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RECENT TERMINATING EQUIPMENT FOR A WATER WORKS IN TOKYO

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I. FOREWORD

Demand for water in major cities has been on a steady increase recently in line with industrial expansion. As a result, water resources have been developed and more water works established in rapid succession. And the receiving equipment installed as an electric source of these water works has been shifting to receiving on a big scale such as 60 kv, 70 kv and even 140 kv from the past 3 kv, 6 kv or 20 kv receiving.

The receiving equipment completed this time is a recent addition to the Kanamachi Water-Works under the Water-Works Bureau of the Tokyo Municipality with reputed water supplying capacity and the latest of equipment. It receives from a 140 kv line instead of the hitherto existing 20 kv line and supplies electric power to the receiving equipment of the said 20 kv line as a secondary substation and, at the same time, to the load newly established. This is the first time in Japan that a water works should receive 140 kv.

Recent aims of a substation are reduced space for installation, prevention of noise, simplification of control mechanism, prevention of mis-operation, freedom from salt-damage and water-damage, reduced cost of operation, etc. and to do them the use of appropriate apparatus is required. These objectives are incorporated in the present substation and a clear demarcation line is marked by a pantograph type disconnecting switch between the equipment and the power company; a V type disconnecting switch is used as a bus-supporting insulator for structureless and reduced floor space; a concrete-enclosed low noise level transformer is employed for reduced noise production; in short, this has been designed as modern large power receiving equipment and we offer the following introduction of its contents for public consumption.

II. OUTLINE OF EQUIPMENT

Fig. 1 shows the main circuit diagram, and the outline of the equipment is as follows:

1) Receiving line

140 kv parallel line of Tokyo Electric Power Co., Inc.

2) Receiving system

Two line receiving—Usually, however, only one line is used and, depending upon the assignment of

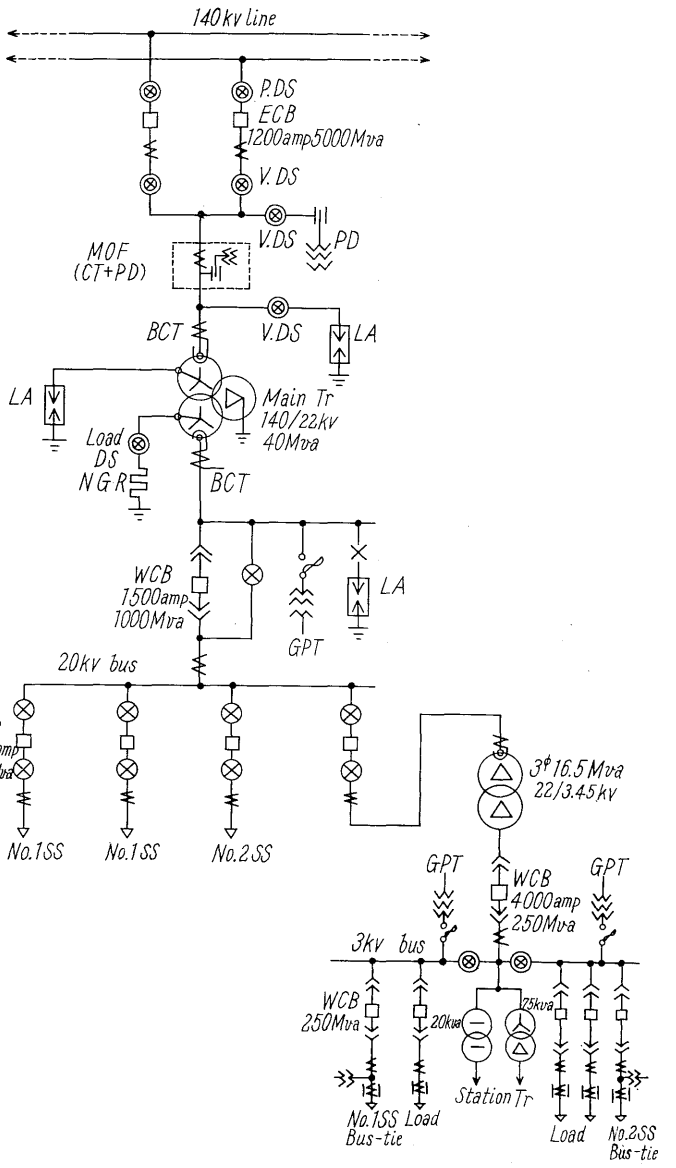
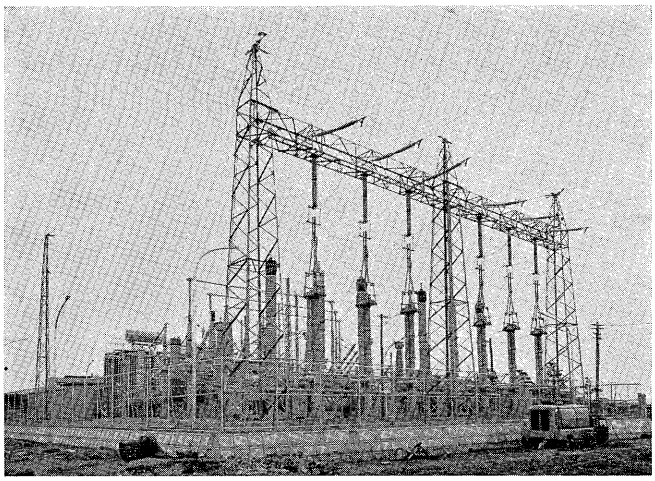
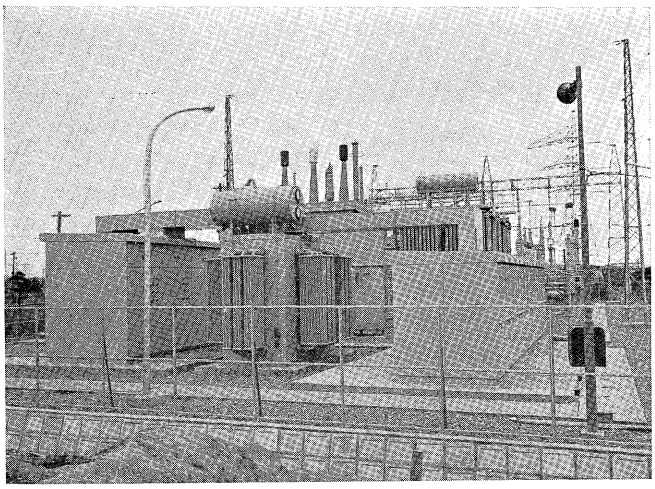


