2. Manual for Improvement of Distribution Network

Contents

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2.1 Planning and Design

2.1.1 Demand Forecast

(1) Techniques for Making Demand Forecasts

Before mapping out a distribution facilities expansion plan, it is necessary to forecast future increases in power demand (peak demand) so that facilities capable of supplying adequate power can be designed and installed.

In estimating demand, large demand and general demand are estimated separately. Estimation of large demand is based on information individually collected from respective customers. Estimation of general demand is based on the past records of growth.

Major indices include:

- Each substation's maximum power rating and power demand growth rate
- Each feeder's maximum power rating and power demand growth rate
- Each mesh's power demand to be met by the maximum power of a substation
- Each big customer's maximum power demand

(2) Demand Density (Mesh-by-Mesh Demand)

When mapping out a distribution substations expansion or installation plan and/or a high voltage distribution line expansion or installation plan, the concept of demand density plays an important role. Demand density is expressed in terms of demand per square kilometer [kW/sqkm]

Adopting the demand density concept makes it easy to build a model to determine the cost efficiency of a facilities installation or expansion plan. For your information, the distribution facilities standards were also formulated on the basis of the concept of demand density.

(3) Classification of Areas

On the grounds that demand data can be processed more efficiently by dividing all areas into groups by demand density and other characteristics for managing distribution facilities, the distribution division has been using a classification approach.

2.1.2 Planning of Substations for Distribution

It becomes necessary to install a new distribution substation or expand an existing distribution substation when capacity shortages begin to pose problems or the quality of electric power has decreased unacceptably due to increased power demand, or if there has been a chronic substandard-quality problem in need of a remedy. In other words, it becomes necessary to install a distribution substation or expand an existing one as the imperative to increase a substation's capacity or to upgrade a distribution line comes up.

In any case, when it is decided to install a new substation or to expand an existing substation, a comprehensive comparative study of all conceivable competing measures such as introduction 22 kV distribution and upgrading distribution lines should be conducted. The study should take into account such criteria as reliability, cost efficiency, and ease of maintenance, in order to choose the best possible measure.

(1) Substation Capacity Enlargement

A substation's utilization rate is obtained by dividing its maximum load by its rated capacity and expressing the result of the calculation as a percentage. A percentage calculated in this manner serves as one measure for determining when to install a new substation or beef up an existing substation.

For example, predetermined basic load limits are expressed in terms of substation utilization rates, as shown in the table below. A distribution substation reinforcement plan is made when these limits begin to be exceeded.

Table 2.1 - 1 Normal substation load limits

	Normal load limit
Banks	100 %
Substations	100 %

(2) Distribution Line Installation Plan

A single distribution circuit capacity is limited by the current carrying capacities of the cables or conductors used at the outgoing of the substation concerned. The capacities of cables or conductors used along major main-line portions as well as the voltage drop along the way can also limit the distribution circuit capacity.

As demand grows and predetermined current carrying capacity and voltage drop limits are exceeded, it becomes necessary to unload some of the burden placed on existing distribution lines by installing new distribution line paths (explained later on). In some cases, however, installing a new substation proves more advantageous. Such cases come up when distribution line-related measures cannot possibly serve as viable solutions or prove to be exceedingly uneconomical due to excessive voltage drops that develop along distribution lines.

Table 2.1 - 2 Substation bank capacities

	Bank capacity
Large cities	20 x 3 – 30MVA x 3
Mid-sized cities, environs of large and mid-sized cities	15 x 3 – 20MVA x 3
Small cities, sub-prefectural areas	10 x 3 – 15MVA x 3

Table 2.1 - 3 Voltage and supply system

Voltage	Frequency	Supply system
6.6 kV	60 Hz	Three-phase, three-wire non-grounded system

Table 2.1 - 4 Voltage drop limits of high voltage distribution line

Voltage	Cities	Sub-prefectural areas
6.6 kV	300 V	600 V

(3) Feeder systems and capacities

There are three categories of outgoing feeders from substations: large-, medium- and small-capacity feeders. Which of these should be used is determined on the basis of the amount of demand in an area to which power is to be supplied, the bank capacity of the substation concerned and other factors.

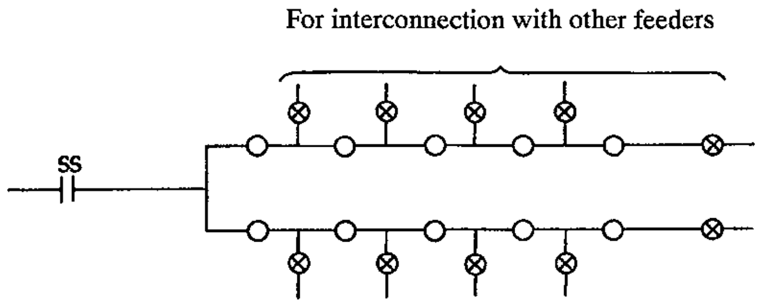
Load limits under normal distribution conditions and under power-interchange conditions are prescribed for the above feeder categories as shown in the table below:

Table 2.1 - 5 Load limits of feeders

Feeder category	Large-capacity feeders	Medium-capacity feeders	Small-capacity feeders
Load limit per circuit	600 A (6,800 kW)	500 A (5,700 kW)	300 A (3,400 kW)

Standard sistem configuration images for large-, medium-, and small-capacity feeder systems are as follows.

(1) Large-capacity feeder

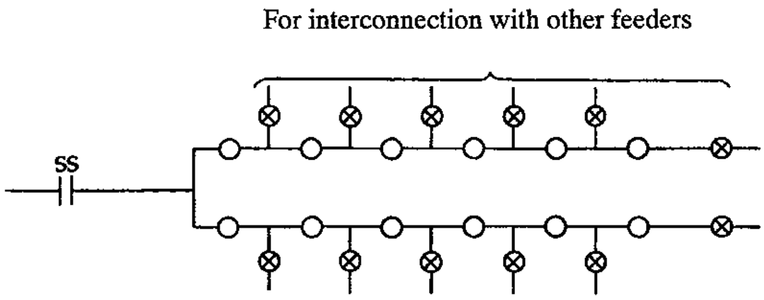


Legend

○ Remote-controlled section Switches (normally ON) for main-line subdivisions

⊗ Remote-control switches (normally OFF) for linkups with other feeders

(2) Medium-capacity feeder



(3) Small-capacity feeder

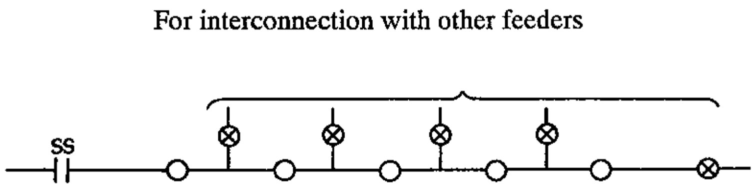


Figure 2.1 –1 Standard path configuration images

2.1.3 Planning of High voltage Distribution Lines

(1) High Voltage Distribution Line System Configurations

A distribution line System configuration is, in short, a network spread over an area, with feeders from substations connected to several points on this network.

This power distribution network is basically made up of overhead distribution lines. Its major lines are called main lines while their offshoots are called branch lines.

Feeders are lines that connect substations and distribution networks. Underground feeders are largely used in cities while overhead feeders are the rule in sub-prefectural areas.

Each main feeder is divided into sections by the required number of automatic switches equipped with remote supervisory and tele-controlled equipment (called remote-controlled switches). Each remote-controlled section links with another feeder so that that section can receive power in the event of a service interruption.

Table 2.1 – 6 High voltage distribution line system configurations

System configurations	*Contents*
Tree branch system	The system which forms the independent feeders, without being interconnected with other feeders. A branch line extends in the shape of a tree if needed from a trunk.
Loop system	The system connects a feeder in the shape of a loop. It is classified into the single loop and the multiplex loop according to the number of interconnected feeders.
Network system	The system connects a feeder in the shape of meshes of a net or in the shape of a lattice.

Conductor and cables of the types shown in the following table are to be used for feeders outgoing of substations.

Table 2.1 - 7 Types of conductor and cables to be used for outgoing feeders of substations.

	Large-capacity systems	Medium-capacity systems	Small-capacity systems
Underground cables	Cu-CVT 600mm2	Cu-CVT 400mm2	Cu-CVT 250mm2
Overhead conductors	Cu-OCW 200mm2	Cu-OCW 150mm2	Cu-OCW 80mm2 ACSR-OC 120mm2

(Note)

Cu ; Copper conductor

ACSR; Aluminum Conductor Steel Reinforced

CVT ; Triplex Cross-linked Polyethylene Cable with Vinyl sheath

OCW ; Water-sealed type Outdoor Cross-linked Polyethylene Cable

OC ; Outdoor Cross-linked Polyethylene Cable

(2) Choice between Employing Overhead and Underground Lines

As a general rule, overhead distribution lines are standard, and the number of high voltage circuits installed side by side should not exceed two. One single high voltage circuit is the common installation of high voltage distribution lines.

(3) Planning High Voltage Distribution Line Reinforcement

(a) When to reinforce high voltage distribution lines

High voltage distribution lines need reinforcing in the following situations. The time to carry out reinforcement is determined after making a comprehensive study of the following:

- ✓ Existing facilities are no longer capable of fully supplying demand; i.e., the normal service condition load limit of one circuit is exceeded on account of increased loads, or the load current limit or voltage drop limit of a line is exceeded.
- ✓ Adequate reliability in power supply can no longer be obtained with existing facilities.
- ✓ Installing lines will probably become difficult or impractical in the future due to external conditions such as the paving of roads and obstacles such as objects buried underground.
- ✓ Supplying power using existing facilities is no longer cost-efficient.

(b) How to implement a reinforcement plan

Each high voltage distribution line should be studied individually while considering the conditions mentioned above (which led to determining the timing for reinforcing those lines), and should be reinforced in such a manner that they conform to system configuration and distribution facility requirements prescribed in the applicable standards.

Furthermore, when devising a plan, it is necessary to seek the highest possible investment returns by taking into consideration probable future line configurations, possible demand growth, predicted voltage drops, and other factors.

Basic points to be followed are summarized in the table below.

Table 2.1 - 8 Basic ideas on how to increase the power supplying capacity of high voltage systems

Expansion method	Description
Installing a new distribution substation	The system which puts a new substation into the supply area of an established substation.
Dividing a circuit	The system which introduces a feeder at the time of the shortage of feeder capacity, and divides load.
Step-up of supply voltage	The system for stepping up voltage of a feeder when the increasing rate of the load is high, or when circuit length is very long.
Re-stringing conductors	The system which does not perform load division but increases current capacity of conductors.
Installing automatic voltage regulating equipment	The system which compensates voltage drops.

(c) Installing line voltage regulators

If a high voltage distribution line's voltage drops below the set limit and the option of installing voltage regulators proves more economical than the re-stringing conductors, line automatic voltage regulators (SVRs) are installed for purposes of voltage compensation.

- ✓ As a general rule, SVRs are installed on feeders that supply power to sub-prefectural areas.

Installing up to three units in series on each feeder is a standard practice.

✓ SVRs with capacity ratings of 1,500 kVA, 2,500 kVA, and 3,500 kVA are installed on poles.

2.1.4 Planning of Low Voltage Distribution Lines

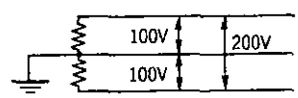
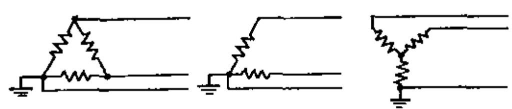
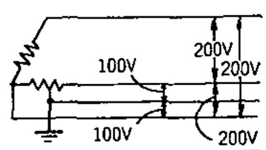
When devising a plan for low voltage line reinforcement, it is important to design facilities with appropriate reserve capacities by studying the following items along with the demand characteristics and environmental conditions of the region concerned. The items are: ways and means for effectively using existing facilities, provisions for interconnection with neighboring facilities and coordination of facilities with pole-mounted transformers and low voltage distribution lines.

(1) Planning Low Voltage Supply Systems

(a) Voltage and supply system

Low voltage distribution lines' voltage ratings and supply systems are shown in the table below:

Table 2.1 - 9 *Voltage ratings and supply systems*

Service category	Voltage and system	Connection chart
Lighting	100/200 V single-phase, three-wire system	
Power service	200V, V-connected three-phase, three-wire system	
Common use	100/200 V V-connected three-phase, four-wire system	

(b) Service reliability

In accordance with the applicable law, voltage fluctuations measured across customer's service entrance terminals should be maintained within the ranges shown in the following table.

Table 2.1 - 10 Low voltage line voltage-fluctuation range (ave. 30minutes)

Customer load category	Terminal voltage range to be maintained
Lighting	Max. 107V, Min. 95 V (101V +/- 6 V)
Power service	Max. 222V, Min. 182 V (202V +/- 20V)

Table2.1 - 11 Low voltage line voltage drop limits

Service category		Limit
Voltage drop	Lighting (100V circuits)	6V
	Power service (200V circuits)	20V

(c) System configuration

Low voltage distribution lines are arranged in radial or tree patterns. No interconnecting facilities are provided for pole-mounted transformers or for low voltage distribution lines.

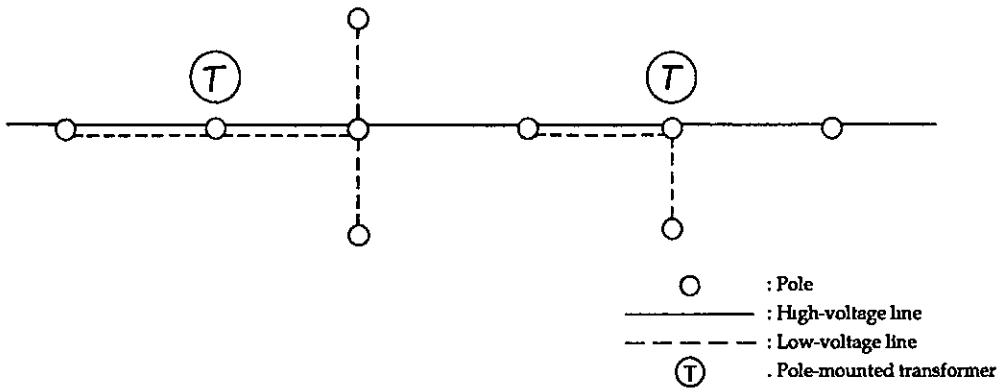


Figure 2.1 - 2 Example of a low voltage distribution system

(d) Makeup of facilities

The types and capacities (sizes) of pole-mounted transformers and low voltage lines are shown in the following table. To protect pole-mounted transformers, cutouts equipped with fuses that limit currents are installed on their primary side.

These cutouts are used to prevent transformer windings from melting down in the event of short-circuits in low voltage lines hooked up to these windings.

Table 2.1 - 12 Types and capacities of pole-mounted transformers and low voltage lines

Type		Conductor size and Tr. capacities
Low voltage lines	Cu-OW	5.0 mm, 38 sqmm
	ACSR-OW	32 sqmm
	Cu-CV	14 sqmm, 38 sqmm
Pole-mounted transformer	Oil-filled transformers	5, 10, 20, 30, 50, 100 kVA

(e) Service wires

Voltages of service wire and supply system are shown in the table below. If there are both lighting and power load circuits, a set of service wires is installed for each circuit.

Table 2.1 - 13 Voltage and system

Service category	Voltages and systems
Light service	100V; Single-phase two-wire system 100/200V; Single-phase three-wire system
Power service	200V; Single-phase two-wire system 200V; Three-phase three-wire system

Table 2.1 - 14 Types of service wires

Type	Number of core conductors	Sizes
DV wires	2, 3	2.6mm, 3.2mm, 14mm2, 38sqmm, 60sqmm
CV cables	2, 3	5.5sqmm, 8sqmm, 14sqmm, 38sqmm, 60sqmm

Note:

CV cables are used in some city districts where maintaining sufficient distances between cables and other objects is difficult and conserving the landscapes of the cities is imperative.

DV ; Vinyl insulated conductor for service wire

2.1.5 Planning of 22 kV Distribution Line

(1) Objective

We have been moving towards distribution at a stepped-up voltage of 22 kV, which is rated as a next-generation distribution voltage, in order to cope with the difficulty of findings sites for new distribution substations and new distribution routes in city areas with high load densities, as well as for the purpose of improving the voltage regulations of long distance distribution lines cutting through sub-prefectural regions.

(2) Present Status of Introduction

The 22 kV rated voltage was employed as a system voltage of five (5) long feeders to improve their supply voltage during 1973 to 1987 in the rural areas.

As a distribution line to supply big spot customer, 22 kV system voltage was employed to supply power to a railroad company in 1986 and to a big shopping centers in 1998.

And in 1996, 22 kV system voltage was employed to supply power to railroad company building, which are located in the load center, and city halls by double circuit supply system as a emergency system.

(3) Introductory Plan

When devising a 22 kV distribution lines, it is therefore important to thoroughly study the following items, after accurately determining current and future demand trends. The items are: the necessity of introducing 22 kV distributions, the timing of the introduction line, the scale of the facility to be installed, and related factors.

