Power Receiving Equipment for Own Supply

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I. PREFACE

Capacity of power receiving equipment for own supply is gradually becoming larger and larger as the scale of the enterprise expands and on this account the present condition is such that for receiving voltage also 140 kV is becoming to be adopted. In this Article, problems for selecting the construction and equipment of receiving station which are necessary to be known when plannnig extension and new construction of power receiving equipment for own use, will be described placing importance on their economy which it is hoped will supply reference for cases when such equipment are planned.

II. COMPONENT OF RECEIVING STATION

1. Selection of voltage

When planning the station, the first important problem that will be confronted with is selection of the receiving voltage. This is because by raising receiving voltage one step up, cost of equipment will increase, as receiving switch gear and transformer in proportion to total equipment cost will occupy roughly two-third of it. However, in this voltage selection, it will often be affected by the condition of transmission network of the supplying power company and so it is necessary to carry out previous negotiations with them.

In cases for iron and steel furnace loads having sudden load fluctuations, it is needless to mentions that power must be received from large high voltage systems having large system capacity.

Next will be the distributing voltage selection in which the plan must be made taking care to the load distribution state, i. e., cost of cable, and in selection of suitable rated current and rupturing capacity of circuit breakers. (see Table No. 1)

Table 1. Ratings of 3.6~36 kV AC circuit breaker

Rated voltage (kV)	Rated rupturing capacity (MVA)	Rated current (A)
3.6	100	600(800) 1,200(1,500)
	150	600(800) 1,200(1,500)
	#200	600(800) 1,200(1,500) 2,000 3,000
	250	600(800) 1,200(1,500) 2,000 3,000
7.2	100	400 600 (800)1,200 (1,500)
	150	400 600 (800)1,200 (1,500)
	#200	600(800) 1,200(1,500) 2,000
	250	600(800) 1,200(1,500) 2,000
12	150	600(800)
	250	600(800)
	#400	600(800) 1,200
	500	600(800) 1,200
	#600	600(800) 1,200
	750	600(800) 1,200
	1,000	600(800) 1,200
	1,500	1,200 2,000 3,000
24	250	600
	#400	600(800) 1,200
	500	600(800) 1,200
	750	600(800) 1,200
	1,000	600(800) 1,200
	1,500	600(800) 1,200(2,000) (3,000)
36	250	600
	#400	600(800)
	500	600(800) 1,200
	#600	600 1,200
	750	600(800) 1,200
	1,000	600(800) 1,200
	1,500	600(800) 1,200

N. B. 1. According to JEC 145 (1959)
2. Under 50 MVA: cut
3. #: For water circuit breaker only
4. ( ): Transient standard current

2. Selection of bank capacity

In deciding bank capacity and number of units, it is necessary to decide the anticipated ultimate capacity and its relation as to time. Keeping down initial investment as low as possible and increasing number of banks one after the other according to necessity is a wise method from the standpoint of interest but disadvantageous conditions will also appear because both H.T. and L.T. side switchgear will increase in number and transformers will accordingly be smaller in capacity, and so cost per kVA will become higher in price, required floor

Table 2. Standard capacity of 3-phase power transformer (20~140 kV)

Capacity (kVA) \ Voltage (kV)	20, 30	60, 70	100	140
300	C			
500	C			
750	C			
1,000	B, C	B, C		
1,500	B, C	C		
2,000	B, C	B, C		
3,000	B, C	B, C		
4,500	B, C	B, C		
6,000	B, C	B, C		
7,500	B, C	B, C		
10,000	B, C	B, C		
15,000	B, C	B, C	B	B
30,000		B	B	B
45,000		B	B	B
60,000		B	B	B

N. B. B: Step down from special H.T. voltage to one
C: Step down from special H.T. voltage to normal H.T. voltage

space will become larger, etc. Consequently, carefully considering increase rate of respective consumers' load, it is desirable to decide ultimate number of banks kept down to 2 banks or at most 3 banks.

Further, what our Company should like to specially request our customers here is to adopt standard kVA transformers as shown in Table No. 2.

It is hoped that although initial investment amount will increase somewhat, keeping in mind that also having some reserve for high efficiency and future load increase will be effective standard capacity transformers should be adopted.

In selection of bank capacity, beside the above considerations. L.T. side circuit breaker rupturing capacity and voltage must be considered.

Especially, when voltage is stepped down to L.T. from 3 or 6 kV, cost of NFB and ACB of L.T. side rather than transformers will often be higher and so it is more economical to adopt 420 V instead of 200 V, reduce circuit breaker current and keep down transformers also to 500 kVA or thereabouts.

3. Busbar system

Busbar system and arrangement of machine and apparatus will greatly influence the various problems on operation and maintenance of the substation and so ample study and investigation must be made on these and decision taken together with the points of economy and required floor space.

1) Busbar connection method

Generally busbar system has 3 kinds

(1) Single busbar (Fig. 1)

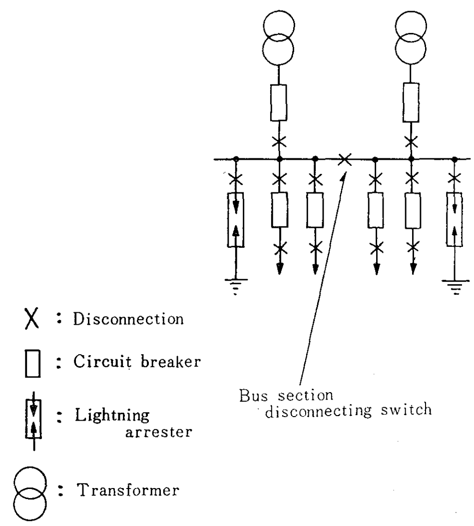


Fig. 1. Example of single busbar

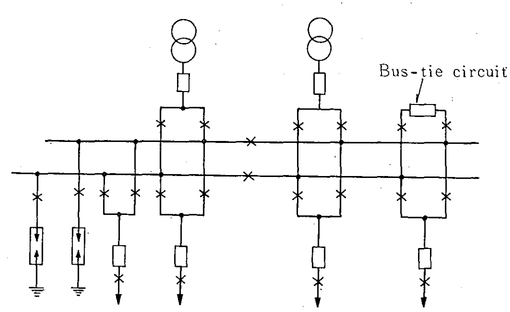


Fig. 2. Example of double busbar

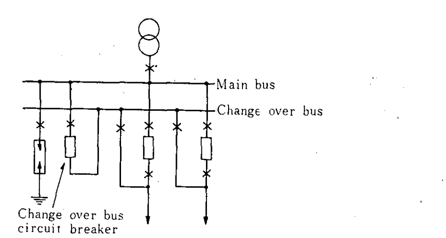


Fig. 3. Example of change-over busbar

(2) Double busbar (Fig. 2)

(3) Change-over busbar (Fig. 3)

but in substations for own use, excluding special cases, nearly always the single busbar is adopted.

This system is simple and economical but on the other side, when one part of the busbar has become faulty, it will mean overall current failure and power receiving will not be possible until fault has been remedied. Also, it has the disadvantage of required current stoppage for inspection and overhaul of busbar insulators.

