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APPLICATION OF FUJI SF_6 GAS INSULATED METALCLAD SWITCHGEAR (VMH) FOR PRIVATE SUBSTATION

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I. INTRODUCTION

With the rapid increases in the utilization of power in industry, there has been a tendency for the receiving voltages in non-public utility receiving facilities to increase. There have also been investigations and improvements of the general construction of systems in industrial compounds. For example, there have been remarkable changes every year even in the outer views of extra high tension receiving facilities over 60 kV class. In 1955, the iron structure substation shown in *Fig. 1* was very common. By 1965, this type had given way to the structureless type shown in *Fig. 2* and from 1970, the cubicle type including ABB as shown in *Fig. 3* has become popular since the space requirements are much less than previously. Recently, in non-public utilities there have been investigations of the use of SF_6 gas insulated metalclad switchgears, which are being used in public utilities. They offer many advantages including labor savings and less maintenance in factories, buildings, etc., and more compact equipment. This article is intended to serve as a reference to those planning the application of the gas insulated metalclad switchgears in non-public utility special high tension substations.

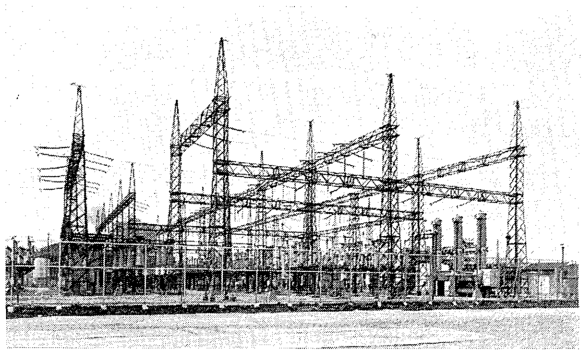

Fig. 1 154 kV class substation of Chiba Works, Kawasaki Steel Co., (1957)

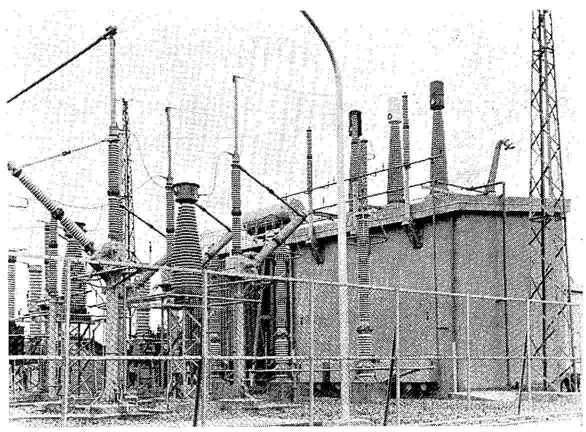

Fig. 2 154 kV class structureless substation of Tokyo Metropolitan Bureau of Water Works (1964)

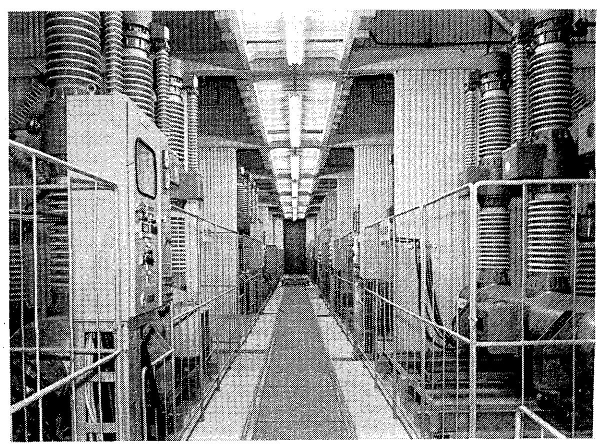

Fig. 3 66 kV cubicle including ABB of Kimitsu Works, Nippon Steel Co. (1970)

II. FEATURES OF THE FUJI VMH

The VMH is a unified switchgear which uses SF_6 gas as the arc extinguishing medium in the breaker and also excellent insulation medium of bus, disconnecting switches, current transformers, etc. This unified form presents many advantages in respect to design and construction. The details are omitted here and only the main features are given below.