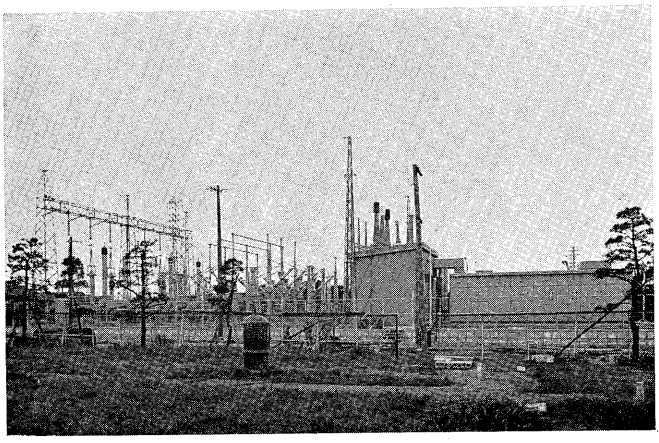
Fig. 1 **Skeleton diagram**



(a) High voltage side



(b) Low voltage side



(c) Front view

Fig. 2 View of the substation

line no-voltage changing will take place with a spare line.

3) Receiving capacity
   40 Mva
4) Transformer
   140/20 kv 40 Mva 1 bank
   20/3 kv 16.5 Mva 1 bank
5) Delivery voltage and number of lines
   (1) 22 kv 3-phase 3-wire system (cable) ..... 3 lines
   (2) 3.45 kv 3-phase 3-wire system (cable) ..... 3 lines
6) Relationship with existing substation (20/3.45 kv)
   (1) Supplies to existing substations (1st and 2nd SS) by 22 kv line
   (2) Main connecting circuit is provided between existing substations in the 3 kv system to make power supply flexible in the event of trouble of any substation.
7) Construction of equipment
   (1) 1 set of 140 kv line apparatus
   (2) 1 unit of 140/22 kv 40 Mva main transformer
   (3) 1 set of 20 kv outdoor-use cubicle
   (4) 1 unit of 20/3.45 kv 16.5 Mva sub-transformer
   (5) 1 set of 3 kv outdoor-use cubicle
   (6) 1 set of supervisory panel with illuminated mimic bus
   (7) 1 set of desk type control board
   (8) 1 set of self-stand type relay board
   (9) 1 set of other auxiliary equipment

III. SPECIFICATIONS OF MAIN APPARATUS

The Kanamachi Water-Works to which the equipment was delivered is one of the most important of all water works in the city with a maximum supply of water. If this water works should fail by any chance, a wide area would be affected by the suspension of water supply and there is a talk of leaving the existing 20 kv receiving as a spare in case the 140 kv receiving line should come to a stop. Thus, stop of power supply due to failure of apparatus must be avoided at all cost and this point was thoroughly considered in the total planning of equipment and selection of apparatus. Except for a few, all the main apparatus are our products with unique characteristics for which there are already a number of satisfied customers in the past.

1. Main Transformer (see *Fig. 3*)

Unit :	1 unit
Type :	Outdoor-use 3-phase forced oil self cooled nitrogen sealed, low noise level with separate radiator
Capacity :	40,000 kva
Frequency :	50 c/s
Voltage :	140/22 kv 1ry no-voltage changing tap : 148 (F)–144 (F) –140 (R)–136 (F) kv
Connection :	Star/star/enclosed delta
Insulation level :	1ry No. 140 1ry neutral No. 80 (with neutral arrester) 2ry No. 20 2ry neutral No. 20
% impedance :	13%