Double busbar is adopted in large scale important substations or in substations used for special purposes in which power receiving is carried out by over 2 circuits at normal times where it is able to change over power receiving to a different system. This system is superior in the points of reliability of operation and versatility and it is possible to overhaul busbar insulators without interruption according to necessity.

When number of feeder lines for the plant is large and power interruption is to be avoided, by this system non-stop inspection and overhaul of circuit breakers can be carried out and further there is the advantage of being able to continue power supply by utilizing change-over busbar in case of faults in feeder line circuit breaker and its branch circuit.

2) Section of busbar

Generally, disconnecting switch of bus-section is for the main purpose of operation and maintenance inspection but recently an economical design is being attempted in which increase of circuit breaker capacity accompanying enlargement of equipment capacity is reduced through utilization of disconnecting switches. That is to say, in case of transformer failure, D.S. are closed and power supply continued. (see Fig 1).

In the case of double busbar, busbar connection is opened and dividing A and B busbars separately, independent operation is carried out. In the case of this method, though current stoppage cannot be avoided during change-over time, breaking capacity will all be sufficient with that corresponding to one bank and is economical.

Next, there is a method using bus-tie circuit breaker. If this method is adopted, breaking capacity can be reduced without being accompanied by power interruption. Moreover, as parallel operation is being normally done, there is the advantage of being able to put load on each bank evenly. In this method, breaking capacity of circuit breaker is to be selected as follows:

(1) Breaking capacity of circuit breaker for transformer secondary, partitioning and for busbar connection will be enough with that corresponding for (n−1) bank.

(2) Breaking capacity of feeder lines will be enough with that corresponding for 1 bank.

Table 3. Economical comparison of bus-system

Single bus system	100%
Double bus system	115%
Transfer bus system	105%

N. B. Condition of economical comparison
1. 60kV 2 line receiving
2. 2×10 MVA TR with on load tap changer
3. 20×3 kV feeder outdoor cubicle

If these methods are not adopted, feeder line circuit breaker must have breaking capacity corresponding to that for n banks and therefore by adopting either one of the above stated two, economical design can be carried out. (see Table No. 3)

4. Arrangement of equipment

On account of progress in electric materials and techniques in design and manufacture, it is natural that machines and apparatus have become smaller in size and lighter in weight but it is a matter of importance to arrange all machines and apparatus as a whole and by designing the equipment so as to match this and cut down required floor space of the substation.

As fundamental conditions from the point of design:

1) Considering rational arrangement, surface area for erection and height of iron structure are to be made as low as possible.
2) For natural conditions, sufficient insulating distance to be taken.
3) Necessary space for maintenance, inspection and overhaul to be provided.
4) To pay consideration on substation accessory equipment such as insulators for live line, washing apparatus, fire extinguishing apparatus, noise silencer, cable pit, etc.

Taking these points as essentials, study must be pushed forward and as concrete counter-measures for this, there are the followings:

(1) Together with making number of banks small, 3-phase transformers to be adopted. Also direct type under-load tap-changing transformer to be adopted.
(2) For switch equipment for under 30 kV, enclosed switch box to be adopted as much as possible. (Fig. 4)
(3) To adopt pantagraph disconnecting switch. (Fig. 5)
(4) In single busbar for 60∼70 kV, to consider pipe busbar system.

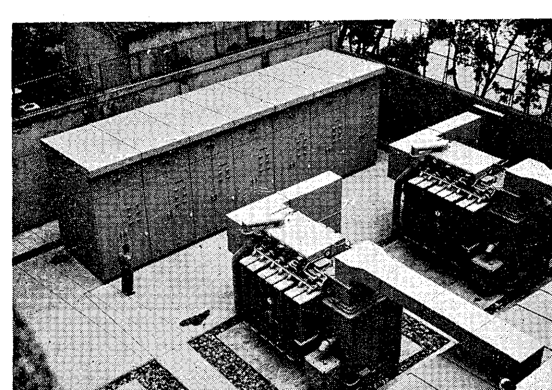


Fig. 4. 20/3 kV enclosed type unit substation

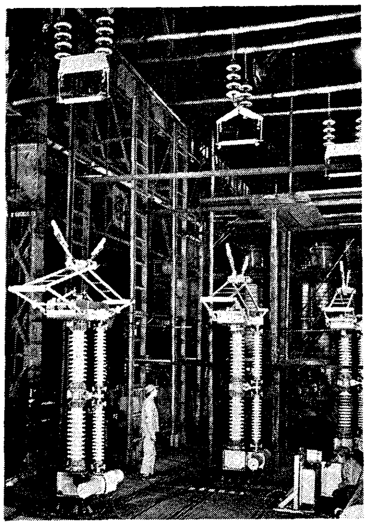


Fig. 5. 161 kV 800 A pantograph type disconnecting switches

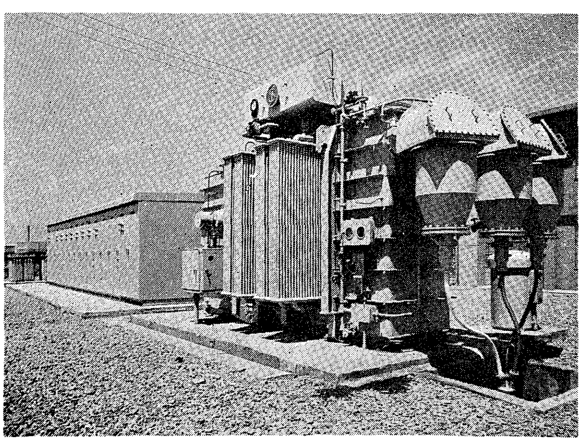


Fig. 6. Elephant transformer

(5) To adopt line switch suited for busbar system.
(6) According to necessity, to make building of 2∼3 storeys to form cubic arrangement.
(7) By adopting "elephant" transformer, to make dispersed arrangement of switchgear and transformer. (Fig. 6)
(8) Adoption of miniature switchboard.

The advantages when the recently developed "elephant" transformer is applied in receiving substations are:

(1) It can be arranged in a separate area from receiving side switchgear.
(2) Extra high tension voltage can led into center part of the premises without danger.
(3) Substation can be located at center part of the premises whereby cost of L.T. side distribution cable can be reduced.
(4) Makes centralized control system easy.
(5) Because transformer is not placed at power line inlet, effect of noise on the neighborhood is small.
(6) When installing indoors, transformer room size can be reduced.

5. Centralized control and automation

In substations for own power supply, there are still some points that require further study for complete automation but on such contents as stated below, from the present manufacturing aud maintenance technical knowledge, adoption is possible and it is hoped that progress will be gradually made toward complete automation.

