5.3.3. Investigation and Study on Protective Relay System

(1) Present situation of protective relay

The system protective relay and transformer protective relay has generally good results in operation and no technical problems at present. The present situation is outlined as follows.

a) 150kV transmission protection relay system

Since 150kV transmission line system had been introduced in East Java, the directional distance comparative carrier relay (unswitched type) has been mainly used up to now, for instance in Karankates Hydro Power Station, Perak Thermal Power Station and the recent installed Gresik Thermal Power Station.
Other systems considered at this moment are the Pilot wire relay system, transfer trip scheme, distance relaying scheme, etc. which are not broadly used in comparison with the directional distance comparative carrier relay.
The type for protective relay on 150kV transmission will be the directional distance carrier relay. (unswitched type)

b) 70kV transmission protective relay system

The distance relay system is applied for a short circuit fault on 70kV transmission line. For a single phase ground fault, the distance relay system with selection ground relay is used on 70kV transmission line.
The pilot wire relay system is partly used for short distance double circuit transmission line.
In order to get the higher reliability needed for system expansion in the future and to shorten the clearing time of the fault, it is recommended to additionally adopt a balance relay

for short circuit on existing distance relay.
The recommendable type for short distance transmission line will be a pilot wire relay from the economical and reliable point of view.

c) Protection of Bus-bar

Bus-bar protection has not been adopted so far in East Java. However, it is scheduled to be installed firstly on 150kV bus-bar in the forthcoming Project of Gresik No. 3 generator, No. 4 generator.
In the double bus-bar system, total protection is adopted by current differential method. That was considered best for the protection of this system.
In the future, with the expansion of system, it is recommendable to install the bus-bar protective relay on 150kV bus-bar of important substations, such as Krian, sukolilo, War and Kebonagung substation. In case of 70kV bus-bar, the operation of double bus-bar is very few and selective breaking is not so effective, accordingly.
It would be not necessary to install the bus-bar protection system on 70kV bus-bar, except for special case.

d) Transformer protection

For the protection of transformer, an electrical system by use of high-speed ratio differential relay is applied to detect an internal fault of the transformer instantly.
Mechanical systems are also adopted by use of the thermometer with trip contact point and alarm contact point for the protection against overload, and by instant operational pressure relay, by using Buchholz relay, etc.
In case of actual operation of the high-speed ratio differential relay, due attention should be paid to avoid mal-operation by

rush current at the time of switch-on.
And for mechanical protection method, it would be necessary to check and decide the setting of the trip or alarm with the effective operation at the relay.

e) Automatic Oscillograph

For the record of faults, the oscillograph with ink made in Carpentier Co. had been used in East Jave. However, recently new inkless oscillograph has been developed in other countries. This inkless oscillograph is recommendable in East Java.
The inkless type has no necessity of exchanging a moving roller intervally, and no continuous operation is required.
So maintenance of inkless oscillograph is very easy.

(2) Study for the adoption of solid state type relay

Mechanical type relay had been adopted formerly. Recently some countries are going to introduce the solid-state.
But, at present, the mechanical type is seemed to have more advantage from the view-points of reliability, maintenance and necessary spare parts.
The advantageous point of solid-state is to make the operating speed faster and to decrease the CT load. And the price of solid-state relay is going down and approaching to that of mechanical type relay.
Since the introduction of solid-state relay is gradually increased in other countries, the recommended would be the preparation for acceptance such as study of basic theory of solid state relay and training of operation and maintaneous of the relay.

Table 5.3-1 Comparison of special condition for Apparatus (1/2)

Item		Belgia	Perancis	Hyundai	S.D.P. (Tender Document)	Remarks
Transformen	(1) Nominal rating	150kV/70kV. 23.5 ONAN 35.0 ONAF	150KV/20kV. ONAN ONAF	150kV/20kV. 15 ONAN 30 ONAF	150kV/20kV. 35 ONAN 42 ONAF 50 OFAF	*
	(2) Connection (vector group)	YNyno	NO Entry	NO Entry	YNyno	
	(3) On-Load tap changer .Tap steps No. .Step voltage(%)	NO.of position 17 1.56 %	NO. Entry 1.39 %	NO.of taps 17 voltage per step 2kV	Tap steps NO. 16 1.25 %	
	(4) Efficiency(%) (at load)	99.48 (2/4)	NO. Entry	99.64/99.58	99.73/99.71/99.68 (By Fuji Electri Co.)	Fnji Ele. Co's Trans. has highest efficiency.
	(5) Impedance voltage (at rated tap)	10%	12.2 %	10 %	10 %	
	(6) special mention	Antomatic fire extinguisher				
Circuit Breaker	(1) Normal rating	10kV and 70kV	150kV	150kV and 70kV	150kV and 70kV	
	(2) Type	small-oil-Volume	SF_6 gas	SF_6 gas	SF_6 gas	
	(3) Operation Type	Motor	Solenoid	Motor	Pneumatic or bydraulic	

Table 5.3-1 Comparison of special condition Apparatus (2/2)

Item		Belgia	Perancis	Hyundai	S.D.P. (Tender Document)		Remarks
Isolator	(1) Normal rating	150kV and 70kV	150kV	150kV and 70kV	150kV and 70kV		
	(2) Operation type	Motor	Motor	Motor	Power operating device Need		
	(3) Operation system				Electrie Remote Operation for 150kV		
	(4) Earthing switch	Provided lt is mechanical interlocked with the line isolator	NO Enty	NO Enty	Provided lt is mechanical interlochd with the line isolator		
Voltage transformer	(1) Normal rating	150kV	150kV	150kV and 70kV	150kV and 70kV	20kV	
	(2) Type	Capacitor type	NO Enty	Capacitor type	Capacitor type	Winding type	Capacitor type has high reliability

Note * ONAN : Natural oil circulation natural air cooling
ONAF : Natural oil circulation forced air cooling
OFAF : Forced oil circulation forced air cooling

