ON THE EQUIPMENT FOR UNIT SUBSTATION

By

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Unit substations have become noteworthy recently as type for distribution substations, being put into practice widely. Our cubicle type unit substations have been delivered to the Tohoku Electric Power Co., The Japanese National Railways, etc. Some have been exported and are in used on India. Our metal-clad types were delivered to more than dozen substations, including those under construction. Our unit substation equipment, chiefly those delivered to recently to Minami Hirakata Substation of the Kansai Electric Power Co. are described in the followings:

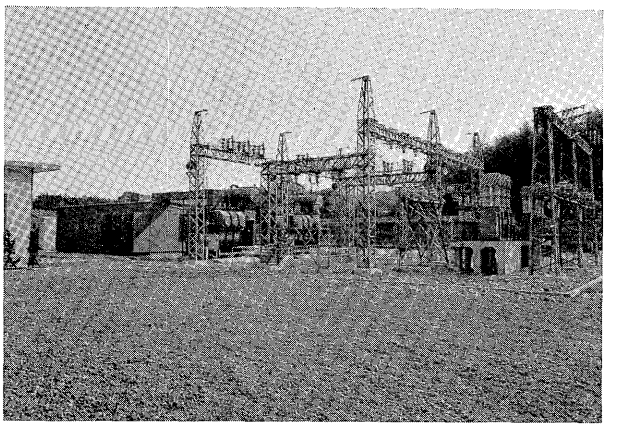


Fig. 2.
General view of unit substation
(Minami Hirakata Substation
Kansai Electric Power Co., Ltd.)

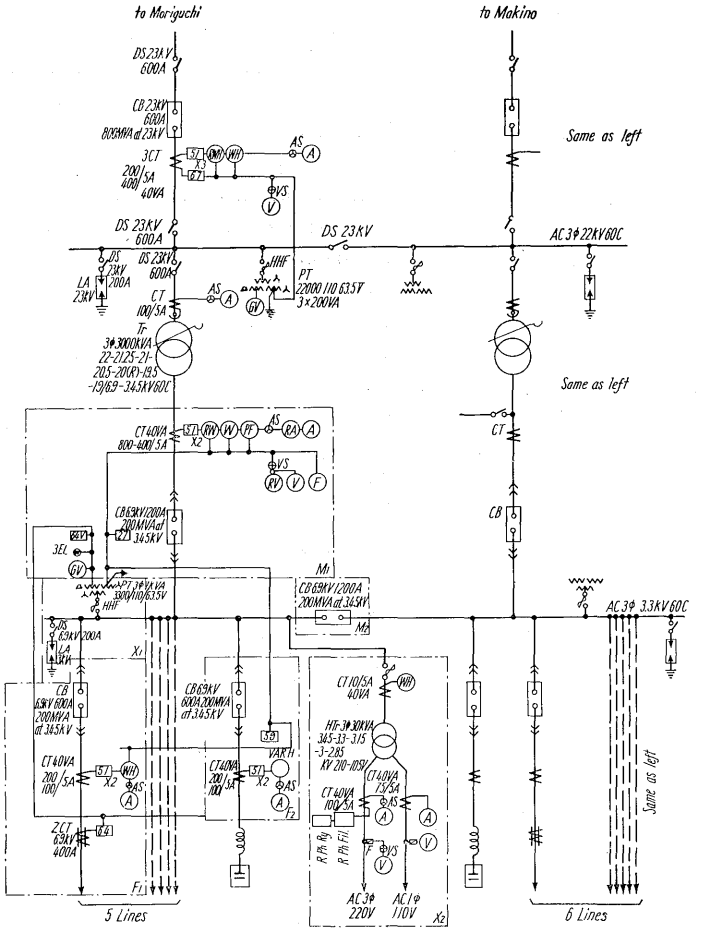


Fig. 1. Single line connection diagram of Minami Hirakata Substation

I. CONSTRUCTION, CONTROL, AND PROTECTION OF EQUIPMENT

A) Construction of Equipment

Fig. 1 shows the single-line connection diagram of Minami Hirakata Substation, and Fig. 2, a general view of the substation.

B) Control and Protection

From the nature of unit substation, only one or two men maintenance during daytime is desirable with exceeding simple control and protection.

1) Control

Simultaneous switching-out for secondary side voltage drop, switching-in sequence after voltage recovery, and automatic voltage regulation are employed for control. Of these, simultaneous switching-out and switching-in sequence are not necessary for every distribution line: The latest practice becoming to open or close the circuit breakers only on secondary side of transformer.

2) Operating Source

Considering in general the range of voltage fluctuation, fault indication and alarm, emergency lighting, and the difficulty of taking A. C. control source directly from primary side, the D. C. source from the storage batteries is desirable, although some difficulties are encountered in maintenance. If an operating source is taken from the secondary side of the transformer, either directly or rectified, it will be necessary, after the receiving voltage is lost, to send next power by manual operation, making such a practice generally undesirable, although our water circuit breakers mark a distinctive feature providing mechanical switching-in for 10 to 30 kV classes.

3) Remote Supervisory Control Devices

For rationalizing power stations and substations, many remote supervisory control devices have been used recently and our products of polygonal type have been delivered to thirty old and new power stations and substations.

Our polygonal types have the following distinctive features:

a) Selection is instantaneous irrespective of the sending and the receiving signal quantity between the controlling and the controlled stations, making possible to respond to various signals in succession without delay, during a fault or other period requiring such signals.

b) A simple one action operates the device, exceedingly facilitating maintenance and inspection. The recording watthourmeter is also manufactured for integrating electrical energy.

4) Protective System

The protective system is the same as for ordinary secondary substations. Transformers are protected by Buchholz relays or differential relays for which, on account of the development of the cold drawn oriented core, the bushing type current transformers with sufficient characteristics are manufactured and will be used gradually for the primary side.