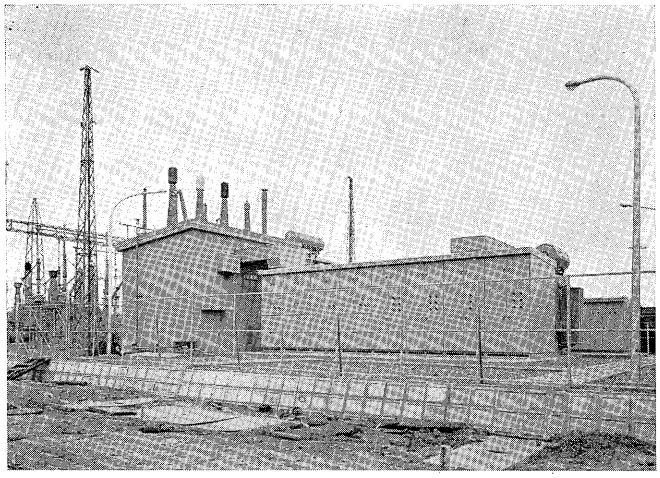


Fig. 3 (a) Main transformer and 20 kv cubicle

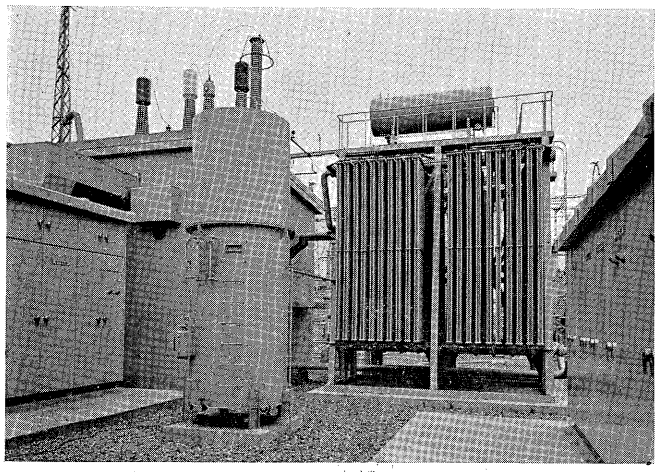


Fig. 3 (b) Separated radiator and FT tank for main transformer

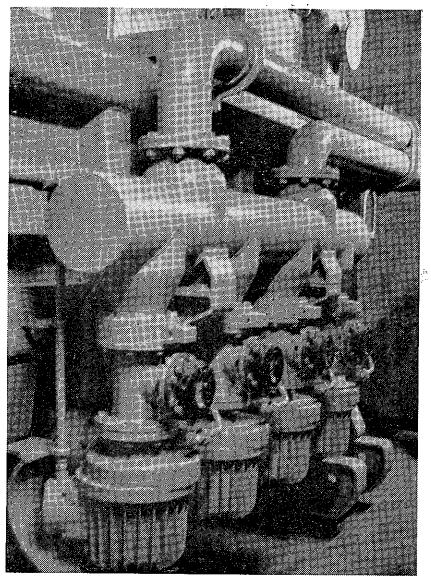


Fig. 3 (c) Oil pump for main transformer

2. 140 kv Side Line Apparatus

1) Breaker (see *Fig. 4*)

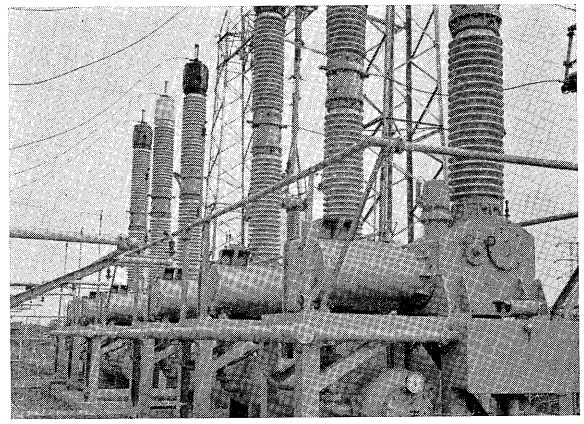


Fig. 4 168 kv 1200 amp 5000 Mva expansion circuit breaker

Type :	Outdoor-use 3-pole single-through porcelain type expansion circuit breaker
Rating :	168 kv 1200 amp 5000 Mva
Operating system :	5 kg/cm^2 pneumatic operation
Operating voltage :	Dc 100 v
Closing time :	0.25 sec
Breaking time :	5 cycles
Duty cycle :	0–1–CO–3–CO

2) DS (see *Figs. 5 & 6*)

(1) For receiving

Unit :	2 units (6-phases)
Type :	Outdoor-use 3PST pantograph type DS
Rating :	168 kv 800 amp
Operating system :	5 kg/cm^2 pneumatic operation
Operating voltage :	Dc 100 v

(2) For bus-tie and other

Unit :	4 sets (12-phases)