(1) Expansion of supervision range through adoption of miniature size meters.
(2) Centralized supervision through adoption of remote measuring and indicating apparatus.
(3) Centralized control through adoption of remote control apparatus.
(4) Automation of measurement through adoption of recording meter.
(5) Automatic power factor regulation by control of phase advanting condenser.
(6) Automatic charging of storage battery.
(7) Automatic reclosing of distribution lines within the premises.
(8) Automatic voltage regulation of under-load tap-changing transformer or induction voltage regulator.
(9) Change-over to spare bus system from normal power receiving system in case of current interruption.
(10) Automatic switching and reclosing upon recovery of circuit breaker for current stoppage time.
(11) Program control of operation and start.
(12) Automatic start and stop of reserve generator diesel engine.

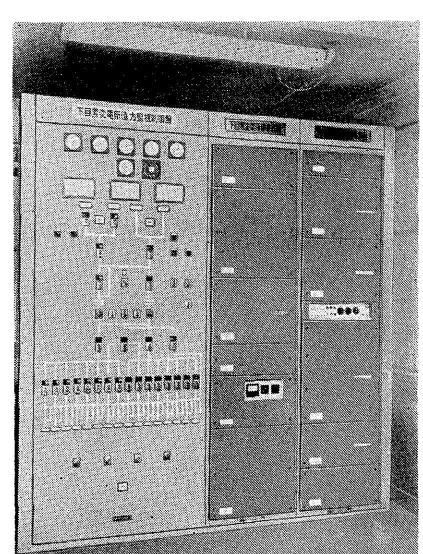


Fig. 7. Tele-controlling equipment with transistor relay

Among the above, when adopting, we think that the points which require most careful study are remote control and indicating apparatus. Our company has developed a new apparatus shown in Fig. 7 utilizing transistor, the favorite gadget of this era, to replace the apparatus using relays which hitherto often was found unsatisfactory and we have already delivered over ten, such sets to our customers. This apparatus while solving the problems of contact abstacle and life which had been the defects of ones using relays further processes the advantage of being small and light and requiring extremely little power consumption (about 50 W). Economy of direct system connected by a direct connecting wire is about 300 m as limitation. Consequently, when over 300 m, it is advantageous to adopt a remote control apparatus.

III. RECEIVING SUBSTATION ACCESSORY EQUIPMENT

1. Countermeasures for insulator deterioration and damage

Generally, as countermeasures against insulator deterioration and damage ;

(1) To contain apparatus indoors or inside enclosed box.

(2) To increase leakage path of insulator and at the same time to carry out live line water pouring washing by jet or spray.

Above countermeasures may be considered. Though it will be different according to conditions, the system of putting apparatus indoors will require roughly twice as much for cost compared with the outdoor water pouring washing method.

However, there are various conditions for receiving station construction other than countermeasures against insulator deterioration and damage such as :

1) When it becomes necessary to make building with 2 or 3 storeys on account of site being restricted.

2) When it is necessary to treat noise prevention by concrete wall of building from standpoint of countermeasure against noise.

3) Difficulty in obtaining washing water.

4) Simplification of maintenance.

When above various conditions are also considered, there are cases where it will be more economical to make it as indoor system so a careful study for each case should be made.

Even in both cases when either of the two methods is adopted, as cost of building and water pouring washing apparatus will depend upon required site area, it should be attempted to make erection floor space as small as possible and carefully consider what machine and apparatus to adopt and how they

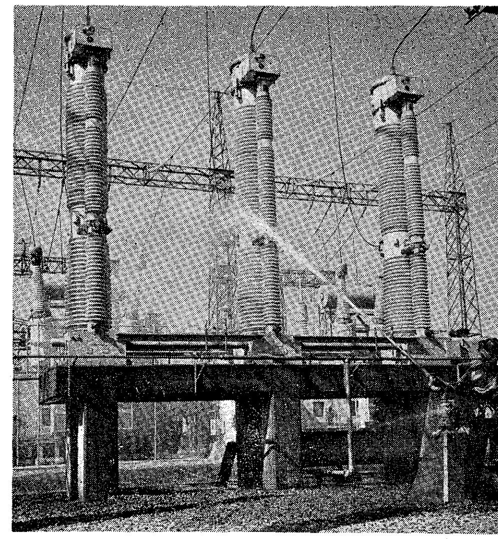


Fig. 8. Washing by jet nozzle for 161 kV ECB under loading

should be arranged. This has already been described in an other article.

Next, when the two methods of water pouring washing apparatus are compared, jet system has water pouring cylinder fixed upon a concrete base and is operated by an attendant. Its specification is 350 l/m, 4.2 kg/cm^2 and though it possess is washing force that powerfully removes adhering dirt, its defect is that because many insulators are tended by one or two washing apparatus, it often happens that while washing one phase, water spray is given to an other phase causing drop of insulation and by being carelessly unnoticed, insulator will be forgotten to be washed. (see Fig. 8)

On the other hand, in the spray system as 2～3 nozzles are fixed to 1 insulator there will be no oversight in washing and also because water pouring is done simultaneously on all 3 phases, there is no such defect as previously stated. As remote operation through automatic operation valve also is possible, compared with the jet system where about 3 attendants are required, it has the advantage that the switchboard attendant can tend this washer at the same time.

As to its defects, cost of piping and valves will be large and because several 3-phase units are washed at the same time as one group, water quantity per unit time will be large and it would require a large type of pump, (about 60 l/m per nozzle, taking 18 nozzle per 1 line switch about 1,000 l/m). Pump motor will also be several 10 HP and it will be necessary to make special consideration in power source. Though it will differ in some cases, cost of jet system and spray system will be in the proportion of 1:2. (see Fig. 9)

Keeping above features in mind, selection of above two must be carried out. Considering also economy,

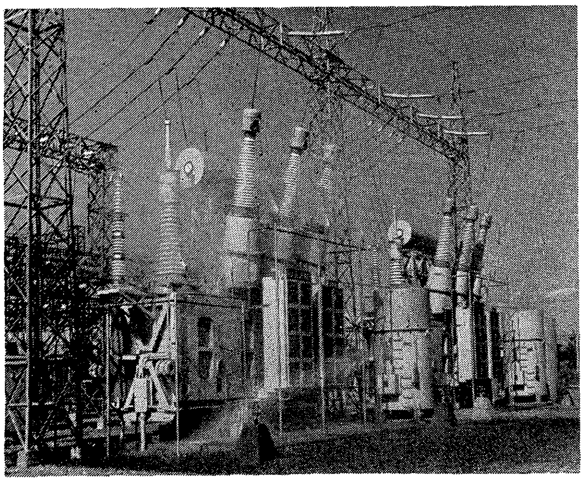


Fig. 9. Washing by spray nozzle for main transformers under loading

a combined system is in many cases adopted in which spray is provided for main equipment as high priced transformer, circuit breaker and lightning arrestor for which it is not easy to raise insulation class of insulator and provide jet for the other apparatus.