II PRIMARY SIDE EQUIPMENT

Being a unit substation, the primary side equipment requires on special consideration and a conventional standard type is used, except in an indoor substation and elsewhere with fire hazard, an oilless type should be used. Our water circuit breakers of 10 to 30 kV classed for such a use have the following advantages over the air-blast circuit breakers:

1) Sound

Breakers up to 30 kV classed are frequently installed inside rooms or near houses, but air-blast circuit breakers involve problems naturally as they make a big noise at interruption.

2) Construction

Use of compressed air of high pressure, simultaneous three phase interruption, and moisture treatment, complicate the air-blast circuit breaker construction. Compared with the water circuit breaker, the maintenance of the air-blast circuit breaker requires much more attention.

3) Extinction of Arc

Water circuit breakers, being self arc extinction type require no forced extinction as the air-blast circuit breaker when interrupting exciting current or charging current, furthermore, should the arc regnite, it causes a very low abnormal voltage. Also taking into consideration the heat transfer effect of the generated gas due to arc extinction at the time of interruption, it can be said that in principle, this is the best.

III TRANSFORMER

Transformers are hermetically sealed or sealed with nitrogen, and are mostly provided with three phase under-load tap-changing voltage regulators. Further, three phase transformers up to 6000 kVA class, which are used in a unit substation in large numbers, can be shipped totally assembled without employing any special transportation facilities. Fig. 3 shows an example of transformer which can be shipped totally assembled.

Of the two systems of voltage regulation, namely the induction voltage regulator and the under-load tap changer, the latter is exclusively adopted at present, because the former, being a rotary machine,

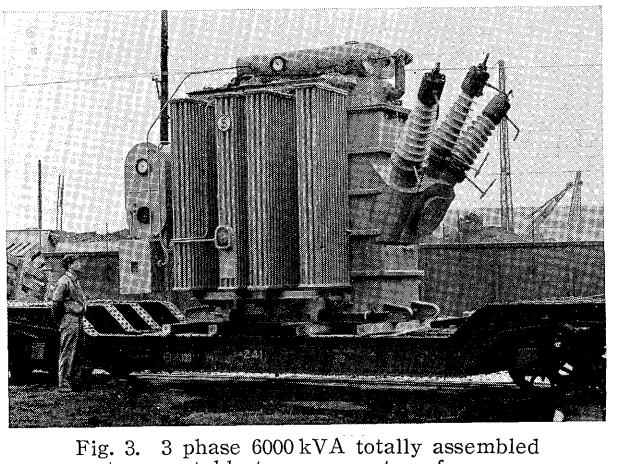


Fig. 3. 3 phase 6000 kVA totally assembled transportable type power transformer

requires mechanical and electrical reliability as well as phase regulation at parallel operation. There are two types of under-load tap-changing voltage regulators: indirect type and direct type.

A) Indirect Type Under-Load Voltage Regulation

The indirect type under-load voltage regulator combines the series transformers and the regulating transformers.

Their connection diagrams and appearances are shown in Fig. 4 and Fig. 5. The current capacity of the tap changer is 125 A. The number of steps is 21 points or 11 points, forming 1% or 2% steps for ±10% voltage regulation. The ratings are: the double capacity regulation of ±10% and ±5%, or the double voltage regulation of 6.9 kV and 3.45 kV, is made possible by changing to series or paralled connection of the series transformers and regulating transformers as shown in Fig. 4.

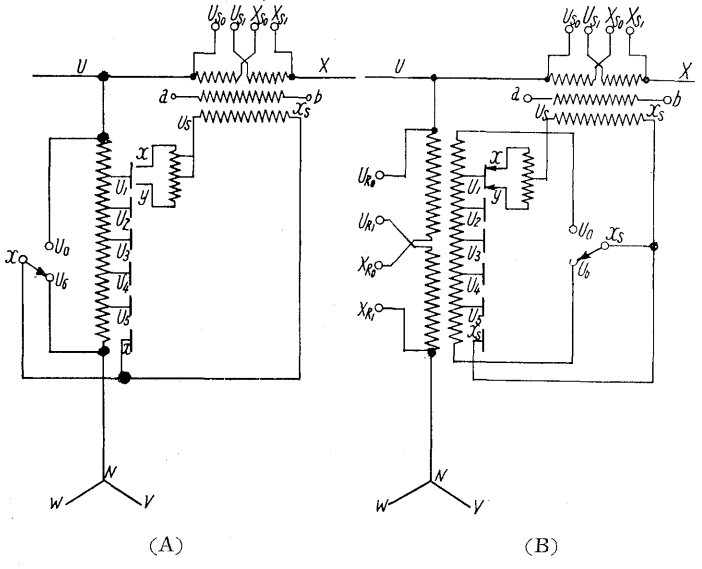


Fig. 4. Connection diagram
(A) Double voltage regulation system
(B) Double capacity regulation system

1) General Construction

The regulator is enclosed in a tank with partitions for the transformer and for the tap changer. The transformer and the tap changer are connected by the repelite bushing, and the insulating oil in two chamber is completely separated. The control motor, the magnetic contactor, and the static condenser for the surge absorber are installed in the lower part of the tap-changing chamber. The transformer chamber contains the nitrogen sealed conservator, and the tap-changing chamber also uses the conservator, with the Buchholz protector and the bursting tube.

2) Transformer

The transformer is the three-leg-

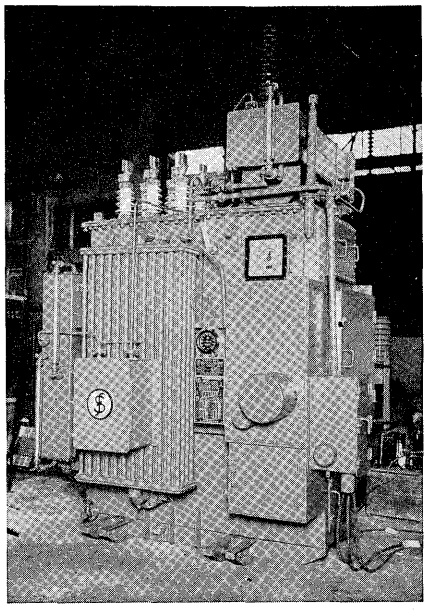


Fig. 5. Type SV. step voltage regulator 3 phase 450 kVA 3,450 V ± 10%, 1% step 50~