2.1.6 Planning Urban Underground Distribution Cable Lines

(1) Basic Guidelines for Introductory Plan

Laying distribution line cables underground improves cityscapes, facilitates fire-fighting activities, and helps increase power supply capability (because a large number of cables can be installed). On the other hand, this strategy has some practical disadvantages in terms of construction expense and problems attendant upon construction and maintenance.

- Construction costs run high (20 times the cost of installing comparable overhead distribution lines). This can push up electricity bills.
- In cities still in the "scrap and build" stage, the numbers of applications for electric power inevitably runs high. This means many holes must be dug in roads to install cable and also that applicants must wait longer periods of time until power is made available to them.
- Recovering time from electrical fault is longer compared to overhead distribution system.

Because of the disadvantages mentioned above, electric company has been making efforts since 1986 at systematically laying underground cables in the central areas of prefectural capitals, where conditions are favorable and the need to bury cables underground can be reasonably justified also from the viewpoint of maintaining a reliable power supply. When burying cables underground, we consulted with the authorities responsible for managing the roads and with various other corporations also interested in running their cables underground.

(2) Completed Underground Cable Installments

Table 2.1 - 15 Completed underground cable installation in Japan

Name of project	Term	Length of line (km)
first term project	1986-1990	1,000
second term project	1991-1994	1,000
third term project	*1995-1998*	1,400
new project	1999-2003	3,000
total		6,400

Furthermore, the Distribution-Facilities Standards (City Area Underground Distribution Facility Edition) was prepared by in 1986 to define basic guidelines and procedure for reinforcing or installing underground distribution cable lines in city districts and thereby providing a means for designing streamlined facilities.

Therefore, it is important to make the necessary studies while referring to the standards when mapping out an actual underground facility installation plan.

In the new project began from 1999, criteria for installing underground cable expanded from high demand density to low demand density.

We are going to take a look at some excerpts from the standards.

(Quoted from Construction Standard)

(City Area Underground Distribution Facilities Edition)

1. Places eligible for underground distribution cable lines

As a general rule, high-and-low voltage underground distribution cable lines can be employed in places that satisfy all of the following conditions:

(1) Places where demand is densely concentrated and stable

As one measure of assessing the eligibility of a place, the demand density should be higher than approximately 120,000 kW/km2 when calculated using the equation below:

$$\text{Load density} = \frac{\text{(Contract power)}}{\text{(Total area excluding roads and parks)}}$$

Most places satisfying this condition are city districts where three-to-five-story buildings stand side by side in rows.

(2) Places where equipment such as switches and transformers can be installed on the ground

Sidewalks must be at least 4.5m wide if cable boxes are to be installed in conjunction with underground cables.

If our cables are to be buried alone, sidewalks should be at least 3.5m wide.

(3) Main streets in the central areas of cities where particular emphasis is placed on the preservation of their cityscapes

2. Discussion with related authorities and companies

When applying underground distribution lines, discussion about installing area, underground method, date of installation, and etc. should be conducted thoroughly with related authorities and companies.

3. Basic policy for creating distribution facility

When installing underground distribution system, following items should be considered.

(1) Cost-effective underground distribution facilities should be designed and installed using long-range distribution plans which consider their possible future (ultimate) configurations. Size of cab system, number of ducts, and etc. should have 20 years' allowance.

(2) In accordance with new project of underground plan, ducts for 22kV distribution lines should be installed as follows.

- In central city areas, number of ducts is as follows.
  Main road : 4 ducts, other road : 2 ducts
- In other areas, reserved ducts are not allowed.

(reference) Future plan for 22kV distribution network in high load density areas

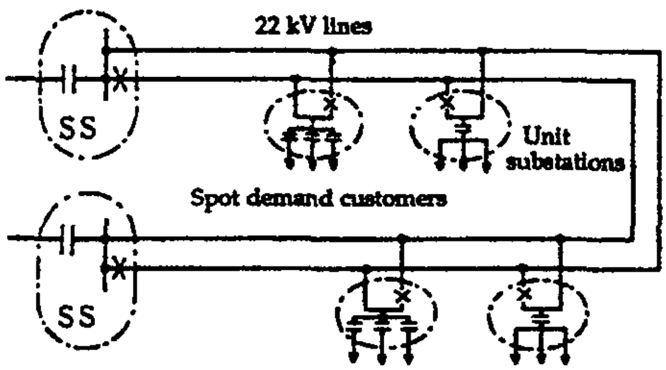


Figure 2.1 - 3 Example double circuit supply system

4. Distribution line capacities

For underground distribution lines, small-capacity and large-capacity system are applied. The load limits in the following table are standard for feeders.

Table 2.1 - 16 Distribution line capacities

	Load limit under normal service conditions (kW)	Load limit under power interchange (kW)
Small-capacity systems	3,000	4,000
Large-capacity systems	6,000	7,400

5. System configurations of high voltage distribution lines

Line configurations of high voltage distribution system are as follows.

(1) System configurations of small-capacity system

a. In the case of a small-capacity system, a three-branching three-linkup system should be employed. In this system, one feeder trifurcates into three branch lines and means, for linking up with other feeders are provided at their tails. The capacity of each branch line is rated at 1,000 kW under normal service conditions and at 2,000 kW at power-interchange time in the event of a failure.

If power must be supplied to a customer using a load greater than 1,000 kW, the size of the branch line to this customer should be increased accordingly. In addition, a configuration such as a *two-branching, two-link-up system, which enables a power interchange in the event of a customer* using a load greater than 1,000 kW should be devised.

b. When linking to overhead distribution lines, proper reserved power to spare should be maintained in case of fault.

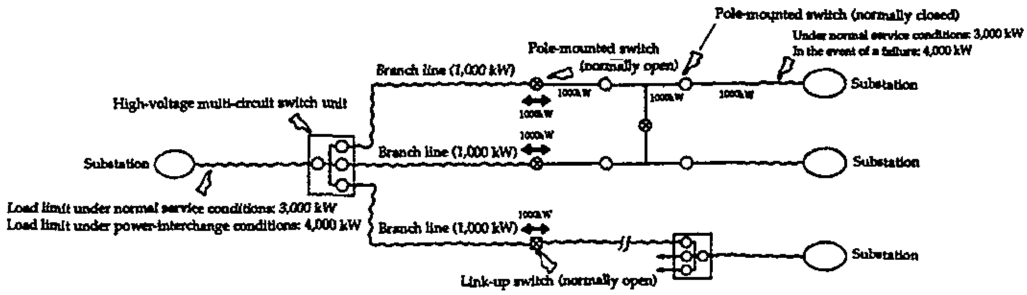


Figure 2.1 - 4 Small capacity system configuration

c. Each high voltage customer and transformer should be π-connected so that, if a section of the high voltage underground line connected to it develops a fault, that section can be cut off by manipulating the connected high voltage multi-circuit switch, and the high voltage branching unit. Power can then be supplied to all other customers without interruption, except for those hooked up to the troubled section.

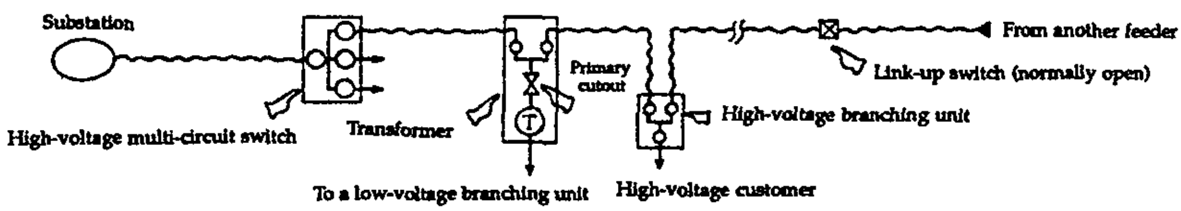


Figure 2.1 – 5 p- connected high voltage customer and transformer

(2) Line configurations of large-capacity system

In large-capacity systems, a set of large-capacity cables from a substation is bifurcated into two small-capacity cable sets in a manhole. The same line configuration as that of the small-capacity cable sets.

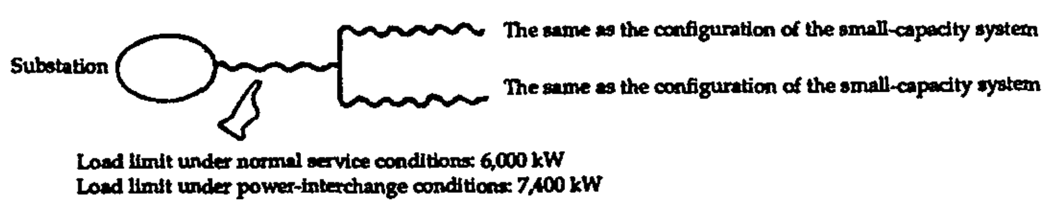


Figure 2.1 - 6 Large-capacity system configuration

(3) Configurations of lead-in power line to high voltage customer

When leading-in power line to high voltage customer, premises cable is connected with high voltage branching unit.

6. High voltage multi-circuit switch unit

Specification of high voltage multi-circuit switch unit is as followed table including function for remote supervisory and tele-control.

Table 2.1 - 17 Specification of high voltage multi-circuit switch unit

Type	Nos. of circuit	No. of circuit	Usage	Amp
air break switch or enclosed gas type switch	5	1	For main line	600A
		2-5	For branch line	400A

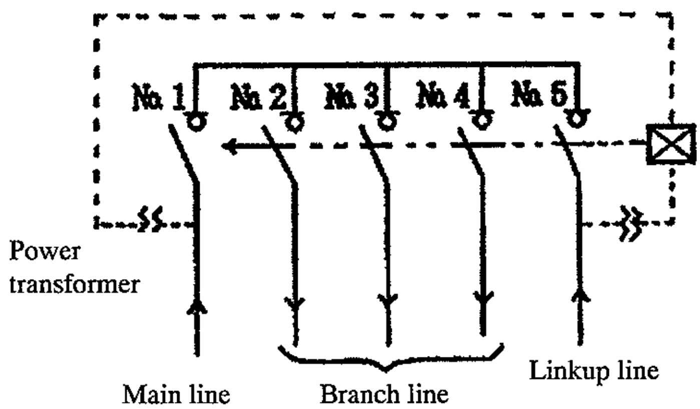


Figure 2.1 - 7 Circuit configuration of high voltage multi-circuit switch unit

7. High voltage branch unit

Specification of high voltage branch unit is as followed table.

Table 2.1 - 18 Specification of high voltage branch unit

Type	Nos. of circuit	Circuit number	Usage	Amp	Function
Air break switch or enclosed gas type switch	3	1,2	For pai-connection	400A	---
		3	For lead-in to HV customer	400A	Directional SOG

SOG : Storage Over current Ground

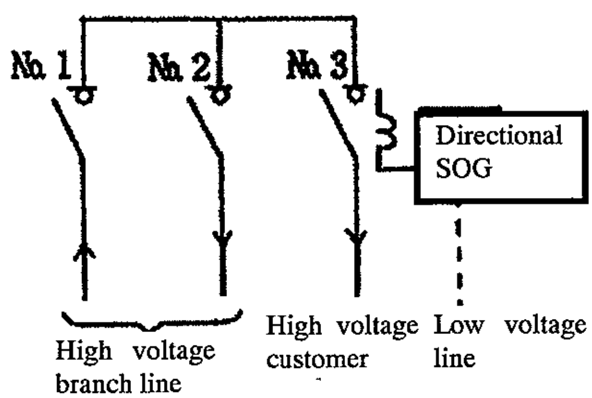


Figure 2.1 - 8 Circuit configuration of high voltage branch unit

(Unquote)

2.1.7 Overview of Components and Equipment for Distribution Facilities

This subsection introduces major components and equipment that are used to construct 6.6 kV distribution lines.

(1) Overhead Distribution Lines

(a) Supports

Reinforced concrete poles are used except in some cases where supports are installed on a provisional basis only where it is impossible to transport or set up reinforced concrete poles in city districts. The type of supports being used and their uses are summarized in the table below. The external views of major supports are shown in Figure 2.1 - 9.

Table 2.1 - 19 Various types of supports

Type	Specifications			Use
	length (m)	Design load (kg)	Construction & other feature	
Wooden poles	8	-------	- Cedar poles impregnated with creosote oil	- For use on a provisional basis - For use in places where short poles are needed and reinforced concrete poles cannot be installed.
	10			
	12			
Reinforced concrete poles	8	350	- A reinforced concrete pole is made by pouring Portland cement into a mold in which there is a steel wire mesh under tension. Then the mold is rotated to apply centrifugal force on the concrete.	- In general use
	10	200, 500		
	12	500		
	14	500, 700		
	16	500, 700, 1,000		
	17	1,000		
Composite concrete poles	12	500	- Two to three steel pole sections are placed on top of a reinforced concrete pole (3.75m long)	- For use in narrow places like alleyways where it is impossible to bring in reinforced concrete poles. - For use in places where wooden poles are likely to last only relatively short period of times.
	14			
	16	500,700		
Steel poles	7	100	- Each pole consists of three steel tubes.	- For use in tight places like alleyways where reinforced concrete poles cannot be brought in
	12	500		
	14	500		
	16	700		
Lightweight steel poles	10	400	- Each pole consists of five to eleven steel tubes	- For use in mountainous secluded areas where it is impossible to transport wooden poles and reinforced concrete poles
	12			
	14	600		
	16			

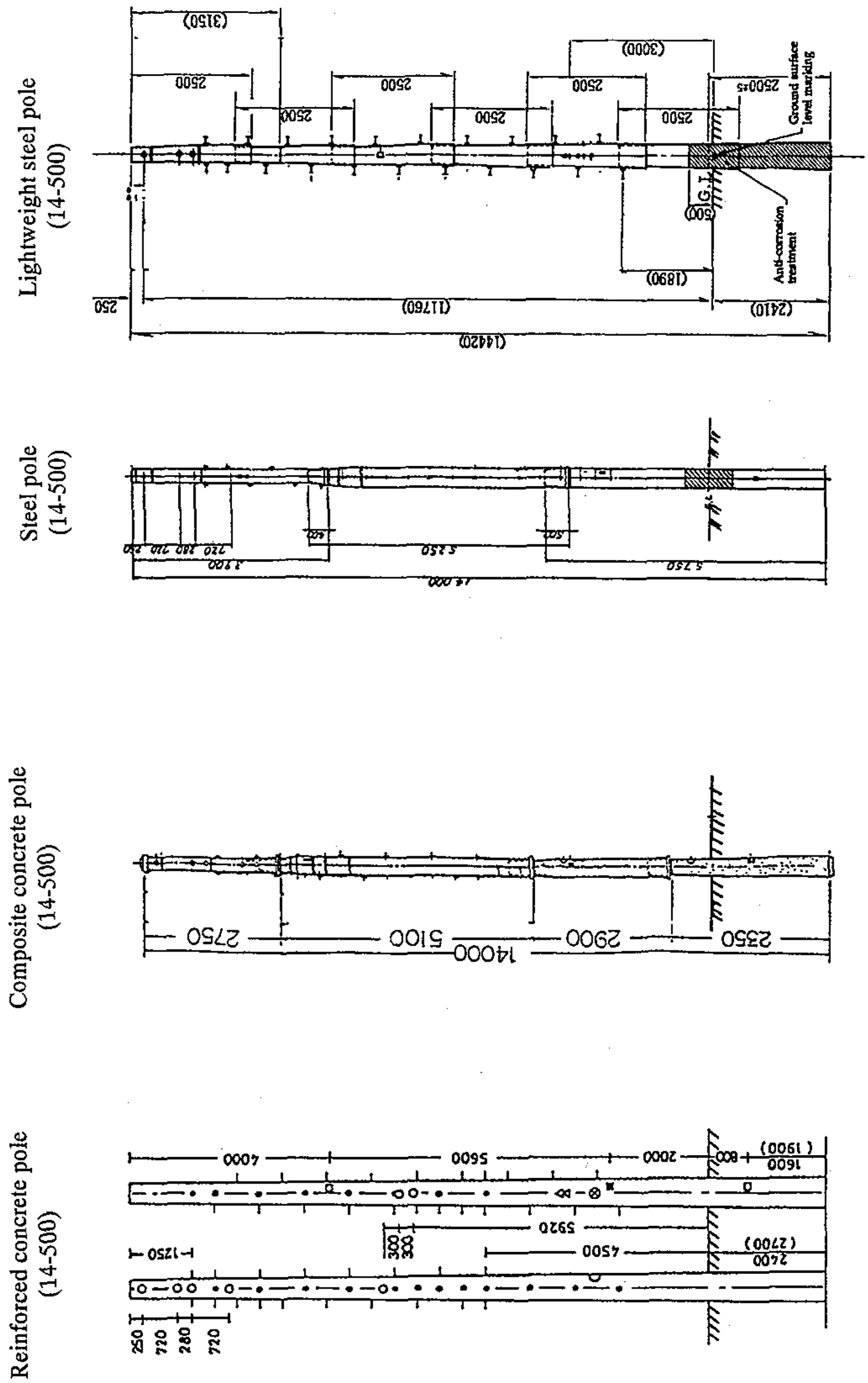


Figure 2.1 - 9 External views of various types of supports

(b) Conductors

As a general rule, outdoor aluminum steel reinforced cross-linked polyethylene insulated conductors (ACSR-OC) are being used as high voltage conductors, while outdoor conductors insulated with polyvinyl chloride (Cu-OW) are being used for low voltage distribution lines.