2. Noise Countermeasures

In general, it is seldom that receiving equipment can be located in the center of the factory site and as factory site boundary is more often close to private houses, by the rise in power receiving voltage and increase in transformation noise, cases where noise countermeasures are required are becoming more and more often. That is, in such places as Tokyo City, noise prevention regulations have been issued. Though it is different according to districts, it is demanded to keep noise down under 55 phon. On the other side, on noise of transformers, by JEM 1118 (1956) shown in Table No. 4 for the case when noise value is to be guaranteed, method for defining it is clearly shown and so keeping all these

Table 4. Standard sound level for oil immersed transformer (JEM 1118)

Equivalent capacity as the two winding kVA									Standard sound level (phon)
Under No. 70 of insulation class			No. 100 of insulation class			Above No. 140 of insulation class			
A	B	C	A	B	C	A	B	C	
300	…	…	…	…	…	…	…	…	56
500	…	…	…	…	…	…	…	…	58
700	…	…	…	…	…	…	…	…	60
1,000	…	…	…	…	…	…	…	…	62
1,500	…	…	…	…	…	…	…	…	63
2,000	…	…	…	…	…	…	…	…	64
3,000	…	…	…	…	…	…	…	…	65
4,000	…	…	…	…	…	…	…	…	66
5,000	…	…	1,000	…	…	…	…	…	67
6,000	…	…	1,500	…	…	…	…	…	68
7,500	…	…	2,000	…	…	…	…	…	69
10,000	2,667	…	3,000	…	…	…	…	…	70
12,500	5,333	…	4,000	…	…	…	…	…	71
15,000	6,667	…	6,000	1,333	…	3,000	…	…	72
…	10,000	…	10,000	2,667	…	4,000	…	…	73
20,000	13,333	…	12,500	4,000	…	6,000	…	…	74
25,000	16,667	12,500	15,000	5,333	…	10,000	…	…	75
30,000	20,000	16,667	20,000	13,333	…	12,500	5,333	…	76
40,000	26,667	20,800	25,000	16,667	6,667	15,000	8,000	…	77
50,000	33,333	25,666	30,000	20,000	16,667	20,000	13,333	6,667	78
60,000	40,000	41,667	40,000	26,667	25,000	25,000	16,667	16,667	79
80,000	53,333	50,000	50,000	33,333	33,333	30,000	20,000	20,800	80
100,000	66.667	66,667	60,000	40,000	41,667	40,000	26,667	25,000	81
…	80,000	83,333	80,000	53,333	50,000	50,000	33,333	33,333	82
…	106,667	100,000	100,000	66,667	66,667	60,000	40,000	41,667	83
…	…	…	…	80,000	83,333	80,000	53,333	50,000	84
…	…	…	…	106,667	100,000	100,000	66,667	66,667	85
…	…	…	…	…	…	…	80,000	83,333	86
…	…	…	…	…	…	…	106,667	100,000	87
…	…	…	…	…	…	…	…	133,333	88
…	…	…	…	…	…	…	…	166,667	89
…	…	…	…	…	…	…	…	183,333	90
								200,000	91

A: O.I.S.C., O.I.W.C., F.O.S.C. & F.O.W.C. transformer
B: Oil immersed forced air cool transformer
C: Forced oil forced air cool transformer

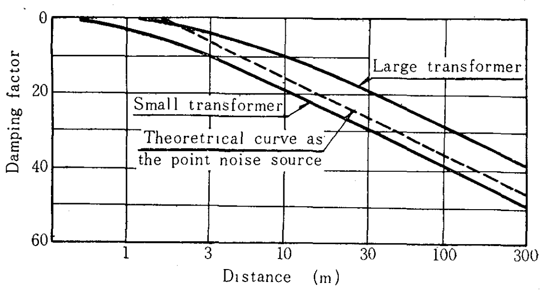


Fig. 10. Transformer noise attenuation versus distance

together in consideration, decision must be made.

In the following, countermeasures will be stated :

1) Distance must be made wide from transformer to private houses.

That is to say, by setting transformer in a position as far away as possible from private houses, noise decreasing effect due to distance as shown in Fig. 10 will be made good use of. Also, placing only H.T. side circuit breaker at the power receiving point close to private houses and sending power to " elephant " transformer installed at factory center by H.T. cable is also a system which is a very effective measure when considering measures against saline harm and easiness of site selection at the same time.

2) To install inside building

This is on account of noise decreasing effect due to concrete wall of building and it can be expected that noise will be decreased by 30 phon. However, when building is to be constructed only for this, it would mean a high cost and so it is not ordinarily used but in cases where countermeasures against saline and dust, and building from point of economy of site in necessary, this system is most effective.

3) Method to make transformer itself for low noise

When the matter cannot be solved by above 1) and 2) cases, it becomes necessary to lower noise emitted by transformer itself by all means and the problem is how to carry this out economically. First coming into consideration is the so-called low noise type in which core magnetic density is made low but this will only decrease noise by 5 phon or so at the most while price will increase about 30% and so this is ordinarily not adopted. With noise-prevention wall type by double tank, about 15 phon can be decreased and price will increase about 10–20 percent. There is a concrete shutting-off type as can be seen in Fig. 11. With this system, it is possible to decrease 30 phon and it has the advantage of being only about 10% higher in price. Hereafter, it is probable that this type will be more often adopted.

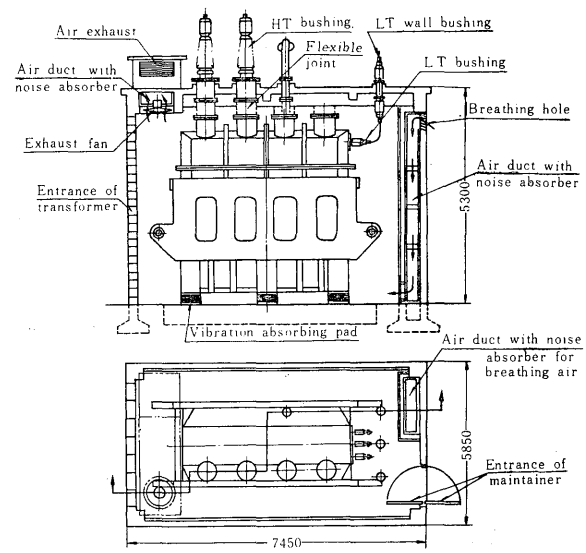


Fig. 11. Section view of low noise level transformer with concrete enclosure, 3-phase 50 c/s 60 kV 45 MVA

3. Electric construction work

1) Special features of recent busbar construction

First, as new form of busbar construction, pipe bus can be mentioned (see Fig. 12). In this system, as conductor, copper pipe (aluminium alloy ones are also being developed) is used. Because by providing supporting pillar on the ground and supporting copper pipe by S.P. (smog-proof) insulator, iron structure which occupied a large proportion in construction costs of hitherto substations has become unnecessary and as insulation dimensions can also be shortened (for instance in 60 kV circuit, dimensions between phases of 1,800 mm can safely made under 1,500 mm), at the same time as enabling smaller setting floor area, height also can be made lower through which a good result in appearance can be obtained. At present from the point of strength and length of copper pipe, it would be difficult to adopt this for super-high tension circuit above 100 kV where demensions between

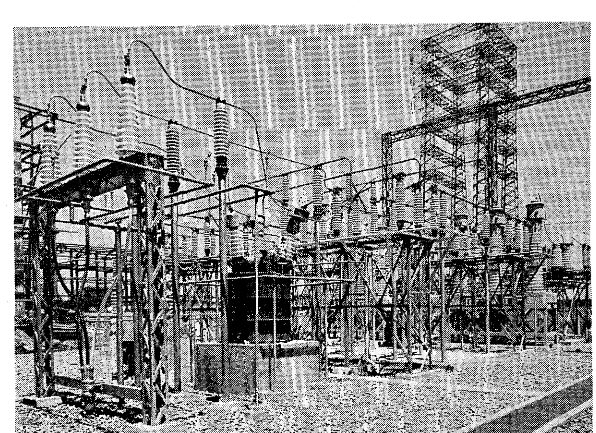


Fig. 12. Gantryless switchyard with pipe bus-system

supporting point becomes long but for under 70 kV single busbar system cases, this is specially effective.