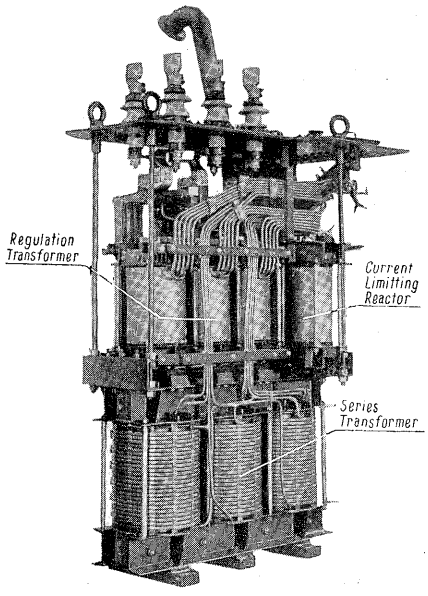


Fig. 6. Type SV step voltage regulator assembly 3 phase 300 kVA 3,450 V ± 10%

ged core type. The regulating transformer, having many taps, has its one tap winding of the cylindrical windings occupy the total length of the coil so that no mechanical force will be produced in the axial direction at any tap. The primary windings of the series transformer are the cylindrical type while the secondary windings are the disc type with the windings properly transposed to make especially strong electrically and mechanically, since the current is large and the number of windings is small. The current limiting reactor has the three legged core with the cylindrical type coil. It is so constructed as to work as reactor under bridging conditions and to become merely coiled resistance under short-circuit condition. Fig. 6 shows their assembly: To prevent voltage rise due to an impulse wave, a static condenser is installed at the neutral point of the regulating transformer.

3) Tap-Changers

The tap-changer consists of the operating mechanism and the load switch jointly used as, a tap selector, all assembled together enclosed in a tank, operating in oil.

a) Operating Mechanism

The operating mechanism consists of a motor, reduction gear, coupling mechanism, and an operating spring provided with the buffer oil dash pot, the limit switch and the like. The motor winds up the operating spring up to the normal position, the operating spring and the motor shaft are disengaged, and the operating spring makes the load switch, jointly used as tap changer, operate one step through the geneva gear. Various limit switches, and the dial type auxiliary contacts for tap position indication and parallel operation are linked to this operating the spring shaft. The limit switch mounted on the operating spring shaft breaks the circuit and stops the motor disengaged from the operating spring shaft. If the operating shaft is turned beyond the normal position of the upper or lower limit, whether operated manually or by motor, the operating spring shaft is automatically disengaged from the operating shaft. The operating shaft thus disengaged can be easily restored from outside.

b) Combination of Tap Chamber and Tap Selector

Fig. 7 illustrates the combination of tap changer and tap selector. Three groups of stationary contacts and movable contacts are mounted on an insulation plate. Of these, two groups are load switches jointly used as tap selectors, each consisting of five point stationary contactors and one movable contactor, the remaining group being for polarity changing consisting of two point stationary contactor and one movable contactor, enabling to take 21 taps in all. Copper tungsten alloy is used for the stationary and the movable contactors.

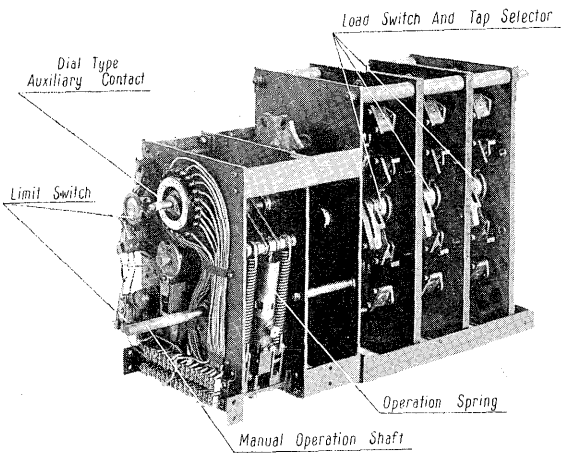


Fig. 7. Type SV under-load tap-changer

B) Direct Type Under-load Voltage Regulation

Direct type under-load voltage regulation is performed by changing taps at the primary or the secondary side of the transformer without removing the load. The tap changer occupies the main part. The tap changer has the current capacity of 300A or 600A, with the number of steps 9 points or 11 points which can be increased to 17 points or 21 points by using the polarity changer, which means 2.5% or 2%, and 1.25% or 1% steps for ±10% voltage regulation. Fig. 8 and Fig. 9 show this kind of transformers by examples. Our company has delivered more than 130 units of tap changers, up to the unit capacity of 40,000 kVA, voltage, 115 kV, covering various transformers for power service and electrical furnaces, total capacity amounting to 1,000,000 kVA.

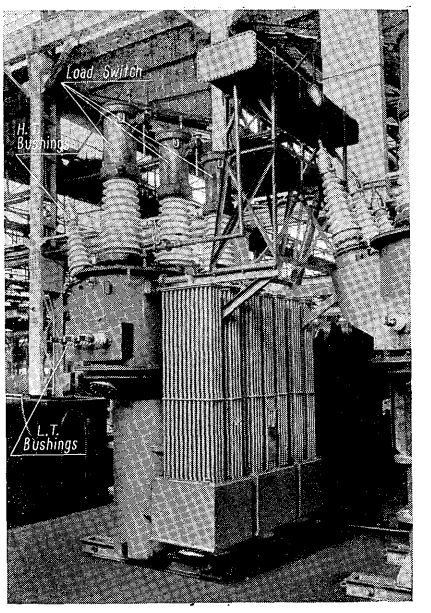


Fig. 8. 3 phase 6000 kVA under-load tap-changing power transformer

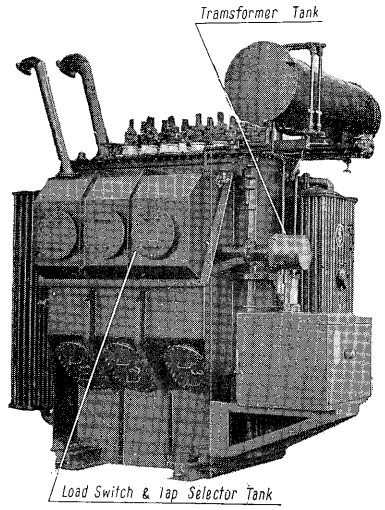


Fig. 9. 3 phase 3,000 kVA under-load tap-changing transformer for contact converter