However, other types of conductors are used in the following cases:

- ✓ If overhead wires must be installed in an area which has briny air or corrosive gases.
- ✓ If overhead wires with larger capacities must be installed.

The types of wires and their uses are summarized in the following tables.

Table 2.1 - 20 Various types of conductors

Type			Size	Construction & other features	Use
Copper	High-voltage	Watertight outdoor cross-linked-polyethylene-Insulated (Cu-OCW)	38, 80, 150, 200 sqmm	-Hard-drawn copper conductors insulated with black cross-linked polyethylene -Spaces between element wires are filled with an admixture to prevent rain water, etc. from seeping in.	-For use in areas with briny air or corrosive gases -Conductors with a cross-sectional area of 150, 200 sqmm are used as large-to-medium-capacity feeders.
		Pressure-tight and watertight outdoor cross-linked-polyethylene-insulated (RW-OC-W)	150, 200 sqmm	-Hard-drawn copper conductors insulated with ditches at surface of wire in order to resist against wind pressure	-For use as large-to-medium-capacity feeders
		Abrasion-tight and watertight outdoor cross-linked-polyethylene-insulated (OC-W-A)	38,80 sqmm	-Watertight outdoor cross-linked polyethylene-insulated covered with abrasion-tight layer	-For use in areas with briny air or corrosive gases and areas which needs to trim bamboo plants in order to prevent electrical faults
	Low-Voltage	Outdoor polyvinyl chloride insulated (Cu-OW)	5 mm 38 sqmm	-Hard-drawn copper wires insulated with polyvinyl chloride resin	-In general use
		600V-rating cross-linked polyethylene-insulated cables (CV)	2-core cables 8 sqmm 3-core cables 8, 14, 38, 60, 100, 150 ,250 sqmm	-Annealed copper wires insulated with cross-linked polyethylene and sheathed with polyvinyl chloride resin	-For use in the central city districts and along major roads
		Polyvinyl chloride service drop wires (DVR)	2-core cables 2.6 mm 3-core cables 2.6, 3.2, mm 14, 38, 60 sqmm	-Hard-drawn copper wires (14sqmm or smaller) or strands of two to three annealed copper wires (22 sqmm or greater) insulated with polyvinyl chloride	- For use as service drop wires led into customers' indoor wiring
Aluminum	High voltage	Outdoor aluminum-conductive steel-reinforced	32, 120 sqmm	-Aluminum-conductive steel-reinforced wires insulated with black cross-linked polyethylene	- In general use

		cross-linked-polyethylene-insulated (ACSR-OC)			
		The same as above (snow-repellent type) (SN-ACSR-OC-)	32 sqmm	- Cable sheathes feature dual flanges at regular intervals for preventing snow from building up	- For use in heavy snowfall areas
		Abrasion-tight outdoor aluminum-conductive steel-reinforced cross-linked-polyethylene-insulated (ACSR-OC)	120 sqmm	- Outdoor aluminum- conductive steel- reinforced cross-linked-polyethylene- insulated wires covered with abrasion-tight layer	- For use in areas with briny air or corrosive gases and areas which needs to trim bamboo plants in order to prevent electrical faults
		The same as above (snow-repellent type) (SN-ACSR-OC-A)	32 sqmm	-Abrasion-tight layers feature dual flanges at regular intervals for preventing snow from building up	-For use in above areas and also heavy snowfall areas
	Low-Voltage	Outdoor aluminum steel-reinforced insulated with polyvinyl chloride (snow-repellent type) (SN-ACSR-OW)	32 sqmm	- Aluminum steel-reinforced wires insulated with polyvinyl chloride resin - Cable sheathes feature dual flanges at regular intervals for preventing snow from building up	- For use in heavy snowfall areas

(c) Pole-mounted Transformers

Pole-mounted transformers come in six different standard rated capacities: 5 kVA, 10 kVA, 20 kVA, 30 kVA, 50 kVA and 100 kVA. Of these transformers use highly orientated silicon steel cores featuring small iron loss to minimize power losses.

And also, amorphous transformers featuring low iron loss are used temporarily for testing since 1991.

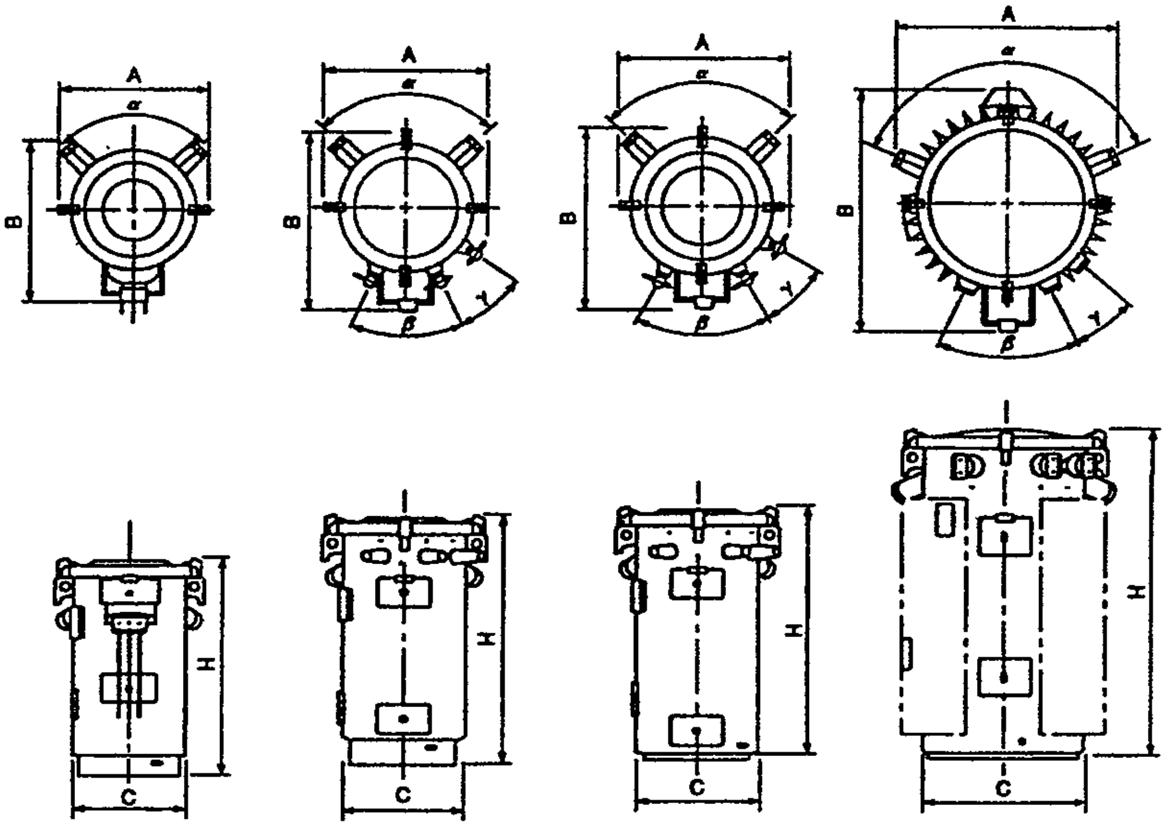
Table 2.1 - 21 Pole-mounted transformer types

Type	Capacity (kVA)
Low-loss-type single phase transformers	5, 10, 20, 30, 50
Single phase transformers	100
Amorphous transformers	20

Table 2.1 - 22 Major specifications of pole-mounted transformers

<table>
<tr><th></th><th>Capacity
(kVA)</th><th>Rated primary voltage
(V)</th><th>Rated secondary voltage
(V)</th><th>Primary Tap voltage
(V)</th><th>No-load loss
(W)</th><th>Load loss
(W)</th><th>Approx. weight
(kg)</th><th>Cooling type</th></tr>
<tr><td rowspan="6">Low-loss-type single phase transformers
Single phase transformers</td><td>5</td><td rowspan="6">6,600</td><td rowspan="6">210 and 105</td><td rowspan="6">6,750
6,600
6,450
6,300</td><td>21 or smaller</td><td>118 or smaller</td><td>60</td><td rowspan="6">Oil-immersed naturally cooled type</td></tr>
<tr><td>10</td><td>35 or smaller</td><td>180 or smaller</td><td>95</td></tr>
<tr><td>20</td><td>53 or smaller</td><td>306 or smaller</td><td>140</td></tr>
<tr><td>30</td><td>77 or smaller</td><td>428 or smaller</td><td>170</td></tr>
<tr><td>50</td><td>112 or smaller</td><td>629 or smaller</td><td>260</td></tr>
<tr><td>100</td><td>210 or smaller</td><td>1200 or smaller</td><td>440</td></tr>
<tr><td>Amorphous transformers</td><td>20</td><td>6,600</td><td>210 and 105</td><td>6,750
6,600
6,450
6,300</td><td>21 or smaller</td><td>310 or smaller</td><td>175</td><td>Oil-immersed naturally cooled type</td></tr>
</table>

Capacity	Dimensions (mm)				Fixing angle for bushing (°)			Amount	Total wei
(kVA)	H	A	B	C	a	ß	γ	of oil (l)	-ght (kg)
5	590	460	405	270	120	---	---	13	60
10	690	445	505	325	90	---	---	25	95
20	790	495	565	365	90	48	31	38	140
30	810	525	585	385	90	58	29	47	170
50	1,030	585	630	425	90	58	29	84	260
100	1,040	685	785	490	130	48	24	105	440



No.1 No.2 No.3 No.4

Figure 2.1 - 10 External views of pole-mounted transformers

(d) High voltage switches

High voltage switches being used for the opening /closing of high voltage distribution lines are shown in the following table.

Table 2.1 - 23 Various types of high voltage switches

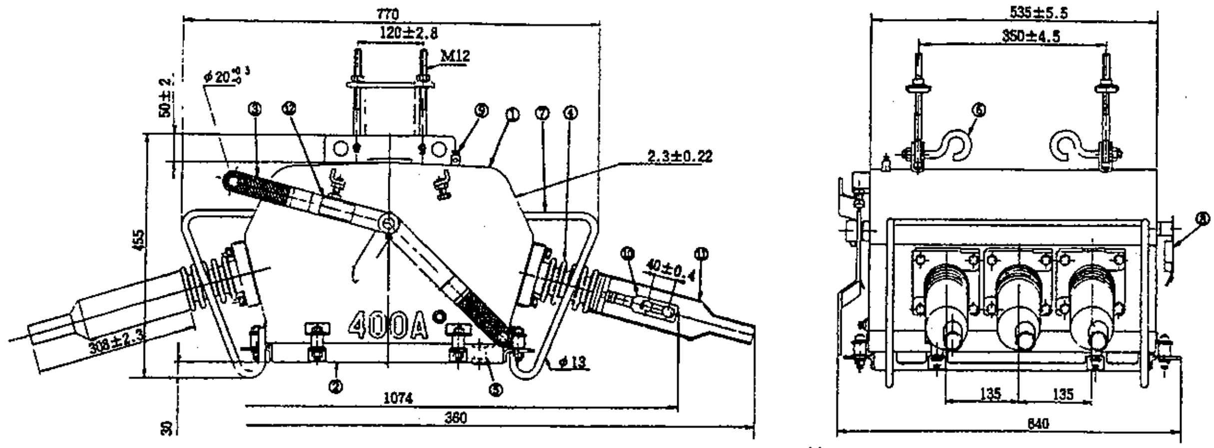
Type	Rated capacity	Structure and features
Closed high-pressure air break switches (manual switches)	200 A 400 A	-These are manual switches designed to open and close distribution paths. The switching electrode section of each switch is housed in a steel box.
High-pressure automatic air break switches	400 A	-These are remote-controlled switches designed to open and close distribution paths. The switching electrode section of each switch is housed in a steel box. -The control circuit of each switch, which is responsible for activating the switch, is installed at a distance from the housing of the switch so that the switch can be activated even if the control circuit is at fault due to lightning-induced surges or secular deterioration.
Manual air break switch	300 A	-These are switches operated manually installed at outgoing of medium capacity feeder
Device for detecting sections with momentary ground faults	300 A	-They are equipped with ZPDs, ZCTs, and CTs. In the event of a momentary ground fault, it indicates whether the ground fault has occurred on the load side.
High voltage air circuit breaker	200 A	-These are intended for installation in areas where substaion OC relays cannot detect a short-circuit occurrence. If a short-circuit occurs on the load side, a switch's incorporated CT detects it and causes the switch to open the distribution path.
Compact-type circuit breaker	400 A	-This equipment is capable of breaking a single fault-ridden circuit only in the event of a fault on large-to-medium-capacity distribution lines -The are consist of main body equipped with ZPDs, ZCTs, and CTs and control box equipped with DGR, OCR, and remote terminal unit.

The major electrical specifications for manual and automatic switches are listed in Table 2.1 - 24 and their external views are shown in Figure 2.1-11.

Table 2.1 - 24 Major electrical specifications

	Rated voltage	Rated current	Rated frequency	Rated short-time current (Effective value)	Rated making current (Crest value)
Manual switches	7,200 kV	200 A 400 A	60 Hz 60 Hz	8.0 kA 12.5 kA	20.0 kA 31.5 kA
Automatic switches	7,200 kV	400 A	60 HZ	12.5 kA	31.5 kA

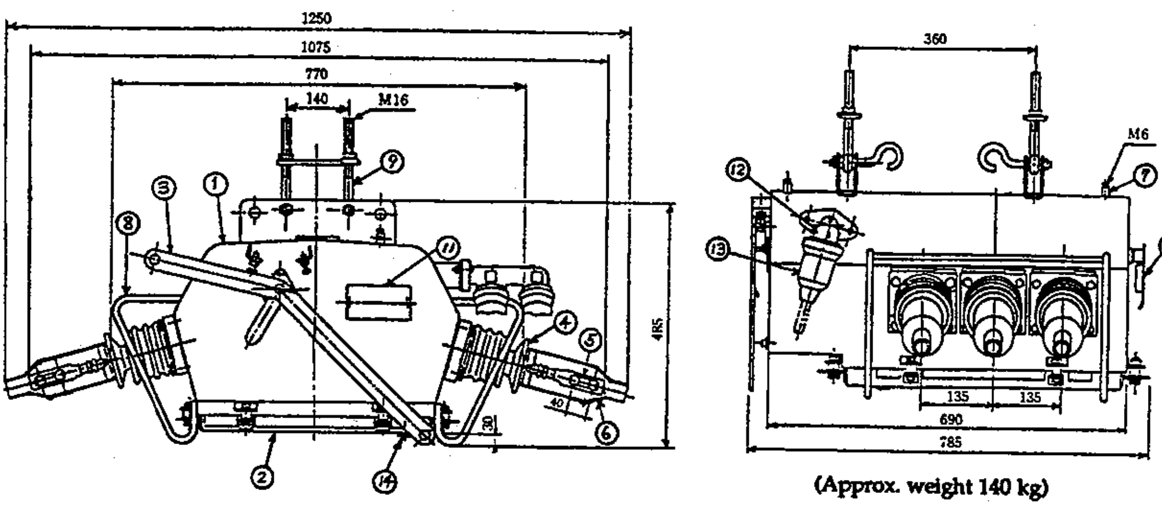
(i) Manual switches (400A)



(Approx. weight 120 kg)

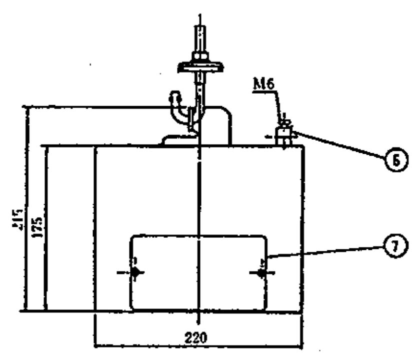
(ii) Automatic switches (400A)

<Main unit>



(Approx. weight 140 kg)

<Control circuit box>



(Approx. weight 6 kg)

Figure 2.1 - 11 External views of high voltage switches

(e) Lightning arrester

The major specifications for the lightning surge suppressor in current use are listed in Table 2.1-25 and its external view is illustrated in Figure 2.1-12.