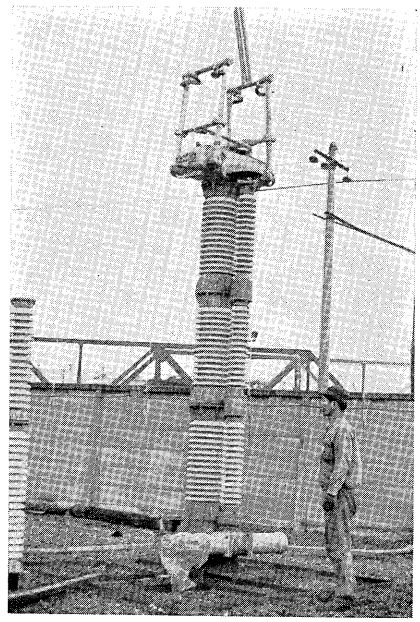


Fig. 5 168 kv 800 amp pantograph type DS

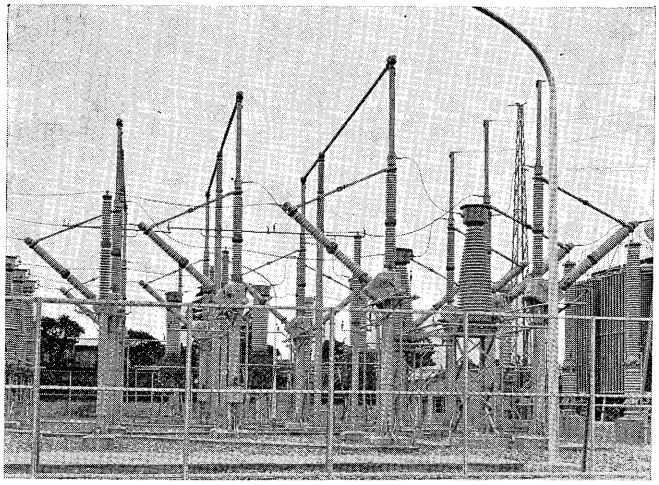


Fig. 6 168 kv 800 amp V-type DS

Type : Outdoor-use 3PSTV-type DS
Rating : 168 kv 800 amp
Operating system : 5 kg/cm² pneumatic operation
Operating voltage : Dc 100 v

3) Current transformer (see *Fig. 7*)
Type : Outdoor-use porcelain type nitrogen sealed type
Rating : 161 kv 200–100/5 amp 40 va
Overcurrent intensity : 150 times

4) Potential transformer
Unit : 1 set (3 phases)
Type : Outdoor-use single phase "OF" type potential device (made by Nisshin Denki Co., Ltd.)
Rating : $\frac{154}{\sqrt{3}}$kv/$\frac{110}{\sqrt{3}}$v/$\frac{110}{\sqrt{3}}$v · 200 va

5) Arrester
Unit : 1 set (3 phases)
Type : Outdoor use magneresist valve type (made by Toshiba RVLE–140, 196 kv)

6) Metering device (mounted by Tokyo Electric Power Co., Inc.)
(1) Porcelain CT 2 sets 161 kv 150–100/5 amp
(2) Condenser type PD 3 sets (mad by Nisshin Derki Co., Ltd.)

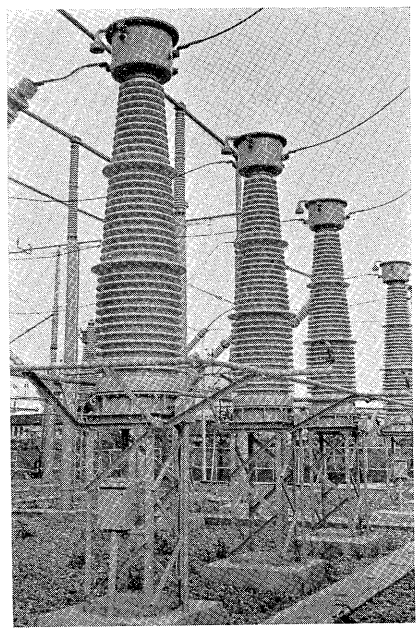


Fig. 7 161 kv porcelain type CT

3. 20 kv Side Line Apparatus

1) 20 kv cubicle (see *Fig. 3*)
(1) Type : Outdoor use self stand enclosed type JEM–1114 class E and D
Insulation level : No. 20
(2) Details of board

for main Tr. 2ry CB	1 cubicle
for feeder CB	4 cubicles
for GPT & LA	1 cubicle
for neutral resistor	1 cubicle
for compressor	1 cubicle

2) Main apparatus (mounted on the cubicle)
(1) Water circuit breaker (for main Tr. 2ry)
3 PST compressed air operation
24 kv 1500 amp 1000 Mva 1 pc.
24 kv 800 amp 1000 Mva 4 pcs.
(2) Neutral resister 1 pc.
22 kv/$\sqrt{3}$ 100 amp 30 sec rating
(3) Load break switch for above 1 pc.
3 PST compressed air operation 23 kv 600 amp breaking capacity 3000 kva (at pf=0.7)
(4) Arrester 1 set
Indoor use Perm-blast type 28 kv (1.4E)
(5) Mold type PT and CT 1 set
(6) Meter board for commercial calculation with seal 1 set
(meter provided by Tokyo Electric Power Co., Inc.)
(7) Control panel for controlling at site 1 set
(8) Compressor 1 set
Indoor use portable type automatic switching between ac and dc, with ac 3.75 kw dc 3 kw motor, 500 liters tank provided also

4. Sub-transformer

Unit : 1 set
Type : Outdoor use 3-phase forced oil self cooled nitrogen sealed low noise level
Capacity : 16,500 kva
Frequency : 50 c/s
Voltage : 22/3.45 kv
Tap voltage : 23 (F)–22 (R)–21 (F)–20 (F) kv
Connection : Delta/delta
Insulation level : No. 20/No. 6
% impedance : 5% at 16,500 kva base