1) General Construction

Tap-changers over 30 kV are supported by the insulators on the tank cover as shown in Fig. 8, while those under 20 kV are contained in a separate tank as shown in Fig. 9, consisting of the following three parts:

a) Load switch and current limit resistance
b) Tap selector
c) Coupling mechanism and drive

For above 30 kV, tap changers are supported by the high voltage insulators as shown in Fig. 10, and are coupled to the tap selectors by the connecting rods penetrating the insulators. The part of the tap changer chamber where the connecting rod penetrates is kept oil tight by gland packing, the insulating oil in the tap changer chamber being separated from that in the transformer proper. Similarly, the tap selector is hung by the high voltage insulator, assembled as one body with one phase of the tap changer as if it were a high voltage bushing. For below 20 kV, the load switch and the current limit resistance are assembled together with the tap selector, and are contained in the tank separated from the transformer body and supported on the insulator, as shown in Fig. 11.

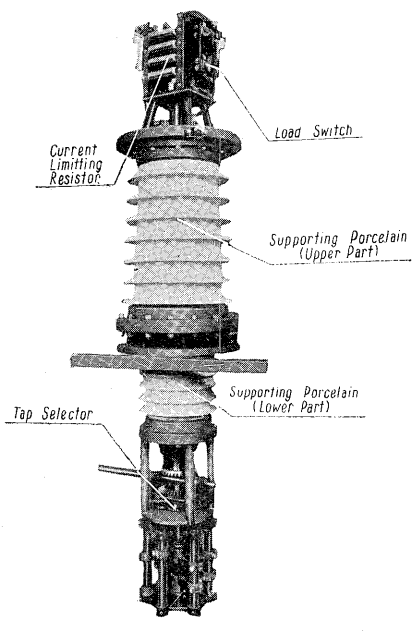


Fig. 10. Load switch aud tap selector (Alone 30 kV)

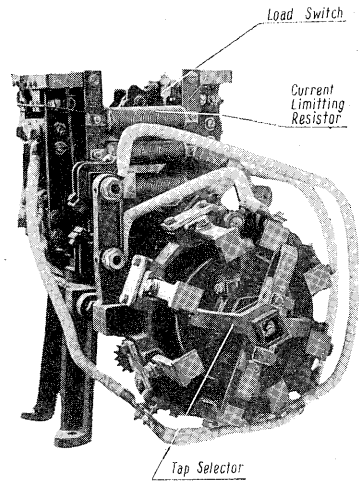


Fig. 11. Load switch and tap selector (Below 20 kV)

2) Load Switches

The load switch ingeniously utilizes a strong spring and the dead point of the link motion, with the current limit resistance mounted at its side as shown in Fig. 10 and Fig. 11. The contacts consist of the main contacts, the auxiliary contacts, and the resistance contacts. The auxiliary contacts protect the main contacts by opening earlier and closing later than the main contacts, and the resistance contacts break the short circuit current of one tap of which the current is limited by the resistance. The switching is accomplished automatically as follows: the slider changes the rotating motion of the operating shaft into the reciprocating motion of right and left, giving tension to the spring and, as soon as it passes the dead point, the stored energy transfers the switch completely all at once and automatically. The switching is completed in a very short time, 0.04 seconds from the start to the finish of switching operation. The construction is such that the contact pressure is fully maintained until the dead point is past, after which the automatic switching is completed without stopping during the operation, without being affected by a fault in the operating shaft or elsewhere. This maintains the operating time of 0.04 seconds constant even for manual operation.

3) Tap Selectors

As stated previously, for above 30 kV, the tap selector is hung in the transformer tank by the high voltage insulator on the opposite side of the load switch, and, for below 20 kV, it is assembled with the load switch as one body 17 points or 21 points tapping is possible for 9 points or 11 points polarity changing.

IV. SECONDARY SWITCHING

From the standpoint of reliability and safety, it is desirable to use a metal-clad switchgear for the secondary switching. However, economical difficulties are encountered, and it is best to make constructions suit the conditions of the installed place.

A) Arrangement of Equipment and General Construction

Fig. 12 shows the general arrangement of Shin Amagasaki Substation under construction, of the Kansai Electric Power Co. The arrangement of equipment must facilitate maintenance and inspection, use as much small types as possible, with similar casings easily interchangeable.

Fig. 13 shows the cross-section of each type of casing. As can be seen from the illustration, inspection of any part inside the casing is exceed-