1) It is of the self standing type with no fabricated base.
2) The overall installation can be more compact since compound component elements are used.
3) The space is reduced because three conductors are located in a common capsule bus system.
4) By giving special consideration to restricting iron loss in the housing, mild steel which is easy to treat and has greater mechanical strength is used.

5) A special base fitting method is employed so that no stress occurs in the housing due to temperature changes during operation.
6) Earthquake proof design is used on the basis of vibration test results.
7) Special design and construction techniques are employed in the epoxy resin mold parts as the internal conductor support. This provides excellent insulation with little chance of corona occurring.

III. SPECIFICATIONS OF THE FUJI VMH AND OTHERS

When the VMH is employed in non-utility receiving substations, it is necessary to plan not only for the specifications of the equipment but also to take into consideration various factors such as connection with external circuits, transport, installation, site tests, operation and maintenance.

1. VMH Specifications

1) Ratings of breaker, etc.

Table 1 shows the F-type circuit breaker series for VMH of the 60∼140 kV class which is the usual voltage range of non-public utility special high tension receiving substations. In all cases, the breakers consist of an arc extinguishing unit with one arc interrupter but the operation of the double pressure type shown in the table is by means of an oil pressure system at 200 atmospheres. The rated currents can be selected between 1,200 A and 2,000 A. The bus are standardized at 1,600 A or 2,500 A and the branching parts (breaker, disconnecting switch, etc.) at 1,200 A or 2,000 A.

There are two types of disconnecting switches: the rectangular type and the linear type. The selection is made on the basis of component advantages. Operation is by means of the 3-pole, single throw motor driven system. In cases where switching capability for small currents or load currents is required, a load switch with motor driven spring operation is used. The rated current in all cases is 1,200 A. There are two types of earthing switches: one with making capacity and one with no making capacity. The former is of the single pole, single throw manual spring type and is attached to the receiving end when required. The latter is attached to the inlet or outlet of the breaker and is of the 3-pole, single throw motor driven type.

2) Current and potential transformers

Table 1 Table of F Schalter for VMH

Rated interrupting current \ Nominal voltage	66/77 kV	110 kV	154 kV
25 kA	VHP 930 Single pressure	VHP 930 Single pressure	
31.5 kA		VH 930 Double pressure	VH 930 Double pressure

The standard current transformer is of the through type. Its characteristics are shown in *Table 2*. As can be seen from this table, the overcurrent constant is small in the region of small primary current in respect to a constant burden. Therefore, various measures can be taken such as connecting a secondary coil in series in the permissible space range or utilizing a transistor type relay with a small burden in the connected load. When the conditions are still not good, a wound type current transformer can be used, and the primary current is led out by a coaxial conductor as shown in *Fig. 4* (applicable in the 60∼100 kV class).

The characteristics shown in *Table 2* can be preserved in this case since it is easy to obtained the required ampere turns on the primary side.

When a potential transformer is used, three single phase grounded type potential transformers are combined. The main insulation is by means of epoxy

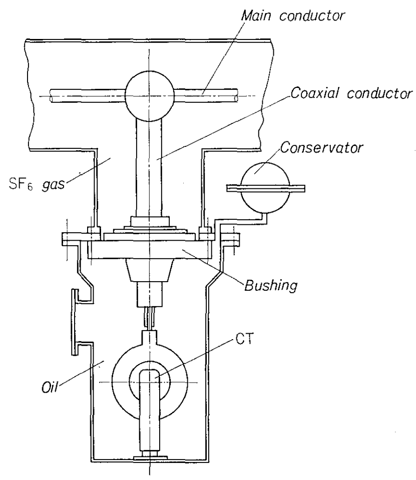

Fig. 4 Wound type current transformer for VMH

Table 2 Table of characteristics of through type current transformer

A \ VA	5	10	15	25	40	100
100	20	10	10	5		
150	20	20	10	10	5	
200	20	20	20	10	5	
300	20	20	20	20	10	5
400	20	20	20	20	10	5
500	20	20	20	20	20	5
600	20	20	20	20	20	10
750	20	20	20	20	20	10
1000	20	20	20	20	20	10
1200 or over	20	20	20	20	20	20