Table 2.1 - 25 Major specifications for the lightning surge suppressor

Electrical characteristics	Zinc oxide element (with a gap)	Power frequency withstanding voltage	22
Rated voltage (V)	8,400	Lightning surge withstanding voltage (kV)	60
Rated frequency (Hz)	60	Lightning surge spark-over voltage (kV)	33 or lower
Nominal discharge current (A)	2,500	Discharge voltage	2500 A at 22 kV
Insulation resistance	2,000 MΩ or greater		

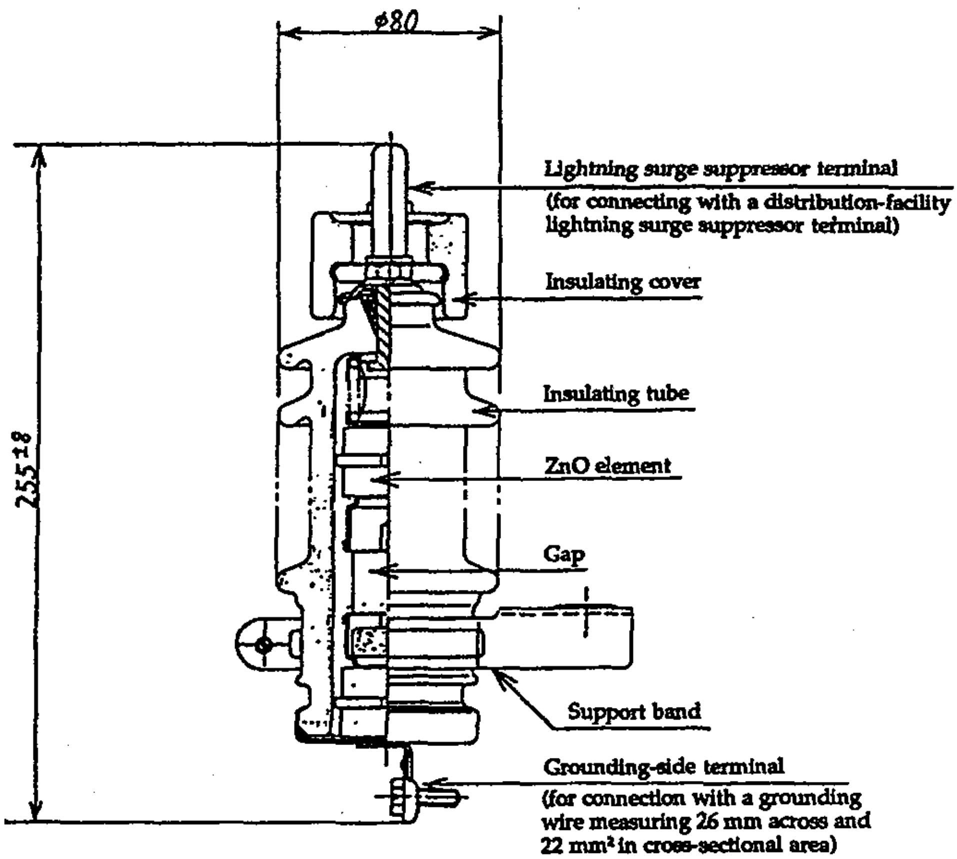


Figure 2.1- -12 External view of lightning surge arrester

(f) Utility-Metering Instruments

Utility-metering instruments are designed to keep track of each customer's power usage for billing purposes. These include watt-hour meters, reactive power meters, maximum demand watt meters, combination instruments, instrument transformers, timer switches, and current limiters.

(i) Types of watt-hour meters

Table 2.1 – 26 Types of watt-hour meters

Meter type	Kind of meters	System	Guaranteed accuracy	Rated current
Meter for direct connection	Ordinary watt- hour meters	Single-phase two-wire system	Class II	20
				60
			Class III	30
				120
		Single-phase three-wire system	Class II	20
				60
			Class III	30
				120
		Three-phase three-wire system	Class II	20
				60
			Class III	30
				120
Transformer-equipped meters	Ordinary watt- hour meters	Single-phase two-wire system	------	5
		Single-phase three-wire system		
		Three-phase three-wire system		
	Precision watt- hour meters	Three-phase three-wire system	------	5
	Extra-precision watt-hour meters	Three-phase three-wire system		

- Meters for direct connection : Meters used alone without any instrument transformer.
- Transformer-equipped meters : Meters that are used in conjunction with their incorporated instrument transformers.
- Class II meters : Ordinary meters whose accuracies are guaranteed from their rated currents down to one-twentieth of the rated currents. Their name plates bear rated current indications such as 20 A (10 A) and 60 A (30 A).
- Class III meters : Ordinary meters whose accuracies are guaranteed from their rated currents down to one-thirtieth of the rated currents. Their name plates bear rated current indications such as 30 A and 120 A.

(ii) Inspection

Measuring instruments to be used billing should be subjected to an official inspection in accordance with the Weights and Measures Act. Only measuring instruments that pass inspection should be used, and they should be withdrawn from service before their expiration dates.

- Inspection classifications

- General inspections

- Submission inspection : Individual measuring instruments are submitted to the inspection authorities together with their application forms.

- Special inspection : This type of inspection applies if the transformer portions of transformer-equipped measuring instruments have been exempted from inspection (if fewer than ten years have passed since their transformers' very first inspection). Individual transformer-equipped measuring instruments are submitted to the inspection authorities together with their application forms.

- Special inspection : Instrument transformers and transformer-equipped measuring instruments are specified in groups and subjected to inspection.

- Validity periods

Table 2.1 - 27 Validity period

Meter type	Rated current	Validity period
Meter for direct connection	30 A, 120 A	10 years
	20 A, 60 A	7 years
Transformer-equipped meters	5 A	5 years

(iii) Introducing combination measuring instruments

Combination measuring instruments are capable of measuring more than 2 items among kWh, kVarh, and maximum demand kW.

Since 1988, the following kinds of electric combination measuring instruments have been used.

- Combination demand measuring instruments
- Season-by-season, combination power measuring instruments (designed for use with 3-time-frame receiving equipment)
- Three-frame-by-time-frame adjusted-rate combination meters (designed for use with 10-time-frame receiving equipment)
- Time-by-time, combination power measuring instruments (designed for use for domestic customer)

(2) Underground Distribution Lines

(a) Duct line materials

Table 2.1 - 28 Duct line materials

Duct line material type	Abbreviated name	Uses	Duct diameter		
Galvanized steel ducts	SGP	For use as risers and like in places where the use of steel ducts is mandatory	As a general rule, ducts with inner diameters of 125 and 150 mm are standard. Ducts with the diameters shown in the following table are, however, being used as underground duct lines.		
Lightweight steel ducts	KGP				
Fiber-reinforced plastic composite ducts	PFP	In general use	Cable type		Inner duct diameter (mm)
Impact-resistant polyvinyl chloride ducts	SVP	In general use	For high-and low voltage lines		125, 150
Fiber-reinforced plastic ducts	FRP	For installation alongside public and private bridges	For high voltage service drop lines		100
Rigid polyethylene ducts (Corrugated ducts)	ND	For use in places where many other objects are buried and it is extremely difficult to bend ducts for fields. (Depending on site conditions, they need to be reinforced all around with concrete)	For low voltage service drop wires	60 mm2 or smaller	75
				100 mm2 – 150 mm2	100

Note : The above uses do not apply if instructed otherwise by road management authorities.

(b) Types of power cables

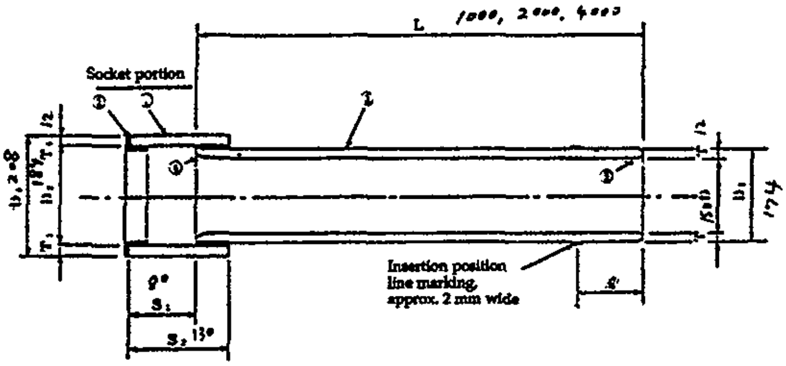
Table 2.1 - 29 Types of power cables

Power cable type		Abbreviated name	No. of cores	Materials	Shape of conductor	Sheath material	Nominal sectional area (sqmm)
High voltage cables	6,600V triplex-type polyvinyl chloride-sheathed cables insulated with cross-linked polyethylene	6.6 kV CVT	Stranded 3 single- core	Copper	Round, compact-stranded	Polyvinyl chloride	60-100-150-250-400-600
	6,600V flame-retardant triplex-type PVC-sheathed cables insulated with cross-linked polyethylene	6.6 kV F-CVT					
Low voltage cables	600V PVC-sheathed cables insulated with cross-linked polyethylene	600V CV	2 core	Copper	Round, compact-stranded	Polyvinylchloride	8
			3 core				14-38-60-100
	600V quadruplex-type insulated with cross-linked polyethylene polyvinyl-chloride-sheathed cables	600V CVQ	Stranded 4 single-core	Copper	Round, compact-stranded	Polyvinylchloride	14-38-60-150-250
	600V flame-retardant duplex-type polyvinyl-chloride-sheathed cables insulated with cross-linked polyethylene	600V F-CVD	Stranded 2 single-core	Copper	Round, compact-stranded	Polyvinylchloride	8

	600V flame-retardant quadplex-type polyvinyl-chloride-sheathed cables *insulated with cross-linked polyethylene*	600V F-CVQ	Stranded 4 single-core	Copper	Round, compact-*stranded*	Polyvinylch londe	14-38-60-1 50-250

Note : Flame-retardant cables are used only in cable boxes.

(Straight duct)



(Bent duct)

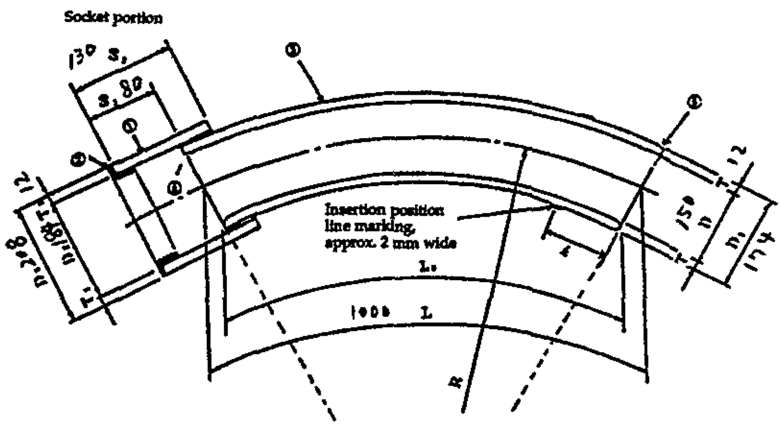
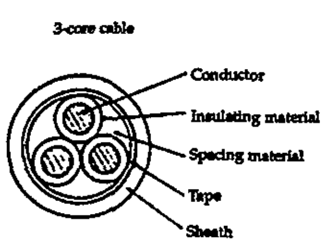


Figure 2.1 - 13 Representative duct materials (Fiber-reinforced plastic composite ducts)

600 V CV cable



6,600 V CVT cable

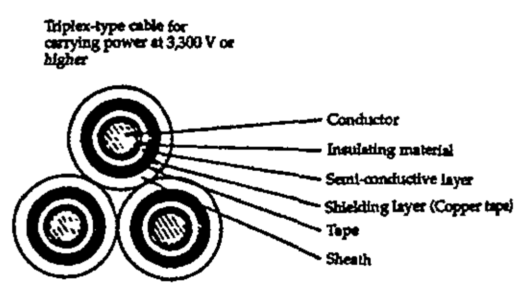
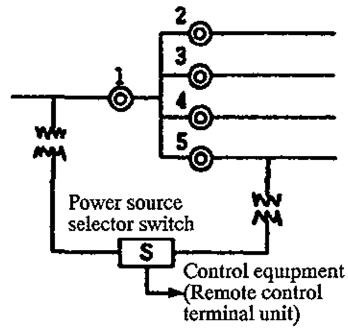
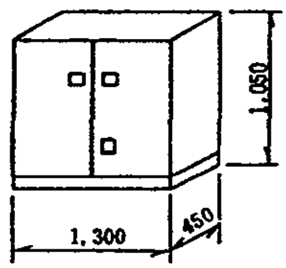
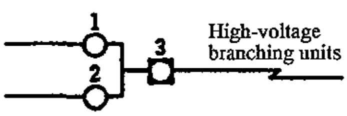
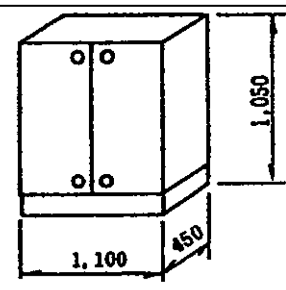
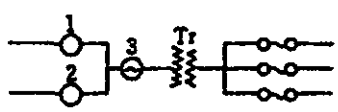
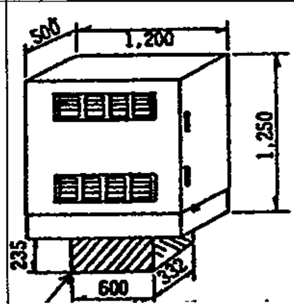
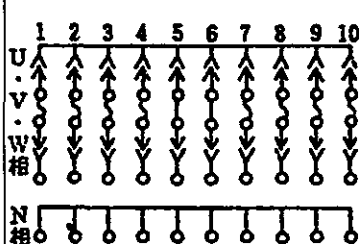
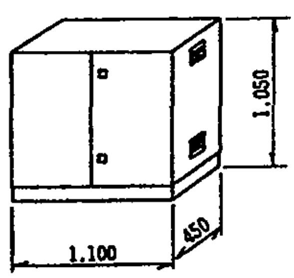


Figure 2.1 - 14 Construction of power cables

(c) Above-ground equipment for underground distribution lines

Table 2.1 - 30 Above-ground equipment for underground distribution lines

Equipment name		Circuit configuration	Capacity, function, and other features	External view
Automatic multi-circuit switches		 ● :Automatic sealed gas-filled switch (or automatic air break switch)	Rated capacity 1 . .... 600A 2-5 ..... 400A 1-5 ..... Automatic switches (Remote controlled terminal unit capable of detecting possible transformer) Tow-way power supply system Molded transformers (0 5kVA×2)	
High voltage branching units		 ○ :Manual sealed gas-filled switch (or manual air break switch) □ :Manual sealed gas-filled switch (or manual air break switch) equipped with SOG	Rated capacity 1,2 ...... 400A (For π-connected circuit) 3 ....400A (For service drop wires) Service drop switch with SOG capability (Ground relay directionally or non-directionally: incorporating a control-circuit power supply (transformer), featuring a over current-blocking capability)	
Pad-mounted transformers		 ○ : Manual air break switch ⊖ : Transformer-primary switch : Low-voltage current-limiting fuse	Rated transformer capacity (100+50) kVA Rated switch capacity 1,2 .... 400A (For π-connected circuit) 3 .... 30A (For service drop wires) Transformer-primary switch features (Single-pole actuation type incorporation high voltage current-limiting fuses)	 Transformer under part (to be inserted into handhole)
Low-voltage branching units	For connecting 8 service drop wires	 : Short bar :Low-voltage current-limiting fuse	Rated capacity ..... 400A 5,6 .... . For main lines and tie lines (outfitted with short bars) 1-4,7-10 . . . For service drop wires (outfitted with low voltage current-limiting fuses) Equipped with a 3-phase (U-, V-, and W-phase) gang switch or gang-switching capability	

2.1.8 Design of Works for Distribution Network

(1) *Design Staff Major Assignments*

(a) Determining a construction method and giving instructions

As a general rule, the design staff conducts a site survey so that they can design facilities that satisfy applicable laws, regulations, standards and specifications, and incorporate provisions for enhanced reliability, safety and ease of maintenance. Based on the results of the site survey, they decide on the best possible work method and give instructions to those responsible for implementing the planned installation.

(b) For smooth installation

The design staff prepares various reference materials, files applications, issues hot-line/ dead-line work instructions, goes through formalities, and conducts negotiations for site acquisition. At the same time, they calculate the required materials and components to avoid possible delays caused by improper amounts of materials.

(c) Calculating installation costs

The staff calculates the estimated cost for each project in order to draw up or supervise a budget. When an installation or expansion project must be mapped out, or when an existing facility must be moved to a new location, the staff calculates the estimated cost for each project to serve as a basis for determining how much the customer will pay. The amount to be paid out as compensation can also be decided here.

(2) Representative Design Tasks

(a) Designing overhead distribution lines

- ✓ Studying various reference materials and getting a clear picture of demand
- ✓ Conducting a site survey and studying/analyzing findings
- ✓ Establishing design policies (Drawing up design guidelines in keeping with design objectives, while at the same time considering basic requirements)
- ✓ Selecting areas through which distribution lines are to be installed
- ✓ Designing each individual portion of distribution-line facilities
- ✓ Supports (types, uses, installation sites, spans, lengths, foundations and strength)
- ✓ Pole assemblies
- ✓ Stay wires, stay wire poles and stay poles
- ✓ Wires (types, uses, sizes, sags, heights above the ground, separation, and layouts)
- ✓ Transformers (types, uses, capacities, scope of supply, installation positions, tolerances, and grounding-resistance values)
- ✓ Other equipment (capacitors, voltage-regulating equipment, switches, and lightning arresters)
- ✓ Measures to prevent damages from briny air, lightning, or snow.

(b) Designing underground distribution lines

(i) Conducting investigation and site surveys

An investigation is conducted to prepare reference materials for selecting a route and designing and installing the planned underground distribution line. This includes an environmental investigation of buried objects and roads, as well as a geo-technical investigation.