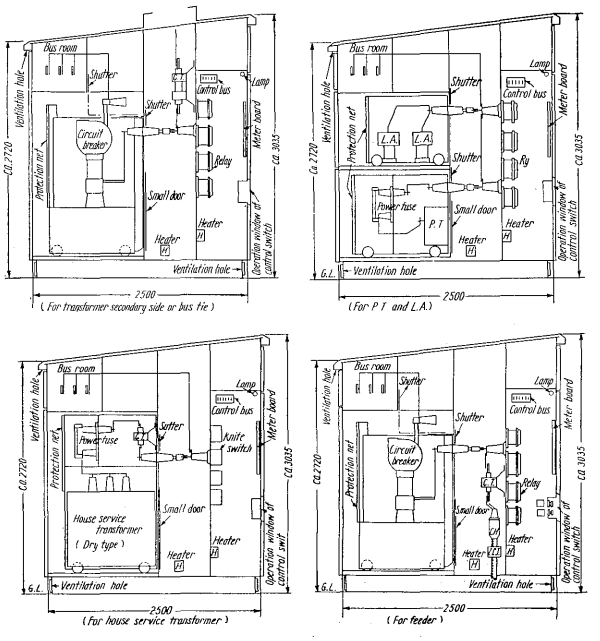
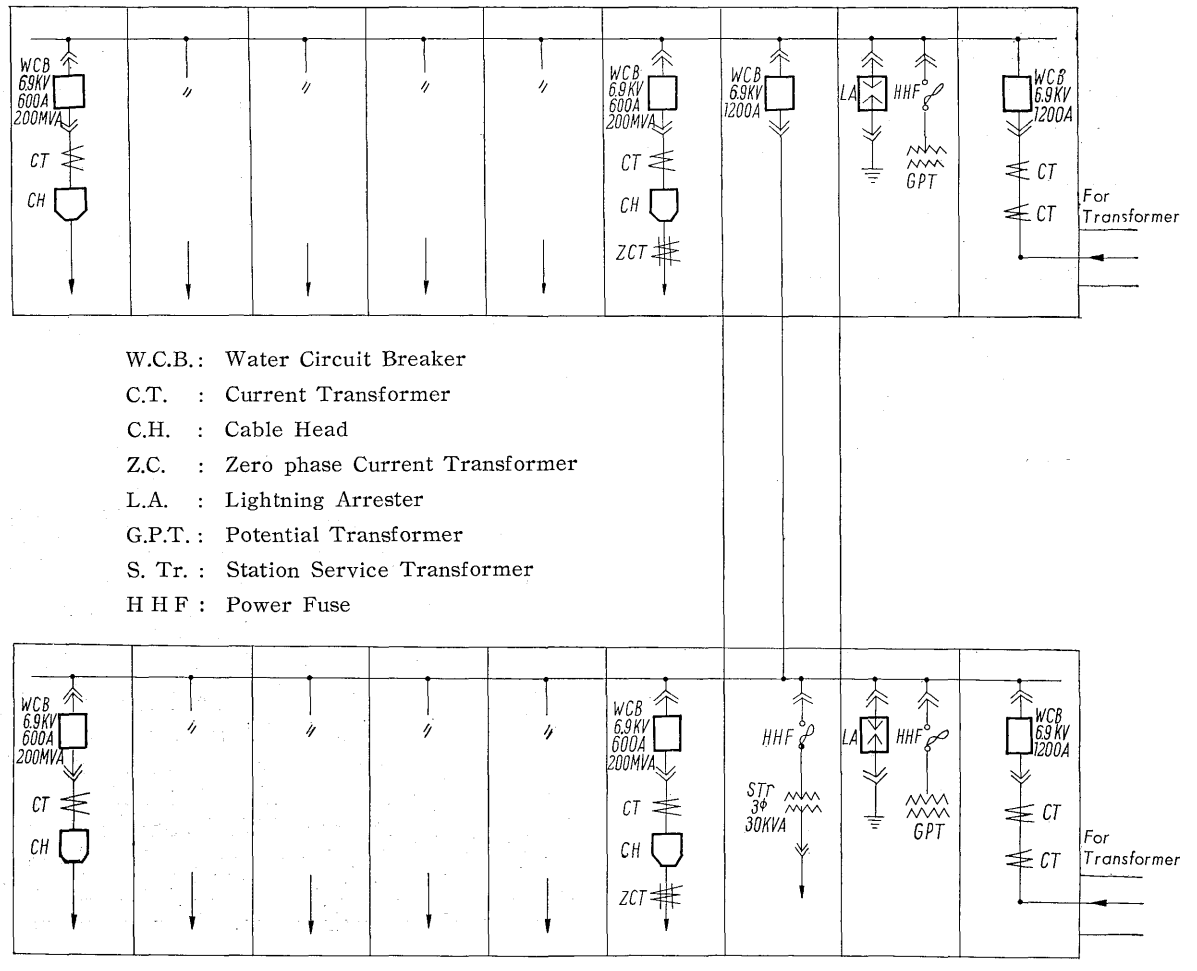


Fig. 13. Cross section of each type easing



W.C.B.: Water Circuit Breaker
C.T. : Current Transformer
C.H. : Cable Head
Z.C. : Zero phase Current Transformer
L.A. : Lightning Arrester
G.P.T. : Potential Transformer
S. Tr. : Station Service Transformer
H H F : Power Fuse

Fig. 12. Schematic connection diagram of metal-clad switchgear

ingly easy. Especially the high voltage bus chamber and the low voltage control bus chamber are brought forward and backward to facilitate disassembly and assembly. The current transformer can be inspected easily by opening a small door after the circuit breaker has been removed, with the bus side shielded by an automatic shutter. For those on the line side which are still energized after the braeker is removed, either a signal lamp is mounted on the front of the small door, or else they are electrically inter-locked.

Relays are of draw-out type, surface mounted, installed in the front low-voltage chamber separated from the high-voltage chamber.

Meters are mounted on the swing type panel, and are watched through the front supervisory window. Various operating switches can be operated by opening only the small window constructed under the supervisory window. Fig. 14 shows the appearance of this part.

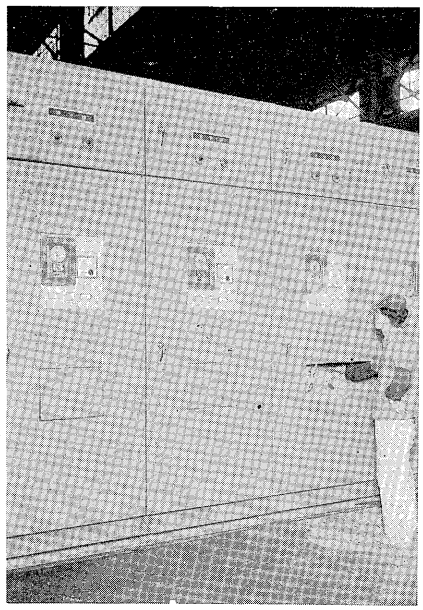


Fig. 14. Supervisory window of meters and operation window of control switches

In order to prevent moisture, a suitable heater is installed in the casing and ventilated, the ceiling is made in double construction, the temperature difference with the outside is produced on the outer ceiling board, and the water drop is driven out over the inner ceiling board. The supervisory window glass is double paned to insulate heat and prevent clouding.