Note:
Class of error 1.0 class
3.0 class
Not available

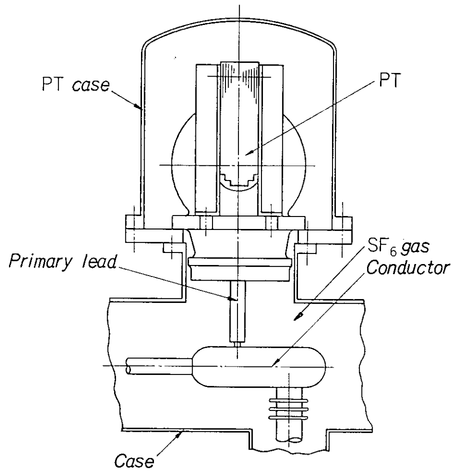

Fig. 5 **Mounting of potential transformer**

resin mold and the SF_6 gas protects against creepage. The epoxy resin mold type is used in the 60∼100 kV class and its mounting to the VMH is as shown in *Fig. 5*. When there are high voltages of over 140 kV, a condenser type potential transformer is used.

3) Detector

Since the VMH is totally enclosed, it is impossible to tell from the exterior whether the internal conductors are charged or not. To counteract this, adetector as shown in *Fig. 6* can be attached when required.

The principle of this detector is to lead the charging current on the insulator to the exterior and indicate it by a lamp or meter. This can also be used as a corona detection terminal.

2. Connection with External Circuits

1) Cable connections

Fig. 7 shows the details of the connection of the VMH with a cable. Standards for the dimensions of this connection part were decided by a committee composed of representatives of power companies, electric machinery manufacturers and wire manufac-

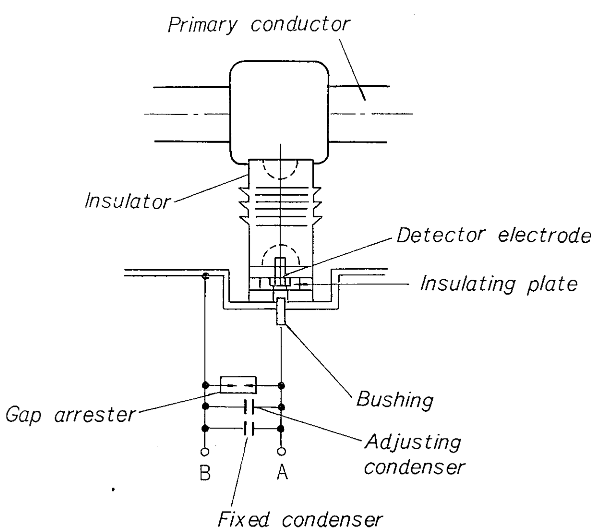

Fig. 6 **Voltage detector**

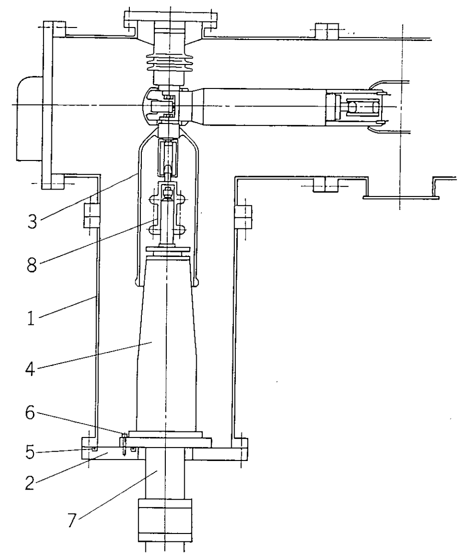

Fig. 7 **Cable connection for VMH**

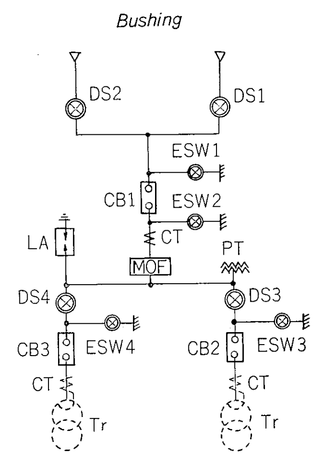

Fig. 8 **A skeleton diagram of receiving line**

turers. *Table 3* and *Table 4* show these specifications.