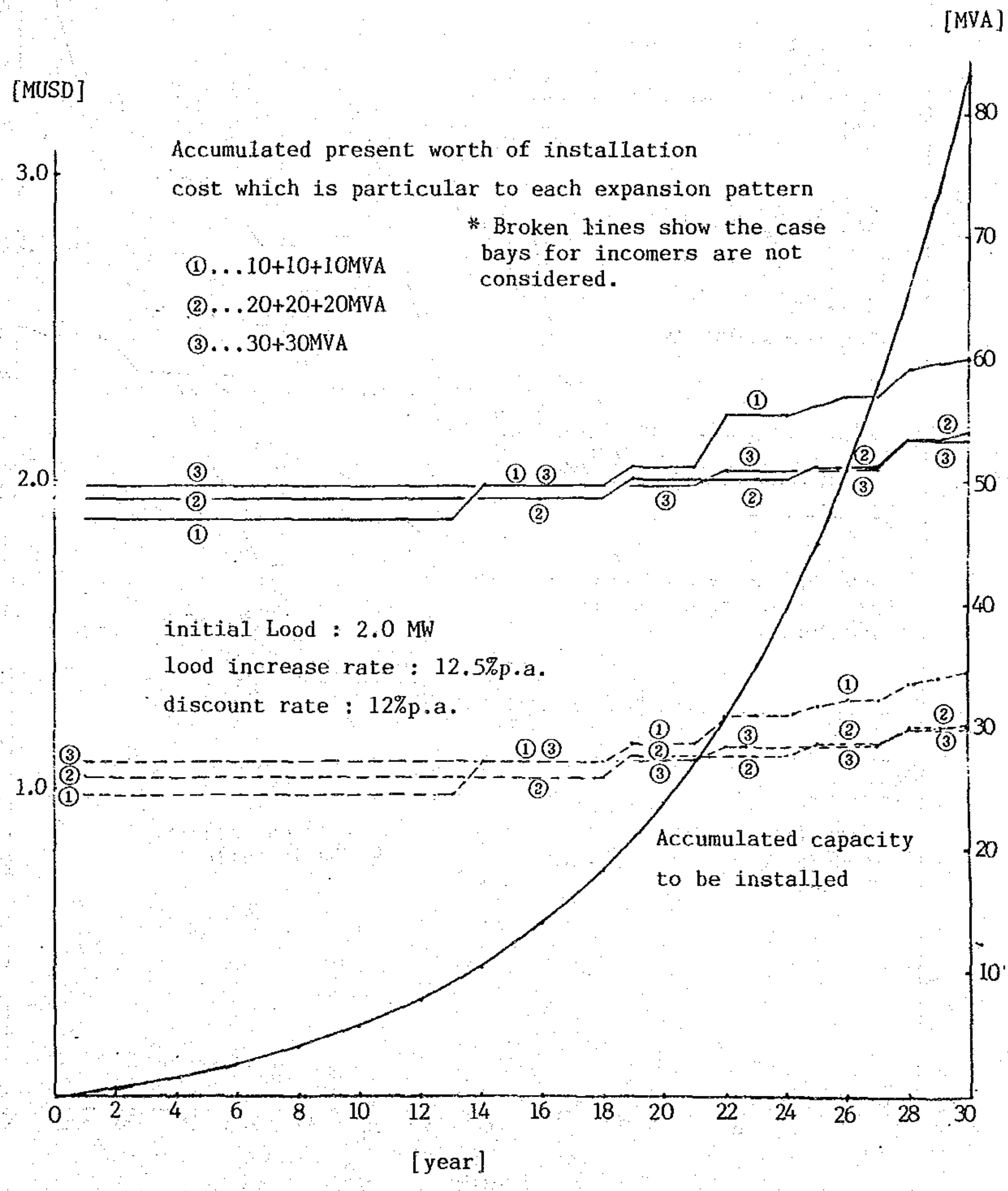


Fig 5.3-1(1) Comparison of Various Expansion Patterns of Substations

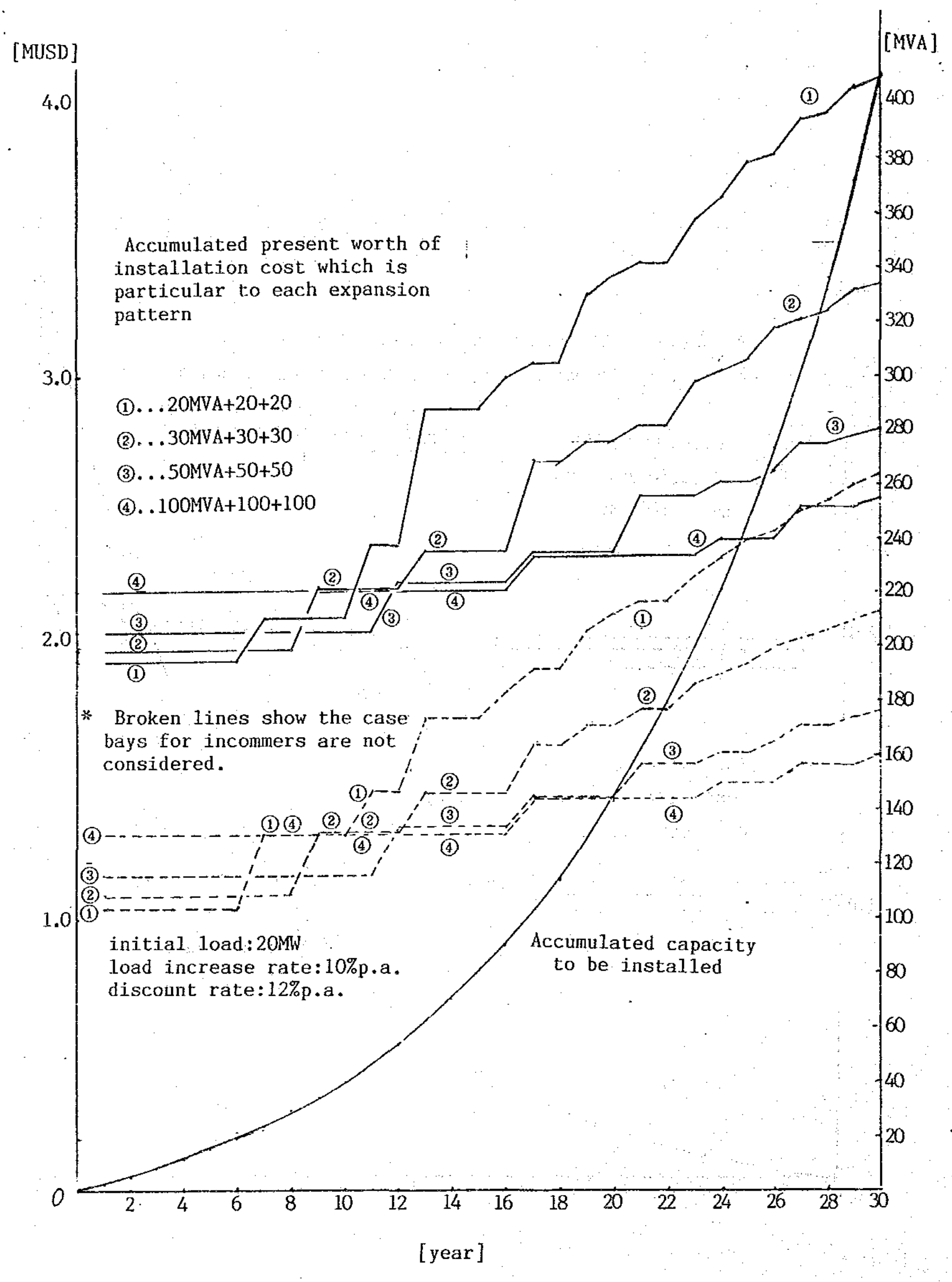


Fig 5.3-1(2) Comparison of Various Expansion Patterns of Substations

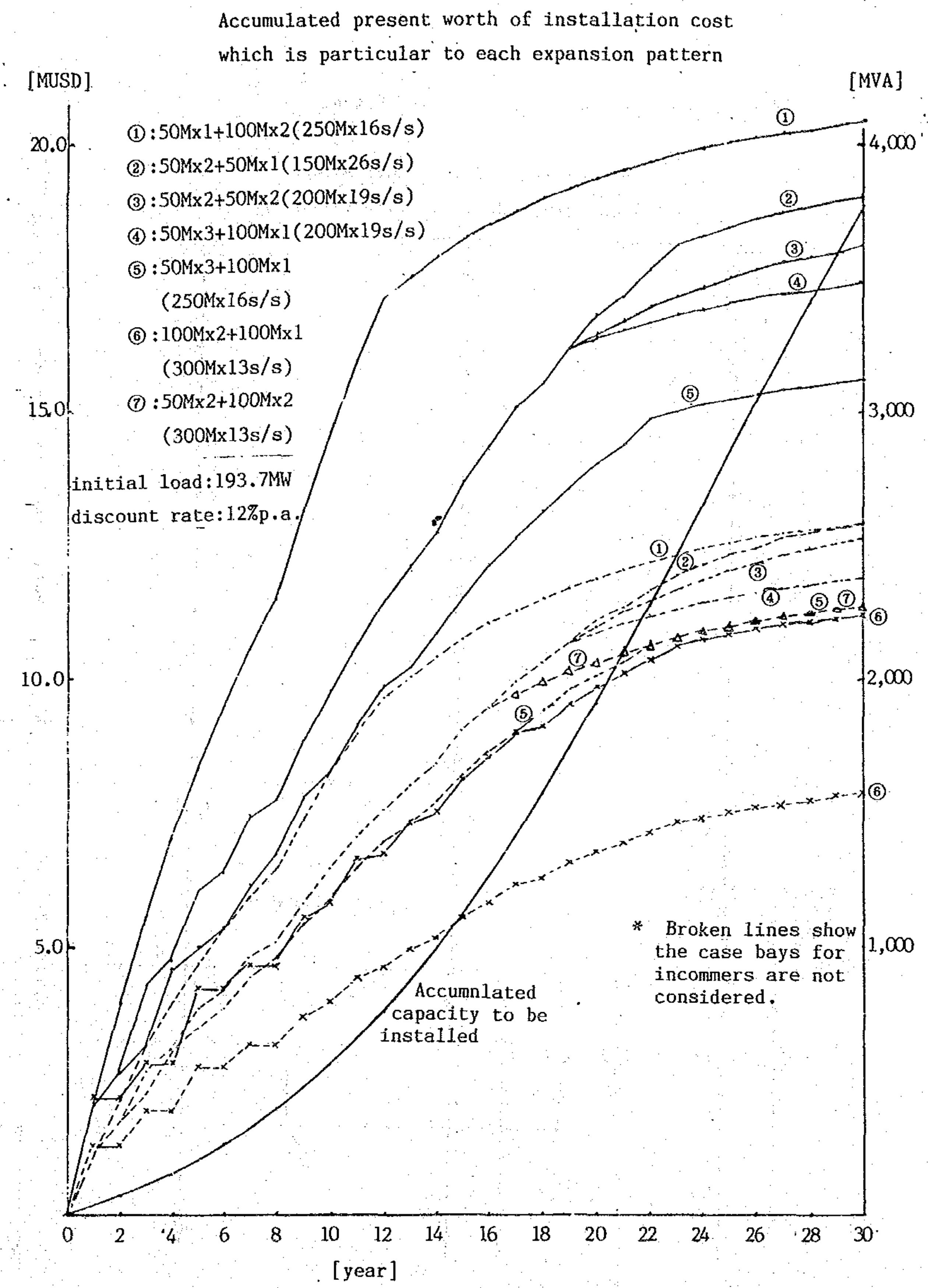


Fig 5.3-1(3) Comparison of Various Expansion Patterns of Substations

Fig. 5.3-2 The Substation of Unit System

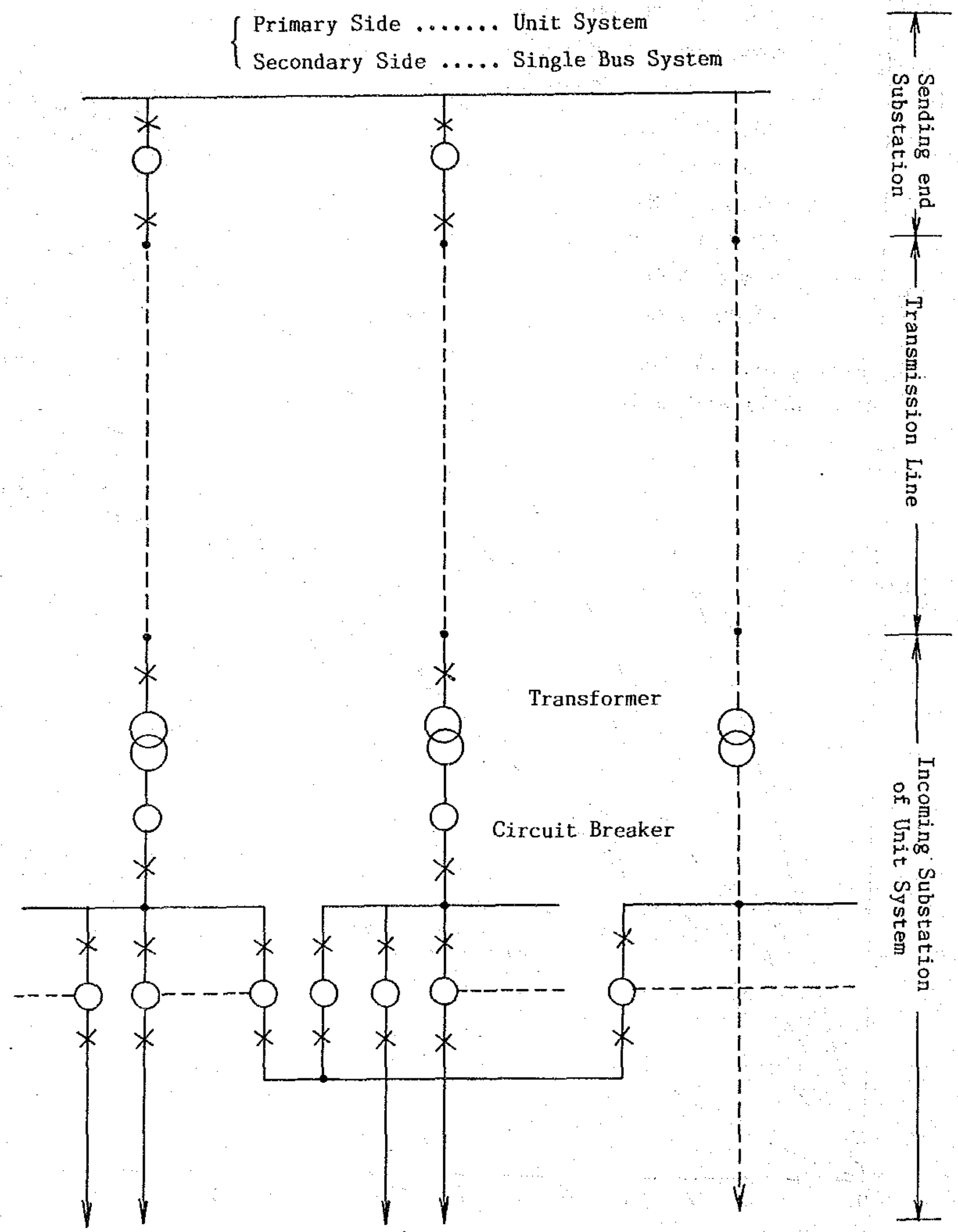
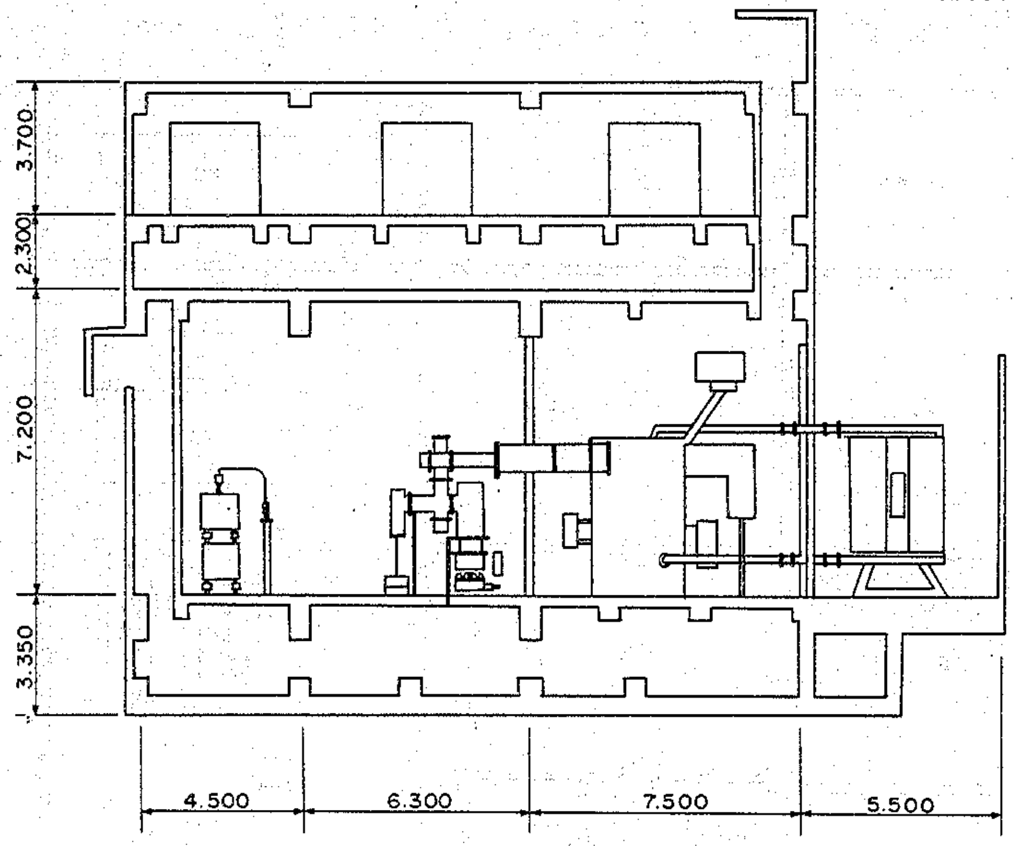


Fig 5.3-3(1/3) Example of lay out for unit Substation

Cross Section



NOTE (1) Tr. Cap. 50MVA x 3

(2) 20kV Feeder 6F x 3

(3) 150kV Line Switch and P.T. are G.I.S. Instrument

Fig 5.3-3(2/3) Example of lay out for unit Substation

1F

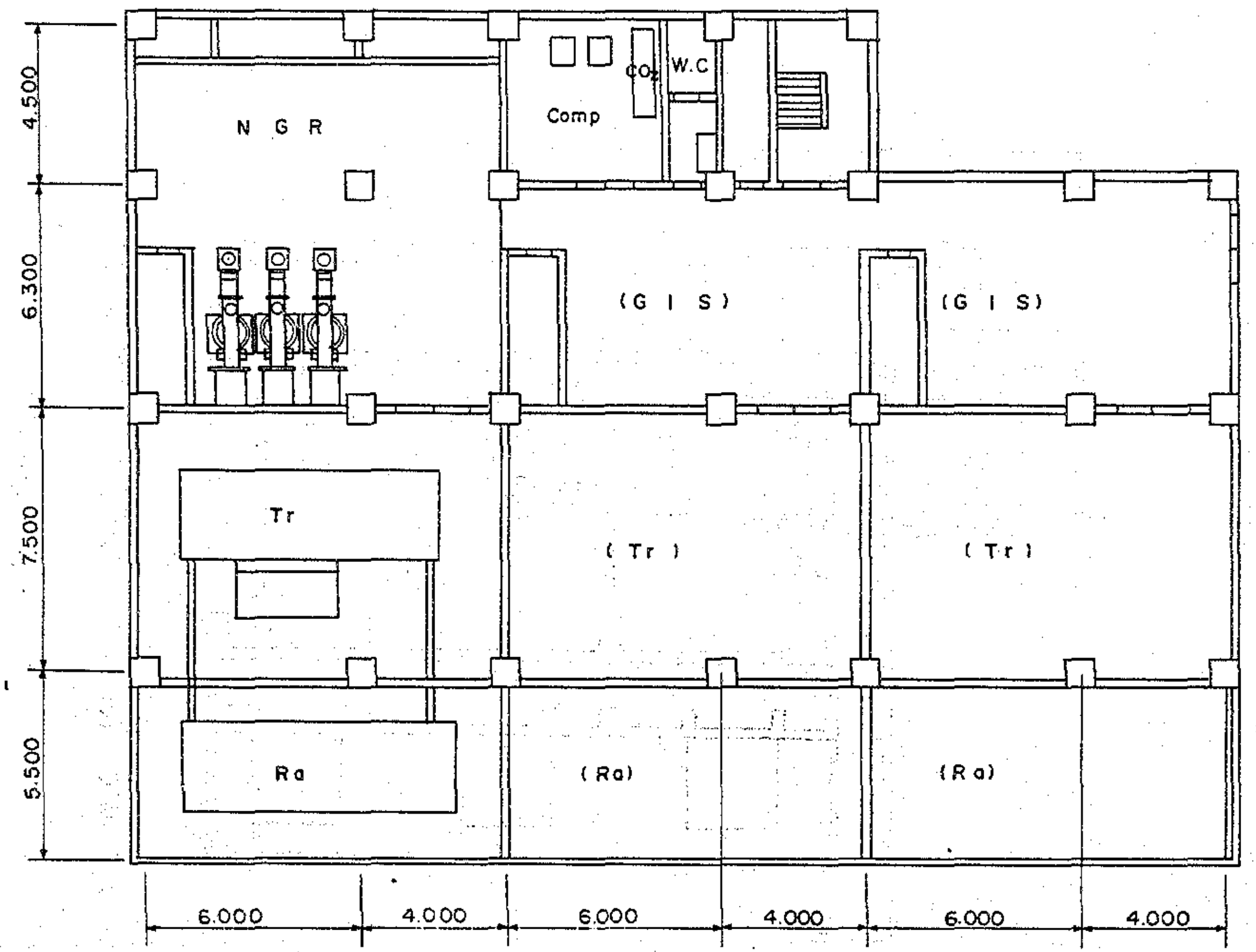


Fig 5.3-3(3/3) Example of lay out for unit Substation

3F

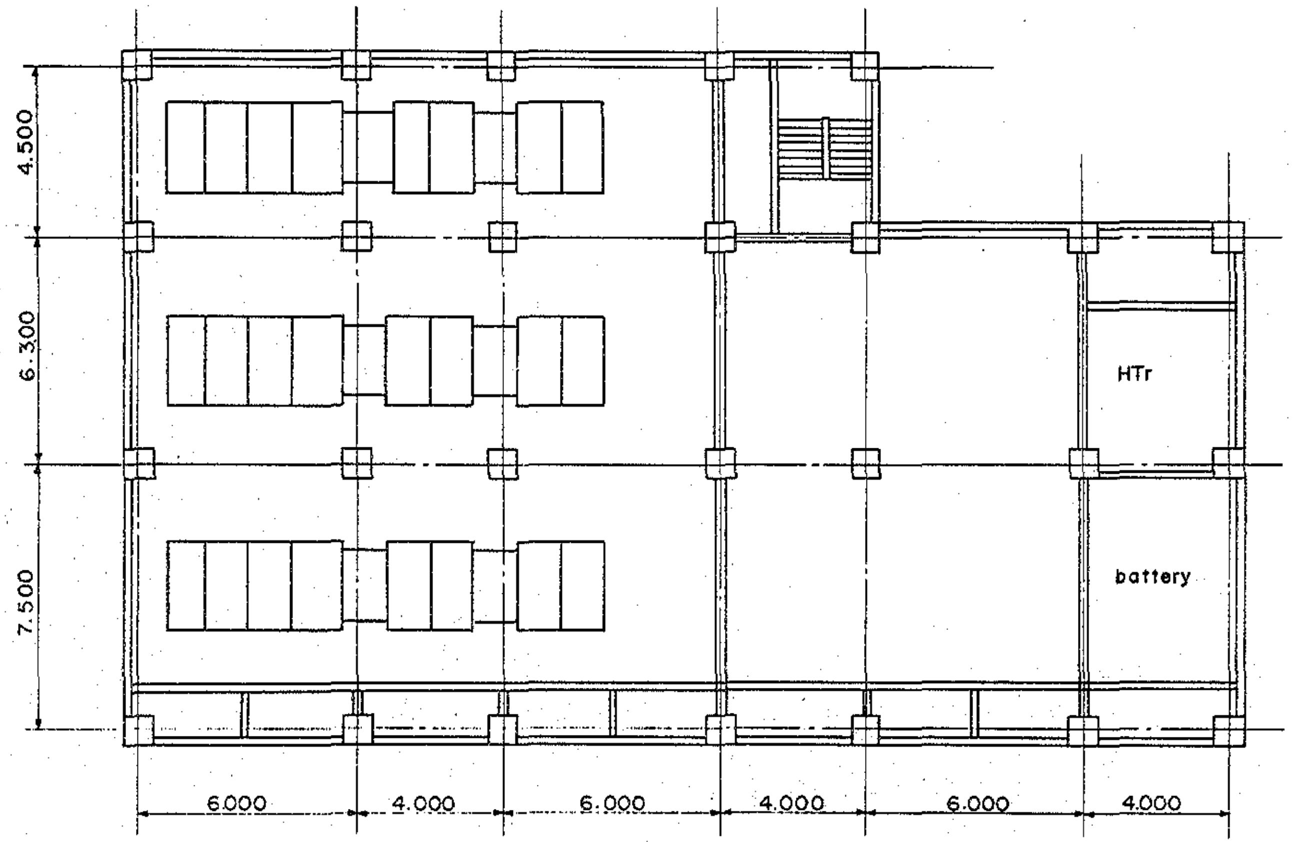
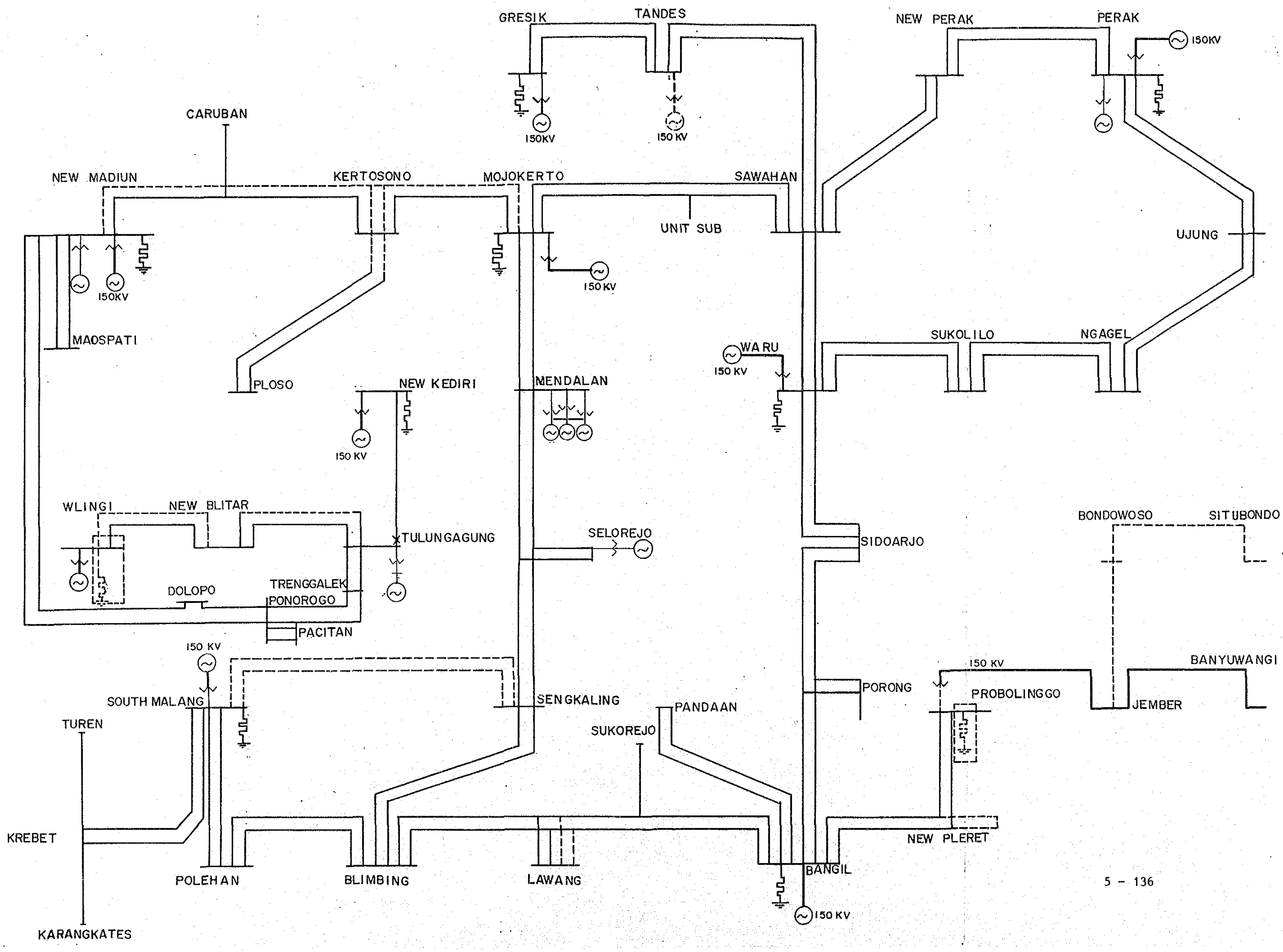


Fig 5.3-4 70KV NEUTRAL GROUNDING SCHEME



5.4. Study of Distribution Facilities

5.4.1. Study on Up-grading of Consumer Supply Voltage (Low Voltage)

(1) Preface

Up-grading of the consumer supply voltage (low voltage) has been decided to execute successively according to the PLN's Regulation enacted in August, 1973 in Indonesia. Study report on this subject was submitted to PLN by NEWJEC as one of a scope of works for consulting services of East Java Transmission and Distribution Network Project Second Stage financed under Japanese Yen Loan in 1972. In this Report, the subject of up-grading was also reported with the study on the present condition of facilities in East Java area, because in this feasibility study JICA requires in Terms of Reference to submit the feasibility study report of East Java Power Expansion Project.