The ventilation inlet is installed on the lower frame as shown in Fig. 13 so that rain will not get in to the casing.

B) Casings

Construction ot the casing differs depending on whether it is used outdoor or indoor. Weather-proof construction is an important requisite for designing the outdoor casing.

Water-proof, snow-proof, and dust-proof constructions can be divided into two systems: one using packings, and the other not using packings. Some packings, on account of the latest development of the material, are durable. However, if they can be spared, so much the better, and our company makes it a general rule not to employ them except for the place where heavy snowstorms and dusts visit.

Water-proof and snow-proof constructions are obtained by not letting the bolts come outside, and where impracticable, covered bolts are used. Where the surfaces of doors and roofs meet, suitable measures are provided to reject water.

The dust-proof construction is shown in Fig. 13. The ventilating duct is located under the casing, and from thence the ventilation is carried out through the ventilating duct in the casing bottom board without making any ventilation window directly on the door.

To prevent heat, the ceiling is double paneled with cork boards piled up inside the inner ceiling board, insulating heat between the outside and the inside of the casing.

C) Mechanism

a) Circuit Breakers

The circuit breaker is fastened by the movable nut in the draw-out mechanism to be described later. The circuit breaker and the disconnecting switch are interlocked as shown in Fig. 15 and Fig. 16. The tip of the operating shaft of the circuit breaker is bent 90° forming the stopper " A " which stops drawing-out and pushing-in of the circuit breaker when it is closed, by touching with the stopper " B " of the casing.

The mechanism to draw out the circuit breaker is the horizontal system allowing a very simple drawing-out or pushing-in by movable nuts. If the

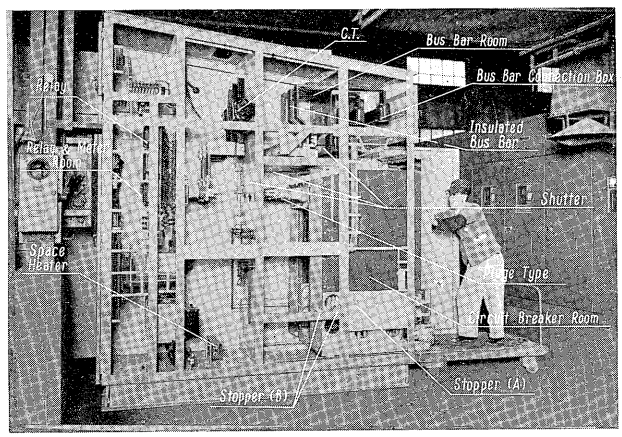


Fig. 15. Sectional view of metal-clad type switchgear

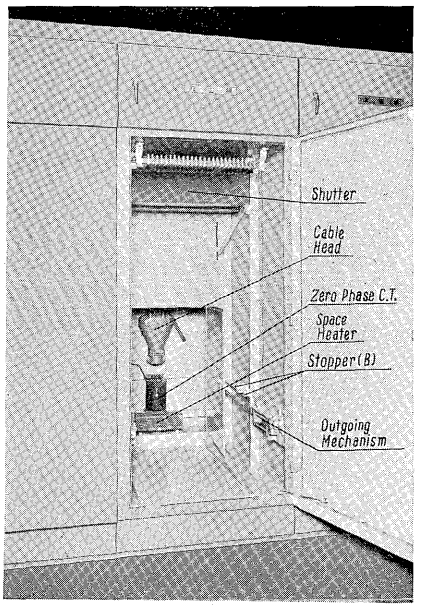


Fig. 16. Inside view of circuit breaker chamber

circuit breaker is to be drawn out of the casing it is separated from the movable nuts by the draw buttons attached.

b) Other Items

The guard net is so constructed that the circuit breaker, the potential transformer, and the lightning arrester can not be removed even if the front door is opened until they are drawn out at their safe positions, and that they can not be pushed back unless the guard net is installed.

The shutter is so constructed that the charged part is automatically shielded when the draw-out equipments are drawn out, and that it is automatically opened when they are pushed in.

c) Bus

As shown in Fig. 15, the high voltage bus is covered by the phenol-resin plastic insulation. The joint is also covered by the phenol-resin cover.

d) Low Voltage Circuits

Vinyl-chloride wires are used for low voltage wiring. The fasteners are of organic insulation, floated above the steel plate surface, obtaining a perfect double insulation construction. The low voltage circuit in the high voltage room is further shielded with the steel plate cover.

The low voltage circuit of the draw out-type equipment is the plug type as shown in Fig. 17, and it can be connected under the running position and no voltage test position.

e) Auxiliary apparatus

The circuit breaker carrier and the vacuum cleaner for cleaning the inside of the casing are the auxiliary apparatus.

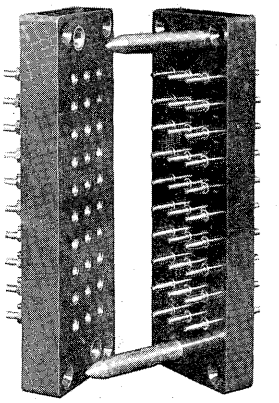


Fig. 17. L.T. Auxiliary contacts

D) Circuit Breakers

The oil circuit breakers or the water circuit breakers are used. Various types of water circuit breakers are shown in Table 1 with approximate dimensions of metal-clad casings.

Water circuit breakers chiefly use, as the arc extinction liquid, water prepared for oilless circuit breakers. Their distinctive features are :

1) No fire is hazard by faults.
2) No sound is produced by interruption.
3) The self arc extinction type makes interrupting capacity constant, without being affected by the high humidity liable to occur when the breaker is metal-clad.
4) Arc characteristic is flat.
5) They are not affected by the specific recovery voltage of the line system.
6) Maintenance and inspection are extremely easy.