5. 3 kv Side Line Apparatus

1) Cubicle
(1) Type : Outdoor use self stand enclosed

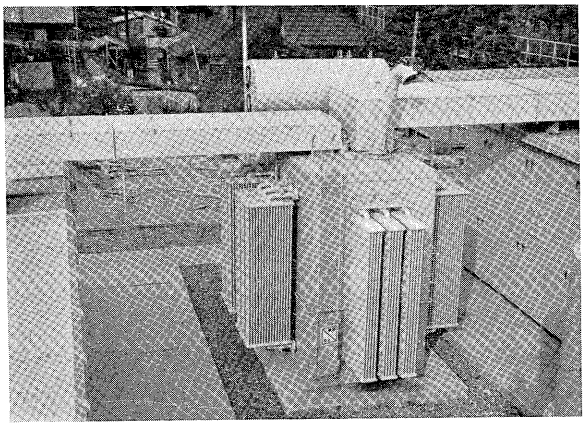


Fig. 8 22/3.45 kv 16.5 Mva transformer

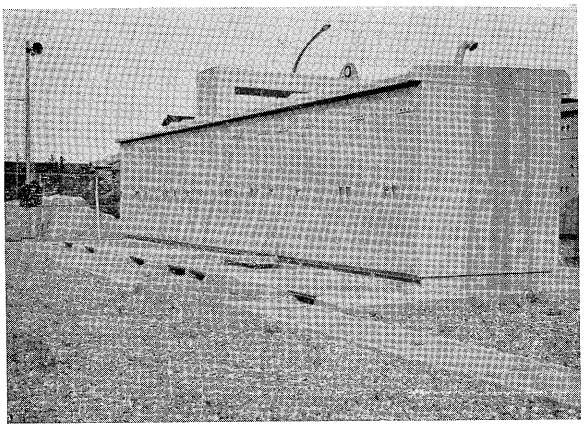


Fig. 9 3 kv cubicle

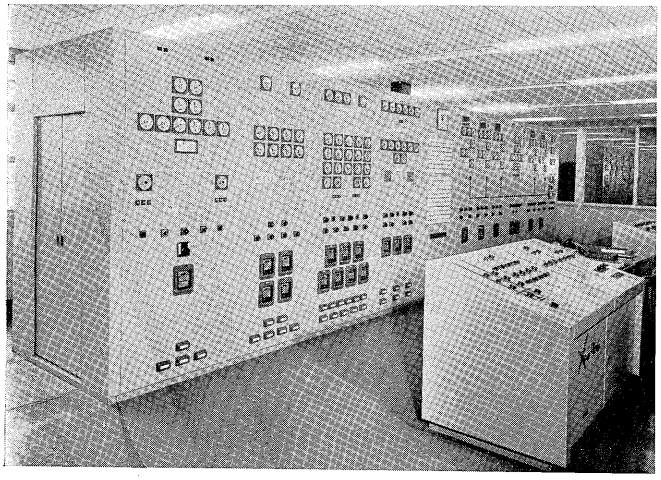


Fig. 10 Control board

type JEM-114 class E
Insulation level: No. 6

(2) Quantity: 13 cubicles

2) Main apparatus (mounted on cubicle)

(1) Water circuit breaker (250 Mva, 4000 amp, 3000 amp and 1000 amp) 6 pcs.
(2) Arrester (Perm blast type) 1 set
(3) Mold type PT and CT 1 set
(4) Station-transformer (75 kva and 20 kva) 1 set each
(5) Battery (alkali type) 144 amp-hr 1 set
(6) Charger for above (with AVR and selen-dropper) 1 set
(7) Compressor ac-dc 0.75 kw 1 set

6. Control Board

(1) Supervisory panel with illuminated mimic bus 1 set
(2) Desk type control board 1 set
(3) Self stand type relay board 1 set

IV. CHARACTERISTICS OF EQUIPMENT

1. Contents of Apparatus

All the equipment and apparatus from 140 kv receiving to 3 kv distributing are our representative products except for a few. It may be termed as a model plant of a recent large power receiving equipment for own use in respect of expansion breaker, pantograph type DS, V-type DS and concrete enclosed low noise level transformer being used.

1) Expansion breaker (ECB)

An ECB is adopted as main breaker. Air blast breaker was talked about in the past as a special high voltage circuit breaker but it leaves a number of unsolved problems such as km-fault and noise which present practical difficulties. On the other hand, ECB is without such problems and is more economical, particularly for own use as the number of sets is reduced. Therefore, the demand for this ECB is on an increase recently because of its merit which was been recognized anew.

2) Pantograph type DS (P.DS)

This is used in the incoming circuit of 140 kv power transmission line. It has many more customers

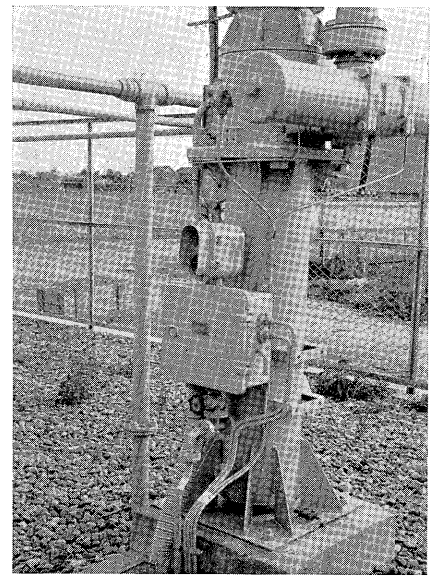


Fig. 11 Supporting frame for DS (combined with secondary air reservoir)

than heretofore obtainable due to a variety of advantages such as: easy maintenance and check-up as it is completely detached from the incoming bus when it is open, by reason of its structure; convenience as a power incoming circuit because of clearcut demarkation line of responsibility; reduced floor area required by means of three dimensional wiring as it is set directly below the bus; less cost for spraying devices due to smaller number of porcelains, etc.