(2) Present feature of the facilities on the low voltage distribution line and the facilities in the customer's premises

(a) Distribution Transformer

Up-grading of supply low voltage (127/220V → 220/380V) had been already considered before the said PLN's regulation, that is, at the time of materials procurement in East Java Transmission and Distribution Network Project First Stage. Accordingly, distribution transformer in conformity to such specifications that the secondary voltage was defined as bivoltage rating and tap change was available, had been procured from First Stage through Third Stage by Japanese Yen Loan. Therefore, except old type transformers of 127V signle tap, the up-grading of supply low voltage is possible to execute by only tap change of transformer.

(b) Low voltage distribution line

The conductor's insulation and size/length of the facilities are considered unchanged for common use in the main existing low voltage distribution line, except the area where the very much demand increase is estimated at the time of up-grading of voltage, and except case that the line length is remarkably long.

(c) W.H.M. and limiter

All of the existing W.H.M. and limiter for 127V/220V should be replaced by those for 220V/380V.

(d) Limiter fuse

All of the existing fuses should be replaced by those for 500V rating.

(e) Facilities in the consumer's premises

(i) Indoor wiring

Replacement of indoor wiring is not required except the deterioration thereof.

(ii) Electric appliances in consumer's premises

Replacement of main switch is not required. However, ratings of fuses and gears should be replaced with those of 500V. Besides, flash plug socket and receptacle should be replaced when the grounding terminal is not attached.

To sum up the above-mentioned, there found many facilities not required to be replaced in consumer's premises. However, some facilities should rather be replaced or repaired, if the deterioration thereof is revealed by the investigation in cnstruction work stage.

(3) Study on implementation schedule for voltage changeover

6 kV distribution system, in the past, had been applied to the areas except Surabaya City. But, at the present time, the standardization of 20 kV distribution system has been expanded in whole areas, so the old facilities of 6 kV distribution system should be changed to 20 kV distribution system. Changeover of up-grading to 20 kV is gradually proceeding in the areas where both 6 kV and 20 kV distribution systems are applied in parallel. Therefore, it is desirable to perform the up-grading in accordance with a schedule that the up-grading of consumer's supply low voltage can be done together with the changeover of up-grading to 20 kV.

The followings are the cases of replacement procedure of existing facilities and appliances in consumer's premises:

(a) Excluding the case of Tariff S1 consumer whose circuit is only one, indoor wiring is divided into two circuits; 127 V and 220 V.

(b) All appliances related to lamps are connected to 220V circuit. Accordingly, existing 100V incandescent lamps and ballasts for fluorescent tubes should be replaced with those of 200V rating.

(c) Circuit of wall suspending plug socket is divided into two (2) types; 127V and 220V, applying the collective step-down measures through the auto-transformer (220V/127V) for 127V circuit. In this case, lending the auto-transformers to consumers is required to be decided, after due discussion with the concerned consumers based on the Regulation.

Cost for up-grading is divided roughly into two (2) categories; the replacement cost for PLN's facilities and the compensation cost for the facilities in consumer's premises. As those costs are estimated to reach a considerable amount, the following four (4) cases are required to be considered:

(i) Case of new area

As this new area is supplied with new 220/380V system, consumers should prepare the apparatus of 220/380V rating according to the Regulation. Neither replacement nor compensation for up-grading are required.

(ii) In case of new and additional supply in the existing 127/220V area.

Consumers should be given their own doublerating voltage apparatus or supplied with phase-to-phase voltage 220V, and there's no need to replace PLN's supplying facilities and to compensate for consumers. In above case, however, it is necessary that the existing old lines have enough supplying capacity for new consumers. If not enough, additional new line (220V or 380V) has to be constructed. Besides when the additional line installation is newly - required by old consumers in the new line area, there needs no compensation to them, but only construction costs for new lines. Because, the consumers can be supplied additionally from the new line.

(iii) In case of the line area newly constructed as a part of expansion project of transmission and distribution network.

When the expansion project of transmission and distribution network are planned and executed by introducing foreign currency, the distribution transformers, W.H.M. and other equipment, all with bi-voltage rating at the secondary voltage have purchased and installed, considering the up-grading of voltage in the future. From the above, following two cases are considered regarding the necessities of compensation for the consumers.

- In case that the compensation is required at the time of up-grading for the facilities in the premises of consumers living in the area in which execution of up-grading plan is confirmed by PLN.

- In case that no compensation is required to the consumers hoping to use the additional capacity for themselves before execution of up-grading of voltage.

(iv) In case of existing power supply area

In this case large cost is necessary to compensate the PLN's supplying facilities and the facilities in the consumers premises.

In the said cases (i) and (ii), the consumers naturally should be supplied by new system of 220V/380V, while in cases (iii) and (iv), commencement time of up-grading work in the old area should depend on whether new lines are constructed around the old area, or existing supply facilities in the old area are replaced by new line.

(4) Conclusion

Up-grading of the consumers supply voltage is basically related to the improvement of distribution system and loss of distribution facilities. Such up-grading will force the power supplier to pay the large compensation not only for supplying facilities but for the facilities in the consumers premises. However, from a long term view, the power supply will increase due to the decrease in loss of distribution facilities, and as a result, the compensation cost required can be recovered. On the other hand, a lot of costs are required for man power, for replacing or repairing facilities and apparatus and for compensation to consumers for investigation or construction accompanied with up-grading work. In the above consideration following should be studied,

(a) to make the careful and suitable planning of up-grading work, based on the said each items,

(b) to simplify the maintenance at and after up-grading work,

(c) Based on item (b) above, to settle the minimum cost for replacing the PLN's supply facilities and the facilities in consumer's premises, and for purchasing the auto-transformer for up-grading and man power for investigation and construction.

According to the data received from PLN, as of December, 1983 there are 550,000 (five hundred fifty thousand) consumers supplied at 127V in the East Java area and PLN is now gradually proceeding the voltage change-over program in the Loss Deduction Project. The effects of the project would be expected to reduce the energy losses in distribution networks from 20% in 1984 to 13% in 1987/88. Accordingly, it is recommended to prepare the up-grading plan and execute it as soon as possible, after estimating the annual budget for the up-grading from each annual plan by service area.

5.4.2. Study on Use of Distribution Line

(1) Study of operating capacity of 20 kV Distribution Line

The line system of overhead distribution line for 20 kV is divided roughly into radial system and loop system. It is thought that single circuit radial system (without interconnection) is almost used as a line system for load-dispatching to a rural district and low load density district, and that multiple circuit loop and radial system (with interconnection) are mainly used as a line system for supply to high load density district in the midtown area for the purpose of raising of supply reliability.

Advantages of multiple circuit loop and radial system (with interconnection) in overhead distribution line are as follows.

(a) When the function of one (1) feeder stops by power failure, it is possible to transfer all load of trouble feeder to another normal feeder of the same substation by operating switch.

(b) In case of power failure at the substation for supplying distribution, it is also possible to transfer load to feeder supplying from another adjacent substation.

(c) At emergency, the scope power failure is reduced and raising of supply reliability is gotten because of transferring load.

From the above-mentioned points, line capacity of one (1) feeder needs to have load of another feeder sufficiently for connection. So, line capacity at emergency must be approx. 1.3 - 1.5 times as large as that at normal. For example, if line capacity of one (1) feeder at normal is 300A, line capacity at emergency must be 400A. In case of single circuit radial system (without interconnection) for supply to a rural district and low load density district, it is impossible to transfer load. So, only line capacity at normal is used. In any case regarding to switching and transferring load at power failure in distribution line, operation manual had better be set up. An excerpt of design criteria for 20 kV distribution line used in KEPCO (Japan) is shown as below for PLN's reference of operation manual of 20 kV distribution.

(2) Study of operating criteria of 20 kV Distribution Line

(a) Line system of 20 kV distribution line and line capacity.

(i) Line system

Loop system or radial system

(ii) Line capacity

The standard of capacity per one (1) circuit is shown as below. So, construction and operation shall be done on the basis of the following standard.

Capacity at emergency	Capacity at normal
400 A	300 A

(Note)

- Capacity at emergency is such capacity as not to affect the equipment if overloaded for a short time. And the fixed power on the basis of allowable currents at short time is used.

- Capacity at normal is such capacity that the equipment itself originally have the normal condition. And the fixed power on the basis of rating current is used in consideration of limited capacity by voltage drop.

- Capacity at emergency is applied to the distribution line of multiple circuit (2∿3) radial, loop system and so on, except for single circuit system.

- Capacity at normal is applied to distribution line of single circuit system.

(iii) Supplying power at normal

Supplying power at normal of medium voltage distribution line is selected as below, in consideration of the line capacity and transferring load in case of power failure of one (1) feeder, and maximum voltage drop.

- Maximum voltage drop

Voltage drop of medium voltage distribution line is decided according to another stipulated voltage drop-table for distribution line.

- Transferring load

As a principle, in case of power failure of one feeder the supplying power is needed so as to enable all load of normal section to switch and transfer from adjacent another feeder (2 circuits) by operating switch. However, in case that it is difficult to interconnect in the section of medium voltage distribution line for switching and transferring load because of conditions of having equipped medium voltage distribution line, and a regional topography in those area a part or most of interconnection load can be omitted in consideration of the actual condition of load. And also in case of power failure in medium voltage distribution system which is caused by power supply side, it shall be considered so as to be able to switch a part of load from distribution line at adjacent substation for supplying distribution.

Power for transferring is as below.

Kind of system	3 circuits radial	2 circuits radial & loop	Single circuit
Transferring load	Supply all load by another 2 circuits	Supply all load by another 1 circuits	Nil

(b) Control of load for distribution line

(i) Control of load for distribution line in multiple radial system and loop system is done by capacity (A) at emergency of each group.

(ii) Control of load for distribution line in single circuit system is done by capacity (A) at normal of system separately.

Control of load in capacity (A) at emergency and normal, as a principle, is done by sending current from substation.

5.4.3. Design of Poles, Conductors, and Transformers

Now in East Java for PLN, almost equipments for each distribution facility have been completed as a standard design except for special requirements. With regard to review of special specifications, the design of poles, conductors, and pole transformer of captioned each equipment is studied in the Report in the following points.

- The ideal way of two (2) circuits arrangement of pole mentioned in Design Report for Surabaya City Power Distribution Network Project made by NEWJEC.

- Definition of applicable scope in the future with regard to now used conductor and pole transformer and review of specification.

(1) Two (2) circuits arrangement of pole for medium voltage overhead distribution line

Now the specification of two (2) circuits arrangement of pole in East Java is defined that two (2) circuits are installed in upper side and lower side arms of the same pole according to Design Report made by NEWJEC; as it is called Vertical Type. However, according to comment from ENEX Report obtained from PLN this time regarding the above-mentioned, it is recommended that arrangement of pole by Flat or Delta type shall be used on the basis of following reasons.

(a) It is impossible to work on the upper circuit when the lower circuit is operating.

(b) The arc on the lower circuit would extend into the upper circuit and cause a fault on both two (2) lines.

(c) A heavy fault on one (1) line would cause inductive interference on the other line and which may produce the possibility of wrong operation of O.C.B. relay.

(d) In case of the arrangement of pole by Flat type, the length of pole used could be reduced by 1 meter.

There are many points to agree of the above reasons. Regarding the design of overhead distribution line for 20 kV system, as a principle, one (1) circuit arrangement of pole shall be used, if possible, except for special cases, judging from maintenance after construction.

The two (2) circuits arrangement of pole should be limited to such a case that the installation of two (2) circuits system overhead distribution line in several spans is seemed unavoidable. Because it is impossible to install outgoing multiple circuits cable to the same direction from substation. On this occasion, insulated conductor shall be needed for safety operation. It is actually difficult to apply two (2) circuits arrangement of pole by Flat type at the place like urban area where there are many obstacles except for rural area. And in case of installing pole transformer, it is actually difficult to adopt Delta type because of complicated interconnection with it.

(2) Conductor to be used for Feeder of 20 kV distribution line

(a) Kind of conductor

A kind of conductor which is used now in East Java is all AAAC conductor. However, according to data gotten from PLN this time, this conductor is used in all West Java area and a part of Central Java area except for all East Java area. According to comment in ENEX Report obtained from PLN, it is recommended to use AAC conductor in that report as a kind of conductor to be used instead of AAAC Conductor for reasons of short length of span for distribution line and economic advantages. Compared with characteristics of AAAC conductor and that of AAC conductor, it becomes clear that AAAC conductor is superior to AAC conductor in braking strength, electric conductivity and corrosion. So, it is desirable to use AAAC conductor at following special places, to review suitableness of using AAC conductor in the future judging from construction cost at other general places, and to establish standardization of conductors applicable in whole PLN.

- Where long spans are required to go across the river and where conductors have to cross railways.

- Where areas are damaged by salt and dust contamination.

(b) Size of conductor

At present, various kinds and sizes of conductors are used in PLN service area. The conductors adopted for trunk line of medium voltage distribution line are of 240 mm^2 and 150 mm^2 in West Java and 120 mm^2

in East Java. This size is minimum for trunk line. In case of distribution system for 20 kV, 120 mm^2 is considered suitable from the supply capacity and voltage drop and stringing work can be done comparatively easily. That is a reason why 120 mm^2 conductor is adopted. Comparison of construction cost per MVA at various kinds of conductors also shows that 120 mm^2 is most advantageous. (see Fig. 5.4.-1). However, with consideration of scope of supply by future increase of demand and increase of line length, necessary conductors to be adopted in the future are large size conductors. As size for trunk line, it is desirable to standardize the size of conductors used in PLN in conformity to IEC standard in the future.

As mentioned in Project proposal made by D.J.T. in PLN, it is considered that in East Java area size which will be used for a trunk line in the future is decided to adopt 150 mm^2 conductors. However, in this case size shall be used for only new trunk line for the present, because there is some problems in relation of installed line until now and maintenance for exchange of clump top of installed line post insulators, etc. Accordingly, it is considered necessary to study the future improvement, maintenance and work for line.

(c) Insulating of conductor

Two kinds of conductor, bare conductor and insulated conductor (OC conductor) are used now for medium voltage overhead distribution line in East Java area. Approx. 30% is occupied by the insulated conductor. It is needless to say that bare conductor can be applied sufficiently in case that conductor for medium voltage overhead distribution line in rural area, etc., and the area where there is no obstruction for construction of medium voltage overhead distribution line. However, in case of construction in urban area and along roads, insulated conductor is required to protect human being, beasts, etc. from the fault in earthing and short circuit, etc. and accidents by obstruction in construction and contact of trees. It is said that cutting of roadside trees along national roads is prohibited by regulation. Accordingly, in purchasing conductor in the future, it is desirable to study much increase of insulation ratio of conductors to be used, and to establish the standardization of insulated conductors.

(3) Pole transformer for distribution

The economic calculations for the capacity selection of pole transformer and its suitable application were carried out with demand density (KVA/2,500 m^2) and loading ratio of transformers as a parameter.

The prices, loss, loading ratio of the transformers and the costs, loss of the low voltage distribution lines as influential factors in its economy have been picked up.

The calculation conditions are as follows:

(a) Calculation conditions

(i) Prices and loss of transformers

Capacity (kVA)	Prices ($)	Loss (W)	
		at no load	Copper loss at rating load
11 ϕ 10	152	80	256
1 ϕ 25	339	148	513
3 ϕ 50	627	234	1,201
3 ϕ 100	1,169	402	2,097
3 ϕ 150	1,688	566	2,904

(ii) Low voltage distribution lines (AAAC-OW, 70 mm^2)

Cost 6,595 ($/km)
Resistance value 0.488 (Ω/km)
Permissible voltage drop 7.5 V

(iii) Others

. Load factor f = 0.7
. Loas factor Lf = 0.553
. Loading ratio of Tr. x = 0.2 ∿ 1.0
. Load density d = 1.0 ∿ 10.0
. Cost at 150 kV bus 70 Rp/kWH
. Discount rate 10%
. O and M cost 3%

(iv) Demand density (D) is to be defined by peak power of the year (KVA) per $(span)^2$ (one span = 50 m)
0.4 d = (MVA/km^2)

The Table 5.4-1 shows the comparison of power supply costs by peak power of the year (KVA) with demand density (1.0 ~ 10.0) and loading ratio of transformers as a parameter. The figuration of the above turns out to be as in Fig.5.4-2, and the combination of the figures make Fig.5.4-3.

(b) Conclusion

(i) It is recommendable that the loading ratio should be over 40% as much as possible on every unit capacity of pole transformer.

(ii) In case the demand density (D) is lower than 4, the number of transformers should be adjusted aimed at 60% of the loading ratio by use of pole transformers with unit capacity of 50 KVA, and if the loading ratio is still over 85% regardless of the above, the pole transformers with unit capacity of 100 KVA should be used for the adjustment.

(iii) In case the demand density (D) is around 4 to 8, the number of transformers should be adjusted aimed at 60% of the loading ratio by use of pole transformers with unit capacity of 100 KVA, and if the loading ratio is still over 75% regardless of the above, the pole transformers with unit capacity of 150 KVA should be used for the adjustment.

(iv) In case the demand density (D) is over 8, the number of transformers should be adjusted aimed at 60% of the loading ratio by use of pole transformers with unit capacity of 150 KVA.

But, it is not economical to supply power to three-phase load by three-phase connection of single-phase transformer.

These single-phase pole transformers should be used only for the supply to single-phase load which can not maintain the phase to phase balance by three-phase pole transformers.

5.4.4. Study of Power Loss Reduction of Distribution Facilities

According to the data obtained from PLN, Loss percentage of distribution facilities in East Java area is now approx. 20%. And it is expected to decrease its percentage to approx. 13% by around 1987 systematically by the execution of the voltage changever program, etc. The subject in this Section is to study the countermeasures of general power loss reduction in distribution line facilities, to pick up the specific distribution line with high loss percentage, and to establish the concrete countermeasure for improving and expanding the sufficient distribution facilities.