Fig. 18 shows water circuit breakers under mass production and the metal-clad. Fig. 19, shows they are housed in the metal-clad.

They can be operated by A.C. or D.C. motors, or by compressed air. The operating duty is

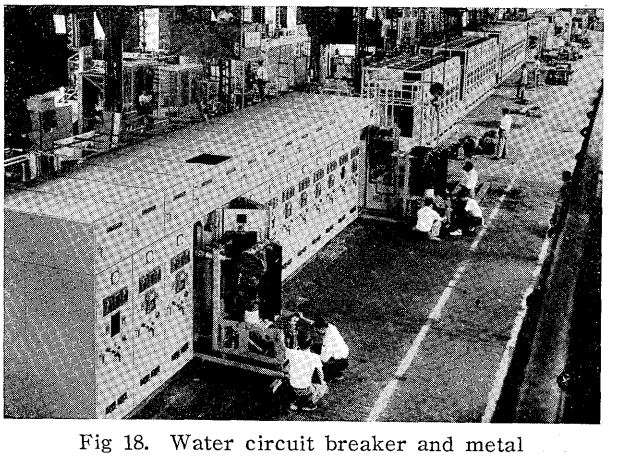


Fig 18. Water circuit breaker and metal clad switchgear at Kawasaki Works

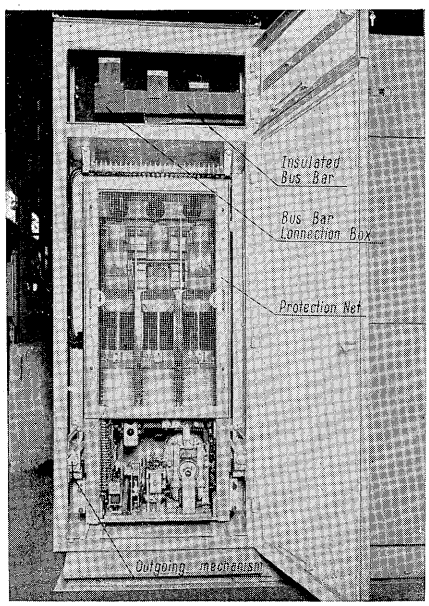
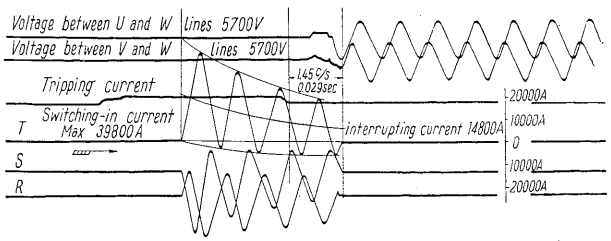


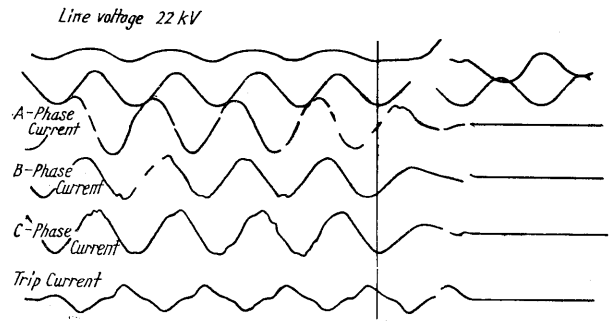
Fig. 19. Water circuit breaker

O—15 sec—CO or O—1 minute—CO—3 minites—CO. The arc extinguishing liquid consists of distilled water mixed with ethylene glycol, made nonfreezing, if necessary, even at extremely cold region. The steam chamber is so tightly sealed that the water vapor discharged into the chamber at current interruption will be condensed to water, and only one annual supply of water and inspection is sufficient even under severe working conditions.

Fig. 20 shows the results of short-circuit current and charging current interruption tests carried out by our short-circuit testing equipment.



(Short circuit current)



(Charging current)

Fig. 20. Result of short circuit current charging current interruption test by water circuit breaker

E) Station Transformers and Potential Transformers

1) Non-inflammable oil, or dry type is used for station transformers to prevent fire. The flashing point of the non-inflammable oil is 150° C or above. No varnish is ever used in manufacturing our transformers from the start, and together with the use of non-inflammable oil, fire proof construction is easily obtained. The dry type transformer uses silicon insulation. Fig. 21 shows an example of the transformer installed in the metal clad.