A site survey is conducted to determine the actual route of the underground distribution line under consideration and to find a site to install ducts to accommodate the line.

(ii) Civil engineering work methods

Methods to be adopted for excavating roads, retaining earth, backfilling and re-paving sidewalks, improving soil, doing foundation work, backfilling and reinstating the roads are determined with consideration to the site's soil, environmental conditions, groundwater level, existing buried objects, and other related factors.

(iii) Designing duct installation work

Since duct installation significantly affects construction costs, it is necessary to determine the method for laying cable (such as a direct-laying conduit, pit or cable-box method), the number of ducts, and the manhole types with careful thought given to possible future plans and cost effectiveness.

(iv) Cabling

The types and sizes of cables are determined for individual sections, such as linkup sections and a substation's outgoing underground feeder line section, with consideration to load conditions in the ultimate current-carrying configuration as well as existing cable-laying conditions. As for lead-in cables, their mechanical strengths such as permissible tension and side pressure are studied when designing a cabling plan.

2.2 Techniques of Construction

2.2.1 Works for Distribution Lines

As for the work methods to be employed, each installation job is conducted in accordance with the company's standardized work methods (Distribution Facilities Installation Work Standards). Representative work methods are introduced hereafter.

(1) Installing Overhead Distribution Lines

(a) Supports installation

As a rule, a pole-erecting vehicle is usually used to install supports. There are, however, some cases where supports are installed by hand such as:

- ✓ When installing poles in tight places where a pole-erecting vehicle cannot be used.
- ✓ When installing lightweight poles such as wooden poles.

Typical methods for erecting pole are discussed hereafter.

(i) Installing a pole using a pole-erecting vehicle

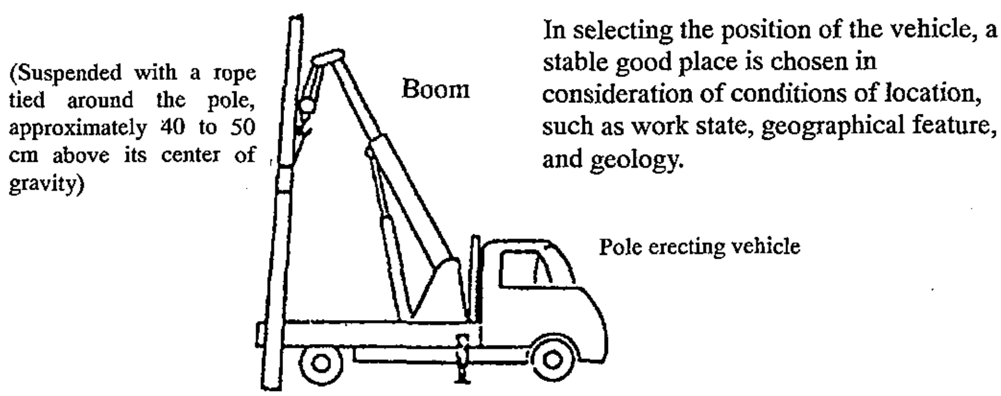


Fig. 2.2 – 1 Installing a pole using a pole-erecting vehicle

(ii) Installing a pole by hand

In sites where pole-erecting vehicles cannot gain access, people install lightweight poles such as wooden poles by hand. A sample method for erecting poles is illustrated below.

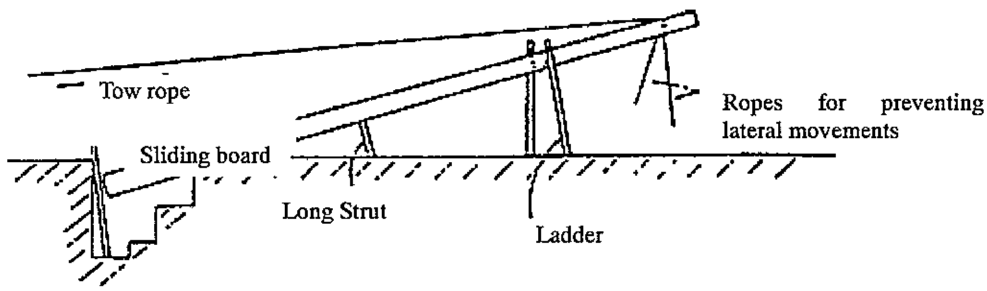


Fig. 2.2 - 2 Wooden pole erection method

(iii) Method for erecting poles in tight places

To erect a steel pole or a composite concrete pole in a tight space, the lowest section is first implanted in the ground as shown in Figure 2.2-3, and then the upper sections are lifted, one by one, and placed on top of each other with the help of the auxiliary pole.

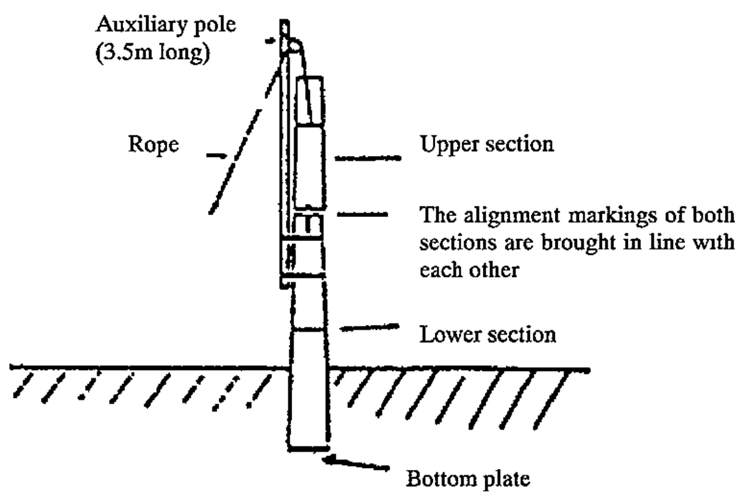


Fig. 2.2 – 3 Erecting a pole in a tight space

(b) Assembling poles

To create pole assemblies that facilitate hot-line work and harmonize with their environments, standardized pole assembly styles have been established for installations in various kinds of areas as pictured below.

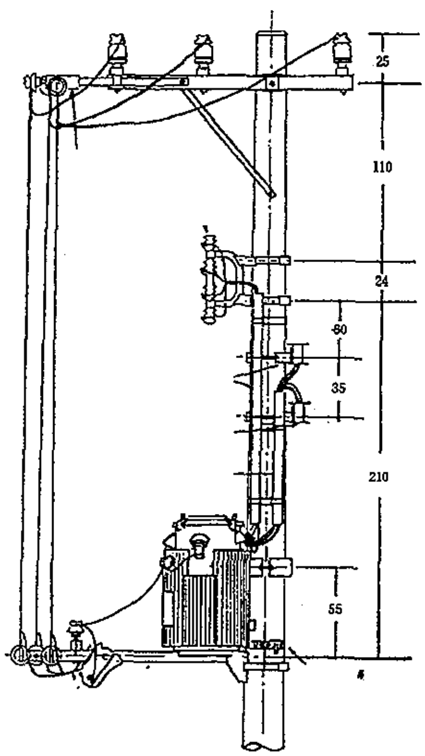
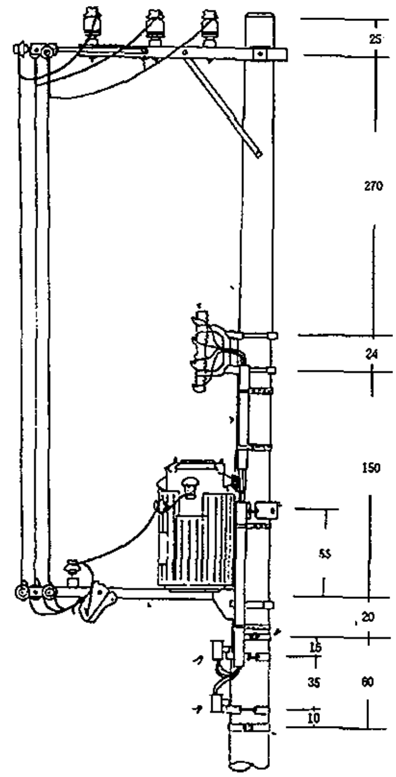
Type H1 assembly (for installations in general areas)	Type H2 assembly (for installations along major roads in area where houses are lined up)
	

Fig. 2.2 - 4 Standardized pole assemblies

(c) Stringing conductors

(i) Conductor support

➢ Conductor support at straight section

There are a method of using the bind with a volume for insulated conductors and a method of using a bind wire.

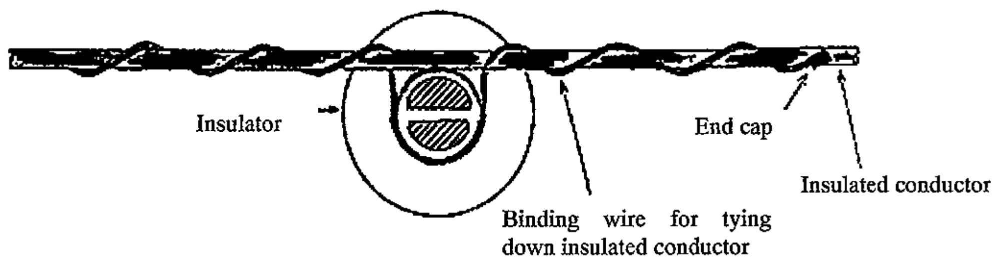


Fig. 2.2 – 5 Insulated conductor binding method

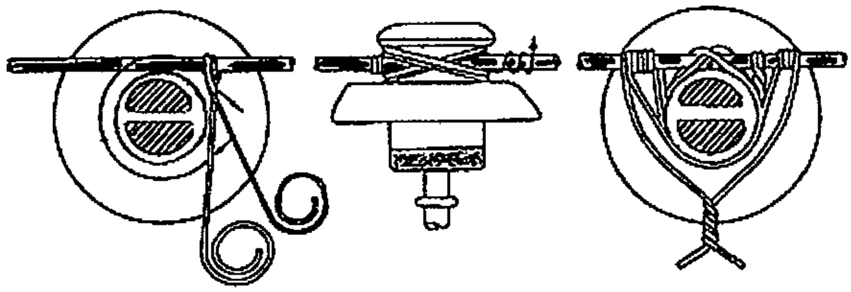


Fig. 2.2 - 6 Binding method

➢ Conductor support at dead-end point

There are anchoring methods by the anchoring clamp and by the anchoring grip with the bind wire.

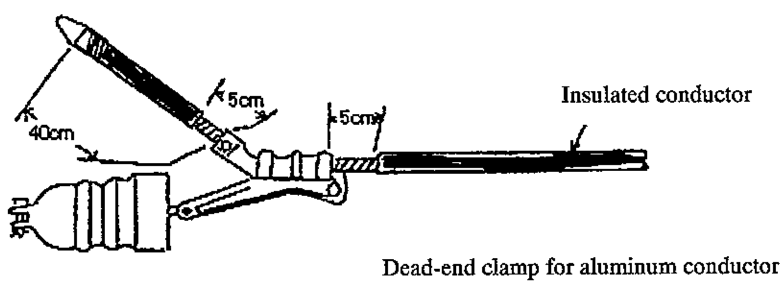


Fig.2.2 - 7 Anchoring method using a dead-end clamp (in the case of an aluminum conductor)

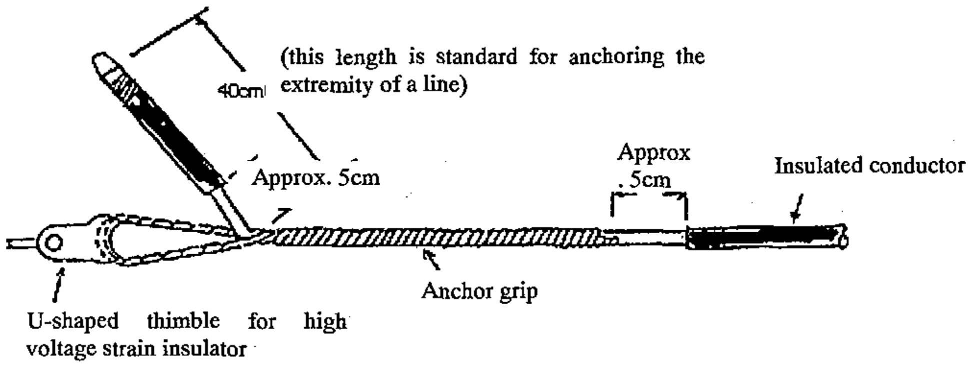


Fig. 2.2 - 8 Anchoring method using an anchoring grip

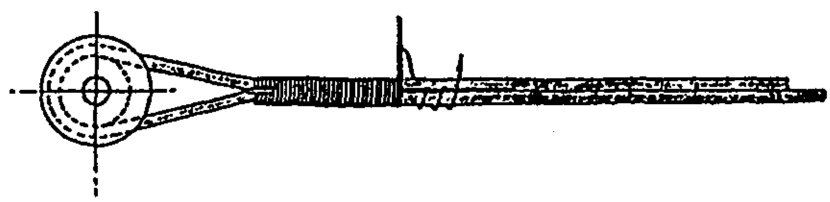


Fig. 2.2 - 9 Method for dead-end support using binding wire (used for anchoring low voltage lines)

(ii) Joining conductors

As for connecting a conductor, there are the connection method of the part in which tension works, and the connection method of the part in which tension does not work. The portion of the conductor to be connected is insulated with insulating tape, insulating cover, etc. to eliminate any bare portion.

- Joining conductors to be strung under tension

There are a method of connecting a conductor by the compressed type straight-line sleeve using a compression tool and a connection method which utilizes "B" type sleeve.

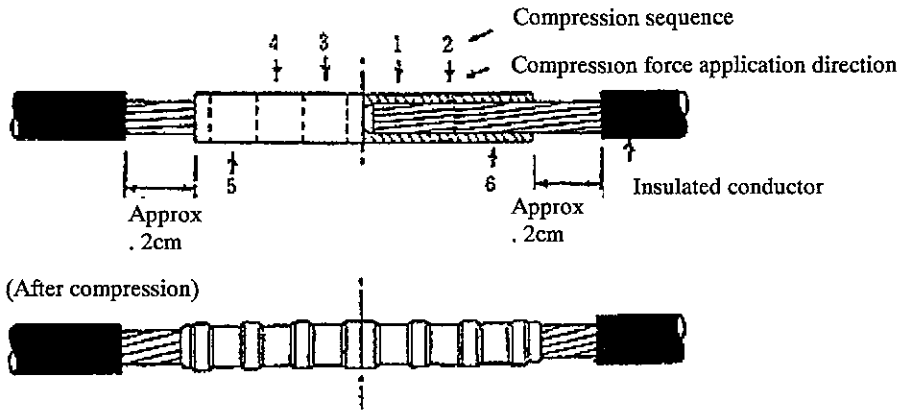
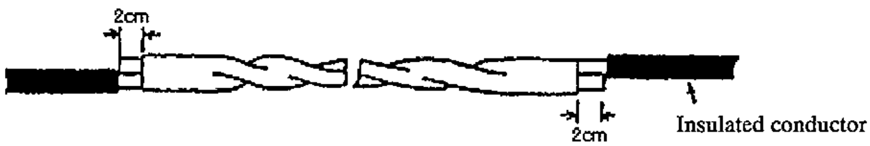


Fig. 2.2 - 10 Directions of compression force imposed on a straight sleeve and their sequence (when joining copper conductors)



Note: B-type sleeves are used to join copper conductors measuring 4.0 mm diameter.

Fig. 2.2 – 11 Conductors joined together by means of a B-type sleeve

➢ Joining conductors to be strung under low tension

There are methods of connecting a conductor by the compressed type branch sleeve using a compression tool and a connection method by the insulated penetration type connector applied when connecting the insulated conductor for high voltage service lines and a lead with a surge arrester connection terminal to the main circuit.

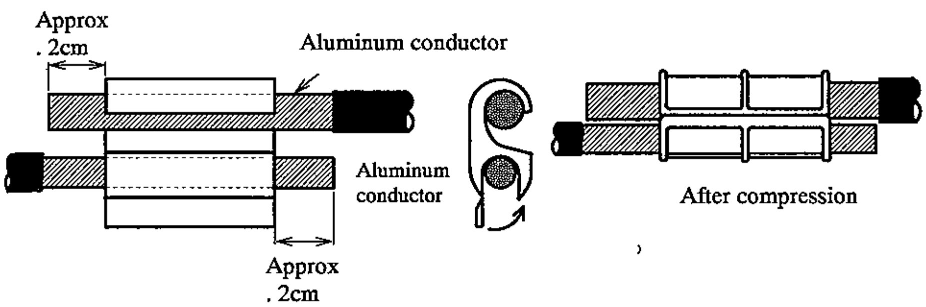


Fig. 2.2 – 12 Connecting method for aluminum and copper conductors

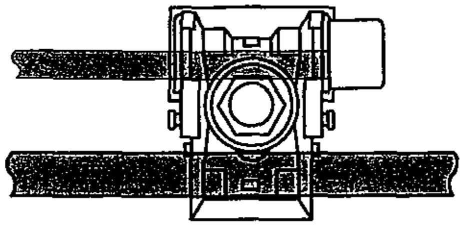


Fig. 2.2 - 13 Joining conductors with a V-shaped connector

Stripped wire portions that have been joined are covered with layers of insulating tape, or some kind of insulating cover so they are adequately insulated and no bare portions remain exposed.