Each phase serves concurrently as a secondary air reservoir by closing both ends of the lower supporting pipe.

3) V-type DS (V.DS)

This is used on 140 kv side in every circuit except the incoming point. This has many satisfied customers with 60 kv and 70 kv ratings, and, by having it structurally serve as a bus supporting insulator, much economy results such as reduced floor area and bus structurallessness, smaller porcelain number and less cost of spraying devices.

4) Concrete enclosed low noise level transformer.

The noise level of a normally designed transformer will come within the JEM standard but when it is necessary to obtain a figure much less than that measures to reduce the noise level as required will have to be taken. The step that has been most often resorted to in the past has been to use a tank of steel plates to contain noise but the limit to which noise has been reduced at most has been on the order of 25 phons.

Against the noise of 81 phons for the main transformer alone (JEM standard) the regulation on the field was 50 phons. This device is our unique conception capable of reducing noise by about 30 phons. This concrete enclosed low noise level transformer has been delivered to electric power companies in large quantities.

In order to prevent temperature rise inside the concrete enclosure, the radiator of a separate type is located outside.

5) Water circuit breaker (WCB)

As the breaker on 20 kv and 3 kv side, a water circuit breaker with many customers behind it as an oilless breaker in the past has been adopted.

This uses mainly water as arc quenching fluid and is easy to handle. As a structural feature, a big current rating may be manufactured fairly small, suitable to be accommodated in the cubicle.

6) Outdoor cubicle

The main trans-2ry side bus is directly connected to the 20 kv cubicle through a concrete enclosure for transformer by a 4-wire system bus duct including a neutral circuit.

The 20 kv cubicle has the main trans-2ry and 20 kv feeder water circuit breaker, DS, CT, PT and arrester, as well as neutral resister, metering panel and compressors. These auxiliary apparatus are housed conveniently as space factor. At the request of the customer, the main trans-2ry water circuit breaker (2000 amp rating) has been made into a draw-out type (JEM class E) and a bypass-disconnecting switch is used for its inspection.

A simple control board is manufactured and housed in the main cubicle for controling at site of the 140 kv and 20 kv side switches. On the other hand, the 3 kv cubicle has a draw-out type water circuit breaker for main trans-2ry of 4000 amp rating and feeder of 3000 amp rating. In the case of water circuit breaker, a special bypass blade is provided so that the size of the cubicle may be kept down in spite of the large current rating as above.

The cubicle accommodates also such auxiliary equipment as station transformer, stational power board and control source (storage battery and charger). By having all these auxiliary equipment in the outdoor cubicle the arrangement of equipment as substation is in order and the space required of the auxiliary equipment in the building is economized.

7) Compressor

Delivered this time are one for operation of apparatus on 140 kv and 20 kv side and one for operation of apparatus on 3 kv side for a total of two, both of which are capable of switching between ac and dc automatically.

One set suffices this time as far as capacity is concerned, but special consideration is paid to see that if one should fail the other would ensure continued operation. Normally, the air system is shared by both.

8) Control source

The storage battery uses a pocket type alkali battery which has recently gained wider acceptance as an easy to handle and long lived time. The voltage per cell of this battery is 1.2 v (average) at discharge and about 1.4 v at floating charge. In consideration of the voltage at discharge, the number of cells is set at 92.

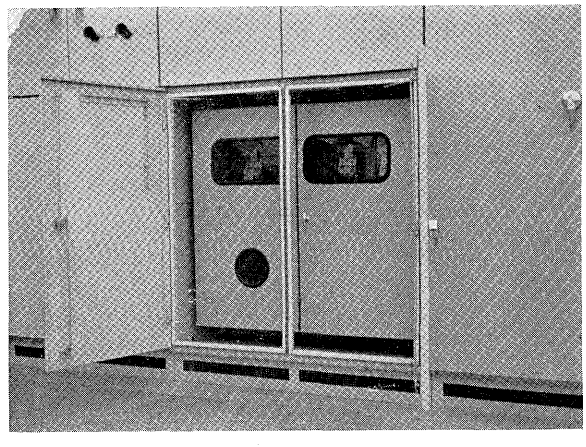


Fig. 12 Metering board

On the other hand, charging device has an automatic voltage regulator and makes sure that the high voltage (about 133 v) during floating charge does ot nappear at the load side by providing a selen-dropper in the dc load circuit.

This selen-dropper is made to automatically short-circuit when the charging source stops and prevents unnecessary drop in voltage during discharging of the battery.