2) Overhead line connections.

There are many cases where non-public utility receiving line is taken from overhead lines. When the disconnecting switch which is the boundry line of responsibility even in cable receiving is of the conventional type, there are also cases when a direct connection can be made between the VMH and overhead lines.

When the overhead line depending on an air insulation is connected to compact gas insulated equipment, it is necessary to give sufficient consideration to the connection conditions. For example, with the overhead line lead-in system shown in the *Fig. 8* skeleton diagram, the arrangement shown in *Fig. 9* can be considered.

3) MOF

MOF should be determined in coöperation with power companies but we are prepared for supply of any form MOF.

4) Connection with power transformers

The layout of the overall receiving equipment will vary considerably in accordance with the connection method between the VMH and the main power transformer.

In the case of $1\sim2$ transformer banks with $1\sim2$ receiving circuits, it is desirable to connect the VMH and the transformer directly via a gas duct in order to make the substation more compact.

When there are more banks, the transformer installation area becomes larger than the overall space for the VMH and the connection with the VMH should be by cable.

The points which must be considered in the case of directly coupled transformers are mixing of insulation oil and the SF_6 gas, separate sinking, transmission of vibrations, etc. *Fig. 10* shows an example of the construction of a connection part. In this system, there is absolutely no worry even if the SF_6 gas should leak since it will still be separated from the transformer side due to the presence of an intermediate chamber.

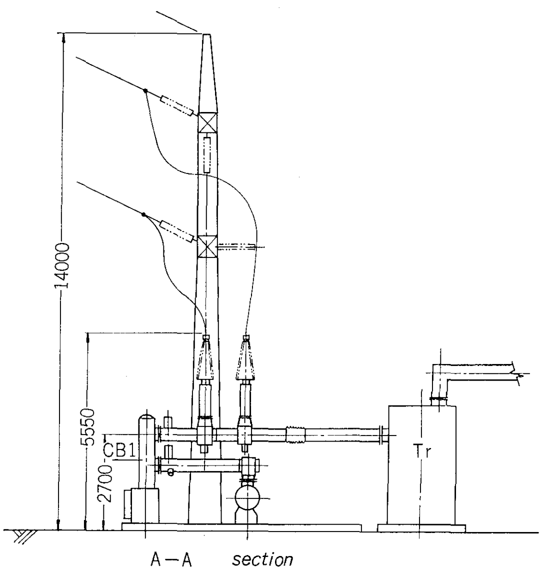

Fig. 9 A layout example of transformer and VMH of overhead line lead-in system

3. Site Operation

1) Transport and installation

Since one VMH unit is transported by an instal-

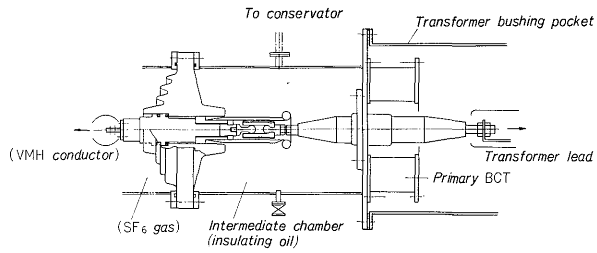

Fig. 10 VMH and transformer connection

lation base, the only work required at the site after transport is fixing of the base, connection of the bus lines, cable connections and control cable connections.

Table 3 **Share of manufacturing**

Manufacturer / Parts	Cable maker	Switch gear maker
Switch gear case (1)		○
Bottom plate (2)		○
Shield ring (3)		○
Bushing (4)	○	
Packings (5)		○
Bolts (6)	○	
Connection tube (7)	○	
Terminal (8)		○

Note: Numbers are those in Fig. 7.

Table 4 **Share of construction work**

Undertaker / Parts	Cable maker	Switchgear maker	Remarks
Connection of connection tube and bottom plate	○		
Connection of bottom plate and switch gear case		○	

As can be seen from the example in *Fig. 11* for the $60\sim100$ kV class, the installation sequence is preparation of a pit in the concrete floor, embedding the channel base in the pit, adjusting the level and finally bolting the attachment base which also serves as the transport base in place.