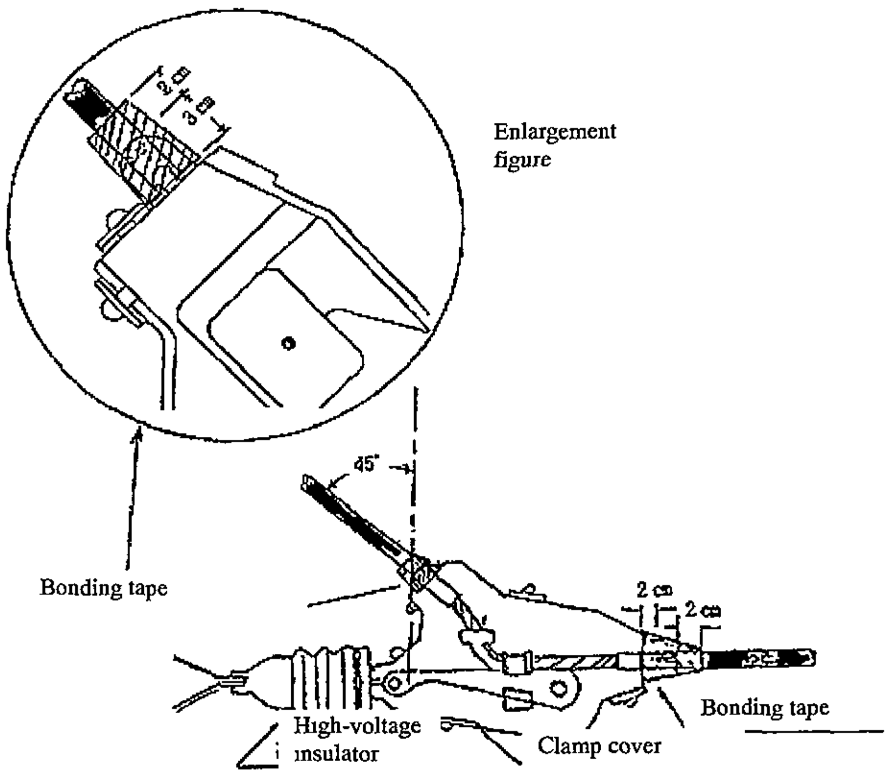


Fig. 2.2 – 14 Examples of insulating measures

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(d) Installing transformers

Transformers are fixed onto supports by means of belts so they won't fall down in the event of a strong earthquake or impact caused by a motor vehicle.

The way to mount transformers and other parts onto a pole is determined in accordance with applicable standards by the type of high voltage-line support used on the pole and by the classification of the service area where it is installed. Typical standardized pole assemblies are pictured below.

On the primary side of each transformer, a cutout switch incorporating fuses is installed to open and close the high voltage paths and to protect the transformer.

600V heat-resistant wires insulated with polyvinyl chloride (SHIV) are used to connect to the secondary windings of the transformer. These wires are run through inside a rigid polyvinyl chloride tube to protect them against possible damage.

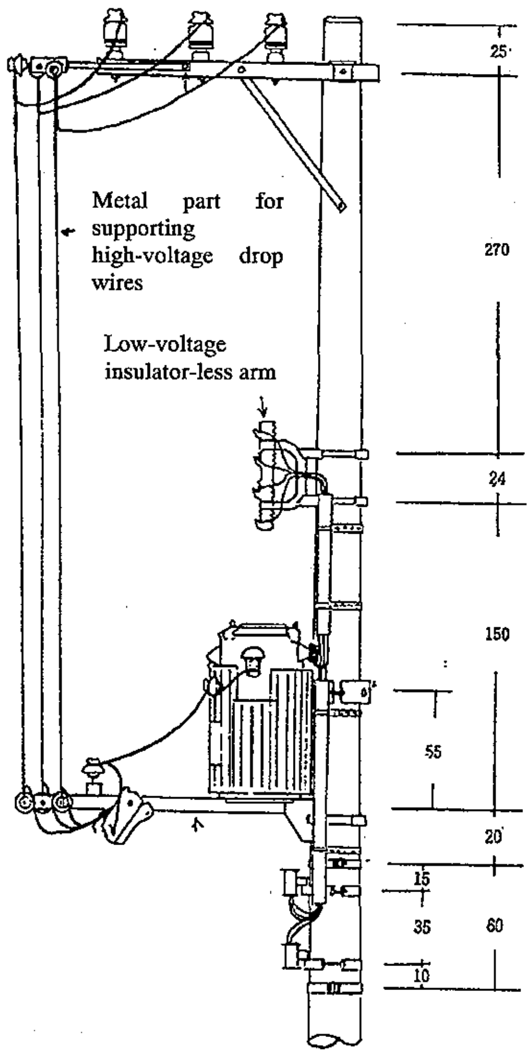


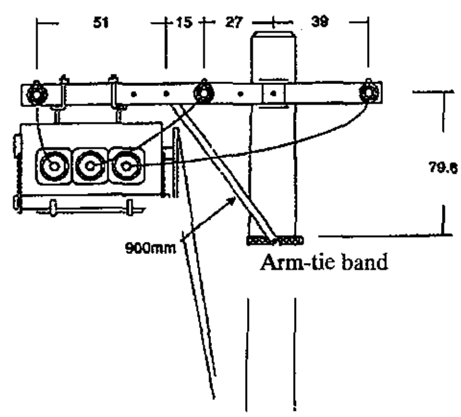
Fig. 2.2 - 15 Example method for mounting transformers on poles

(e) Installing high voltage switches

The way to mount a high voltage switch on a pole is determined by the type of high voltage-line support used on the pole. In addition, there are standardized methods for mounting automatic remote-controlled switches on poles along with their power transformers and remote terminal units (RTUS).

On-site manual switching (namely throwing switches on or off) can be done by pulling switch-operating ropes attached to the actuation levers of those switches. These switch operating ropes are tied down in place with metal fixtures equipped with locks. The fixtures are usually installed 4.6m above the ground.

Installation on horizontal arm



Installation on exclusive arm for switches

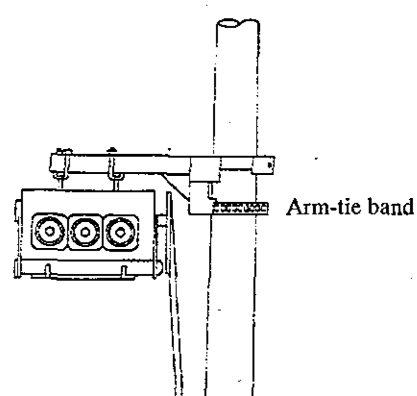


Fig. 2.2 – 16 On-pole installation of high voltage switches

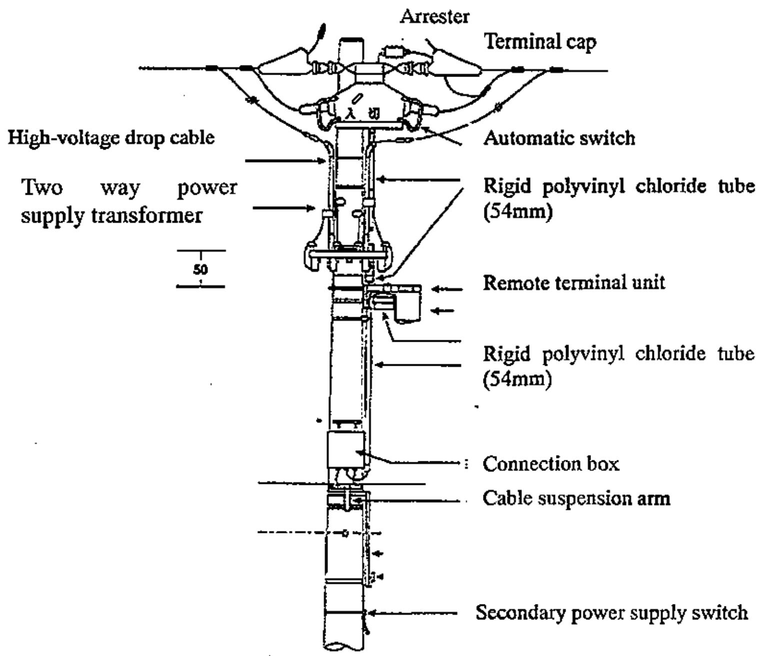


Fig. 2.2 - 17 In case of control cable system

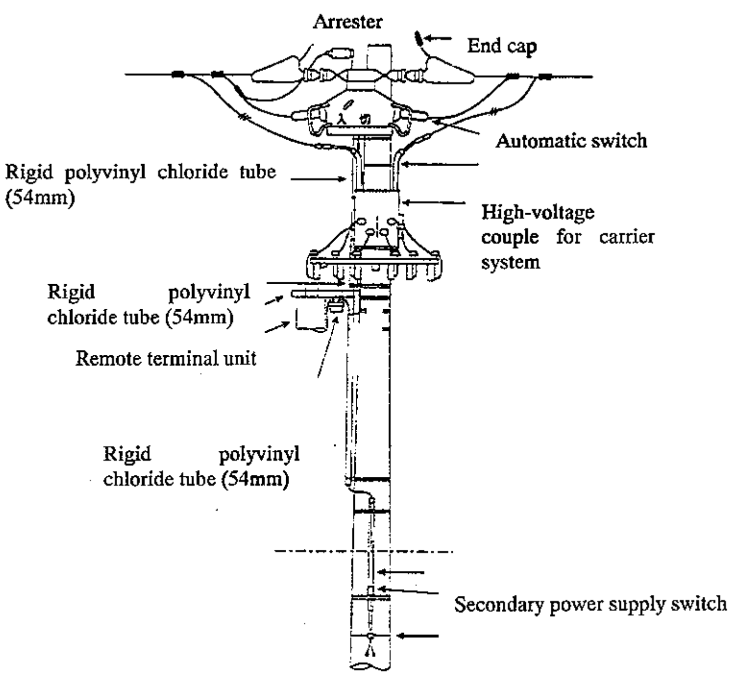
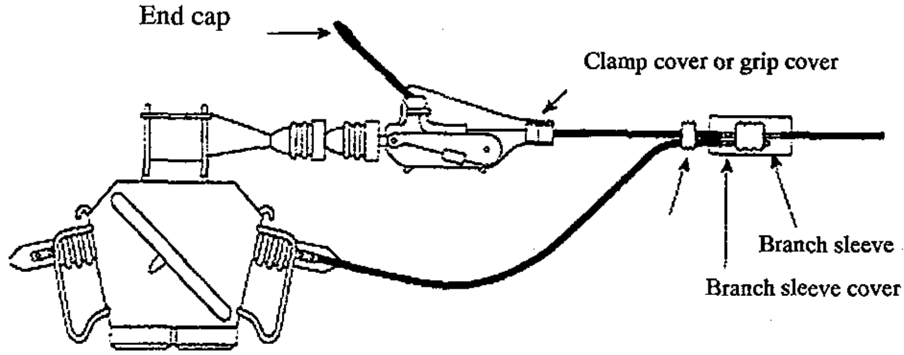


Fig. 2.2-18 In case of power line carrier (distribution line)

Connection between a switch lead wire and a high voltage main



Note: When installing a switch simultaneously with conductors, connection between leads is avoided as much as possible. The lead is connected to the terminal of a switch directly.

Fig. 2.2 - 19 Installation method of remote-controlled automatic switch

(f) Installing service wires

Lead-in conductors insulated with polyvinyl chloride (DVR) or 600V cables insulated with cross-linked polyethylene (CV) are used as service wires. To protect these wires, fuses are installed on poles. These fuses are housed in an aggregate catch box mounted on a service drop arm.

As a rule, service wires are led into customer's facilities directly from a pole.

However, if there is a need to maintain some distance between a pole and a building, a lashing is strung horizontally to support service wires so they can be branched out and dropped at any convenient point along the lashing.

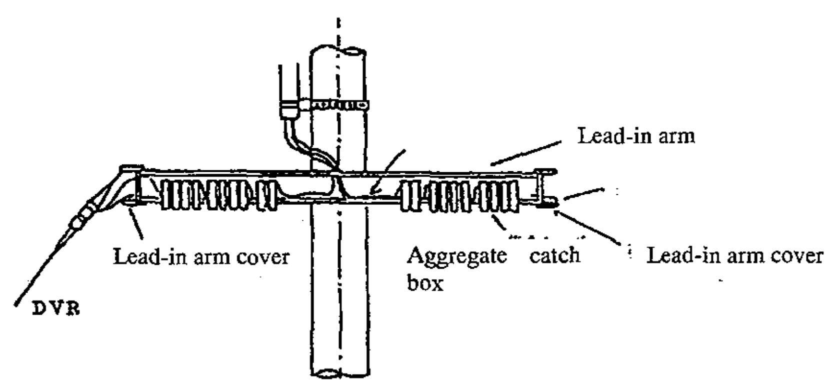
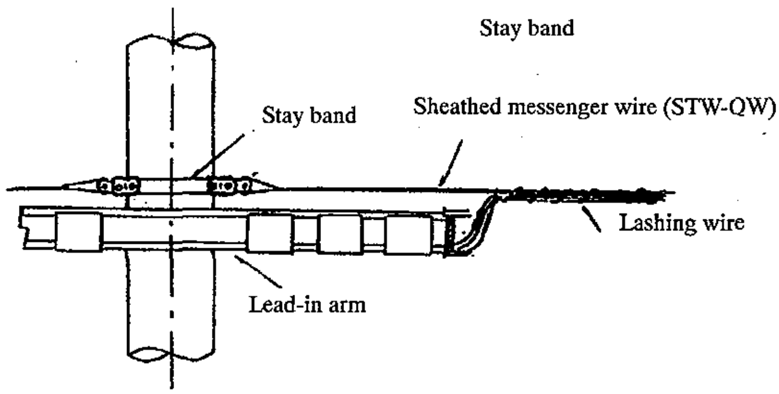


Fig. 2.2 – 20 Common direct lead-in method

Pole side



Branch side

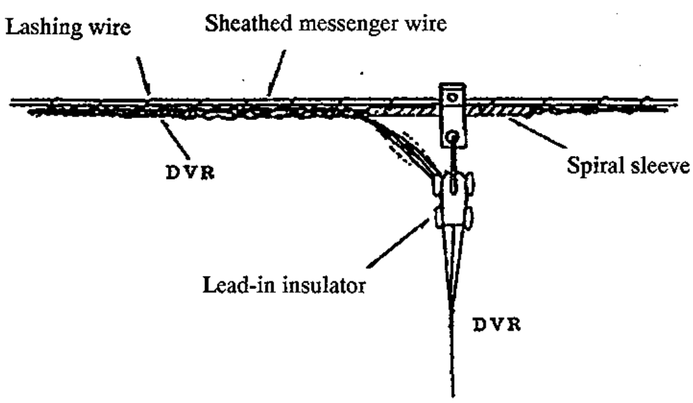


Fig. 2.2 - 21 Lead-in method supported by lashing

(g) Lightning arrester installation

(i) Lightning arrester installation

As a general rule, lightning arrester is installed upright. However, they can be mounted horizontally if they are to be installed on switch poles featuring a horizontal high voltage line arrangement or a vertical high voltage line arrangement.

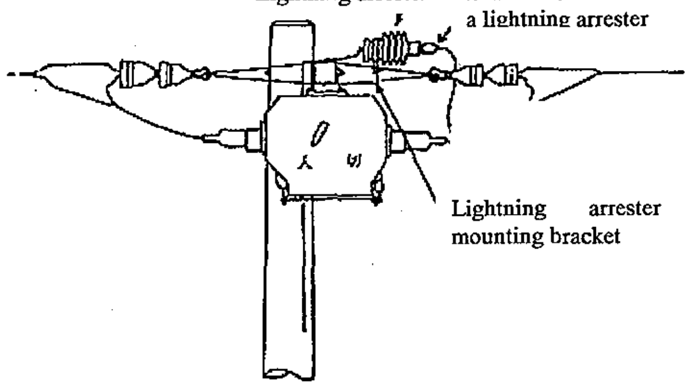


Fig. 2.2 - 22 Lightning arrester installed horizontally

(ii) Overhead ground wire installation

Bare hard-drawn copper conductors with 38 sqmm in cross-sectional area are used as overhead ground wires in areas with a lot of briny air and/ or corrosive gases, whereas stranded Class 1 galvanized steel wires are used in all other areas. As a rule, overhead ground wire metal supports are used to hold them up.