For insulators, hitherto pin type insulator and suspension type insulator were used but due to progress in manufacturing techniques, quite recently S.P. insulator and long trunk insulator are especially used and washing is being carried out very effectively.

As outdoor iron structure in general bolt tightened ones with angle iron as material are being used but recently welded iron structure in which material is assembled together by welding are also being used. This welded structure is very effective for good appearance but because it has to be galvanized after assembly has been carried out by welding, factory processing cost will be high and transport cost will also become relatively high. Also from the construction compared with bolt fastened system, it is considerably inferior in strength and therefore this is used in small scale substations with comparatively simple circuit formation.

2) Totally indoor type substation

Recently, with the development of factory equipment, being located in a city or such similar environment, there are frequent cases where area to be occupied by substation will be extremely restricted and in addition these to noise prevention will often be demanded and in such cases considerable results can be obtained by making the substation as a totally indoor type. Also, at the same time, this will be very effective against saline and dust damage and so a few problems on this matter will be touched upon.

First, for making installing area small, cubic arrangement can be considered. One example of this is to contain extra H.T. side apparatus on the ground floor and H.T. side machine and apparatus and control apparatus on the second floor (see Fig. 13). Because it is totally indoor type, there is no necessity to make any consideration for wind pressure and so strength of spanned lines can be reduced, insulation spacing made smaller and further by making pillar of building for common use, cost of construction can be economized.

As countermeasures against noise of transformer, by making the construction such as transformer will be totally enclosed inside room and increasing thickness of side wall and when necessary by further coating side wall inside with noise absorbing material, noise prevention against noise emitted from transformer itself can be effected. For shutting off vibrations coming in through ground convection, this can be solved by isolating building foundation and transformer foundation.

As cooling method for transformer enclosed in such a way the idea of leading outside air into transformer room through an air filter by wind tunnel and dissipating heated air in to space from building top by exhaust fan can be conceived but construction of exhaust fan, exhaust air duct and noise prevention are extremely difficult problems and so indvidual separate radiator system is the rational solution.

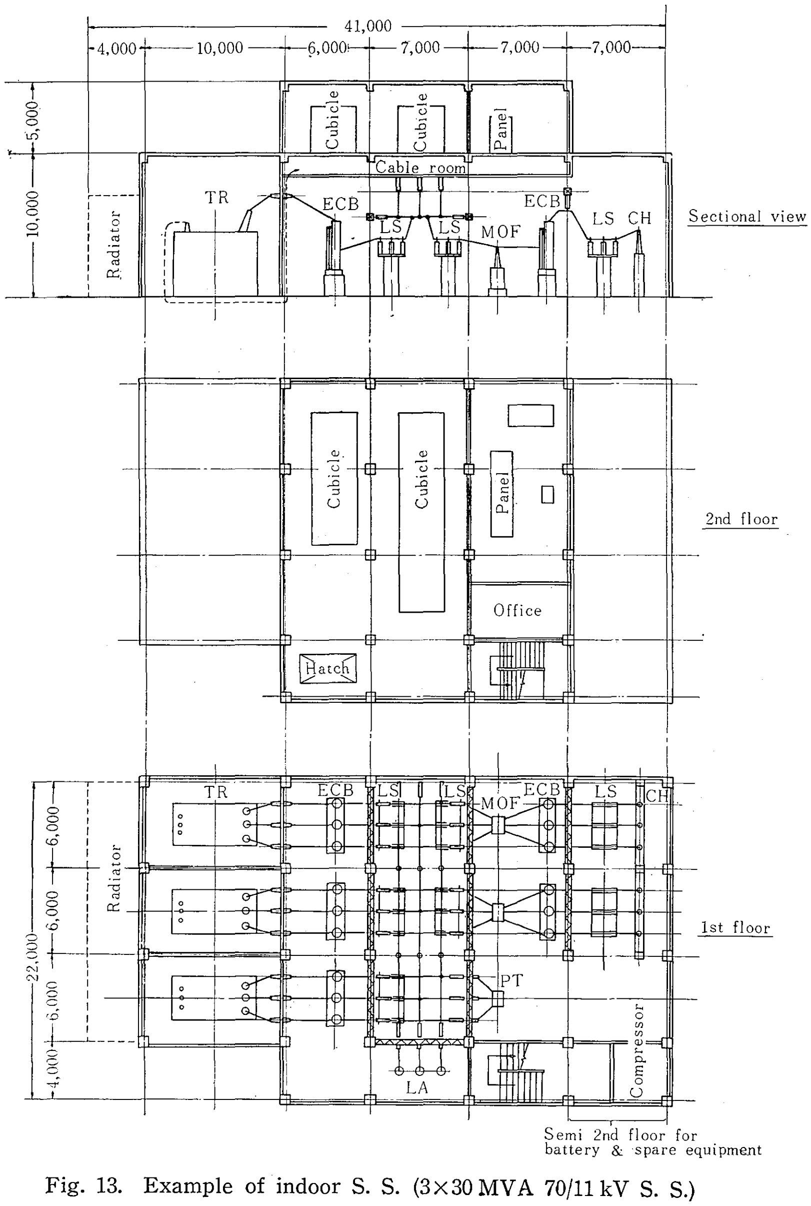


Fig. 13. Example of indoor S. S. (3×30 MVA 70/11 kV S. S.)

IV SELECTION OF MACHINE AND APPARATUS

1. Under-load voltage regulating transformer

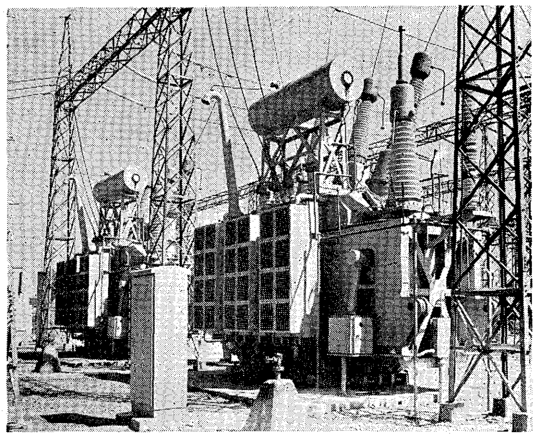


Fig. 14. 2×140 kV 30 MVA transformer with on-load tap changer

1) Kinds and application

System of under-load voltage regulation can be classified into:

(1) Direct system

(2) Indirect system

Direct system is one that is direct changed over taps by means of tap changer provided on H.T. side or L.T. side of main transformer and is what generally is called under-load tap-changing transformer. (Fig. 14).