(1) General countermeasures for loss reduction in distribution line facilities

(a) Loss reduction by up-grading of voltage

As countermeasures of loss reduction for distribution facilities, it is clear that up-grading of voltage is the most effective countermeasure. Medium voltage distribution line in East Java area was in 6 kV system as old facilities, but that was standardized to use 20 kV system by regulation. Up-grading from old system to 20 kV is systematically promoted and scheduled to be completed within a period from 1984 to 1987. And with regard to low voltage distribution line, it has been decided to change 127/220V with 220/380V by regulation, and it is scheduled to execute the said changing systematically as Loss Reduction Project from 1984 by IBRD Loan. So, it is expected to have the considerable loss reduction by completion of voltage changeover program for medium and low voltage facilities.

(b) Loss reduction by other countermeasures

The voltage changeover program in the above mentioned item (a) is the most effective work as work of countermeasure for loss reduction. However, it needs to take various more detaield countermeasures for loss reduction of distribution line, and generally following cases are considered.

i) Countermeasure for medium voltage distribution line

- In case that route length of line is long and load is concentrated on the end of line, the characteristics and forms for distribution line shall be inspected and the most suitable countermeasure of loss reduction with improvement of voltage shall be established. (Detailed in Item (2) below)

- With regard to transformers of large capacity against load, it shall be planned to normalize capacity by changing them on the basis of results of periodical measurement of load for transformers for the purpose of reducing iron loss of pole transformer as much as possible. (Improvement of load factor for pole transformer)

- It is planned to recommend installation of condencer for consumers for the purpose of improving power-factor for medium voltage distribution line.

ii) Countermeasure for low voltage distribution line

In case that route length of line is long and value of voltage drop at the end of line is out of standard, it shall be planned to change size of usual conductor with large size or divide load by means of increase of pole transformer.

iii) Other countermeasures

- Proper control for limiter fuse in the consumer (tariff S1) and the street lighting of the fixed-rate system.

- Promotion of chngeover from the fixed-rate system to the meter-rate system for consumers.

- Changeover to the meter-rate system, or proper control by time switch for the public mass street lighting. The above-mentioned are main cases of various countermeasure. However, with regard to study for improvement of distribution line with high loss percentage, countermeasures which complies with the inspection and characteristics and form of the line are considered as below.

(2) Study for improvement of medium voltage distribution line with high loss percentage

(a) Picking up medium voltage distribution line with high loss percentage

Picking up medium voltage distribution line with high loss percentage is done by following mannter.

i) Supply energy of each feeder is recorded during the fixed period.

ii) Energy sales of consumers connected with the feeder during the same period is calculated by the inspection of a meter and tariff card.

iii) Loss percentage of each distribution line is calculated judging from the above results. In this case, in order to catch correct energy sales of each distribution line, the important or specially noted is that load of consumers connected with the feeder is not absolutely connected with other distribution line with interconnection because of power failure and so on during the period for inspection and measurement.

(b) Inspection and measurement of the medium voltage distribution line with high loss percentage

On the medium voltage distribution line with high loss percentage obtained in the above item (a), the following points should be inspected and measured so as to get characteristics of the line.

i) Supply voltage (kV), terminal voltage (kV) and current value (A) at peak hour

ii) Route length of line (KM) and size (MM^2) for feeder

iii) Stage of load distribution
(even load distribution on the line and concentrated load distribution at the terminal)

iv) Total capacity (kVA) of pole transformer connected with feeder

v) The member of houses, capacity, stage of distribution of big consumers connected with feeder, etc.

On the basis of the above inspection and measurement, it will be needed to study countermeasure pointed out in (i) of (b) of item (I) and following countermeasures and to establish the most suitable countermeasure for loss reduction.

vi) Size of conductor for feeder is changed with larger size.

vii) Load is dispersed by means of new installation of feeder and division of load to adjacent feeder.

viii) Switched capacitor is installed near the end of distribution line.

5.4.5. Study of Interconnection with Distribution Line between East Java and Central Java

As a result of doing inspection and study of the captioned matter, it is difficultly thought to execute the captioned matter judging from following reasons.

Earthing system of distribution line in East Java area is high resistance system, and that in Central Java area is low resistance system. It is technically impossible to interconnect both distribution lines by different earthing system. Boundary area between East Java and Central Java is almost composed of an isolated area with wide mountains except for just a little part of north area. Interconnection with distribution line in such depopulated area is rather expensive in construction judging from demand and supply, viewpoints, even if distribution line is connected by same earthing system.

In Japan there is no connection of distribution line with other electric company except for transmission line. Even in the service area of a same electric company, connection in distribution line is limited to the area where it is especially requested for the consumers because of very high load density required.

In a part of the area around the boundary of both territories, on the assumption that the new facilities be installed capable of enough supply either in East Java or in Central Java to a certain number of important customers by low voltage distribution lines, the following consideration will be required.

(1) To interlock without fail the switch on East Java side and that on Central Java side for the important customers, and to avoid a parallel use of both lines.

(2) To make the receiving voltage and the phase rotation completely equal on both sides for the important customers.

5.4.6. <u>Study of Overhead Grounding Wire Installation on Distribution Line</u>

(1) Countermeasures for prevention of lightning fault on the medium voltage distribution line

As countermeasures for prevention of lightning fault on the distribution line in heavy and many lightning area, strengthening of lightning arrester, overhead grounding wire and insulation level of the line, etc. are generally considered. In area where lightning occurs very often in every rainy season in whole Java island in Indonesia, it is considered that standardization of countermeasure for prevention of lightning against medium voltage distribution facilities is required to establish. As a premise, analysis of contents of lightning fault on the medium voltage overhead distribution line, the actual survey of induced lightning surge wave on the specific line, etc. are considered.

(2) Results/analysis of fault inspection on the medium voltage distribution line

According to IKL MAP obtained this time, IKL value in East Java area is estimated approx. 100 on an average, which shows a specific high value in the tropical zone. So it was forecasted that lightning fault against each electric facilities in this area would frequently occur. However, according to the tripout report of distribution facilities in 2 months of November, 1983 and April, 1984 when fall in rainy season in East Java area, only 17 cases are counted as the number of above lightning tripouts. (However, for the month of November, 1983 the number of lightning tripouts at Surabaya north branch is not recorded.) But, in addition, 134 cases for the month ov November, 1983 and 185 cases for the month of April, 1984 are counted as other tripouts. Accordingly, in the said tripouts, this is considered to include the major part of the lightning tripout. The above reason is presumed that, except in case of direct lightning stroke for facilities, the stripout by an induced lightning stroke is liable to be almost treated as other tripout in the following case. The case is that the effect of the induced lightning stroke appears in several days later. Accordingly, in case of supposing that a half of other faults in lightning and rainy season is caused by lightning tripout, the average number for the month is 89 cases, the sum of lightning stroke and other tripouts, as shown in Table 5.4-2, and the number of lightning stroke per year is 534 cases (89 x 6 = 534), supposing that the period of lightning and rainy season is six months. In the actual results no great difference is found between the number of these faults and that of lightning stroke for the year of 1982, 400 faults, in KEPCO, Japan (Table 5.4-5). Tables 5.4-2 and 5.4-3 are the excerpts from the actual tripout reports of PLN.

(3) Applicable range of overhead grounding wire

The effect for installing overhead grounding wire together on the overhead distribution line is written in the description of the distribution line in Design Report of Surabaya City Power Distribution Project made by NEWJEC in June, 1981.
As explained in the above report, the parallel use of overhead grounding wire and lightning arrester is very effective, because suppression factor of flush-over to induced lightning stroke is zero. However, it is very costy to install overhead grounding wire uniformly in all area for prevention of lightning tripout. So it will be required to decide applicable range of overhead grounding wire by establishment of standardization as mentioned in item (1). For reference, as an example for standardization of applicable range of overhead grounding wire, following points are considered.

(a) Area where lightning tripouts occur frequently and where more than 3 lightning arresters are installed within 1 km.

(b) Area where it is very difficult to keep grounding resistance of lightning arrester continuously under regulated value.

As the unapplicable areas for installing overhead grounding wire, following area and place are considered.

i) midtown area where high buildings (builgins exceeding grounding wire height above ground) stand continuously.

ii) place where wire goes across railways and long spans.

Regarding line on which overhead grounding wire is not installed, it is considerable to install arcing horns in insulators in order to protect wire and insulator from lightning surge and continuous current by arc.

(4) Conclusion

In East Java area, overhead grounding wire has been mostly installed since commencement of East Java Transmission and Distribution Network Project. But it is impossible to compare and study between the number of lightning tripouts during the period when the wire was not installed (during this period the underground cable was mainly used as the medium voltage distribution line,) and that of present. And also regarding comparison between the number of lightning tripouts in West Java area and that in Central Java area, it is difficult to get the value of decrease for lightning tripouts caused by installing overhead grounding wire. Accordingly, following matters were proved as a result of studying lightning tripouts recorded in KEPCO. Namely, the installation of overhead grounding wire was limited to the special area (where IKL value is around 30 and especially lightning tripout occurs frequently,) until 1975 because it is very costy. However, as shown in Table 5.4-5, this installation promoted year by year since 1976. In accordance with change of the number of lightning faults as shown in Table 5.4-5, a little difference is observed in the number of lightning tripouts per year according to frequency of lightning in each year. It can not be judged generally that parallel installation of overhead grounding wire and lightning arrester contributes to the decrease of lightning tripout, but it can be supposed that the general effect of this parallel installation. In other Japanese electric company, for example, Tokyo Electric Power Company (TEPCO), parallel installation has been made from the past and the rate of parallel installation is 82.7% as of 1983, that means most area are installed already in Japan. Taking into account the Japan's present situation above-mentioned, it is considered necessary to project the parallel installation of overhead grounding wire and lightning arrester in East Java area, according to the standard for installing the overhead grounding wire as countermeasure work for prevention of lightning fault mentioned in item (1) and (3). Whichever is the lightning tripouts or other tripouts on the medium voltage overhead distribution line, the important is to understand exactly the contents of tripout for analysis and the countermeasures for decrease of tripout. The exact report from the tripout site, such as where and when tripouts occurred, is required as basic data for study.

Now in KEPCO, damage conditions, etc. by cause and facility are understood by computer processing on the basis of contents report (input card) from the site. A sample of input card form and actual reporting is shown in Table 5.4-6 for reference.

Table 5.4-1 Comparison of Unit Cost on 380V

density of demand	Pole Tr. (KVA)	Loading ratio of Pole Tranoformer (x)													$/KVA	
		0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.9	1.0
1.0	10	49.28	41.50	36.64	33.44	31.28	29.82	28.84	28.22	27.86	27.71	27.72	27.85	28.09	28.81	29.77
1.0	25	41.53	36.10	32.96	31.11	30.08	29.59	29.48	29.65	30.03	30.56	31.22	31.98	32.83	34.70	36.76
1.0	50	33.95	29.62	27.13	25.69	24.90	24.55	24.51	24.69	25.03	25.51	26.08	26.74	27.46	29.05	30.80
1.0	100	33.69	30.41	28.81	28.15	28.10	28.44	29.06	29.89	30.86	31.96	33.14	34.40	35.72	38.49	41.41
1.0	150	34.73	32.31	31.46	31.52	32.15	33.15	34.42	35.88	37.49	39.20	41.00	42.87	44.80	48.79	52.91
2.0	10	48.52	40.56	35.51	32.13	29.78	28.13	26.97	26.16	25.61	25.27	25.09	25.04	25.09	25.43	26.02
2.0	25	39.65	33.76	30.14	27.83	26.33	25.37	24.79	24.49	24.40	24.46	24.66	24.95	25.32	26.26	27.38
2.0	50	32.69	28.06	25.25	23.50	22.40	21.73	21.38	21.25	21.28	21.44	21.70	22.05	22.46	23.43	24.55
2.0	100	31.19	27.28	25.05	23.78	23.10	22.81	22.81	23.01	23.36	23.83	24.38	25.02	25.71	27.23	28.90
2.0	150	30.98	27.61	25.83	24.96	24.65	24.71	25.04	25.56	26.23	27.01	27.87	28.80	29.79	31.90	34.15
3.0	10	48.27	40.25	35.13	31.69	29.28	27.57	26.34	25.47	24.86	24.46	24.21	24.10	24.09	24.31	24.77
3.0	25	39.03	32.98	29.20	26.73	25.08	23.96	23.23	22.77	22.52	22.43	22.47	22.60	22.82	23.44	24.25
3.0	50	32.28	27.53	24.63	22.77	21.56	20.80	20.34	20.10	20.03	20.09	20.24	20.48	20.79	21.55	22.46
3.0	100	30.35	26.24	23.80	22.32	21.43	20.94	20.72	20.71	20.86	21.12	21.47	21.89	22.37	23.48	24.73
3.0	150	29.73	26.05	23.96	22.77	22.14	21.90	21.91	22.12	22.48	22.94	23.49	24.11	24.79	26.27	27.89
4.0	10	48.15	40.09	34.95	31.47	29.03	27.29	26.03	25.13	24.49	24.05	23.78	23.63	23.59	23.74	24.14
4.0	25	38.72	32.58	28.73	26.18	24.45	23.26	22.45	21.91	21.58	21.42	21.37	21.43	21.57	22.03	22.69
4.0	50	32.07	27.27	24.31	22.40	21.15	20.33	19.82	19.53	19.40	19.41	19.51	19.70	19.95	20.61	21.42
4.0	100	29.94	25.72	23.18	21.59	20.59	20.00	19.68	19.57	19.61	19.76	20.01	20.33	20.71	21.60	22.64
4.0	150	29.10	25.27	23.02	21.67	20.89	20.49	20.35	20.40	20.60	20.91	21.30	21.77	22.29	23.46	24.76
5.0	10	48.07	40.00	34.83	31.34	28.88	27.12	25.84	24.92	24.26	23.81	23.51	23.35	23.29	23.41	23.77
5.0	25	38.53	32.35	28.45	25.86	24.08	22.84	21.98	21.40	21.02	20.81	20.72	20.73	20.82	21.19	21.75
5.0	50	31.94	27.12	24.13	22.18	20.90	20.05	19.50	19.18	19.03	19.00	19.08	19.23	19.45	20.05	20.80
5.0	100	29.69	25.41	22.80	21.15	20.09	19.44	19.06	18.88	18.85	18.95	19.13	19.39	19.70	20.48	21.39
5.0	150	28.73	24.80	22.46	21.02	20.14	19.65	19.41	19.37	19.47	19.69	19.99	20.36	20.79	21.77	22.89
6.0	10	48.02	39.93	34.76	31.25	28.78	27.01	25.72	24.78	24.11	23.64	23.34	23.16	23.09	23.18	23.52
6.0	25	38.40	32.19	28.26	25.64	23.83	22.56	21.67	21.05	20.65	20.40	20.28	20.26	20.32	20.63	21.13
6.0	50	31.86	27.01	24.00	22.04	20.73	19.86	19.29	18.95	18.78	18.73	18.78	18.92	19.12	19.67	20.38
6.0	100	29.52	25.20	22.55	20.86	19.76	19.06	18.64	18.42	18.35	18.40	18.55	18.76	19.04	19.73	20.56
6.0	150	28.48	24.49	22.08	20.58	19.64	19.08	18.79	18.68	18.72	18.87	19.11	19.42	19.78	20.65	21.64
7.0	10	47.99	39.89	34.71	31.19	28.71	26.93	25.63	24.68	24.00	23.53	23.21	23.03	22.94	23.02	23.34
7.0	25	38.31	32.08	28.13	25.48	23.65	22.35	21.44	20.81	20.38	20.11	19.97	19.92	19.96	20.23	20.68
7.0	50	31.80	26.94	23.91	21.93	20.61	19.72	19.14	18.79	18.60	18.54	18.58	18.70	18.88	19.41	20.08
7.0	100	29.40	25.05	22.37	20.65	19.52	18.79	18.34	18.09	18.00	18.02	18.13	18.32	18.56	19.19	19.96
7.0	150	28.30	24.26	21.81	20.27	19.28	18.68	18.34	18.19	18.19	18.29	18.49	18.75	19.07	19.84	20.74
8.0	10	47.96	39.86	34.67	31.14	28.66	26.87	25.56	24.61	23.92	23.44	23.12	22.93	22.84	22.90	23.20
8.0	25	38.25	32.00	28.03	25.36	23.51	22.20	21.27	20.62	20.18	19.89	19.73	19.67	19.69	19.92	20.35
8.0	50	31.76	26.88	23.84	21.85	20.52	19.62	19.03	18.67	18.46	18.39	18.42	18.53	18.70	19.20	19.86
8.0	100	29.31	24.94	22.24	20.49	19.34	18.59	18.12	17.85	17.73	17.73	17.82	17.98	18.20	18.79	19.51
8.0	150	28.16	24.10	21.61	20.03	19.02	18.38	18.00	17.82	17.79	17.86	18.02	18.25	18.53	19.24	20.07
9.0	10	47.94	39.83	34.63	31.10	28.61	26.82	25.51	24.55	23.86	23.37	23.05	22.85	22.75	22.80	23.10
9.0	25	38.20	31.93	27.95	25.27	23.41	22.09	21.14	20.48	20.02	19.72	19.55	19.47	19.48	19.69	20.09
9.0	50	31.72	26.84	23.79	21.79	20.45	19.55	18.95	18.57	18.36	18.28	18.30	18.40	18.56	19.05	19.68
9.0	100	29.24	24.85	22.13	20.37	19.20	18.43	17.94	17.66	17.52	17.50	17.57	17.72	17.93	18.48	19.17
9.0	150	28.06	23.97	21.45	19.85	18.81	18.14	17.74	17.54	17.47	17.52	17.65	17.86	18.12	18.77	19.55
10.0	10	47.92	39.81	34.61	31.07	28.58	26.78	25.47	24.51	23.81	23.32	22.99	22.78	22.69	22.73	23.02
10.0	25	38.15	31.88	27.89	25.20	23.32	21.99	21.04	20.36	19.90	19.59	19.40	19.32	19.32	19.50	19.88
10.0	50	31.69	26.80	23.75	21.74	20.40	19.48	18.88	18.49	18.28	18.19	18.20	18.29	18.45	18.92	19.55
10.0	100	29.19	24.78	22.05	20.27	19.09	18.31	17.81	17.50	17.35	17.32	17.38	17.51	17.70	18.23	18.89
10.0	150	27.98	23.86	21.23	19.70	18.64	17.96	17.54	17.31	17.22	17.25	17.36	17.54	17.78	18.39	19.14

Table 5.4-2

Actual results of fault on Midium voltage Distribution line by Weather Condition (1983 Nov.19, 1984 Apr. extraction from fault Report by PLN D.J.T.)