9) Control board

The control board is set in a lump at the control room of No. 4 water distributing pump to which load is just added, and its system is vertical self standing enclosed type supervisory panel and desk type control board combined. The supervisory board has a built-in meter in the illuminated mimic bus (flickers at operation and trouble).

The illuminated lamp of the mimic bus is 24 v rating and derives from ac 100 v source at all times but in anticipation of ac source stop there is an automatic switching system with SCR inverter from dc 100 v to ac 24 v.

The control board has a built-in illuminated type control switch in the metal type mimic bus. The illuminated type control switch employed at this time is of two stage action which confirms control circuit with 90° rotation of the handwheel (by means of flickering of illuminated mimic bus) and a further 45° rotation to control on-off control. When the hand is released off the handwheel after the operation, it returns 45° automatically. Then, the position of the handwheel (either in the same direction as the mimic bus or in the right angle) shows the state of opening and closing of apparatus. When the handwheel position is different from the actual opening and closing state (at control or trouble breaking time) the lamp inside is made to flicker.

2. Arrangement of Apparatus

In installing special high voltage receiving equipment, what requires most space is the special high voltage side line apparatus and the structure attendant upon it. By using our unique products of pantograph type DS and V-type DS much economy is realized in terms of land price and saving of structure and porcelain plus economy in spraying devices.

As illustrated in photos (*a*) and (*b*) in *Fig. 2* the structure is only used as the supporting of incoming wire and overhead grounding wire. When the overhead grounding wire is not required and the incoming wire is of cable-incoming system, more economy will result. In the case of the present system when the bus connecting various equipment is long a bus-supporting post is used in consideration of electromagnetic force at the time of dead short. This is not so expensive when compared with the structure, other material and the working cost that are saved. By adopting the present system, saving on the 140 kv side is as follows when compared with the usual structure system: about 20% for installation area, about 20% for working cost, about 30% for porcelain spraying device. Both the V-type DS and other special type DS of our unique conception have been employed for the past several years in 60 kv and 70 kv receiving equipment but this is the first time that it is used in the 140 kv circuit.

3. Measures against Salt Damage

1) Fundamental principle

There have been a number of measures to protect the porcelain from salt damage. This time a water spraying device has been taken as one of the most usually practised systems. Main conditions that necessitate the resort to this device comprise the dirty limit of porcelain, water-resistance and withstand voltage in spraying. As for the dirty limit of porcelain, the limit is set for 0.02 mg/cm^2 in terms of salt deposit of a suspended porcelain usually classified as light contamination.

Next to be considered is the resistance of spraying water. Normally, it is stipulated that more than 6000 ohm cm shall be used, but this time, because of the water supply system, the lowest limit is set for 5000 ohm cm.

Then the question of withstand voltage on spraging. And in the case of that a neutral point shall be grounded with resister such as the 140 kv line the size of porcelain depends largely upon whether this with stand voltage on spraying will be standard voltage ($1/\sqrt{3}$ of line voltage) or line voltage. In the instance, the worst case is considered in which spraying and grounding fault take place simultaneously and the line voltage aims at the withstand voltage on spraying. Required dimensions of porcelain should be examined on the basis of the above conditions, and the ones fitted this time have been examined on the basis of the above spraying conditions.

2) Spraying device

The apparatus uses uniformly a fixed nozzle for spraying. The nozzle used this time is a new one as illustrated in *Fig. 13*. In order to avoid uneven spraying of porcelain due to the wind, this nozzle, as compared with the nozzles of the past, has a wider spraying angle than before, and in order to make flow smaller for higher withstand voltage at the time of spraying, provisions are made. The total equipment is divided into six blocks for spraying, each block provided with an automatic magnetic valve. Each block is thus sprayed by remote control from the spraying board. The spraying board has a control circuit for a pump motor in addition to the remote control of the magnetic valve (for start, stop and star delta changing device) and it is possible by a single push button to obtain: start of pump—checking of water pressure—start of spray—change-over of order of each block—stop of spray—pump