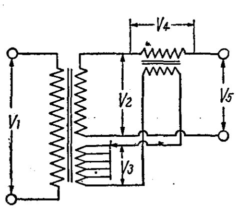


Fig. 15. Connection of on-load voltage regulator

Indirect system is one that as shown is Fig. 15 carries out voltage regulation indirectly by combining regulating transformer with series transformer and there are 2 kinds, in transformer tank contained system (called transformer with under-load voltage regulating device) and separated system (called under-load voltage regulator).

In general, direct system is:

(1)	Increase of equipment cost	small
(2)	Power loss during operation	small
(3)	Setting floor space	small

For example, making a comparison on 3-phase, 154/66 kV (voltage regulating range ±10%), 40,000 kVA set, compared to indirect system, both total weight and oil quantity will be 25% less and efficiency can be made 0.2% higher. As our Company has the Jansen type tap changer which in capability and actual results is far superior to similar device of other makers, we make it a rule to adopt the direct system. However, in existing substations when it becomes necessary to have voltage regulation later, adoption of the indirect system with voltage regulator is convenient.

2) Selection of tap range and intervals

Tap range, even though in direct system has become to be under-load tap changing, should be made for range prescribed by J.E.C.

When power source voltage fluctuation is especially great and including voltage variation due to change of load it is needed to maintain secondary side voltage constant, power source voltage fluctuation and voltage variation rate could be calculated and designed beforehand but as this goes contrarily to the trend of standardization, this should be avoided by all means. In voltage regulators, ±5 and 10% are standard.

Tap intervals considered from the object of voltage regulation would be better the closes they are made but this decision should be made from the following points:

(1) Flickering phenomena when changing over.

(2) Harmony between sensitivity of voltage relay for automatic control.

(3) Frequency of change-over switching.

About 2% is the most practical and economical.

3) Control method

As operating system of under-load voltage regulating apparatus, in general there are the following control methods:

(1) Handoperated — motor operated { n bank individual / n bank parallel }

(2) Automatic (by relay)— motor operation { n bank individual / n bank parallel }

In these, with change-over switch change over Hand—Automatic, Individual—Parallel are possible.

Time limit of tap changing is generally chosen for from several ten seconds to several minutes but it is wished that our customers will first fully understand nature of the load and then set the time limit accordingly.

4) Latest practice

Recently, our Company makes our basic policy for under-load voltage regulating transformer design as given below and by fully using our Jansen tvpe

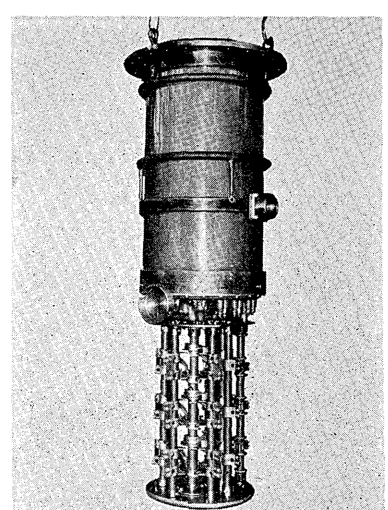


Fig. 16. Jansen switch, total enclosed type

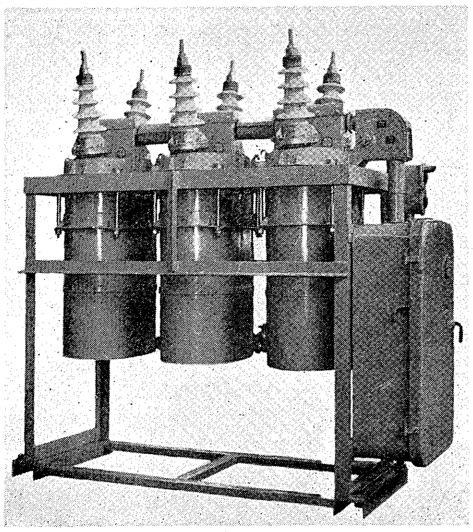


Fig. 17. Oil circuit breaker
24 kV 600 A 1,000 MVA

tap changer, this is the most rational system both technically and from the point of economy.

(1) H.T. side direct system is adopted.
(2) Tap winding arranged on neutral point side.
(3) Imbedded type is adopted (system with under-load tap changer contained inside tank). (Shown is Fig. 16)
(4) Transportation of under-load tap changer in complete assembled state.
(5) Adoption of 3-phase unit and unit capacity increased.
(6) Adoption of automatic voltage regulation control.

2. Application of switchgear

As circuit breaker, at present ECB (12～168 kV), OCB (3.6～84 kV) (Fig. 17) and WCB (3.6～36 kV) (Fig. 18) are being manufactured. Especially WCB (water circuit breaker) is same as magnet blast, high in price but with this there is no fear of fire hazards and quite many have been used in indoor type substations and other important substations.

This WCB is manufactured only by our Company in Japan and it has the following merits:

1) It is an oil-less type.
2) Rated current and rupturing capacity can be made larger compared with OCB and magnet blast. (see Table No. 5)
3) Does not issue a detonating sound when operating and so does not require a noise silencer as in the case with air blast type.
4) As size is compact it is most suited for use in cubicle.

As one new kind of apparatus, from the standpoint of making erection space smaller, saving in insulators and safety of maintenance, pantograph type disconnecting switches are being manufactured for above 100 kV and especially for indoor substations in districts where there is fear of damages from saline air and dust, these are to be recommended.

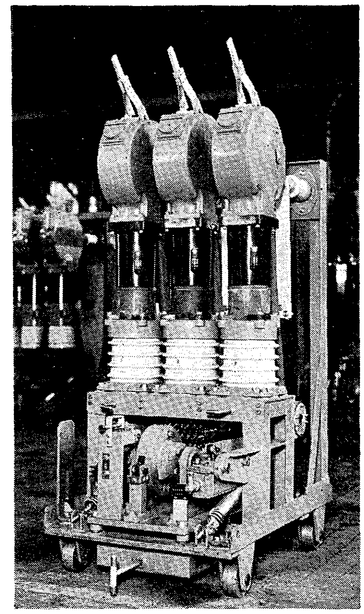


Fig. 18. Water circuit breaker
7.2 kV 600 A 250 MVA

Also, from the standpoint of extremely simplifying switchgear, air blast type line switch is able to switch exciting current of transformer or charging current of cable is being developed and at present these for 80.5 kV, 115 kV have been completed and at tests have switched exciting current of 15A, charging current of 18A by 84 kV. (Fig. 19)

For fuse type D.S. which are named HH fuse, a new series ranging from 3 kV 100A to 70 kV 20A shown in Table No. 6, Fig. 20 & Fig. 21 have been completed and so by combining with load break switch manufacture of simple substation has become possible, merits of this HH fuse are:

1) As it is enclosed current limiting type, does not release gas when breaking.