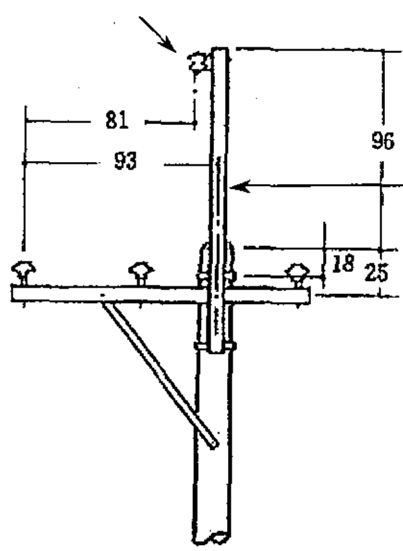


Fig. 2.2 - 23 Method for installing overhead ground wire

(h) Installing grounding electrode

The place to install grounding electrodes and the characteristics of those grounding electrodes are determined by technical regulation. Some major items specified by law are shown in Table 2.2-1. If there is a need to install two or more grounding electrodes for a particular support, those electrodes and the wires connected to them are installed at some distance from one another to prevent them from coming into contact with each other.

Grounding electrodes can be divided into grounding nets and grounding rods. If the minimum required grounding resistance value cannot be reached, two or more grounding electrodes are buried and/ or a grounding resistance-reducing agent is mixed with soil.

Grounding with a single electrode   Grounding with two or more electrodes

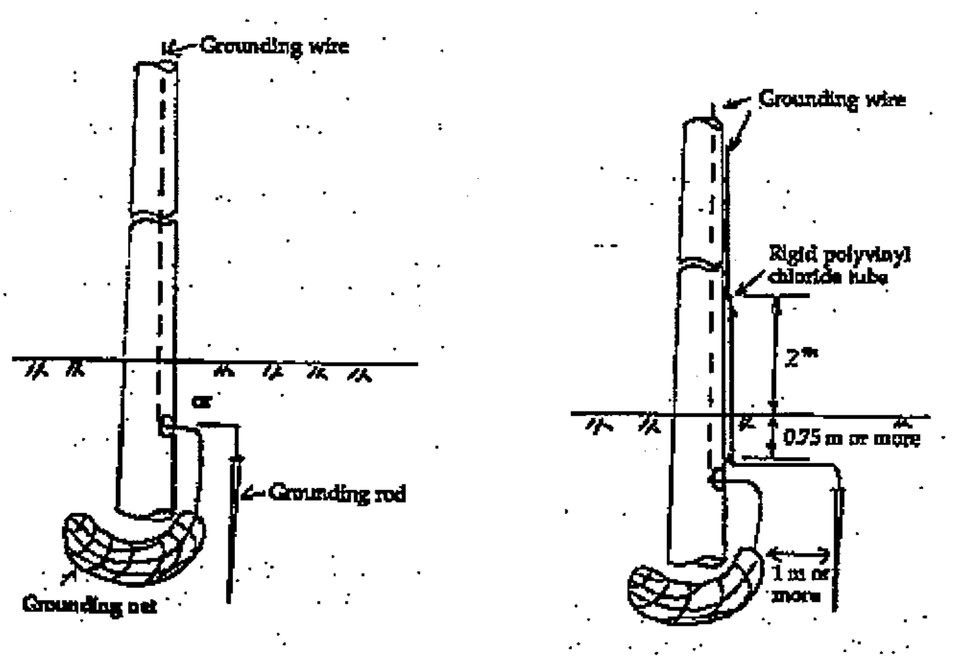


Fig. 2.2 - 24 Grounding electrode installation methods

Table 2.2 - 1 Major grounding requirement

Classification of grounding	Grounding resistance value
A class grounding	10Ω
B class grounding	30Ω (a value in ohm derived by dividing 150(*) by single line grounding current in the high or extra high voltage side circuit of a transformer)
C class grounding	10Ω (On a low voltage circuit. It is eased to 500 ohms if a device is installed, which automatically breaks the circuit within 0.5second when grounding occurs.)
D class grounding	100Ω (On a low voltage circuit. It is eased to 500 ohms if a device is installed, which automatically breaks the circuit within 0.5second when grounding occurs.)

Note; (*) 300 if a device is provided, which breaks the high or extra-high voltage circuit of a transformer of which service voltage is less than 35,000 V within a time range greater than 1 second and up to 2 seconds when the voltage to ground of the low voltage circuit exceeds 150 V due to contact between the high or extra-high voltage circuit and the low voltage circuit. 600 if a device is provided, which breaks the circuit within 1 second.

(2) Installing Underground Distribution Lines

(a) Duct installation

Underground distribution lines are installed using the following classified cable laying methods.

Table 2.2 - 2 Cable laying methods

Cable laying method		Scope of application	
	Duct structure	Number of ducts	Places and cases
Direct burial method	Concrete tough Productive ducts	One or two holes	-For use on the premises of a substation when cables are required to be provisionally installed -For use in places where the duct method is uneconomical or impractical for burying branch wires, service wires, or the like.
Duct line method	Simple ducts	No more than 15 holes	-For use in ordinary
	Concrete-packaged ducts		-For use in places where wires cannot be buried deep enough and ducts need to be reinforced all around by ferro-concrete
	Propulsion ducts		-For use in places where the open-cut method is impractical
Pit method	Open conduits	------	-For use on the premises of a substation when the location is inaccessible to heavy equipment or impractical
	Covered conduit	No more than 16 holes	-For use in places other than those mentioned above
Cable-box method	--------	--------	-For use in places designated for underground distribution (For use, as a general rule, along sidewalks measuring 4.5 m or greater in width)
C-C-BOX	--------	--------	-For use in places designated for underground distribution (For use, as a general rule, along sidewalks measuring 3.5 m or greater in width)

(i) Direct burial method

A metal-armored cable or a cable which is run inside a cable-protecting duct (such as a trough or a protective duct) is placed directly into a ditch and buried. To change the buried distribution line, it will be necessary to excavate.

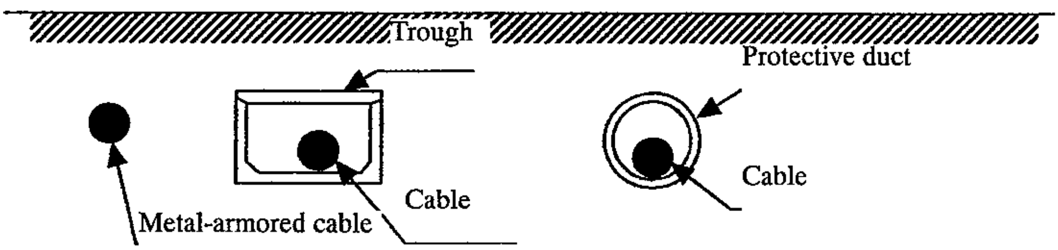
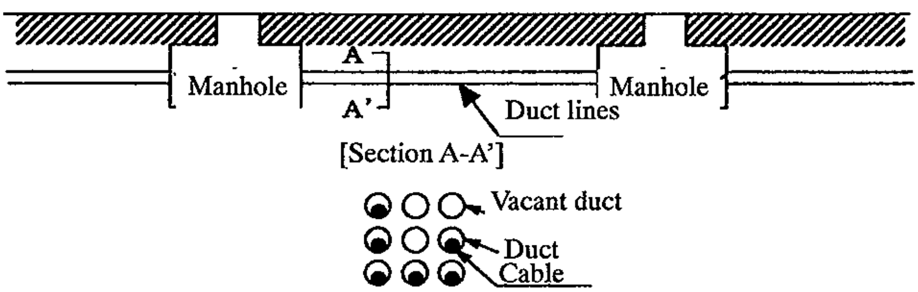


Figure 2.2 - 25 Direct burial method

(ii) Duct line method

Underground ducts are installed in advance, and cables are run inside them. Manholes (or hand holes) are provided in some places along these ducts so that the cables run inside them can be replaced with new ones without having to excavate those ducts.



Notes : The number of ducts to be buried must be decided on which probable future facilities expansion in mind. In other words, when installing ducts for immediate occupation, some vacant ducts should be installed.

Figure 2.2 - 26 Ducts line method

(iii) Pit method

A covered conduit or open conduit is built in advance to accommodate underground distribution cables. Cables are placed on cable-supporting shelves (cable hangers) mounted on the inner walls of the conduit. For information, a tunnel-like conduit with a unitized topside is called a covered conduit while a conduit with a removable lid is called an open conduit.

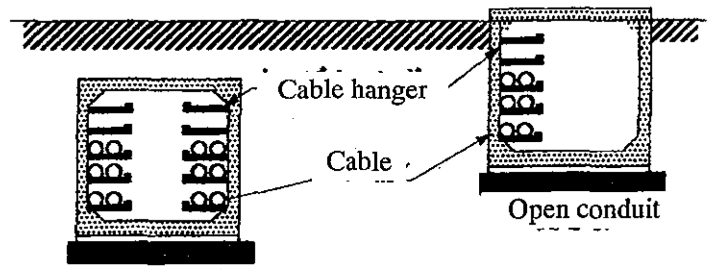


Figure 2.2 – 27 Pit method

(iv) Cable box method

In the cable box method, a U-shaped conduit with removable lids or concrete-packaged (concrete-wound) duct lines are installed in advance as an integral part of a road. Road management authorities make these installations to accommodate cables. In the case of the former, cable-supporting shelves (cable hangers) are mounted on its inner walls. Various corporations can thus share the same underground cable-housing facilities to run their cables (such as electric-power distribution cables, NTT telephone/communications cables, streetlight cables, and traffic signal lines).

Lidded U-shaped conduits are embedded below sidewalks while concrete-packaged duct lines are built underneath roadways.

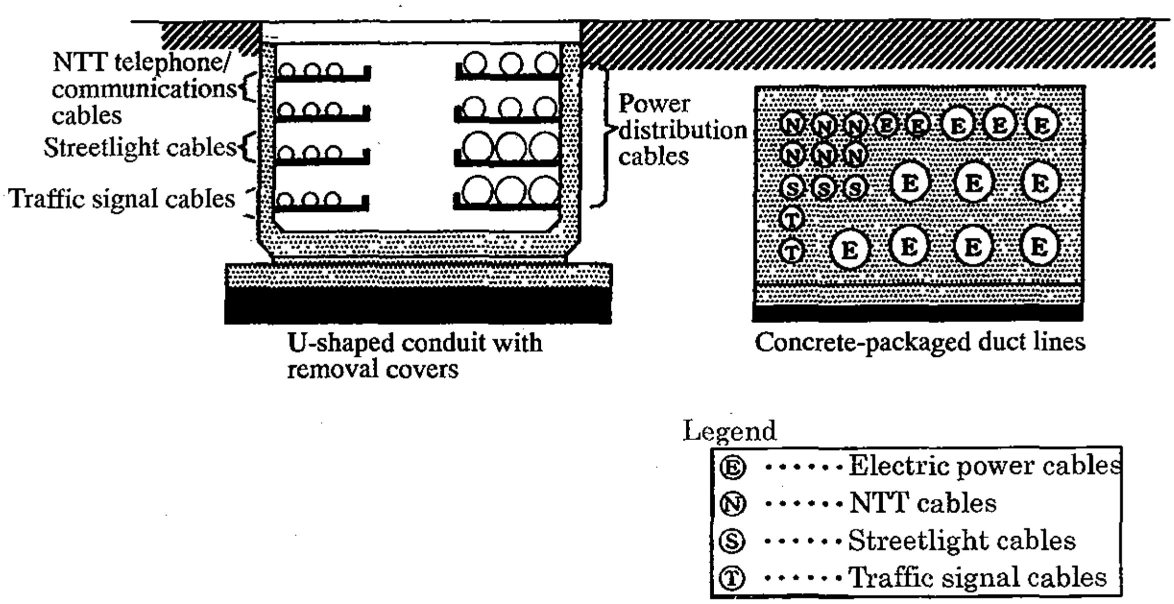


Figure 2.2 - 28 Cable box method

(v) C-C-BOX (Community, Communication, Compact-Cable-BOX) method

C-C-Box method is compacted type of existing cable box method. It consists of standard part and particular part. Standard part is the same as duct line method. Particular part is the same as U-shaped conduit with removal covers of cable box method. Road management authorities make conduits and ducts to accommodate cables and cable management companies such as electric power company, NTT, etc. install cables.

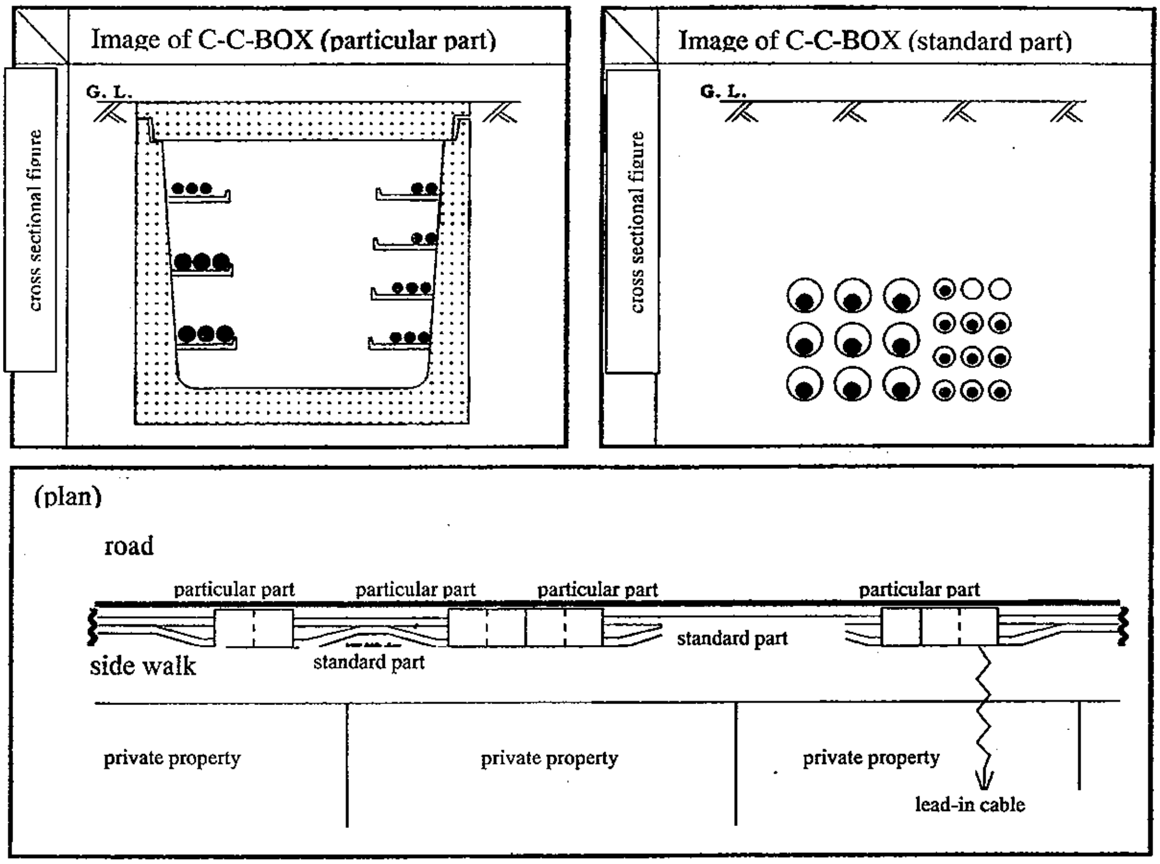


Figure 2.2 - 29 C-C-BOX

(b) Manhole installation

It is standard to install manholes at intervals of 200m in terms of conduit distance. The conduit distance between manholes should never exceed 300m in view of various cable installation-related aspects and lengths of cables that will need to be replaced in the event of a cable failure.

If there are curves along a duct, manholes should be provided at shorter intervals so that the following conditions can be satisfied:

- ✓ Cable lead-in tension <= Cable's permissible tension
- ✓ Cable lead-in lateral pressure <= Cable's permissible lateral pressure (500 kg/m)

Manhole locations should be decided with consideration to the configuration of the system concerned, the ease of maintenance, and other factors. Furthermore, crossings and the entrances or parking lots should be avoided as manhole sites for obvious reasons. Types of manholes and their intended used are summarized in the following table.

Table 2.2 - 3 Manhole types and their intended uses

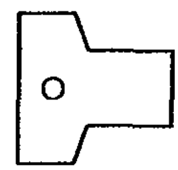
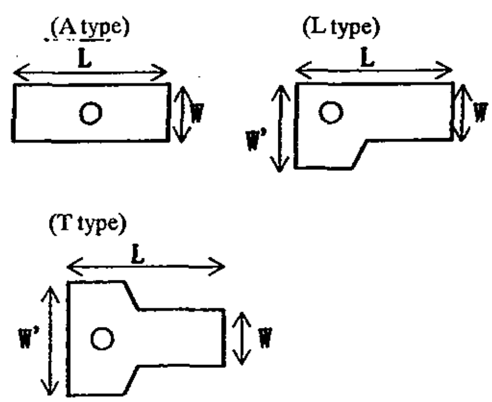
Type	Abbreviated name	Use	Shape
Straight type	Type A manholes	For installation in rectilinear conduit sections	
Unilateral branching type	Type L manholes	For installation in places where a conduit branches off on one side	
Bilateral branching type	Type T manholes	For installation in place where a conduit branches off on both sides	
Special type	------	For use in places where type A, L, and T manholes are of no use	------

Table 2.2 - 4 Manhole sizes classified by duct counts and inner manhole dimensions

Number of ducts	Size	Inner dimensions (mm) H	L	W	W'	Explanation of inner dimensions
6 holes or fewer	A-5	2.0	4.0	1.5	---	H---Height L---Length W---Width W'---Width of projecting portion
	L-5	2.0	5.0	1.5	2.3	
	T-5	2.0	5.0	1.5	3.1	
7 to 9 holes	A-3	2.0	4.0	2.2	---	
	L-3	2.0	5.0	2.2	3.0	
	T-3	2.0	5.0	2.2	3.8	
10 to 15 holes	A-1	2.0	5.5	2.2	---	
	L-1	2.0	6.0	2.2	3.0	
	T-1	2.0	6.0	2.2	3.8	

There are three manhole installation methods to choose from : the cast-at-site method, the prefab method, and the finished-product installation method. The method to adopt is determined on the basis of cost efficiency, available time to complete a given project, and other factors. They are studied in the following order : the finished-product installation method, the prefab method, then the cast-at-site method.

