture or dust. However, careful testing is also performed to ensure suitable reliability.

VMH technology is based on two main points: the prevention of gas leaks and mold insulator performance and these points are very severely tested. With respect to air tightness, air tightness is tested at all points using a high sensitivity helium leak detector for the metal tanks forming the outer casing of the VMH before assembly. Pressure withstand tests are also performed using water pressure. Before shipment, an air tightness test is performed by the integration method using an SF_6 gas leak detector with the entire VMH transport units wrapped in an airtight bag. With respect to the insulation materials such as the insulating spacers and insulating supports, corona and voltage withstand tests are performed at all points before assembly and parts with no abnormalities are used.

For each component, type tests are performed in accordance with various standards. For the VMH as a whole in the assembled condition, operation, temperature, short-time current, voltage endurance, corona and seismic (*Fig. 15*) tests are performed to make sure there are no problems.

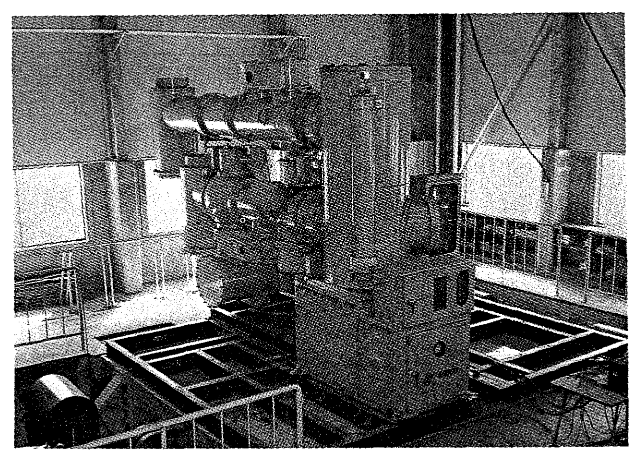


Fig. 15. View of earthquake testing

VII. TRANSPORT AND INSTALLATION

Two assembled feeders on an installation base which also serves as the transport base are transported directly on a trailer. Therefore, the only work at the site is fixing of the base, connection of the busbars, connection of the main cables and bushings and connection of the control wiring. During transport, the parts which are not disassembled at the site are filled with SF_6 gas and the parts which are disassembled with dry nitrogran at a pressure slightly in excess of atmospheric pressure. Therefore, little time is required at the site for gas filling.

After or in parallel with installation work, operation, airtightness, contact resistance, voltage endurance and other tests are performed.