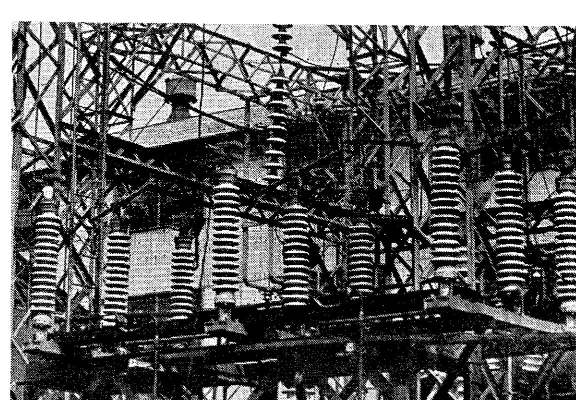


Fig. 19. Air blast line switch, 80.5 kV

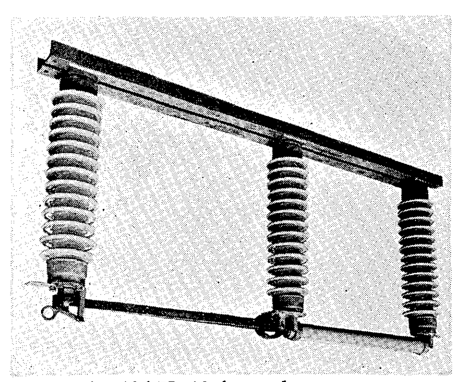
Table 5. Rating table of WCB

Type		Closing system	Rated voltage (kV)	Rupturing capacity (MVA)	Rated current (A)	Approximate weight (kg)	Rupturing liquid (*l*)
HF 623 b Ⅲ/106	600	D, M	7.2	150 at 3.6 kV	600, (800)	400	5
	1,200			250 at 7.2 kV	1,200		
HF 623 c Ⅲ/106	1,000	D, M	7.2	200 at 3.6 kV	600, (800) 1,000	500	8
	1,200	D, M			1,200	520	
	2,000	D, M		400 at 7.2 kV	2,000	600	
	3,000	D, M			3,000	700	
HF 623 g Ⅲ/106	1,000	D	7.2	300 at 3.6 kV	600 (800) 1,200	600	10
	1,500	D			(1,500)	620	
	2,000	D		600 at 7.2 kV	2,000	700	
	4,000	D, M			3,000 4,000	800	
	6,000	D			5,000 6,000	1,100	
HF 623 b Ⅲ/1010	600	D	12	250 at 12 kV	600, (800)	420	5
HF 623 g Ⅲ/1010	1,000	D, M	12	500 at 7.2 kV	600 (800) 1,200	650	12
	1,500	D, M			(1,500)	670	
	2,000	D, M		600 at 1.2 kV	2,000	750	
	4,000	D			3,000 4,000	875	
	6,000	D			5,000 6,000	1,150	
HF 623 h Ⅲ/1010	1,000	D, M	12	750 at 7.2 kV	600, (800) 1,200	900	14
	1,500	D, M			(1,500)	920	
	2,000	D		1,000 at 12 kV	2,000	1,000	
	4,000	D			3,000 4,000	1,100	
	6,000	D			5,000 6,000	1,200	
HF 623 h Ⅲ/1013	1,000	D	14.4	1,000 at 14.4 kV	1,200	950	16
	1,500	D			1,500	970	
	2,000	D			2,000	1,050	
	4,000	D			3,000 4,000	1,150	
HF 623 g Ⅲ/30	600	D, M	24	600 at 24 kV	600, (800)	1,000	16
	1,200	D, M	36	600 at 36 kV	1,200	1,025	
	2,000	D			2,000		
HF 623 h Ⅲ/30	600	D, M	24	1,000 at 24 kV	600 (800)	1,100	20
	1,200	D, M	36	1,000 at 36 kV	1,200	1,125	
	2,004				2,000		
HF623 j Ⅲ/30	600	D	24	1,500 at 24 kV	600 (800)	1,150	22
	1,200	D	36	1,500 at 36 kV	1,200	1,175	
	2,000	D			2,000	1,300	
	4,000	D			3,000 4,000	1,500	

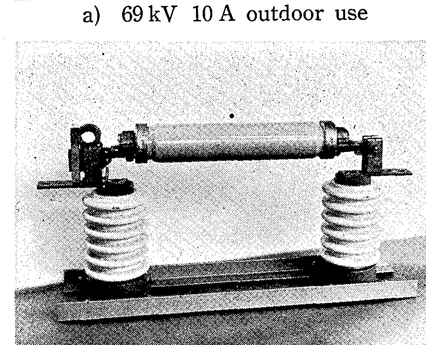
N. B. 1. ( ): Semi-standard
2. D: Compressed air drive, 5 kg/cm²
M: DC motor drive, DC 100 V

Table 6. Table for application of HH fuse for transformer or condenser

Suitable HH fuse rated current (A)	Rated current of transformer or condenser circuit (A)	3.3 kV	6.6 kV	11 kV	22 kV	33 kV	66 kV	77 kV
		3-phase capacity of transformer or condenser (kVA)						
5	2	10	20	30	75	100	200	250
10	4	25	50	75	150	250	500	600
20	8	50	100	150	300	500	1,000	1,000
30	13	75	150	250	500	750		
40	18	100	200	300	600	1,000		
50	36	150	300	500				
75	44	250	500	750				
100	53	300	600	1,000				
150	88	500	1,000					
200	105	600						



a) 69 kV 10 A outdoor use



b) 23 kV 40 A indoor use

Fig. 20. HH fuse with D.S.

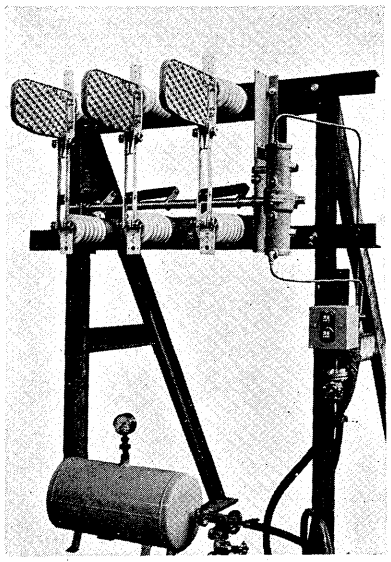


Fig. 21. Load break switch 23 kV 400 A

Table 7. Comparison of equipment style

Condition	Type	Space	Cost
10×23 kV feeder except the transformer and the other	Outdoor open type 1) Insulation class No. 20 2) Included the cost of the structure & etc.	100%	100%
	Outdoor open type 1) Insulation class No. 30 for insulator 2) Included the cost of water washing device for salt proof	100%	150%
	Outdoor cubicle type, insulation class of No. 20	50%	160%

2) Has unlimited short-circuit current rupturing capacity.
3) Non-uniformity of fusing characteristics is small so can easily cooperate with other relays.
4) Small and light.

Also, Fuji lightning arrester for 3 kV to 140 kV have been completed and are being manufactured.