2) Site tests

With the revision of technical standards for electrical equipment, new standards have been added for gas insulated devices including protection equipment, alarm conditions.

The site test items are given below on the basis of the tests required from these standards and at the time of installation. At present, investigations are underway concerning the general standardization of the VMH by IEC standards.

(1) Construction checks
  a) General structural test
  b) Leakage test
  c) Main circuit resistance test
(2) Switching test
(3) Sequence interlock test
(4) Withstand voltage test at site

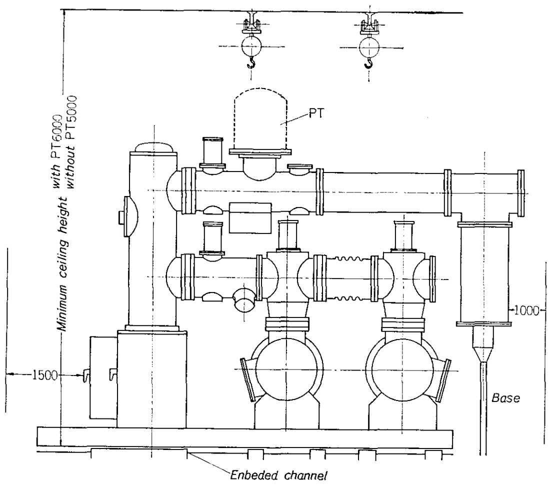

Fig. 11 VMH setting at site

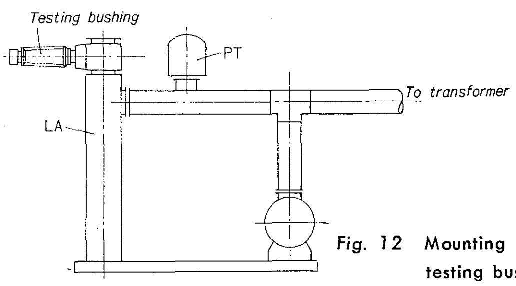

Fig. 12 Mounting of testing bushing (a)

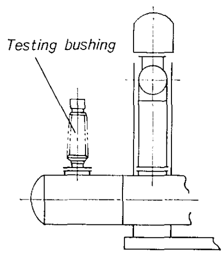

Fig. 13 Mounting of testing bushing (b)

There are two methods for performing these tests. One is the method of attaching a bushing at the head part of the breaker or lightning arrester as shown in *Fig. 12* and the other the method of attaching the test bushing to the bus tube as shown in *Fig. 13*. Since it is easy to make a three-phase connection in the bus, three phase tests were conducted in all cases using one bushing for testing. When the VMH is connected directly to a power transformer, the test transformer must have a capacity such that the transformer can be tested simultaneously.

When it is planned to use the VHM indoors, it is necessary to give sufficient consideration to transportation, testing and maintenance.

4. Checking and Maintenance

It is not necessary to make daily inspections and all that is needed is to change the moisture absorbent once every six years. Therefore, the inspection space can be small when the VMH is installed indoors but in cases when the switching frequency is high or in cases when internal inspections must be considered after long periods of use, the installation space required indoors is a minimum ceiling height of 6 m with a potential transformer and 5 m with no transformer as shown in *Fig. 11*. It is also recommended to have a space of more than 1.5 m in front of the breaker and a space of more than 1 m behind the cable connection part.