Year and Month	KV	Damage of structure	Collapse of tree	Contact of birds/ beasts	Lightning fault	Others	Strong wind	Heavy rain	Total	Remarks
83	20^{kV}	17	54	5	5	122	2	1	206	* In the case of North Surabaya S. Office it was not counted fault times, only recorded hourly statistics
Nov.	6^{kV}	10	14	0	1	12	-	-	37	
	Total	27	68	5	* 6	134	2	1	243	
84	20^{kV}	19	47	13	5	161	6	5	256	
Apr.	6^{kV}	5	9	4	6	24	-	-	48	
	Total	24	56	17	11	185	6	5	304	
Ave.	20^{kV}	18	51	9	5	142	4	3	232	
/ mon.	6^{kV}	8	12	2	4	18	-	-	44	
	Total	26	63	11	9	160	4	3	276	

Table 5.4-3

Power tripout rate annually per route length KM on Medium voltage Distribution line (Assumption)

from the Fault Report by PLN D.J.T. by Apr. 1983 - Nov., and by Apr., 1984

Item \ Year/Month	83/4	5	6	7	8	9	10	11	84/4	Assumption value of power fault frequency
All fault frequency on Medium voltage Dis., line	165	136	126	126	147	93	227	261	335	average 180/month x 12 2,160
Route length on Medium voltage Dis., line	3,717	3,727	3,750	3,829	3,866	3,890	3,905	3,921	4,345	4,345
Frequency / KM	0.044	0.036	0.033	0.032	0.038	0.023	0.058	0.066	0.077	0.5 times/KM/year

Reference : KEPCO

All power fault frequency on Medium voltage Distribution line (20kV+6kV) 939 times

(Results of 1983)

Route length on Medium voltage Distribution line (KM) 10,634 KM 0.09 times/KM/year

Lightning frequency respective damaged equipment on Medium voltage Distribution line

Table 5.4-4

(KEPCO)

Damaged equipment / Year	74	75	76	81	82	83
1. Pole	1	0	0	1	0	0
2. Cross-arm	0	0	0	0	0	1
3. Insulator	30	40	50	32	111	38
4. Conductor	110	290	190	80	161	88
5. Transformer	73	130	83	47	75	40
6. Switching device	34	55	39	8	13	8
7. Arrester	17	14	14	12	19	9
8. Overhead or underground cable	1	2	1	0	2	0
9. Others	2	2	2	0	10	0
10. Unknown	6	13	7	4	9	8
Total	274	546	386	184	400	192
A Route length on M.voltage line (KM)	47,480	48,956	50,677	59,646	61,435	62,899
B Route length on Overhead g.wire (KM)	514	728	2,017	11,750	14,881	18,886
C Installation factor B/A %	1.08%	1.5%	3.98%	19.7%	24%	30%

Table 5.4-5

Table of transition of installation Overhead grounding wire (KEPCO)

Item \ Year	74	75	76	77	78	79	80	81	82	83
Medium voltage distribution line A Route length(KM)	47,480	48,956	50,677	52,223	54,052	56,113	57,928	59,646	61,435	62,899
Overhead grounding wire B Route length (KM)	514	728	2,017	3,930	6,019	7,810	9,772	11,750	14,881	18,886
Installation factor B/A %	1.08	1.49	3.98	7.53	11.1	13.9	16.9	19.7	24.2	30
Remarks :	TEPCO Recorded by 1983 Route length of Medium voltage distribution line Route length of Overhead grounding wire							Installation factor B/A % 82.7% 106,997KM ... A 88,467 KM ... B		

Table 5.4-6

Forms of Input data for Damage equipment on Medium Voltage distribution line

For example

Equipment -------------- Transformer

	Damage Equipment																										
	Supply voltage(kV)			Assortment of equipment (A)		(B) Details for Assortment of equipment								Manufacture						Install				(D) Portion of Damage		(E) Condition of Damage	
														Maker (C)		Year		Month		Year		Month					
						A	B	C	D	E	F	G	H														
Code No.	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
	0	6	6	4	0	3	1	0	5	0	8	6	4	1	1	6	7		2	6	7		4	1	1	1	1

(C) Maker
Number 11 ~ 17
for example 11 ..... Daihen

(D) Portion of Damage

Number		Portion
1	1	Winding
1	2	Case
1	3	Outside lead
1	4	Inside lead
1	5	Bushing
1	6	Tap
1	7	Terminal
8	8	Others

Note: (A) Assortment of equipment

Number		Assortment
0	0	Supportor (Pole)
0	1	Guy wire
1	0	Cross arm
2	0	Insulator
3	0	Conductor
4	0	Transformer
4	1	Tie-transformer
5	0	Switching devices
6	0	Lightning arrester
7	1	Voltage Regulater
7	2	Other Apparatus
7	3	Underground cable

(B) Details for Assortment of equipment

Details	Contents	Number	for example
A	Transformer and Bushing	0 ~ 3	3... Salt-proof Bushing
B	Phase	1.3.8.	1... 1ϕ
C	Capacity	001 ~ 133	050 ... 50kVA
D	Indication by		
E	3 figures		
F	Winding — Secondary	1 ~ 8	8... B type winding iron core stad
G	Using Condition	0 ~ 9	6... Δ(Delta)
H	Utility Factor	0 ~ 9	4... Under 120%

Notice

In case of cause by lightning fault, it is obliged to be written those distance and earthing resistence value of arrester, existence and earthing resistence value of grounding wire, and 3 phase short circuit current (KA).

(E) Condition of Damage

Number		Contents
1	1	Worse insulation
1	2	Breaking of wire
1	3	Breakage
1	4	Crack
1	5	Corrosion
8	8	Others

Fig 5.4-1 Comparison of M.V.Line Unit Cost (US$/KM.MVA)