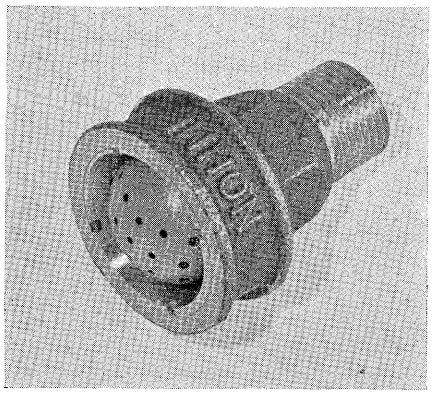


Fig. 13 (a) Spray nozzle

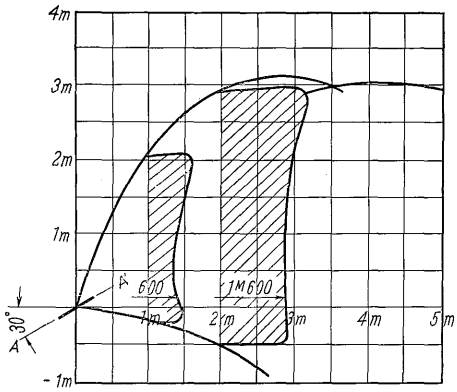


Fig. 13 (b) Spraying character of nozzle

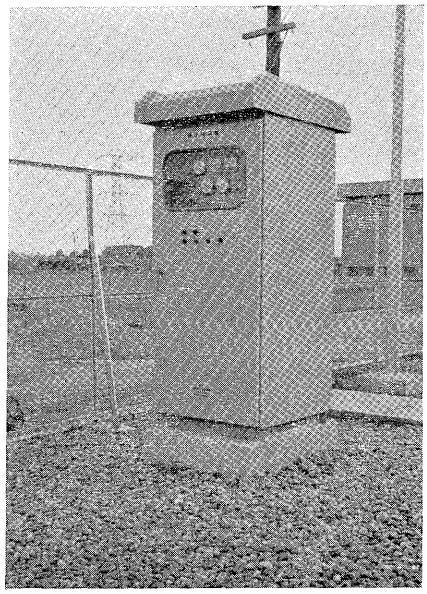


Fig. 14 Control board for spray set

stop in a series of automatic operation.

For the sake of good look and shield from climate, the pump device and the magnetic valve are housed in a pit about 1.5 m deep from the ground.

Water for spraying purposes is directly supplied from the water pipe of the water works so that no special reservoir tank is provided.

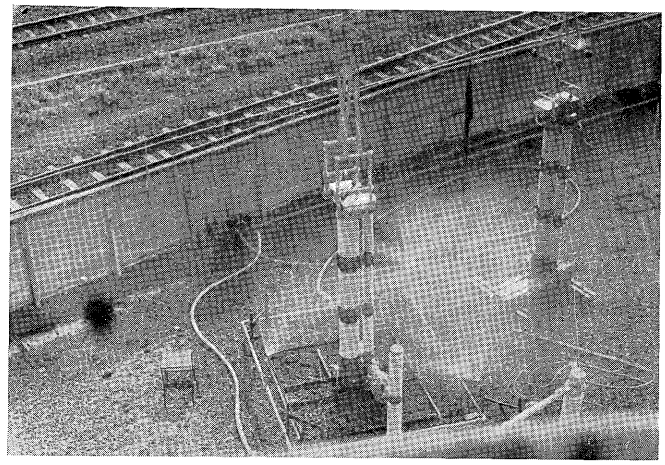


Fig. 15 Pantograph type DS under spray test

4. Others

1) Mechanical strength of main bus and supporting insulator

In the case of a normal structural system, the mechanical strength at the time of dead short does not pose any serious problem because the bus supporting makes use of the tension of the bus-tension insulator. However, the arrangement of the 140 kv side circuit does not use any structure and the bending strength of the supporting insulator for the main bus begins to matter. For this reason, a bus-supporting post is provided where the connecting line between apparatus is long, and, in addition, the following consideration has been paid :

(1) With the purpose of lessening the tension due to the weight of wire (strand wire) a strand wire of aluminum with a less weight is used. The use of aluminum wires involves a compressed type terminal between apparatus for connection, and the hole for terminal-fitting bolt on the side of the apparatus is made an oval so that it will be possibe to make dip-arrangement after the connection.

(2) Where the span is particularly long such as in the bus-tie circuit, the pipe bus is used lest the tension (bending load to the insulator) be applied to the supporting insulator such as would be present in the utilization of a strand wire. In determining the size of the pipe bus, current capacity and the intensity at the time of dead short are examined ; in addition, due consideration is paid so that the beautiful look may not be lost by the constant weight of its own. For the connection between the upper part of the insulator of the V-type DS and the pipe bus, a sliding type supporting device is used to avoid influence caused by temperature variation in the total length of the pipe bus and deflection due to the bend of the pipe bus.

The following represents the results of calculations of strength that can hold up under the worst conditions of trouble on the basis of the above specifi-

cations.

The worst conditions set imply the simultaneous taking place of 3-phase dead short (back power of line 3500 Mva) and wind pressure (40 m/sec).

(1) Pipe bus (span = 7800 mm)

Safety rate against moment of bend	6.07
Safety rate against cutting off power	149
Constant bend	7.78 mm
Maximum bend in case of trouble	100 mm
Displacement of sliding section in case of trouble	11.2 mm
Displacement of sliding section (max.) by temperature change	10.83 mm

(2) Supporting insulator for pipe bus (severest deflection)

Safety rate against load of bend	4.75

(3) Supporting insulator for V-type DS

Safety rate against load of bending	2.67

2) Drainage of pit

Water that may enter the cable pit and the spray pump pit is gathered together in the collective drainage pit provided in the station (depth about 3 m) for drainage. This is automatic drainage by two draining pumps. When the water level in the pit should abnormally go up due to the fault of the pump, for instance, it will sound a warning in the central control room.

3) Prevention of water damage by flood

The place where the station is located is below other levels, and, in consideration of the floods that hit such area in the past, the station ground was raised by about 1 m from the surrounding ground.

V. CONCLUSION

The foregoing has been a description and outline of characteristics of the 140 kv receiving equipment delivered to Kanamachi Water-Works of Tokyo Municipality; the equipment started operation as from April 15, 1964 and is in good working condition at the present time.

In adopting the main bus supporting system as seen in this 140 kv equipment the mechanical strength of insulator against magnetic force at the time of dead short has to be examined.

What effects of economy may result from the employment of this system will differ according to the connecting system of the circuit and requires serious consideration when thinking of installing such equipment.