3. Kinds of enclosed switchboard and application

1) Significance

As significance of enclosed switchboard :

(1) Safety for persons.
(2) Safety for apparatus themselves.
(3) Prevention of spreading of faults.
(4) Safety for control and convenient for maintenance, inspection.
(5) Making equipment as unit system (changeability, standardization, high reliability).
(6) Making occupied space smaller.
(7) Safety against saline damage.
(8) Cubic arrangement in indoor substation.
(9) Good appearance.
(10) Fire hazard prevention (use of oil-less apparatus).

Such points as above can be enumerated contributing greatly to rationalization of up-to-date equipment.

As to economy, as shown in Table No. 7. compared to ordinary open type substation, it will be somewhat higher in price but when all what has been described are considered together, it can be perceived that there will be more in its value than its difference in price.

2) Kinds

Enclosed switchboard are those so-called metalclad or cubicle and are generally adopted for 30 kV to 3 kV circuits. Its kinds are as shown in Table No. 8 classified into 7 kinds by the Japan Electric Machine Industry Association with JEM 1114 (inacted 1956 May, first revised 1958 May)

Interpretations of metalclad and cubicle also differ but commonly, types A to D are called cubicles and types E~G metalclad, but from the idea of metalclad defined in NEMA, we consider that it would be proper to call G type metalclad and the other types cubicle. (in our Company G type only is called metalclad) but for expressing construction of enclosed switchboard, it should be defined by the form ruled by JEM 1114.

3) Application

When voltage becames high as 10~30 kV, for satisfying the above mentioned high-degree demands, it becomes very disadvantageous from the point of demensions and economy and on the other hand also from maintenance considering that switchings are not so often, in general at most A~D types are taken in more cases.

On the other hand, for 3~6 kV, there is no problem in dimensions, also, from point of maintenance, high-degree ones as possible are desirable but from the standpoint of economy, active attempts are recently being made to simplify as much as possible and standardize the products. In our Company we should like to recommend E type.

Further, dimensions are for 20 kV outdoor type, width 1,700 mm × depth 2,800 mm × height 4,000 mm and for 6 kV outdoor type, width 700 mm × depth 2,450 mm × height 2,600 mm as standard sizes. (Fig. 22)

Table 8. List of metal-enclosed switchgear (JEM 1114)

Types for metal-enclosed switchgear							Construction requirements
A	B	C	D	E	F	G	
○	○	○	○	○	○	○	1. All parts for each unit circuit should be enclosed within a grounded metal enclosure.
—	○	○	○	○	○	○	2. Major parts of the primary circuit should be isolated from the monitoring control board by grounded metal barriers.
—	—	○	○	○	○	○	3. Interclocks should be provided to prevent the disconnecting switch from being operated while the braeker is closed.
—	—	—	○	○	○	○	4. The power circuit breaker and the apparatus mounted thereon should be so constructed as to be extractable.
—	—	—	—	○	○	○	5. The breaker should be of the removable type, equipped with self-coupling type primary and control disconnecting contact.
—	—	—	—	—	○	○	6. Major part of the main circuit should be isolated from each other by grounded metal barriers, or by insulated barriers.
—	—	—	—	—	—	○	7. Conduction parts (buses, connections and joints) should be totally insulated.

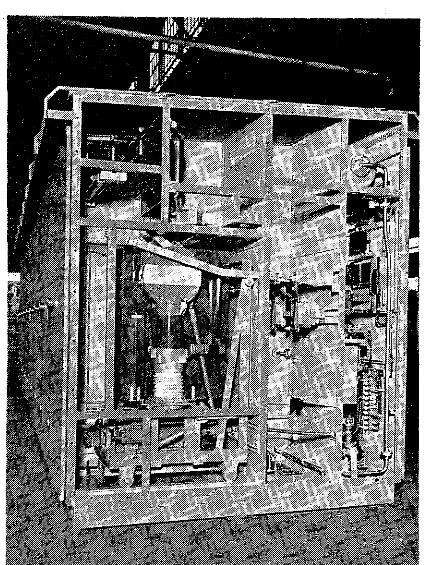


Fig. 22. Sectional view of metal-clad switchgear

4. Control center

Control center are units formed of a combination of switch and protection apparatus for motors under 600 V and put together and arranged cubically in a box with standard dimensions and is very convenient for control and maintenance. (Fig. 23 & Fig. 24)

However, at present range of application is :

(1) Rupturing capacity under 15,000A.

(2) For 200 V, motor up to 40 kW (cage), 50 kW (wound)
For 400 V, motor up to 80 kW (cage), 100 kW (wound)

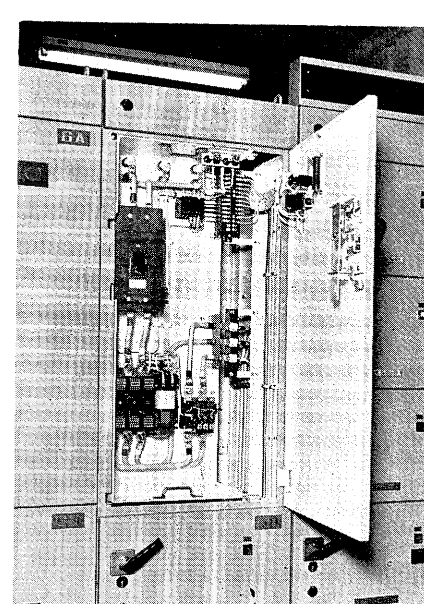


Fig. 23. Control center with NFB.

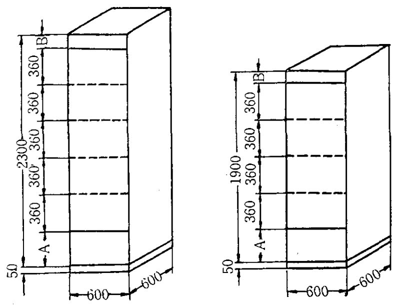


Fig. 24. Standard size of control center with NFB

When to be applied for larger medium capacity motors, it will be necessary to use ACB (rupturing capacity 50~70 kA)

As L.T. AC source cubicle, load center using NFB or ACB is also manufactured (see Fig. 25).

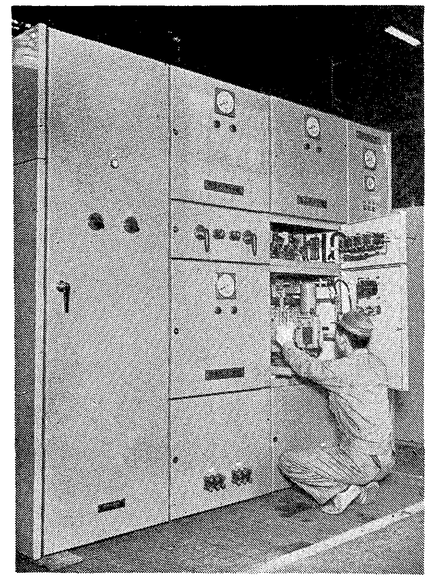


Fig. 25. Load center with ACB