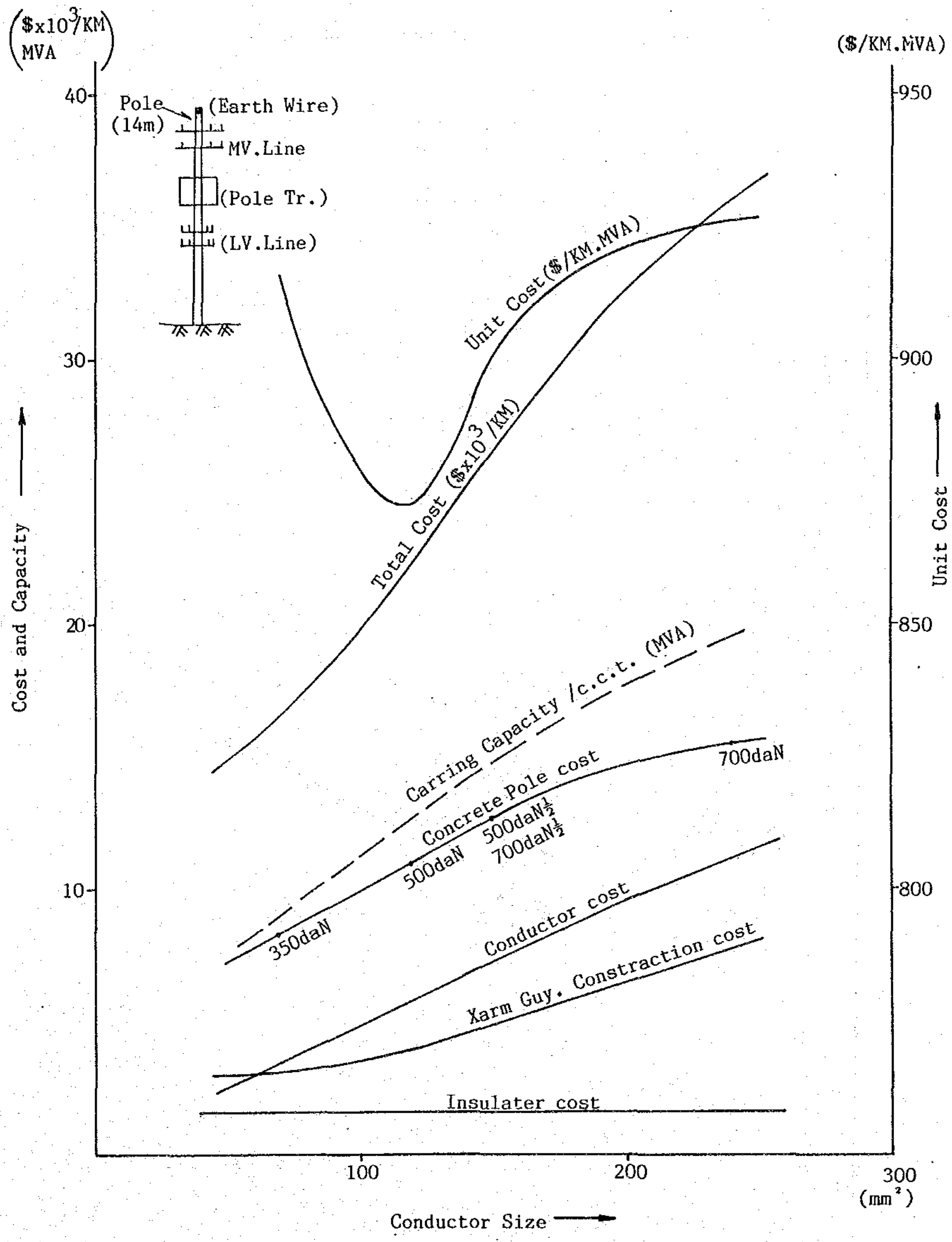


Fig 5.4-2(1/3) Comparison of Unit Cost

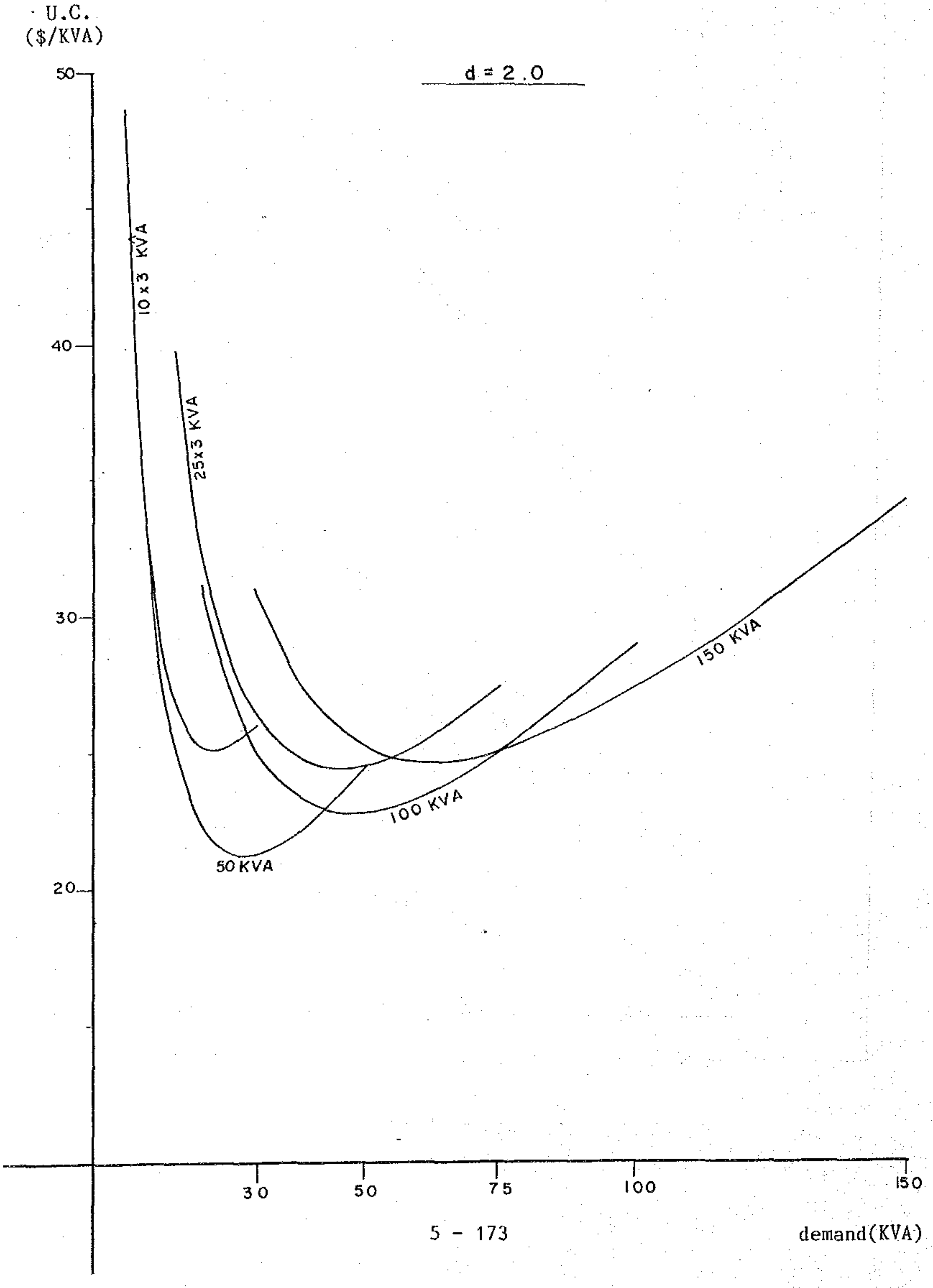


Fig 5.4-2(2/3) Comparison of Unit Cost

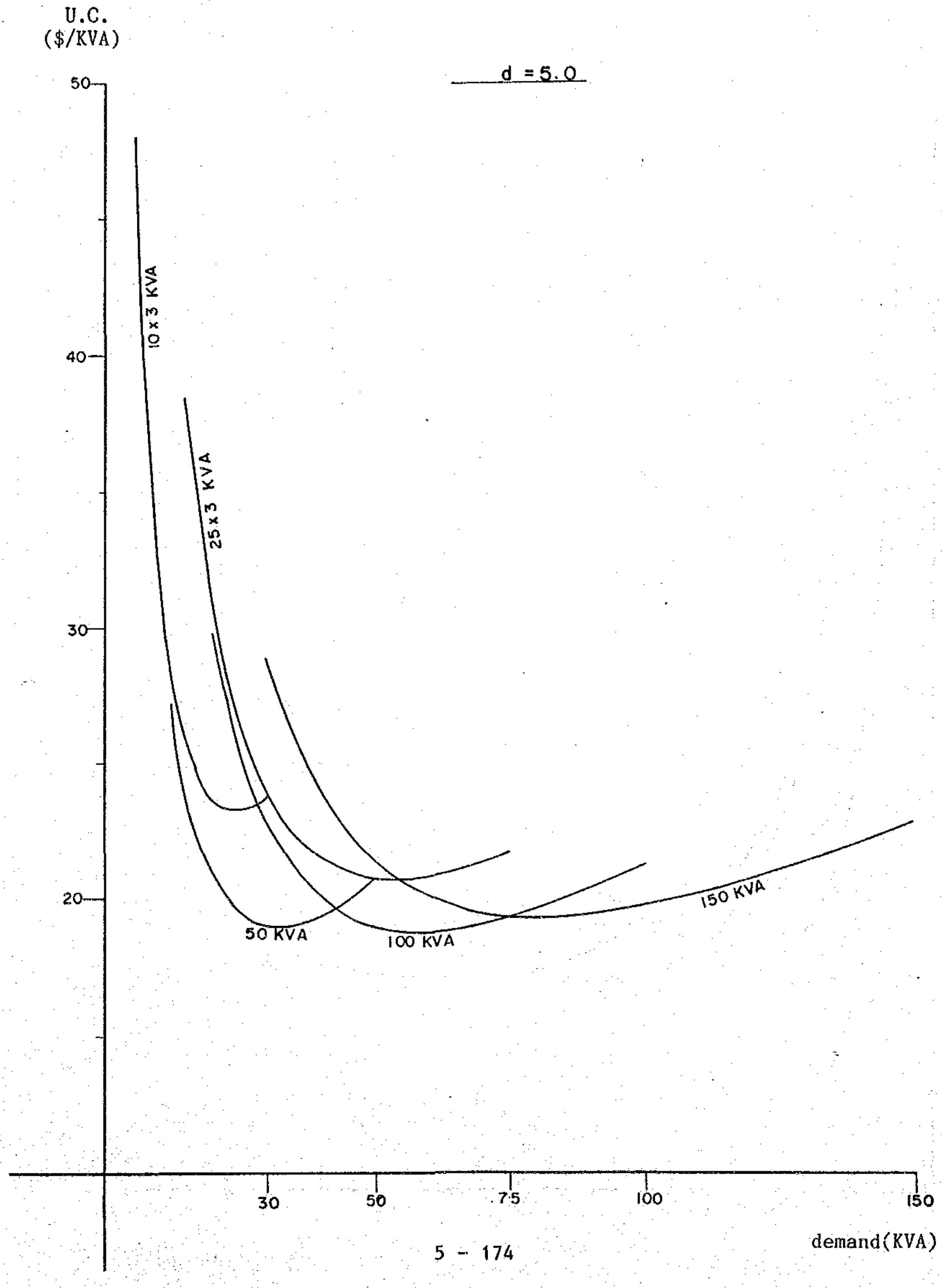


Fig 5.4-2(3/3) Comparison of Unit Cost

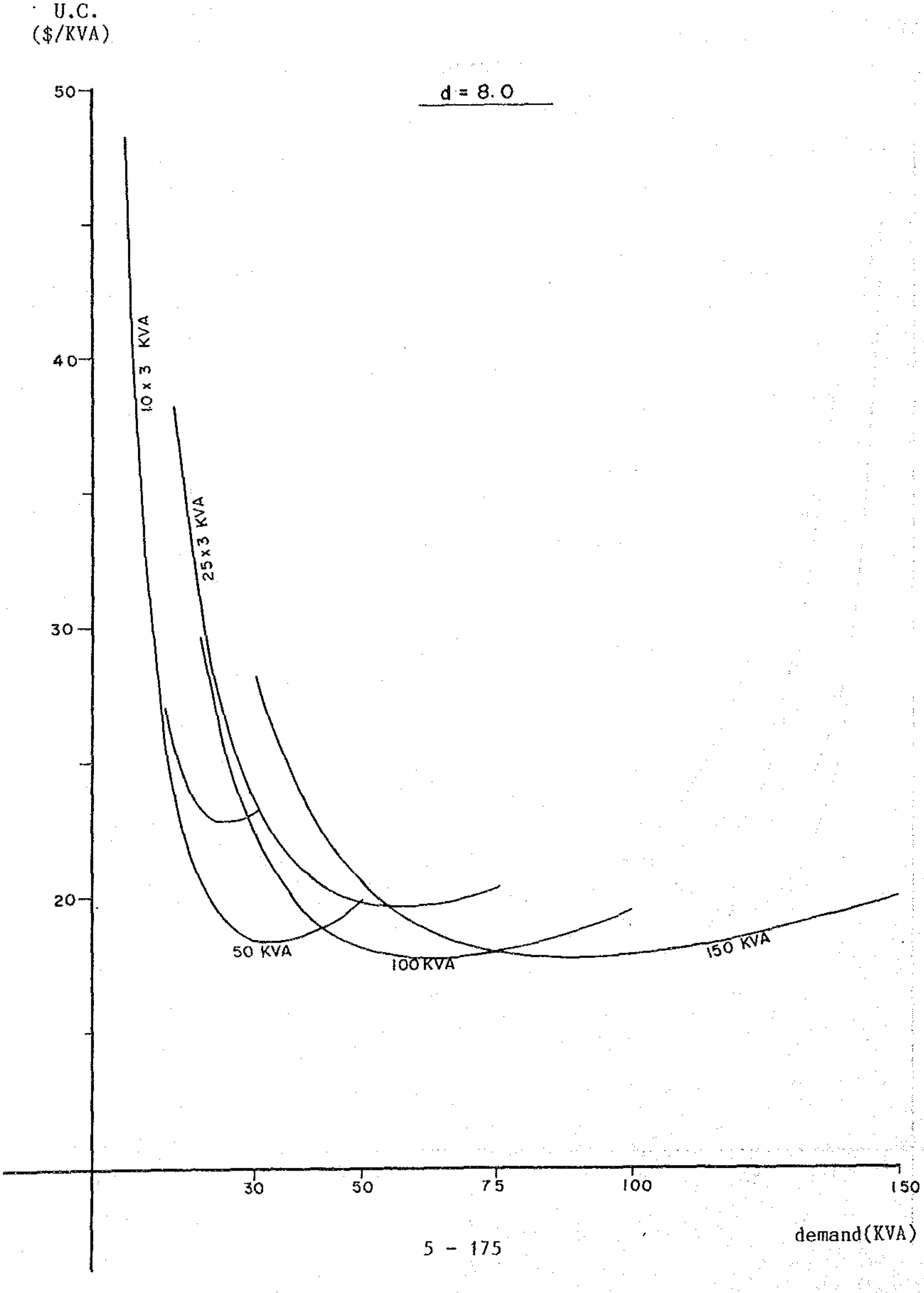
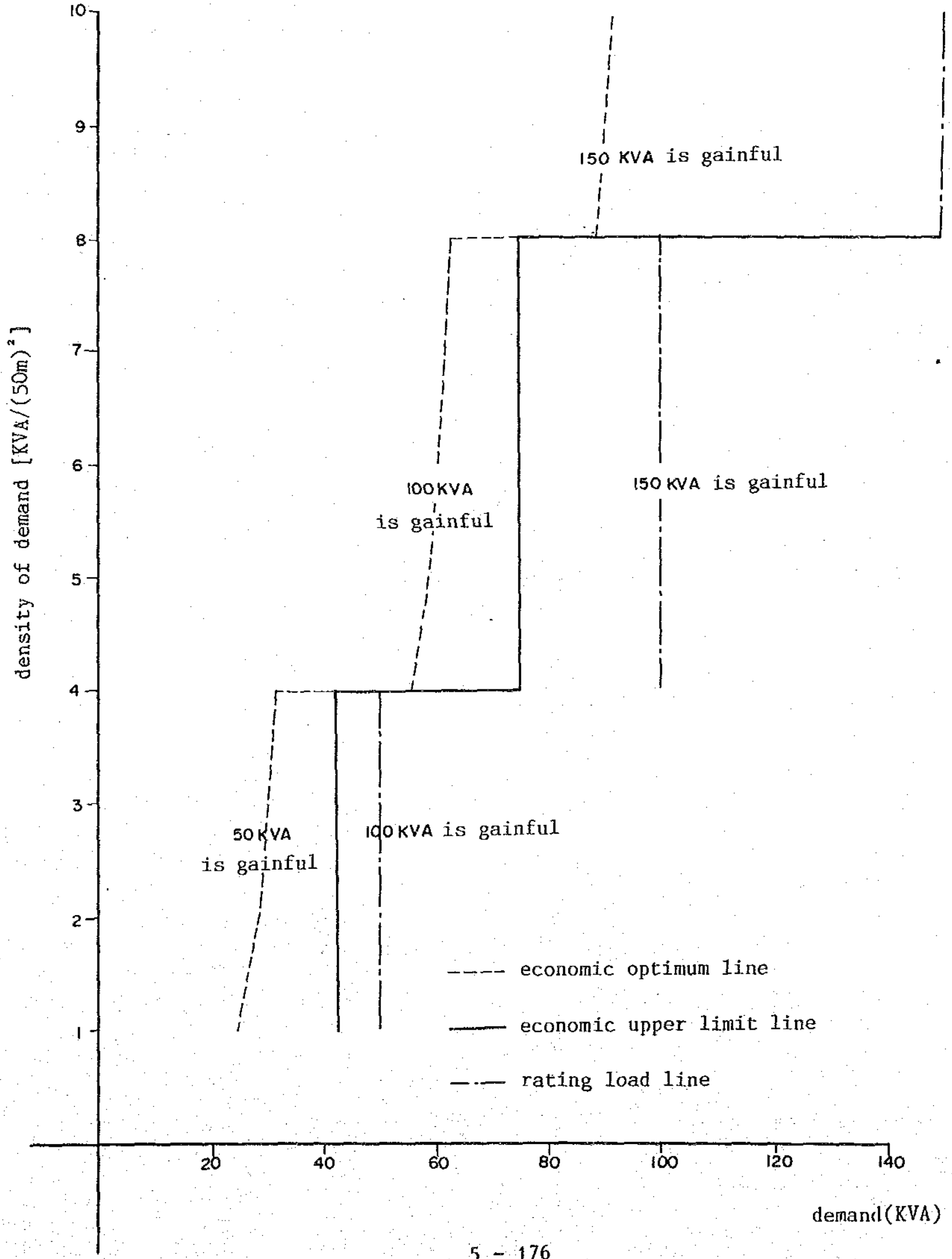


Fig 5.4-3 Choice of Transformer Capacity



APPENDIX - A

THE METHOD OF FORECASTING LOAD BY REGION BASED ON THE HISTORICAL DATA OF SALES

A.1 Introduction

In order to forecast the demand regionally, the time series trend analysis method is either necessitated similarly to the case for the whole area gross forecast.

Accordingly, the regional historical data which suggest growth trend in future are required; however, the data obtained at substations contain such a serious problem that those supply areas are not fixed for making them reasonable to meet the variable conditions of power facilities.

So called "Ikhtisar Langganan" which are prepared monthly at PLN Distribusi Java Timur through an electric data processing prior to the issue of bills are very useful when they are well arranged and historically stored for an enough period.
Because, they are grouped of "Zones" which determined by the location of each customer and can be related to the substation from which they fed. (Hereafter this statistics will be called "Billing Summary")

As the statistics, in addition, are prepared for each tariff/contract kVA, rough demands could be calculated when a set of adequate contract to the demand conversion factors is established. They are multipliers for every hour of a weekday on the basis of a set of careful estimations for several use categories.

A general illustration for the whole procedure is schematically given on the following Fig.A-1.

Fig. A-1(1) Schematic Illustration of the Regional Load Forecast

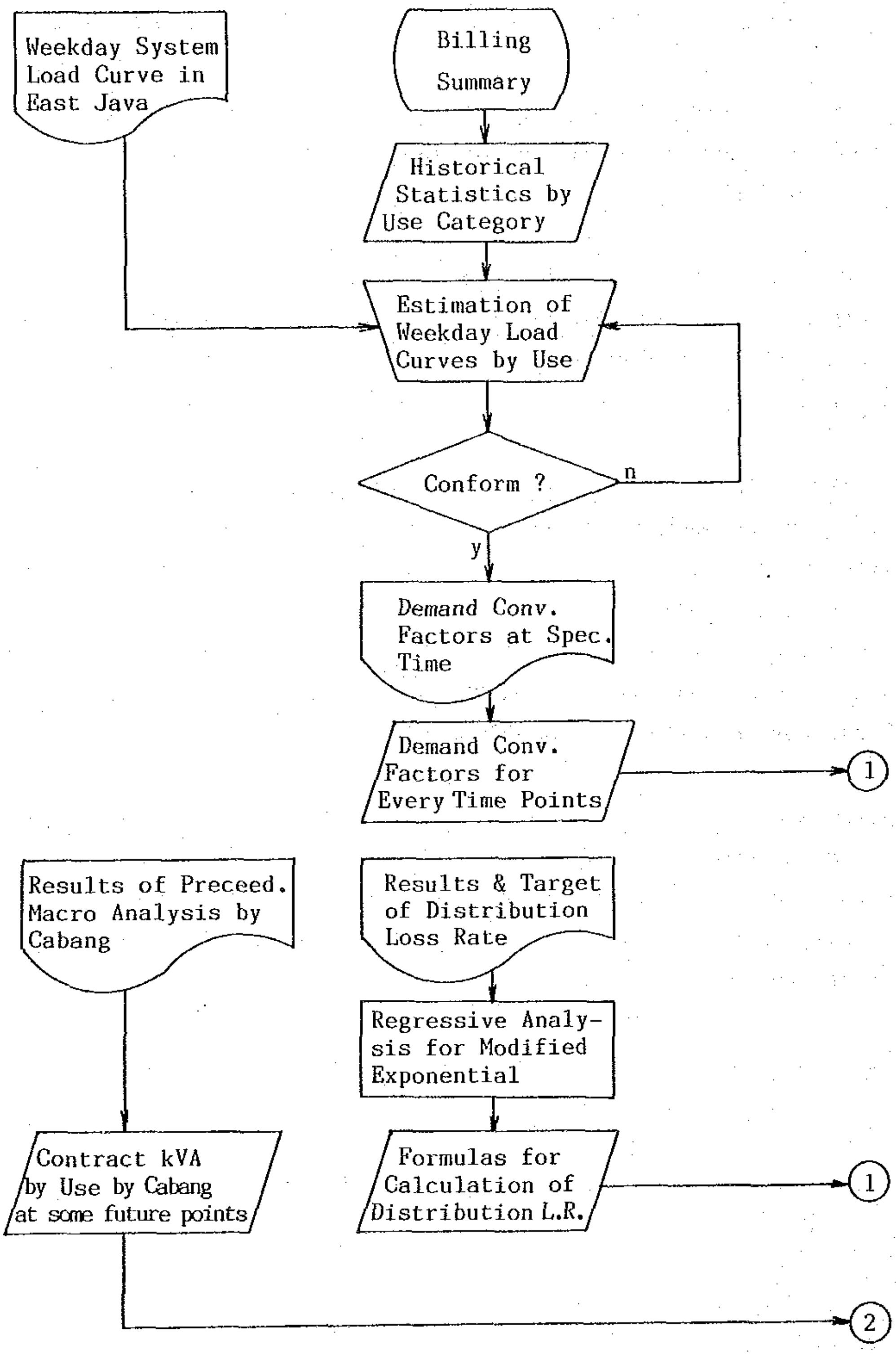
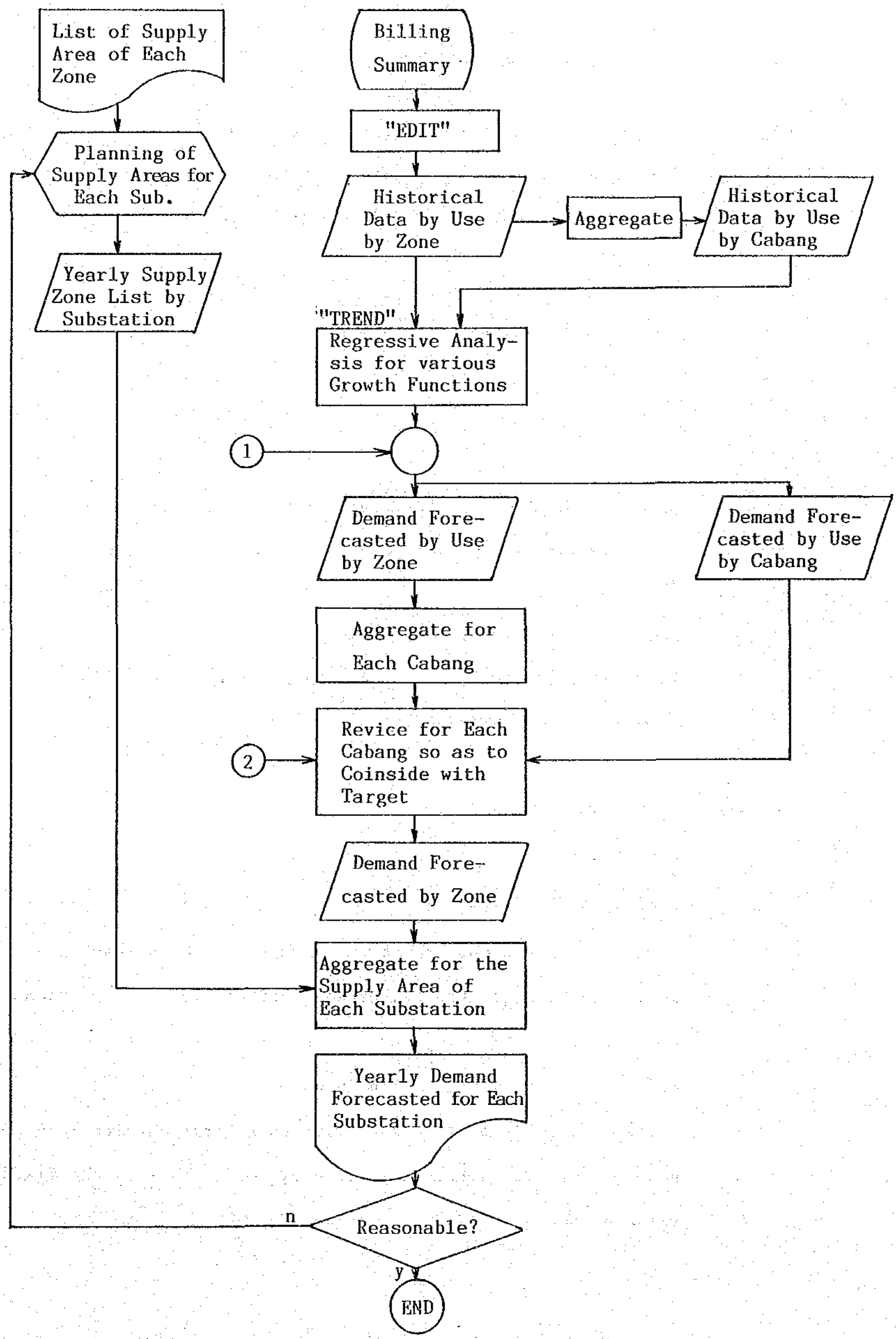


Fig. A-1(2) Schematic Illustration of the Regional Load Forecast



A.2 TIME SERIES TREND ANALYSIS

The electric power demand, in general, increases year by year. As a method to show the demand increase charasteristic the trend curves such as exponential function [1] or power function [2] are usually applied.

Note 1 : Exponential function

$$y = ab^x \qquad a>0,\ b>1$$

$$\frac{dy}{dx} = a(\ell n\ b)b^x = (\ell n\ b)y$$

Namely, the electric power demand constantly increases at the growth rate corresponded to the compound interest ratio.

And $\ell n\ y = \ell n\ a + (\ell n\ b)x$

Therefore, it is plotted as a straight line on a semi-logarithmic graph paper.

Note 2 : Power function

$$y = ax^b,\ a>0,\ b>0,\ x\geqq 0$$

$$\frac{dy}{dx} = abx^{b-1} = by/x$$

Namely, although the growth rate decreases in inverse propotionate to x, y itself increases infinitely as x approaches to infinity.

And $\ell n\ y = \ell n\ a + b\ \ell n\ x$

Therefore, it is plotted as a line on a both-logarithmic graph paper. This means that the elasticity of y to x is the fixed value b, because, $(dy/y)\ /\ (dx/x) = b$

therefore, the increase ratio of y is b times the value of the increase ratio of x.

In each above expression, it is not considered that as y increases, y will give effect which controls the growth of y itself.
In other words, it is feared that the estimation will become extremely high in an extra-long term extrapolation, because the model used is such that y increses infinitely following increase of x.
As the electric power demand is connected with the expansion of population, it is far apart from the saturation as a whole and difficult to know the upper limit. No matter how enormous value it might be, however, the existence of upper limit for long run future, that is to say, the saturation tendancy should be considered.

2.1 Requirement to Introduce Growth Curves

As mentioned above, in such a case that the demand as a whole, for example, is growing exponentially, respective demand arises stepwise by nature. That is to say, the accumulation of new demand in step is to be formed an exponential figure on the whole. The more limited the region or the kinds of demand will be, the more many of them are near to the level of demand saturation individually. On the other side, it is also a fact that many unknown new demands exist in potential in undeveloped region for the future.
In this study, it is the intention to develop the program by which suitability of each demand growth curve can be assessed, by determining the individual parameter which fits reasonably to various kinds of growth curves. Followings are ten (10) types of curves which have been taken up.