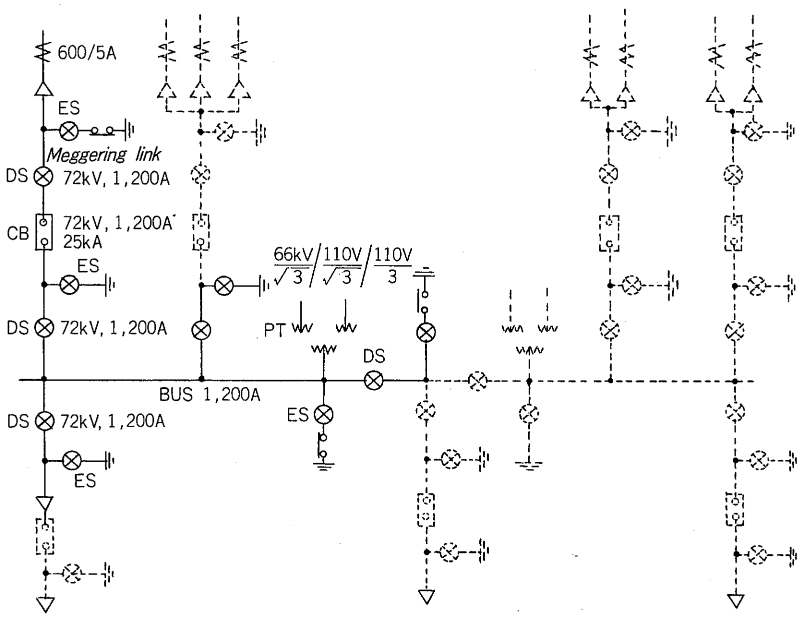


Fig. 16. Single line diagram of Soen substation

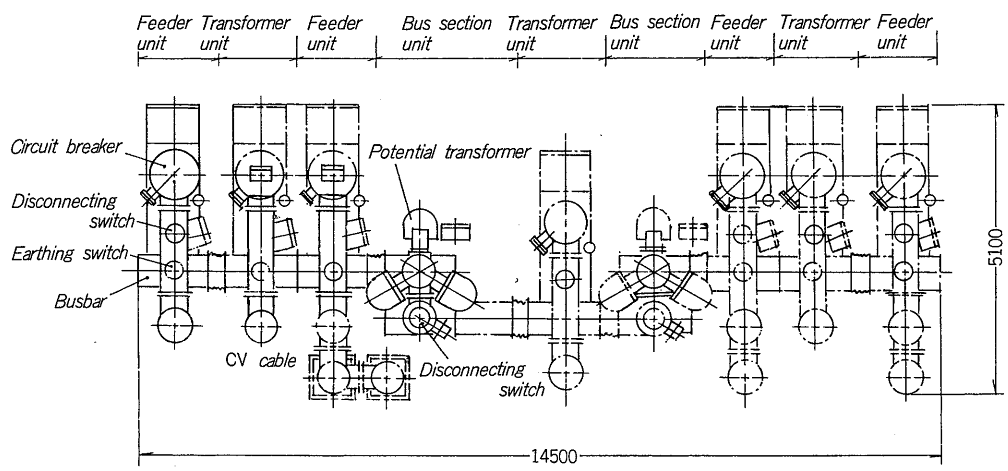
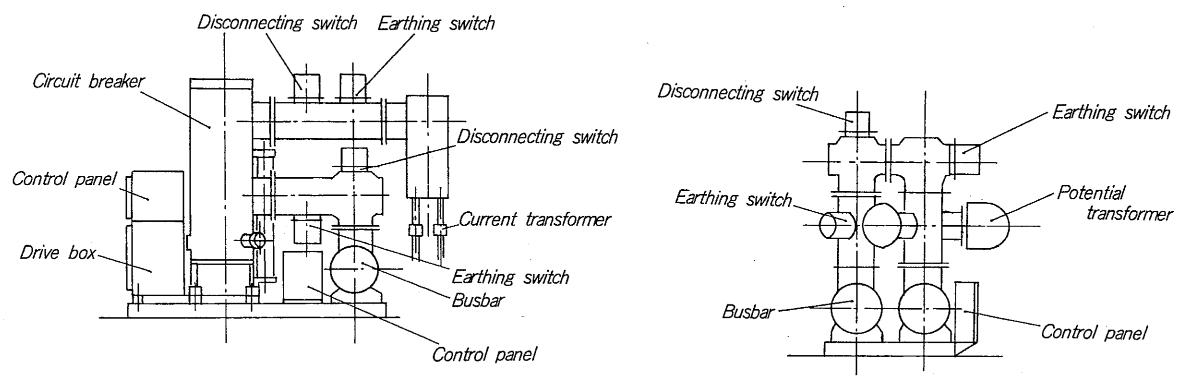


Fig. 17. Plan of Soen substation



(a) *Receiving unit* (b) *Bus section unit*

Fig. 18. Feeder unit and bus section unit

VIII. 72.5kV TRIPLE-POLE COMMON-TANK VMH DELIVERED TO THE SOEN SUBSTATION OF HOKKAIDO ELECTRIC POWER CO.

The Soen Substation, part of which went into operation from November, 1975 will be an indoor distribution substation with three transformer feeders units and four receiving feeders units. *Fig. 16* shows a single-line diagram and *Fig. 17* a plan of the substation delivered by Fuji Electric. The broken lines show parts to be added in the future. *Fig. 18* shows side views and *Fig. 19* a photo of the VMH assembled in the factory. Disconnecting and earthing

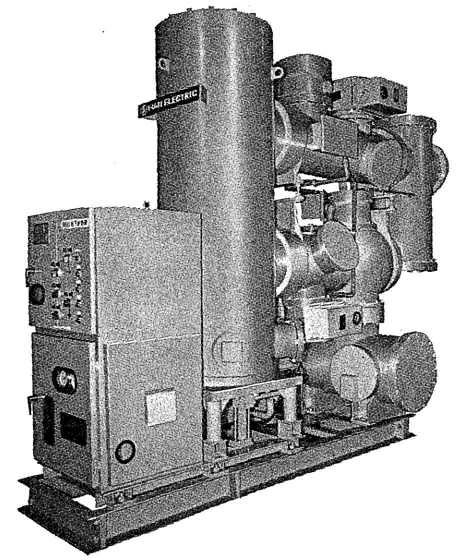


Fig. 19. VMH for Soen substation in the factory

switches have been provided so that there will be no power interruptions, and to facilitate the additional construction work, future parts including the gas and control systems were delivered.

For voltage endurance tests at the site, gas bushings were attached to the upper part of the cable connection head. In the case of VMH test the conductors connected to the cables were removed and an AC voltage was applied and in the case of the cable test, the conductors connected to the VMH unit were removed and a DC voltage was applied. The bushings for site voltage endurance tests can be seen at the back of *Fig. 1.*

IX. CONCLUSION

This article has given an outline of the 72.5kV triple-pole common-tank metal-clad switchgear (VMH). This triple-pole common-tank type satisfies various requirements for switchgears to a greater extent than the phase separated type from such standpoints as less space required, simplified equipment, higher reliability and shorter construction period. In the future, it is planned to promote development and arrange the manufacturing system of equipment to achieve more rational substations in keeping with users' requirements.