IV. APPLICATIONS OF FUJI VMH

1. Applications to the Standard Skeleton Diagram

These are various types of combinations in non-

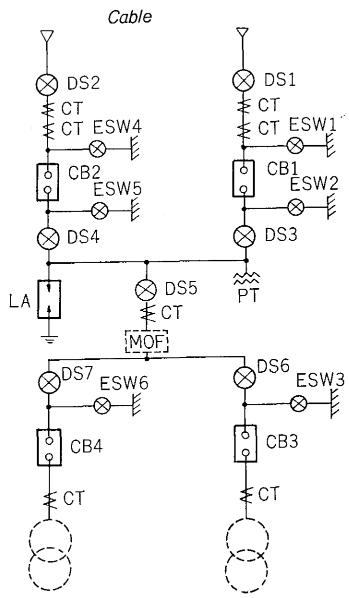

Fig. 14 A skeleton diagram of two receiving circuits and two transformer banks

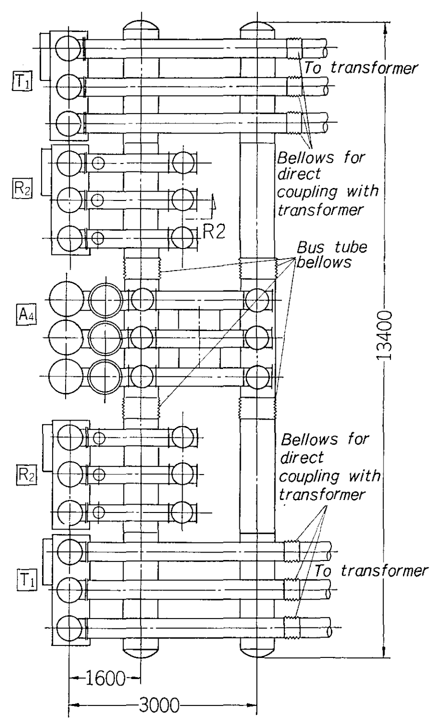

Fig. 15 A layout example of VMH with two receiving circuits and two transformer banks