AAA Monotonously increase and not saturate

(1) straight line

(2) logarithmic

(3) power

(4) exponential

(5) parabola

BBB Monotonously increase but have a limitted value (saturation tendency)

(1) modified exponential

(2) hyperbolic

(3) Logistic

(4) Gompertz

(5) modified Logistic (our original idea)

Assuming that the limit value is enough big in these functions which retain the saturation tendency, it can be easily verified that (3),(4) and (5) include the aforementioned exponential or power function in the early stage of the growth.

Note : exponential is included in Logistic or Gompertz and power is in Modified Logistic.

2.2 Recommendable Growth Curves

As for the growth curve, we recommend three (3) types as follows:

(1) Logistic Curve

This is given as the following formula in general expression.

$$y = K/(1 + \exp^{\phi(t)})$$

Ordinarily $\phi(t) = A + B \cdot t$

then $y = K/(1 + ab^t)$ .... (1)

where $a = \exp A$, $b = \exp B$ ..... (2)

To determine the parameters K, a, b, the following transformation is applicable.

Rewriting expression (1),

$$\frac{K}{y} - 1 = ab^t$$

$$\ell n\left(\frac{K}{y} - 1\right) = \ell n\ a + t \cdot \ell n\ b$$

Denoting $\ell n\left(\frac{K}{y} - 1\right) = Y$, and

using expression (2) $\ell n\ a = A$, $\ell n\ b = B$

Obtain :

$Y = A + Bt$ .... (3)

It might be considered that the observed set of historical data (ti, yi) is applicable directly to determine A, B by ordinary least squres method if K was given. But such a conversion, $\ell n\left(\frac{K}{y} - 1\right) = Y$, yields a serious ununiformity of varience.

Therefore, we have prepared some weighted least squares method to avoid serious error and to increase the precision even on the case where y(K - y) nearly equal to zero. That is to weight historical data with y (K - y). (Will be mentioned later)

(2) Gompertz Curve

This is given as the following expression

$y = K \cdot a^{b^t}$ .... (4)

$K/y = (1/a)^{b^t}$

$$\ell n\ (K/y) = \ell n\ (1/a)\ b^t$$

$$\ell n\ (\ell n\ (K/y)) = \ell n\ (\ell n\ (1/a)) + \ell n\ b \cdot t$$

Denoting $Y = \ell n\ (\ell n\ (K/y))$,

$A = \ell n\ (\ell n\ (1/a))$, $B = \ell n\ b$

Obtain $Y = A + Bt$ .... (5)

For the same reason as above, the set of weight $y\ \ell n\ (K/y)$ have to be applied to each historical data. (Will be mentioned later)

(3) Modified Logistic Curve

The two functions mentioned above could not be equal either zero or K unless set t equal to plus or minus infinitive.

This "Modified Logistic Curve" that we originally propose is belongs the Logistic Curve in its wide sense mentioned above[3], nevertheless it is possible to be equal zero when t = 0.

Its expression is

$y = K \cdot t^m/(t^m + a)$ .... (6)

$$(K - y)/y = a\ t^{-m}$$

$$\ell n\ ((K - y)/y) = \ell n\ a - m\ \ell n\ t$$

Denoting $Y = \ell n\ ((k - y)/y)$,

$A = \ell n\ a$, $B = -m$, $T = \ell n\ t$

Obtain $Y = A + BT$ .... (7)

As same as paragraph (1), the set of weight $y\ (K - y)$ have to be applied to each historical data. (Will be mentioned later)

Note 3 : Reducing t^m in expression (6)

Obtain $y = K/(1 + a\ t^{-m})$

This is a particular case in the general formula of Logistic function foresaid, substituted the following expression.

$$\phi(t) = \ell n\ a - m\ \ell n\ t$$

2.3 Characteristics of Growth Curves

For reference, a set of normal form of these growth curves including exponential function has been calculated under the conditions given below:

Conditions : $y = 1.0$ at 1981 or $t = 37$

$y = 10^{-3}$ at 1945 or $t = 1$

$K = 100$ for the three saturatable curves

The result is shown on Fig.A-2 and Fig.A-2(2).

The features are as follows.

- Exponential

  The future growth rate is maximum and it will reach into astronomical figures such as 8.77×10^9 at 2,100.

  The annual growth rate is fixed at 20.5% and the curve is shown as a straight line on Fig. A-2(2)

- Logistic

  Logistic curve laps over exponential one in the initial stage.

  The inflection point is shown between 2000 and 2010 and the value is just fifty namely K/2 according to its inherent characteristic.

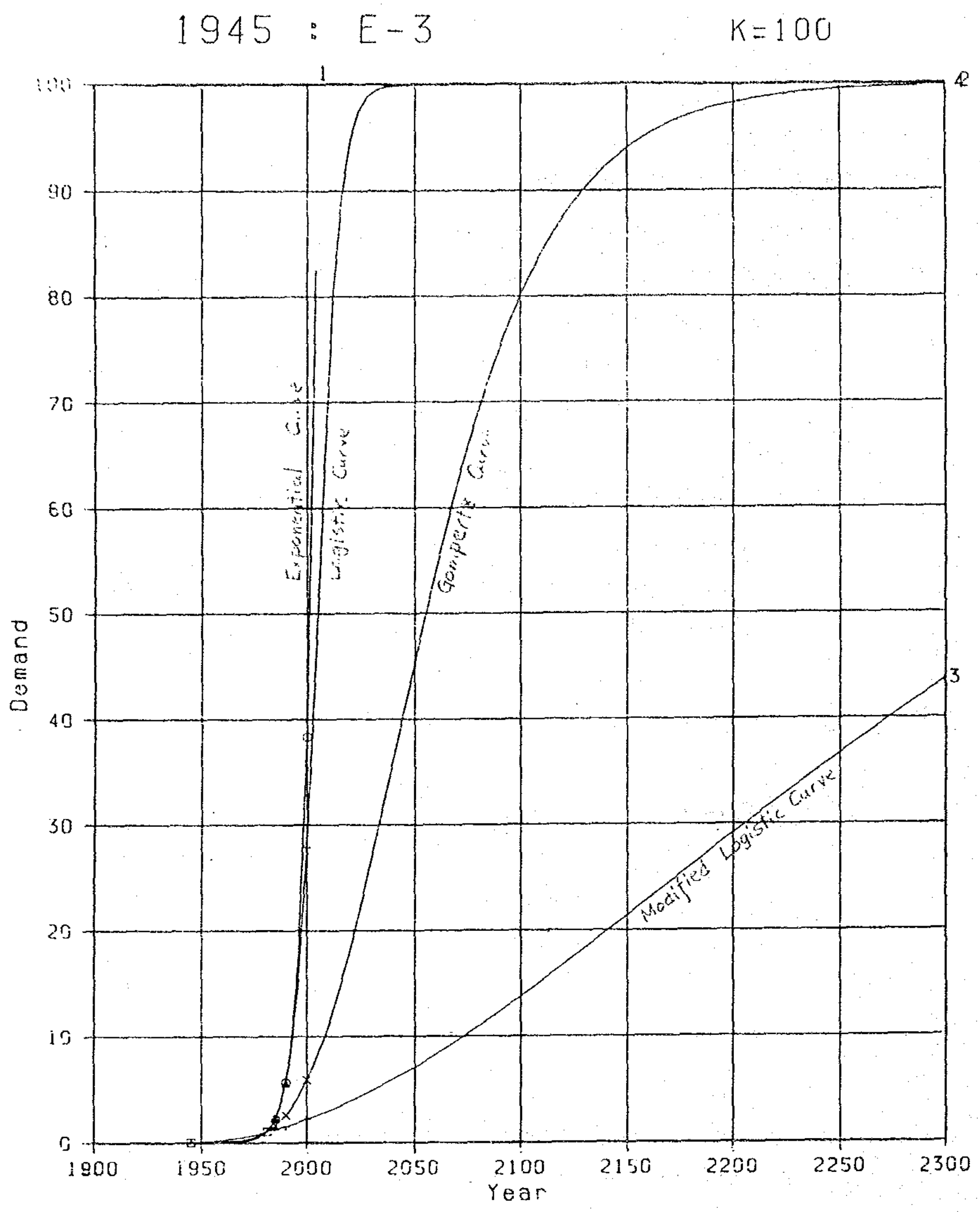
  This curve saturates earliest among those three saturatable curves.

- Gompertz

  Gompertz curve exceed the exponential and Logistic ones in the past period and the future annual growth rate is less than that of Logistic.

  Saturation is slower than Logistic.

  The inflection point is shown around 2040 and the value is 36.79 that corresponds 100/e according to its inherent characteristic.



NO.	R	1985	2000	T=Year-1944
1. ○	1.0000	2.2	38.3	Y=0.825E-3*(1.212**T)
2. △	1.0000	2.1	28.0	Y=100.00/(1+EXP(11.71-0.192*T))
3. +	1.0000	1.2	2.2	Y=100.00*(T**(1.916))/(T**(1.916)+10.000E4)
4. ×	1.0000	1.6	5.8	Y=100.00/EXP(11.81*(0.975)**T)

Fig.A-2 Characteristics of Growth Curves

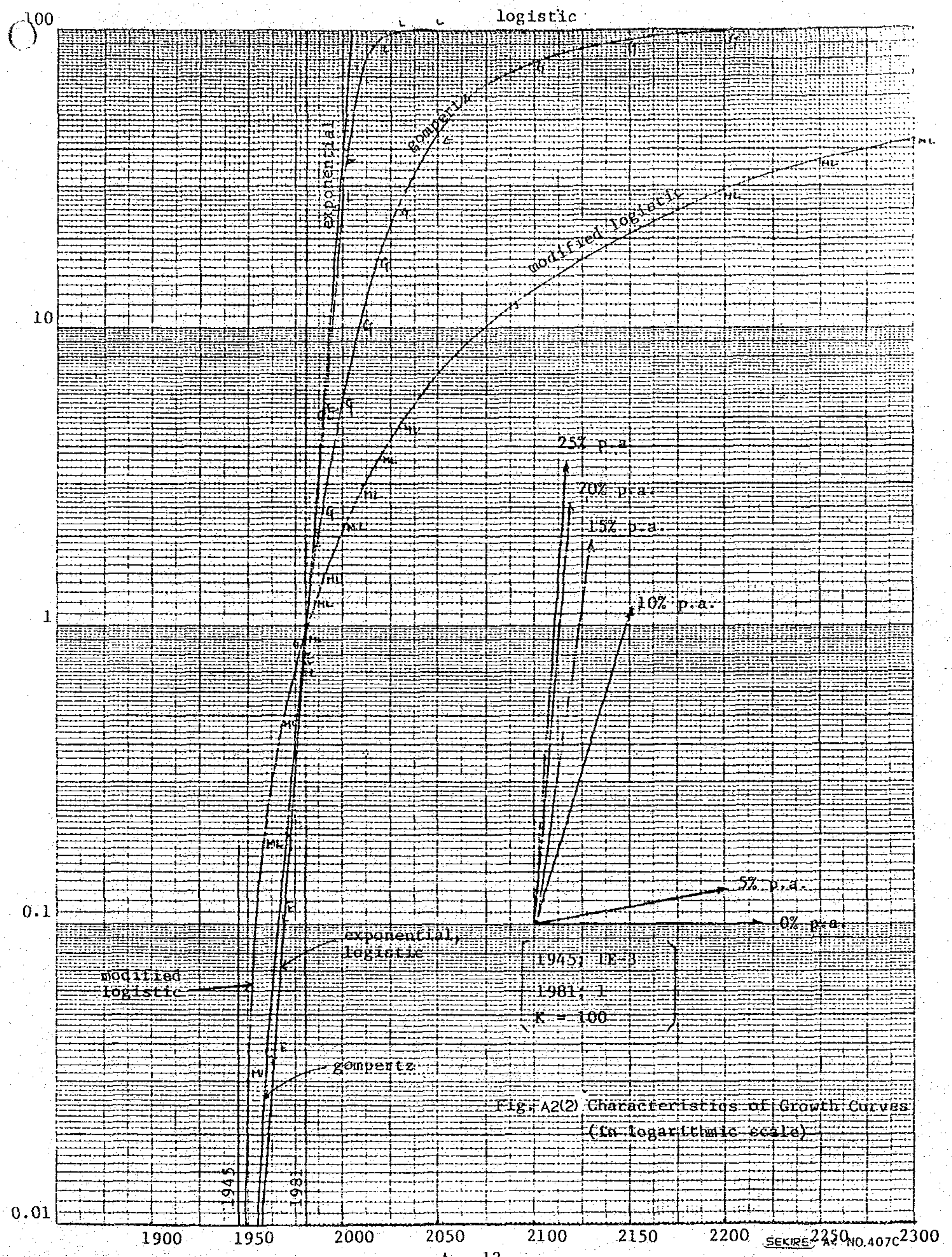


Fig. A2(2) Characteristics of Growth Curves (in logarithmic scale)

· Modified Logistic

Modified Logistic curve is raised in a very drastic rate at the initial stage, but the rate relaxes early.

The future growth rate is smallest among these curves under such a low K value.

The curve saturates latest and the limitted value must be very large in general.

Fig. A-2 and Fig.A-2(2) show the features of curves when Ks' are given a fixed value 100. In applying these curves to historical data for a trend analysis, K is not given in general, and it must be determined by iteration process so as to the fitness (squre of corelation coefficient) approaches to unit. Therefore, when a set of historical data is given, the most fittable K should be different by each curves. In general, the saturation value K and the period to saturate are largest in Modified Logistic, Gompertz is the next, and Logistic saturates earliest at the smallest value of K. As to the fitting tendency, it depends only upon the nature of given set of historical data.

A Sample of Time Series Trend Analysis Using Growth Curves

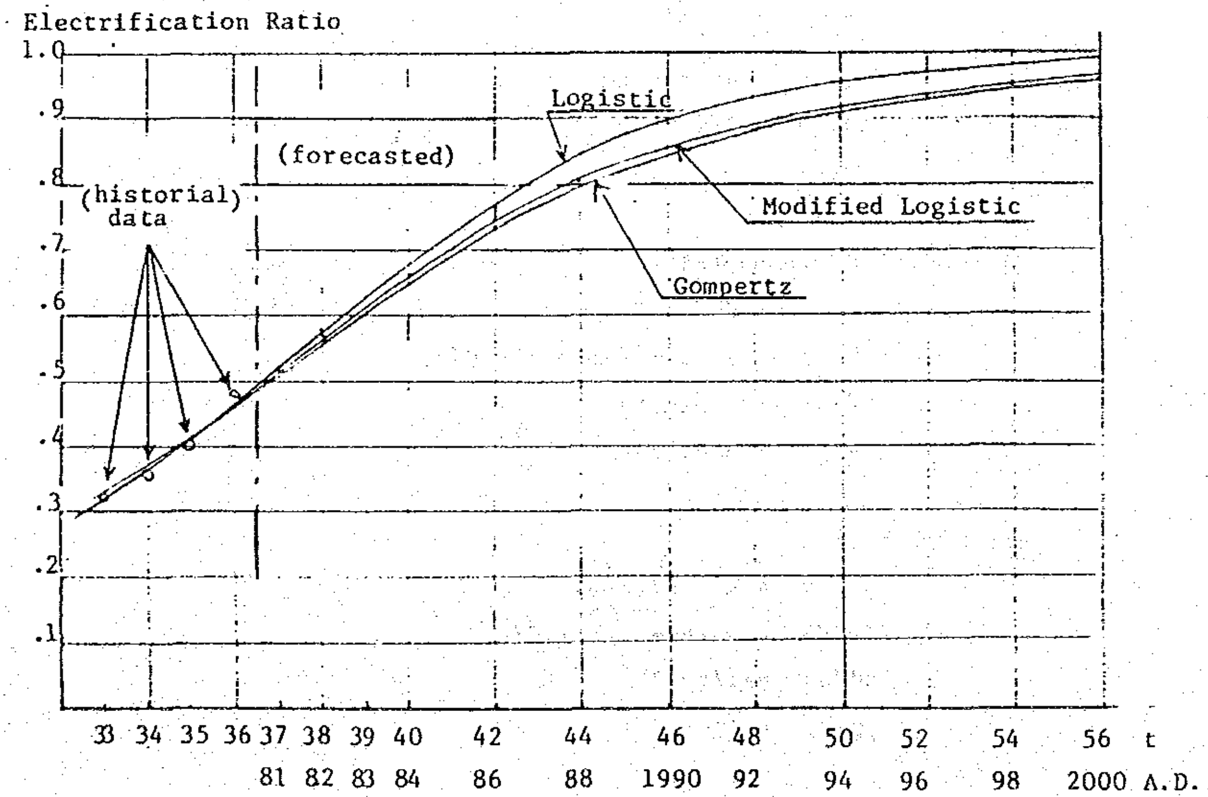
Using the following historical data, forecast the electrification ratios for MALANG City up to 2000/01.

Historical Electrification Ratios

1977/78	78/79	79/80	80/81
t = 33	t = 34	t = 35	t = 36
0.32	0.35	0.40	0.48

The obtained coefficients culcurated setting K=1.0 are shown on the following table, and obtained future forecasts are figured below.

Curve Expression	K	a	b	corelation coefficient r	decision coefficient r^2
Logistic $y=K/(1+e^a \cdot e^{bt})$	1.0	8.2336	-0.22519	-0.98233	0.96497
Gompertz $y= K \exp(-e^a \cdot e^{bt})$	1.0	4.9545	-0.14517	-0.97714	0.95479
Modified Logistic $y= Kt^{-b} /(t^{-b}+e^a)$	1.0	27.8960	-7.74802	-0.97983	0.96006



Weighting for Time Series Regression Analysis

When the linear regression formula is expressed as $\emptyset(t) = A + Bt$, the variance of $\emptyset(t)$ should be uniform regardless the observed value through a historical trend; however, the values of time are considered include no error.

In the case the variance $\emptyset(t)$ could change widely, the weighting technique should be applied to the set of data to avoid any extreme magnification of error which produce a bad effect on the results.