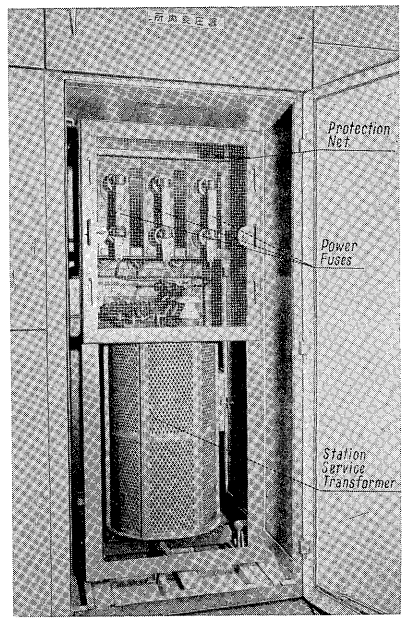


Fig 21. Station service transformer 3 phase 30 kVA 50/60~

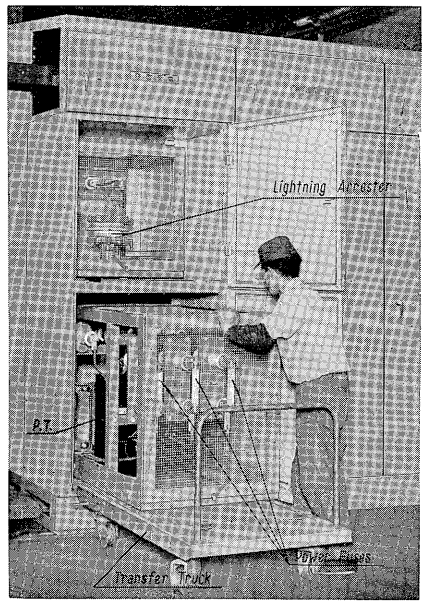


Fig. 22. Lightning arrester and potential transformer

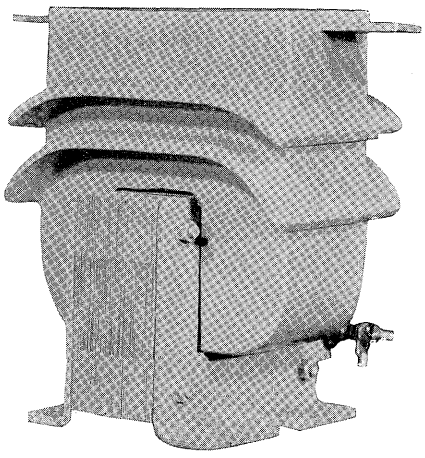


Fig. 23. Mold type current transformer

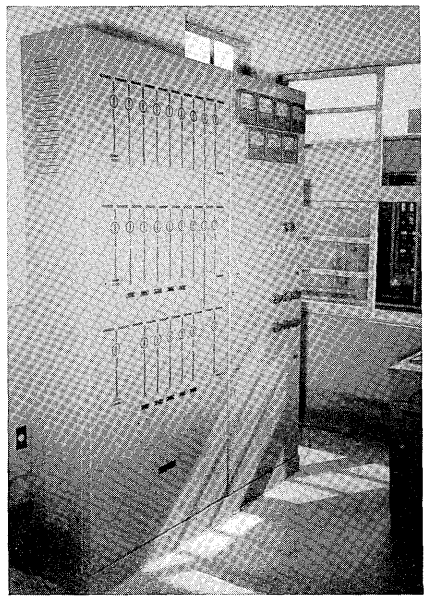


Fig. 25. Illuminating type switchboard

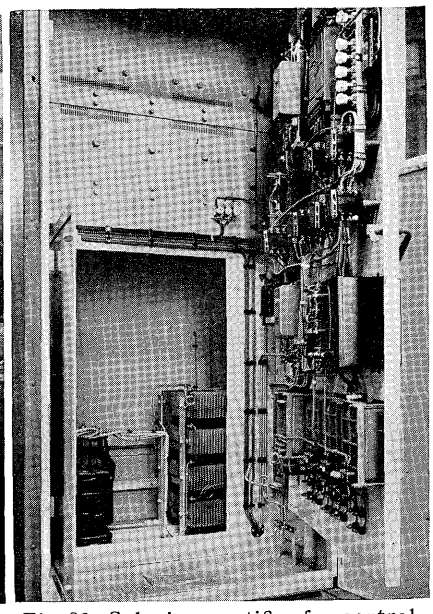


Fig. 26. Selenium rectifier for control source of metal-clad switchgear

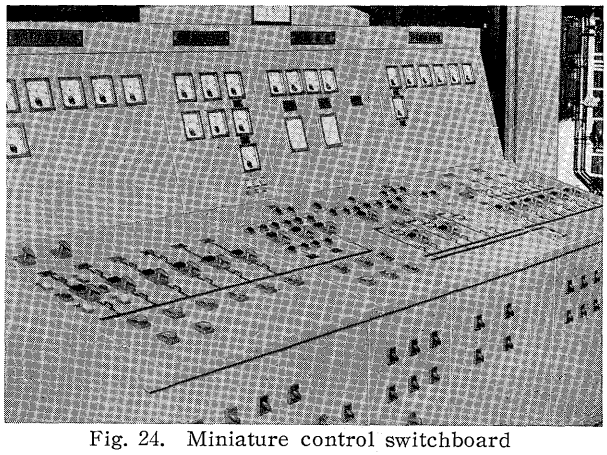


Fig. 24. Miniature control switchboard

2) The potential transformer is dry type or mold type. Fig. 22 and Fig. 23 show examples of the potential transformer installed in the metal-clad and mold type current transformer.

F) Miscellaneous

1) Totalized Control Board

Small appliances are recommended for a totalized control board. Fig. 24 illustrates such a totalized control board using small control switches and small instruments of wide angle scales. Fig. 25 illustrates a simple illuminating type supervisory board.

2) Power Source Devices

Storage batteries can be placed in the metal-clad as a sealed unit. Fig. 26 shows the selenium rectifier used for the power source.

Type	Insulation Level kV	Phase Voltage kV	Rated Current A	Rup. Capacity MVA	Approximate dimension of metal clad casing (current up to 2000A) Outdoor Width	Outdoor Depth	Outdoor Hight	Indoor Width	Indoor Depth	Indoor Hight
HF 624b/ 103	10	3.45	400~1000	100	900	2350	2850	800	2000	2700
HF 624b/ 106		6.9		200						
HF 624b/1010		11.5		200	900	2350	2850	800	2000	2700
HF 624b/2010	20	11.5		200	1000	2500	3950	1000	2200	3800
HF 624b/2020		23		200						
HF 624c/ 103	10	3.45	600~2000	200	900	2350	2850	800	2000	2700
HF 624c/ 106		6.9		400						
HF 624c/1010		11.5		400	1000	2350	2850	1000	2000	2700
HF 624c/2010	20	11.5		400	1200	2500	3950	1200	2200	3800
HF 624c/2020		23		400						
HF 624g/ 103	10	3.45	1000~4000	300	1000	2350	2850	1000	2000	2700
HF 624g/ 106		6.9		600						
HF 624g/1010		11.5		600	1200	2500	2950	1200	2200	2800
HF 624g/3020	30	23	600~4000	500	1400	3250	4100	1400	2800	3900
HF 624g/3030		34.5		600						
HF 624h/ 106	10	6.9	1000~4000	800	1400	3000	4000	1400	2500	3800
HF 624h/1010		11.5		1000						
HF 624h/3020	30	23		850	1400	3250	4100	1400	2800	3900
HF 624h/3030		34.5		1000						

Table I. Various type of water circuit breaker and approximate dimension of metal clad casing