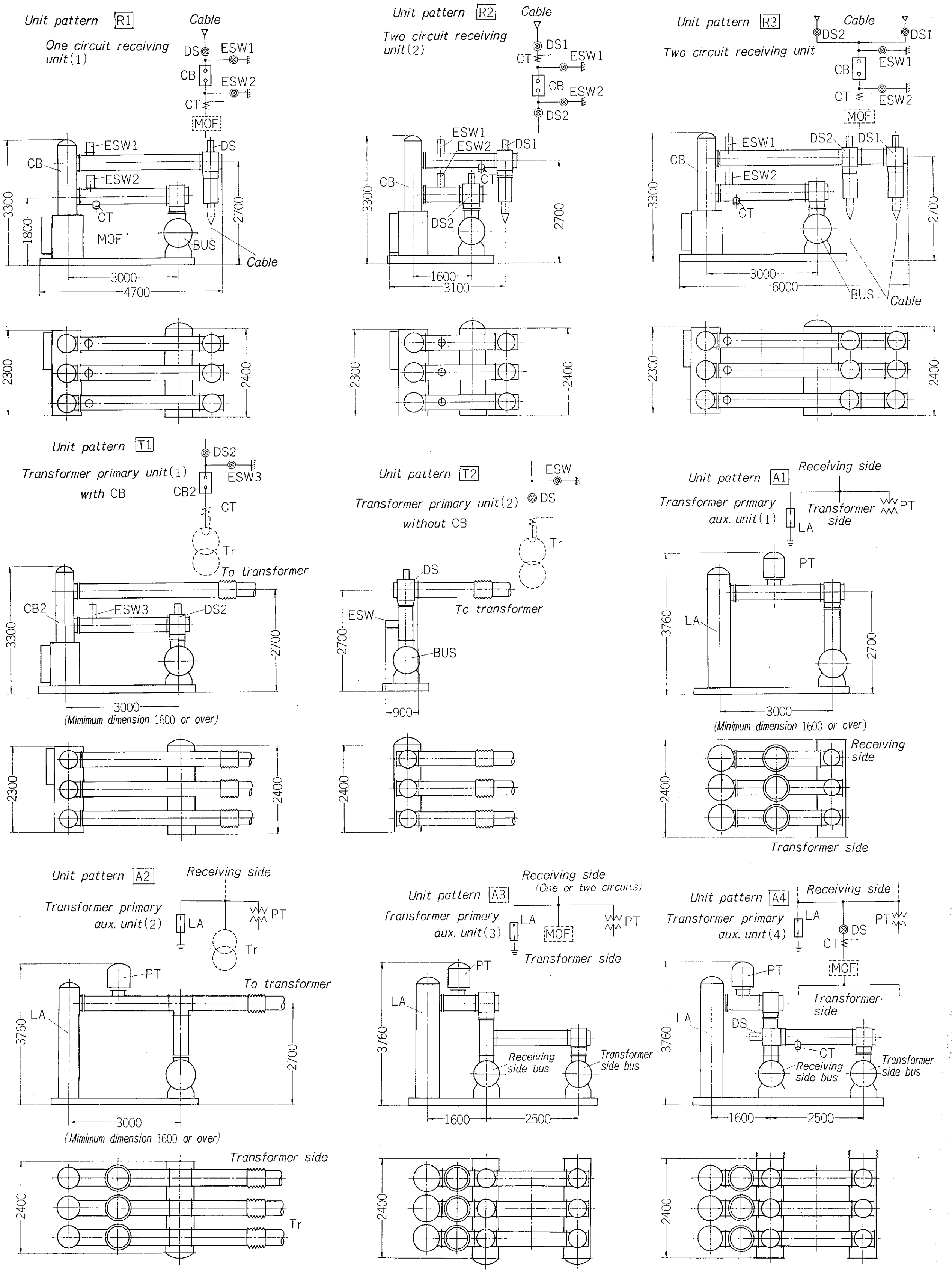

Fig. 16 **Unit patterns**

public utility special high tension receiving circuits but for all cases, the compound pattern is standardized and it is easy to make any layout by various combinations of these patterns.

Fig. 16 shows 9 types of standard unit patterns classified in accordance with receiving circuit, power transformer and other auxiliary circuits. Table 5 shows combinations in respect to standard one line diagrams. *Table 5* shows combinations in respect to standard one line diagrams.

Fig. 14 shows a one line diagram from this table for application of a VMH when there are two receiving circuits and two transformer banks (with a breaker on the primary side of the power transformer). This layout can be planned as $R_2 \times 2 + A_4 + T_1 \times 2$ as shown in *Fig. 15*. The following points, however, demand close attention:

(1) Since the width of the power transformer unit T_1 is only 2,400 mm, it is necessary to use a cable for connection on the transformer side when arranging T_1 consecutively.

Table 5 An example of combination of receiving system and unit pattern

Receiving system	Combination of unit pattern
One circuit receiving and one bank	$R_1 + A_2$
One circuit receiving and two banks	$R_1 + A_1 + T_1 \times 2$ With circuit breaker for transformer primary
Normal and standby circuit receiving with two DSs and one transformer bank	$R_3 + A_2$ With circuit breaker for transformer primary
Normal and standby circuit receiving with two DSs and two banks	$R_3 + A_1 + T_1$ With circuit breaker for transformer primary
Two circuit receiving with two circuit breakers and two banks	$R_2 \times 2 + A_3 + T_2 \times 2$ Without circuit breaker for transformer primary
Two circuit receiving with two circuit breakers and two banks	$R_2 \times 2 + A_4 + T_1 \times 2$ With circuit breaker for transformar primary

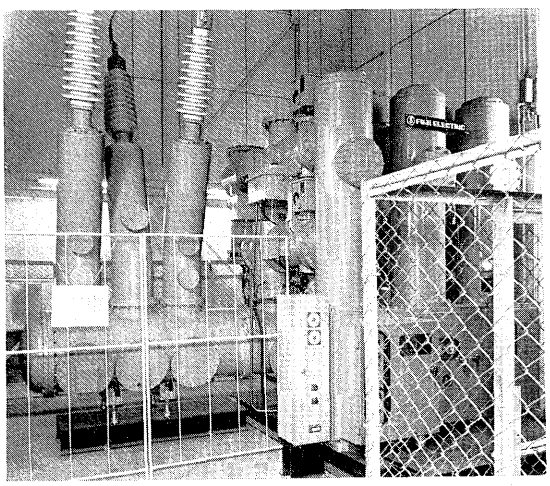

Fig. 17 66 kV VMH for Kimitsu Works, Nippon Steel Co.

(2) It is necessary to connect a bellows in the direct coupling part with the power transformer in order to eliminate transfer of vibrations and separate sinking.

(3) It is necessary to attach a bellows between main bus tubes, because of thermal expansion.