Applicable weight functions w(y) by each trend function are expressed as follows;

1) power

$$y = a\,t^{b}$$
$$\ln y = \ln a + b \ln t = \emptyset(t)$$
$$d\emptyset/dy = 1/y$$
$$w(y) = y$$

2) exponental

$$y = a\,e^{bt}$$
$$\ln y = \ln a + bt = \emptyset(t)$$
$$d\emptyset/dy = 1/y$$
$$w(y) = y$$

3) modified exponental

$$y = K - ab^{t}$$
$$\ln(K-y) = \ln a + (\ln b)t = \emptyset(t)$$
$$d\emptyset/dy = -1/(K-y)$$
$$w(y) = ABS(K-y)$$

4) hyperbolic

$$y = K + b/(t-a)$$
$$1/(y-K) = -a/b + t/b = \emptyset(t)$$
$$d\emptyset/dy = -1/(y-K)^{2}$$
$$w(y) = (y-K)^{2}$$

5) logistic

$$y = K/(1 + ab^t)$$

$$\ln(K/y - 1) = \ln((K - y)/y) = \ln a + (\ln b)t = \emptyset(t)$$

$$-d\emptyset/dy = 1/(K - y) + 1/y = K/(y(K - y))$$

$$w(y) = y\ (K - y)$$

6) Gompertz

$$y = K\ a^{bt}$$

$$K/y = (1/a)^{bt}$$

$$\ln(K/y) = (\ln(1/a))b^t$$

$$\ln(\ln(K/y)) = \ln(\ln(1/a)) + (\ln b)t = \emptyset(t)$$

$$d\emptyset/dy = -1/(y\ \ln(K/y))$$

$$w(y) = y\ \ln(K/y)$$

7) modified logistic

$$y = K\ t^{-m}/(t^{-m} + a)$$

$$(K - y)/y = at^m$$

$$\ln((K - y)/y) = \ln a + m \ln t = \emptyset(t)$$

$$d\emptyset/dy = -K/(y(K - y))$$

$$w(y) = y(K - y)$$

Development of Correlation Coefficient and
Regression Formula for Weighted Data

1. Ordinary Formula

As for a set of data"(x_1, y_1), (x_2, y_2),... ,(x_i, y_i),... ,(x_N, y_N)", the number defined as the following formulas (A-2-2-1) or (A-2-2-2) is called the "covariance" with x and y;

$$C_{xy} = \frac{1}{N}\Sigma(x_i - \bar{x})(y_i - \bar{y}) \quad \text{.......... (A-2-2-1)}$$

or $$C_{xy} = \frac{1}{N}\Sigma xy - \bar{x}\,\bar{y} \quad \text{.......... (A-2-2-2)}$$

here, $\bar{x}$ or $\bar{y}$ means the average value of x_i or y_i that is $\frac{1}{N}\Sigma x_i$ or $\frac{1}{N}\Sigma y_i$ respectively.

In order to use the covariance into evaluate the relationship between variables, those should be previously normalized by the following expressions where s_x and s_y is the standard deviation of x_i and y_i respectively;

$$u_i = (x_i - \bar{x})/s_x,\ v_i = (y_i - \bar{y})/s_y$$

Correlation coefficient r_{xy} is obtained as the average value of $u_i v_i$, or as the quotient of C_{xy} divided by standard deviation s_x and s_y.

Namely,

$$r_{xy} = \frac{1}{N}\Sigma u_i v_i = \frac{1}{N}\Sigma\left(\frac{x_i - \bar{x}}{s_x}\right)\left(\frac{y_i - \bar{y}}{s_y}\right)$$

$$= \frac{1}{s_x s_y}\cdot\frac{1}{N}\Sigma(x_i - \bar{x})(y_i - \bar{y}) = \frac{C_{xy}}{s_x s_y}$$

$$= \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{(\Sigma(x_i - \bar{x})^2\,\Sigma(y_i - \bar{y})^2)^{\frac{1}{2}}} \quad \text{....... (A-2-2-3)}$$

As for calculation formula of the correlation coefficient, the expression which is reduced from expression (A-2-2-3) and shown below as expression (A-2-2-4) would be useful.

$$r_{xy} = (\frac{1}{N}\sum x_i y_i - \bar{x}\,\bar{y})/(s_x^2 \cdot s_y^2)^{\frac{1}{2}}$$

$$= \frac{N\sum x_i y_i - \sum x_i \sum y_i}{((N\sum x_i^2 - (\sum x_i)^2)(N\sum y_i^2 - (\sum y_i)^2))^{\frac{1}{2}}}$$

..... (A-2-2-4)

If the linear regressive function is expressed as the next formula,

$$y = A + Bx, \quad \ldots\ldots (A\text{-}2\text{-}2\text{-}5)$$

the regressive coefficients A, B are shown as follows;

$$B = \frac{\sum((y_i - \bar{y})(x_i - \bar{x}))}{\sum(x_i - \bar{x})^2}$$

$$= \frac{N\sum x_i y_i - (\sum x_i)(\sum y_i)}{N\sum x_i^2 - (\sum x_i)^2} \quad \ldots\ldots (A\text{-}2\text{-}2\text{-}6)$$

$$A = \bar{y} - B\,\bar{x}$$

$$= \frac{\sum y_i - B\sum x_i}{N} \quad \ldots\ldots (A\text{-}2\text{-}2\text{-}7)$$

2. Weighted Formula

In certain cases, for example mentioned in the preceding paragraph the set of data (x_i, y_i) must be revalued using weight w_i for each i. The correlation coefficient applicable to such cases is obtained by means of revaluation with w_is'; that is to multiply every elements by w_i in each summing process, and substitute N by summation of w_i.

Hence, the correlation coefficient for weighted data is formulated as follows

$$r(x,y) = \frac{SW*SXYW - SXW*SYW}{((SW*SX2W - SXW**2)*(SW*SY2W - SYW**2)) ** \frac{1}{2}}$$

..... (A-2-2-8)

where

$$SW = \sum w_i,$$
$$SXYW = \sum x_i y_i w_i,$$
$$SXW = \sum x_i w_i, \qquad SYW = \sum y_i w_i,$$
$$SX2W = \sum x_i^2 w_i, \qquad SY2W = \sum y_i^2 w_i.$$

The regressive coefficients A, B are shown as follows;

$$B = \frac{\sum (w_i(y_i - \bar{y}')(x_i - \bar{x}'))}{\sum (w_i(x_i - \bar{x}')^2)} \quad \ldots\ldots (A\text{-}2\text{-}2\text{-}9)$$

where, $\bar{x}'$ or $\bar{y}'$ means the weighted average of x_i, y_i respectively; that is,

$$\bar{x}' = \frac{\sum x_i w_i}{\sum w_i},$$

$$\bar{y}' = \frac{\sum y_i w_i}{\sum w_i}.$$

Then,

$$A = \frac{\sum (y_i w_i) - B \sum (x_i w_i)}{\sum w_i} \quad \ldots\ldots (A\text{-}2\text{-}2\text{-}10)$$

A.3 Regional Load Forecasting

(1) Weekday System Load Curve in East Java

The East Java system load curves for every days of a week are shown on the Table A-1 for dry (July) and wet (December) season.
After an attentive observation, the following opinions had clearly established.

a. Any seasonal distinctions are hardly found.

b. Any distinctions by the day of a week are also hardly found from Monday through Friday; so those days may be similarly dealed as weekdays.

c. In a weekday, the peak demand occurs around nineteen (19) hours, and the sub-peak demand occurs at around nine (9) or fourteen (14) hours; hence nineteen (19) hours is chosen as the peak time at evening and fourteen (14) hours is chosen as the sub-peak time at daytime because the more afternoon demand growth will be in future than the one in the morning.

d. Comparatively small but an obvious demand decrease is found on the weekend; consequently the average demand on a weekday is somewhat greater than the one through a week or a month.

Table. A-1 System Load Curves for Days of a Week (1/2)

hour	Mon. Jul. 25/83	Percent to average	Mon. Dec. 19/83	Percent to average	ave percent of Monday	Tues. Jul. 26/83	Percent to average	Wed. Jul. 27/83	Percent to average	Wed. Dec. 21/83	Percent to average	Thurs. Jul. 28/83	Percent to average	Thurs. Dec. 22/83	Percent to average	ave % L.C.for Jul~Thur
1	292	96.5	316	100.6	98.6	306	101.3	283	98.5	310	96.3	276	94.1	302	92.6	96.6
2	296	97.8	297	94.6	96.2	304	100.7	311	108.2	322	100.0	279	95.6	326	100.0	100.9
3	282	93.2	281	89.5	91.4	297	98.3	306	106.5	320	99.4	274	93.9	322	98.8	99.4
4	287	94.9	288	91.7	93.3	290	96.0	288	100.2	303	94.1	296	101.5	327	100.3	98.4
5	275	90.9	323	102.9	96.9	278	92.1	296	103.0	344	106.8	296	101.5	318	97.5	100.2
6	291	96.2	265	84.4	90.3	284	94.0	275	95.7	309	96.0	304	104.2	307	94.2	96.8
7	249	82.3	245	78.0	80.2	246	81.5	234	81.4	297	92.2	244	83.6	270	82.8	84.3
8	262	86.6	292	93.0	89.8	242	80.1	244	84.9	278	86.3	285	97.7	305	93.5	88.5
9	294	97.2	295	94.0	95.6	290	96.0	254	88.4	303	94.1	284	97.3	318	97.5	94.7
10	298	98.5	301	95.9	97.2	279	92.4	254	88.4	270	83.9	253	86.7	320	98.1	89.9
11	294	97.2	308	93.6	95.4	276	91.4	255	88.7	298	92.5	252	86.4	298	91.4	90.1
12	257	84.9	262	83.5	84.2	268	88.7	244	84.9	255	79.2	251	86.0	269	82.5	84.3
13	277	91.5	269	85.7	93.6	287	95.0	248	86.3	266	82.6	273	93.6	312	95.7	90.6
14	267	88.2	303	96.5	92.4	286	94.7	258	89.8	303	94.1	251	86.0	303	92.9	91.5
15	276	91.2	291	92.7	92.0	259	85.8	246	85.6	273	84.8	241	82.6	309	94.8	86.7
16	257	84.9	265	84.4	84.7	256	84.8	245	85.3	289	89.8	251	86.0	307	94.2	88.0
17	308	101.8	317	101.0	101.4	291	96.4	278	96.8	311	96.6	287	98.4	326	100.0	97.6
18	397	131.2	396	126.1	128.7	370	122.5	360	125.3	410	127.3	370	126.8	394	120.8	124.5
19	376	124.3	400	127.4	125.9	389	128.8	361	125.6	427	132.6	360	123.4	393	120.5	126.2
20	372	122.9	409	130.3	126.6	392	129.8	366	127.4	427	132.6	360	123.4	395	121.2	126.9
21	386	127.6	402	128.0	127.8	387	128.1	359	124.9	386	119.9	346	118.6	372	114.1	121.1
22	326	107.7	367	116.9	112.3	343	113.6	337	117.3	363	112.7	358	122.7	388	119.0	117.1
23	331	109.4	340	108.3	108.9	336	111.3	312	108.6	330	102.5	326	111.7	319	97.8	106.4
24	312	103.1	303	96.5	99.8	292	96.7	282	98.1	334	103.7	285	97.7	325	99.7	99.2
total	7,262		7,535			7,248		6,896		7,728		7,002		7,825		
ave	302.58		313.96			302.00		287.33		322.00		291.75		326.04		

Table. A-1 System Load Curves for Days of a Week (2/2)

hour	Fri Jul. 29/83	Percent to average	Fri Dec. 23/83	Percent to average	ave % L.C.for Friday	Sat Jul. 30/83	Percent to average	Sat Dec. 24/83	Percent to average	ave % L.C.for Sat.	Sun Jul. 31/83	Percent to average	Sun Dec. 25/83	Percent to average	ave % L.C.for Sun.	ave % L.C.for Weekday	d.o rounded
1	258	87.1	323	102.8	95.0	277	96.9	304	100.7	98.8	294	112.4	285	104.6	108.5	96.7	97
2	276	93.1	288	91.6	92.4	273	95.5	300	99.4	97.5	278	106.3	307	112.7	109.5	98.3	97
3	276	93.1	316	100.5	96.8	273	95.5	309	102.4	99.0	258	98.7	303	111.2	105.0	97.3	97
4	272	91.8	287	91.3	91.6	281	98.3	324	107.4	102.9	260	99.4	272	99.8	99.6	96.0	96
5	288	97.2	324	103.1	100.2	288	100.7	306	101.4	101.1	281	107.5	297	109.0	108.3	99.5	99
6	271	91.4	295	93.9	92.7	296	103.5	271	89.8	96.7	250	95.6	263	96.5	96.1	94.7	95
7	261	88.1	251	79.9	84.0	245	85.7	280	92.8	89.3	228	87.2	204	74.9	81.1	83.4	83
8	247	83.3	274	87.2	85.3	280	97.9	290	96.1	97.0	217	83.0	198	72.7	77.9	88.1	88
9	277	93.5	295	93.9	93.7	252	88.1	264	87.5	87.8	222	84.9	218	80.0	82.5	94.7	93
10	272	91.8	274	87.2	89.5	246	86.0	261	86.5	86.3	207	79.2	229	84.0	81.6	91.3	92
11	274	92.4	293	93.2	92.8	245	85.7	260	86.2	86.0	205	78.4	241	88.5	83.5	91.7	92
12	250	84.4	277	88.1	86.3	255	89.2	247	81.8	85.5	219	83.8	213	78.2	81.0	84.7	85
13	252	85.0	283	90.0	87.5	227	79.4	254	84.2	81.8	222	84.9	237	87.0	86.0	90.6	91
14	283	95.5	288	91.6	93.6	225	78.7	257	85.2	82.0	224	85.7	233	85.5	85.6	92.1	92
15	275	92.8	275	87.5	90.2	238	83.2	246	81.5	82.4	210	80.3	207	76.0	78.2	88.5	89
16	268	90.4	275	87.5	89.0	217	75.9	256	84.8	80.4	198	75.7	208	76.3	76.0	87.5	88
17	272	91.8	340	108.2	100.0	286	100.0	298	98.7	99.4	256	97.9	306	112.3	105.1	98.8	99
18	407	137.3	374	119.0	128.2	366	128.0	370	122.6	125.3	328	125.5	323	118.6	122.1	126.1	126
19	393	132.6	413	131.4	132.0	374	130.8	371	122.9	126.9	355	135.8	343	125.9	130.9	127.3	127
20	393	132.6	381	121.2	126.9	375	131.2	397	131.5	131.4	333	127.4	336	123.3	125.4	126.8	127
21	383	129.2	368	117.1	123.2	345	120.7	366	121.3	121.0	348	133.1	353	129.6	131.4	122.9	123
22	336	113.4	399	126.9	120.2	353	123.5	342	113.3	118.4	336	128.5	343	125.9	127.2	116.8	117
23	323	109.0	355	112.9	111.0	343	120.0	326	108.0	114.0	290	110.9	325	119.3	115.1	107.8	108
24	306	103.2	296	94.2	98.7	302	105.6	344	114.0	109.8	256	97.9	295	108.3	103.1	99.2	99
total	7,113		7,544			6,862		7,243			6,275		6,539				2,400
ave	296.38		314.33			285.92		301.79			261.46		272.46				

The ratio of average demand on a weekday to the one on a week or a month that is hereafter called "weekday factor" is determined as shown below, after an analysis of actual results. (Refer Supplement A, Table A-2)

Weekday Factors for various Uses

Uses	Weekday Factor
Residential	1.000
Commercial/Public	1.035
Industry	1.050
Total	1.030

As shown on Table A-2, respecting residential use in the East Java in 1983/84, for instance, which is contracted 319.46 MVA will consume 319.46 * 6.104 = 1950 MWh in a weekday; and so on.

(2) Standardized Weekday Load Curves by Use

The normalized standard weekday load curve in East Java System that is shown at the last column of Table A-1(2) is illustrated by a diagram on Fig. A-3.
An itterative approach which includes

i) to assume standard load curves for several use categories

ii) to weight each curve with the corresponding sold energies using billing summary

iii) to sum up every assumed demand for each hour and normalize by average demand

Supplement A Determination of Weekday Factors

The actual results of generated energy in East Java System on each day of the week which shown on Table A-1 have been referred; and the average energy on a day from Monday to Friday is determined as 1.03 times of the one which averaged through a week. Applied this value to the yearly energy sales[1)] shown at the first (1st) line of Table A-2, the weekday factors by uses are determined as follows;

Residential	: 1.00
Commercial	: 1.03
Industry	: 1.05
Public	: 1.038 (reckoned backward with energy)
Commercial/Public	: 1.035 (ditto)

Note 1) Obtained by editting Billing Summary, in which, as for Mar. 1984, the data were estimated by means of extrapolation which applied those values from Mar. 1983 to Feb. 1984.

Table. A-2 Weekday Load Factors Compared with Contract Capacities by Use (1983/84)

Items \ Uses	Residential	Commercial		Commercial /Public				Industry	Total
		Commercial	Public		L.I.(I1+I2)	I3	I4		
Yearly Energy Sales (MWh)	713,670	108,744	173,958	282,702	107,850	418,834	472,726	999,411	1,995,783
Average Demand (MW)	81.247	12.380	19.804	32.184	12.278	47.681	53.817	113.776	227.207
Weekday Factor	1.00	1.03	1.038	1.035	1.05	1.05	1.05	1.05	1.03
Average Demand in a Weekday (MW)	81.247	12.751	20.560	33.311	12.892	50.065	56.508	119.465	234.023
Average Energy in a Weekday (MWh)	1,949.93	306.02	493.44	799.46	309.41	1,201.56	1,356.19	2,867.16	5,616.55
Contract Capacity averaged through a Year (MVA)	319.46	82.41	91.00	173.41	96.10	205.55	94.20	395.85	888.73
Weekday L.F compared with Contract Capacity (%)	25.433	15.473	22.593	19.209	13.415	24.357	59.987	30.179	26.332
(Weekday C.L.F.) × 24	610.4	371.4	542.2	461.0	322.0	584.6	1,439.7	724.3	632.0