2. Application with Existing Equipment

In the case of the 66 kV feeder circuit breaker unit as shown in *Fig. 17* delivered to the Kimitsu Works, Nippon Steel Co., Ltd., a 66 kV cubicle space was used but the breaker unit was accommodated in one span including the through-type bushing unit for connection of the air insulation bus to the totally enclosed bus.

In the unit delivered to the Fukiai Works, Kawasaki Steel Co., Ltd., it was necessary to connect the

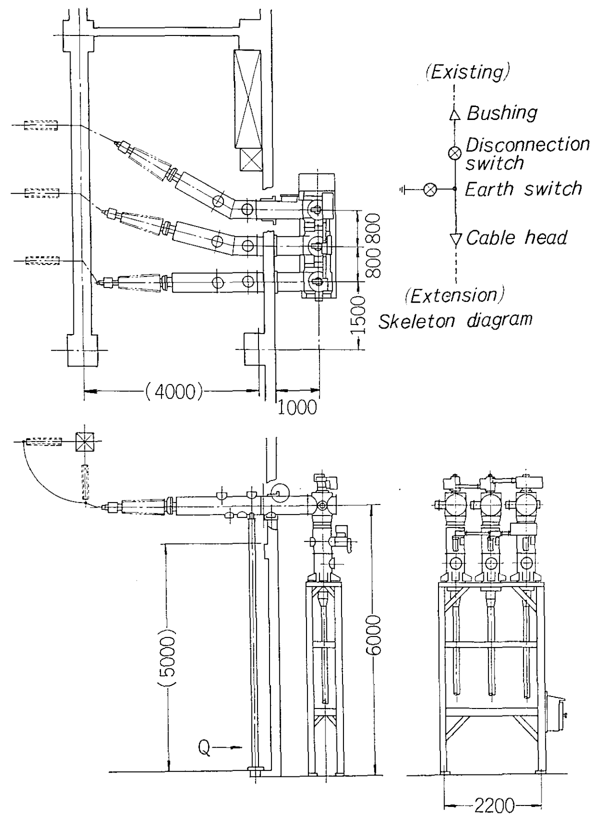

Fig. 18 VMH for extension by Fukiai Works, Kawasaki Steel Co.

new and existing bus by means of a 77 kV SF_6 gas bus tube since the new substation must be constructed at the adjacent space outside the building, when plant load was increased. This is an example of the VMH unit including a section switch (refer to *Fig. 18*).

V. APPLICATION MERITS

The design and structural features of the VMH were given in section II. Here, an outline of the merits of the VMH from the standpoint of planning a receiving station will be outlined.

1. Sapce (Volume) Savings

The VMH is a combination of power system unit equipment which can be unified because of SF_6 gas insulation and in the 60∼140 kV class VMH, the space required for the VMH is about 10% less than that required for conventional substation using air insulation. Considering indoor use in buildings, the volume ratio is reduced by about 5%.

Therefore, in cases where space is scarce because of rising land prices or the need for expansion, the VMH is particularly advantageous.

2. Easy Plant Planning

Since the VMH is a combination of several formerly separate units, planning is possible by combining units. There is also considerable freedom in the layout since the charged parts are totally enclosed and there is no influence from the exterior such as salt contamination.

3. Easy Construction

Since it is possible to bring one unit to the site completely assembled, the only site work required is connections. The connection parts between the buses employ the plug-in connection system. Therefore, highly reliable equipment is possible because of the short, simple site work.

4. High Reliability, Maintenance Free

Unlike in conventional cases where various types of units are assembled at the site and the functioning of the equipment depends on the site work, the VMH is completely assembled and tested in the factory and brought to the site in units with minimum disassembly. Highly reliable equipment can be achieved. Since external conditions are also sealed out, there are very few parts which age and almost no maintenance is needed.

The maintenance and inspection free system not only saves maintenance labor but also avoids losses due to power shutdowns required for maintenance.

5. Large Labor Savings

There has recently been a tendency to save labor by the introduction of central supervisory control and electronic computers but this is the first time high reliability and maintenance-free characteristics are possible simultaneously for the main circuit equipment. As was described previously, the VMH has various characteristics as a labor saving system.