(i) Finished-product installation method

In this method, a pre-cast manhole unit with no bottom board and top board is placed on the ground. Earth is removed from its bottom in order to let the unit sink under its own weight with its side walls serving as earth retaining walls. After the unit has reached the desired installation position, its top and bottom boards are installed in place.

Unlike the cast-at-site method and the prefab method, this method eliminates the need to install an earth-retaining system before a vertical shaft is dug. Furthermore, since the amount of earth which must be removed from and returned to the shaft can be minimalized, the installation cost can also be significantly reduced, and a mere three days on the site will be required at most, this method is suitable for a wide range of manhole-installation projects.

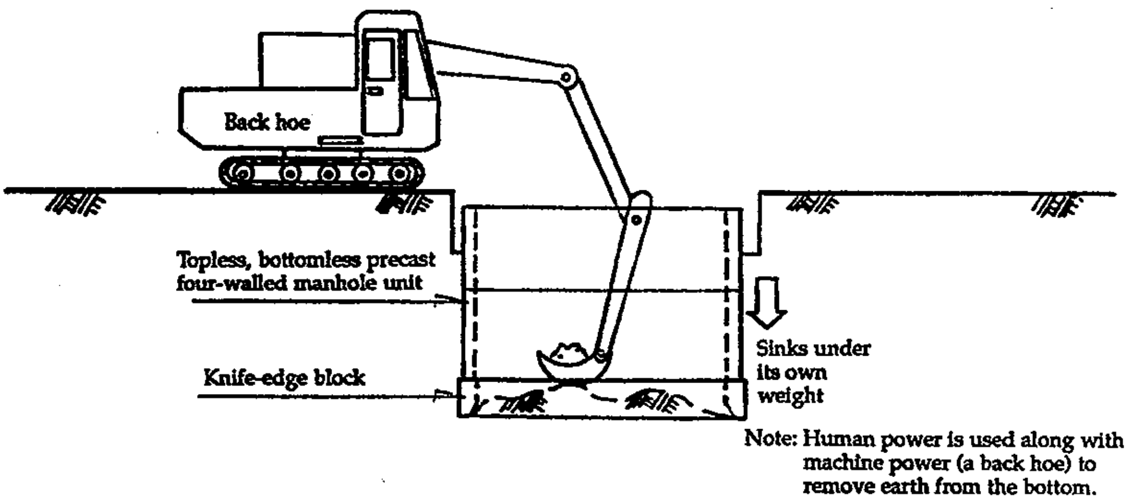


Figure 2.2 – 30 Illustration depicting the finished-product installation method

(ii) Prefab method

In this method, manhole blocks that have been manufactured at a factory are transported to a manhole-installation site and are put together at the site. As with the above cast-at-site method, more of the same kinds of incidental tasks must be conducted at the site.

Since this method eliminates the need to construct the manhole itself at the site, it takes only about seven days to excavate a vertical shaft and put a set of blocks together at the site. This method is therefore adopted in places where the ground is weak or where some other underground facilities, such as sewers which cannot be moved already exist, or when using the finished-product installation method is impractical due to attendant difficulties.

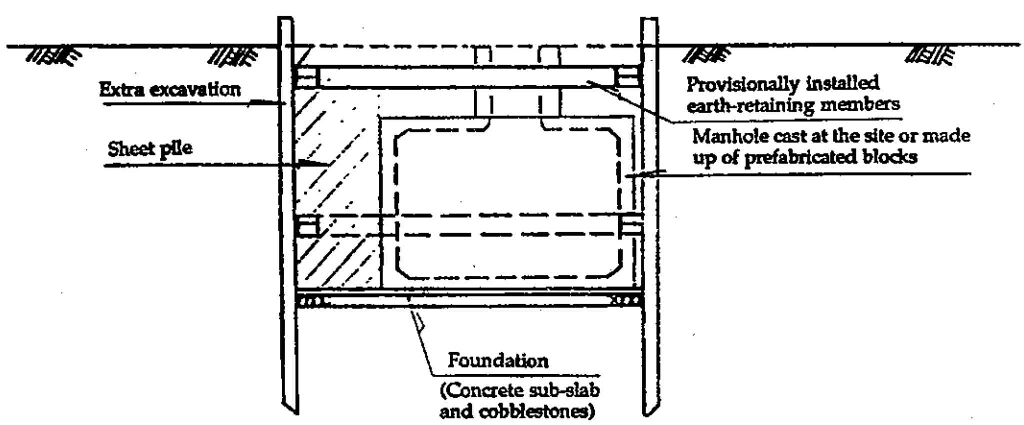


Figure 2.2 - 31 Illustration depicting the cast-at-site method and the prefab method

(iii) Cast-at-site method

In this method, a range of manhole construction tasks, such as placing reinforcing steel bars, installing molds, placing and curing concrete, and dismantling the molds, as well as work which is incidental to these construction tasks such as excavating vertical shafts plus some extra space for facilitating manhole construction, sheathing soil and backfilling, are performed at the site.

Since it requires a relatively long period of time, say 35 to 40 days, to place reinforcing bars and to cure deposited concrete, this method is suitable for constructing manholes of special types.

2.2.2 Construction Supervision

As discussed in Subsection 2.2.1, installing distribution facilities can be divided into direct installation work, unit-rate sub-contracted installation work, and general sub-contracted installation work. Most work is unit-rate sub-contracted installation work which is contracted out to companies specializing in installing electrical facilities.

Control of unit-rate sub-contracted installation is explained below:

(1) Entering Data about Design Details (Input)

After a design has been made, a range of data about the work such as its design details, expected implementation date and the name of the sub-contractor are written on a prescribed input form, and entered into the computer.

(2) Outputting Installation Implementation Forms

After the computer has processed and compiled each work's design details, it outputs a list of required materials and components, the number of elemental installation works that must be executed and estimated installation costs. Furthermore, a record to keep track of the progress of already-inputted projects can be outputted by entering data on the projects in progress.

(3) Making a Plan

Based on the above-mentioned progress management record, a work-implementation plan is made which takes into consideration such factors as whether there is a need to perform dead-line work, the scale of the work, the ability of the sub-contractor, and so forth.

(4) Procuring Materials and Components

After the date to begin work has been decided, it is entered into the computer. The computer then makes the necessary arrangements to procure and deliver the required materials and components (transformers and electrical wires) to the sub-contractor in time for the scheduled work.

(5) Contracting Out and Executing Work

Work is contracted out to a sub-contractor by giving him a set of documents required to execute the work. Based on these documents, the sub-contractor procures other required materials (miscellaneous materials are procured by sub-contractors) and then executes the work.

(6) Reporting Completion of On-site Work

Upon completing the work, the sub-contractor informs us of the completion. The completion date of the work is inputted into the computer.

(7) Reporting Completion of Work

We check to determine whether reimbursements for the materials and components used in the course of the work have been made correctly, whether the completed facilities satisfy the design specifications, and whether the installation has been done in accordance with applicable regulations and standards. If everything turns out all right, the electric utility enters the information about the completion of the work into the computer.

(8) Keeping Tabs on Budgets

Every month, the conditions of each installation are outputted for comparison with pre-determined distribution-facilities installation budgets. Differences are analyzed and reduced by making adjustments to subsequent work schedules.

2.2.3 Construction Inspection

Inspections are conducted on completed distribution facilities to check that they have been built or installed in accordance with pertinent regulations and standards as well as with their design specifications/ instructions. The facilities should be capable of working up to their intended performance levels, and should satisfy the following aspects: giving stable supply of power, working in harmony with their environment, and there should be adequate provisions for maintenance and safety. The inspections also serve as a means for providing technical guidance to sub-contractors and enhancing their design skills of the company's staff.

(1) Self-imposed Inspections

In the case of direct installation and piece-rate sub-contracted installation, self-imposed on-site inspections on completed distribution facilities are conducted by the builders themselves. They use a check list to see whether the facilities have been properly built or installed.

(2) Completion Inspections

After completing self-imposed inspections, the company conducts completion inspections in response to completion reports submitted by builders. Completion inspections are divided into paper inspections and on-site inspections.

(a) Paper inspections

Paper inspections are conducted on every work to check:

- ✓ The type classification of the piece-rate work concerned and the number of elemental jobs making up the contracted work; also the construction costs are audited
- ✓ Delivered/warehoused materials against design specification sheets and design drawings; required payment adjustments are made
- ✓ Other documents related to work completion to properly enter required information
- ✓ The number of days delayed while executing work and the number of days required for reworking, if any

(b) On-site inspections

Documents related to work completion which have undergone paper inspections are checked against completed on-site work based on such criteria as the installation method employed, the materials/ components used, the type classification of piece-rate work completed, the number of elemental jobs making up the contracted work and construction costs. In addition, required measurements such as the height of completed facilities above the ground and the distances between them and neighboring objects, along with required tests, such as grounding resistance measurements are conducted.

Although all work is subject to on-site inspection in principle, inspections through photographs or sampling inspections are applied to those completed facilities that are unlikely to pose any serious problems in terms of safety and in relation with their surroundings.

(3) Re-inspections

If completed facilities are found to need additional work due to having been made with a cost-cutting method or slipshod workmanship, the electric utility issues a re-work directive to the construction company concerned. After completion of the re-work, another inspection is made on the facilities, in the same way that completion inspections are usually conducted.

(4) Witnessed Inspections

In cases of technically advanced or important projects, special projects, projects implemented using newly-adopted methods and projects which defy inspection or re-working after their completion, the necessary inspections are conducted in the presence of the electric utility's inspectors while the facilities are being constructed.

2.3 Techniques of Operation

2.3.1 Supply Reliability

(1) Recording Service Interruptions

Since it is mandatory in Japan to inform the responsible authorities of the average incidence and duration of service interruptions per customer for service interruptions caused by outside faults and work-related service interruptions, every electric power company keeps tabs on service interruptions.

Table2.3 - 1 Incidence of service interruptions and their durations per customer (Average of 10 electric companies)

		1990	1991	1992	1993	1994	1995	1996	1997	1998
Fault-caused service interruptions	Incidence (times per year and customer)	0.14	0.27	0.09	0.11	0.08	0.08	0.08	0.07	0.10
	Duration (min. per year and customer)	18	142	8	28	31	5	11	10	17
Work-related service interruptions	Incidence (times per year and customer)	0.09	0.07	0.06	0.06	0.03	0.04	0.04	0.04	0.04
	Duration (min. per year and customer)	10	8	8	5	3	3	4	4	5

Source; Agency of Natural Resources and Energy Electric Security Statistics

(2) Measures to Reduce Fault-caused Service Interruptions

Efforts have been made to prevent service interruptions and achieve earlier recovery, and in turn maintain supply reliability. Such efforts include measures against lightning damages, measures against induced incidence, provision of instantaneous ground fault and short circuit section detectors, and measures against typhoon damages.

Table 2.3 - 2 Incidence of high voltage fault-caused service interruptions by cause (Total of 10 electric companies)

		1993	1994	1995	1996	1997	1998
Maintenance inadequacies Facilities imperfections		1,021	989	1,174	1,026	1,089	1,099
Natural phenomena	Lightning	916	1,793	1,562	1,177	1,214	1,235
	Wind, rain, floods, etc.	4,047	2,045	1,153	1,982	1,719	3,136
Extrinsic causes	Extraneous ripple effects	585	538	534	536	500	412
	Contact with foreign objects	1,008	958	1,246	1,401	1,286	1,792
	Negligence	0	4	2	5	10	187
Unknown causes		566	583	875	633	734	1,045
Total		8,143	6,910	6,546	6,760	6,552	8,906

Source; Agency of Natural Resources and Energy Electric Security Statistics

(a) Measures to decrease the faults due to lightning

Lightning arresters and overhead ground wires are installed depending on the area.

Table 2.3 - 3 The outline of measures to counter faults caused by lightning

Area classification		Measure
The area where the danger of lightning damage is large	The section in which equipment is installed comparatively densely	● A surge arrester or a ground wire is installed on an apparatus and the end of a track. ● A surge arrester is installed on an apparatus that may produce big electric supply trouble.
	The section with fewer pieces of equipment	● A surge arrester and a ground wire are installed on an apparatus and at the end of a track. ● Ground wire is installed in a section where frequent lightning damages are expected.
	Tension insulator	● Two high voltage strain insulators are used in the dead-end of a track.
The area where the danger of lightning damage is comparatively large	The section where lightning damage occurred in the past	● A surge arrester is installed in an effective protection area of equipment.
	At the connecting point of a section with ground wire and a section without ground wire, and at the end of a track	● A surge arrester is installed according to the actual conditions of a place and a track.
The area where the danger of lightning damage is small		● A surge arrester is installed on an apparatus that may produce big supply trouble.

(b) Measures to counter faults caused by the ripple effect

A fault caused by the ripple effect originates from a fault developing within a customer's facilities that makes its way beyond the customer's premises (when the fault is of a great magnitude), into distribution lines. For this reason, electric utilities have been asking major customers to check on their facilities and make repairs on their faulty facilities or equipment, and recommending them to install lightning arresters. Electric utilities have been strongly encouraging them to install section switches in particular. A section switch is designed to block the flow of electricity to a customer's facilities when distribution line switches are turned on again to recover from a service interruption caused by a ground fault occurring in the customer's facilities.

(c) Others

In response to the increasing demand, measures have been taken to secure supply capability in areas where a distribution line trouble may cause power shortage and service interruption may have large impacts. Such measures include a new distribution line route for interconnection, replacement of conductors with those of larger capacity, and increase in capacity of switches and SVRs.

Instantaneous ground fault and short circuit section detectors are effective in preventing service interruptions and earlier detection of fault-causing factors. They are installed on high voltage feeders of long distance and on feeders showing higher frequencies of instantaneous ground faults. Equipment for transmitting detection information is provided in areas where much trouble is needed in verifying the information, such as remote islands and in mountains.

In order to prevent typhoon-caused faults, routes of distribution lines are changed in mountains, and stay wires and anchors are reinforced in strong wind areas.

(3) Measures to Reduce Dead-line Work

Service interruptions related to dead lines have been decreasing year after year in terms of both frequency and duration. This is accomplished by reducing service interruption areas through expansion of facilities such as upgraded linkup distribution routes and addition of switches. It is also accomplished by reducing the duration of interruption per work through more rational operation, and development, improvement and positive use of techniques and equipment for allowing work while supplying power to the customers. Some measures to reduce dead-line work are shown below.

(a) Using work switches to prevent service interruptions

In this method, a work section is cut off by a pair of temporally-installed work switches in order to minimize the area of interrupted service.

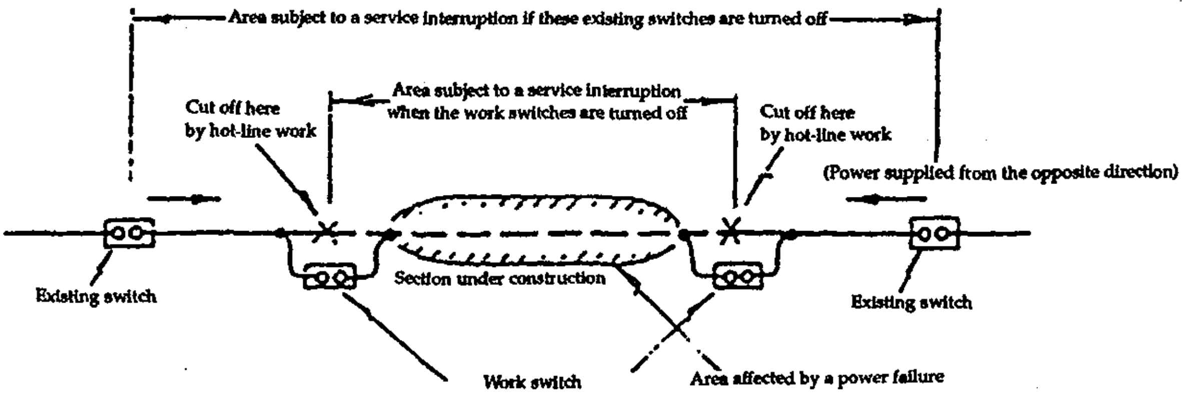


Fig. 2.3 - 1 Method using switches for working

(b) Method to prevent service interruptions using temporary power supply facilities

(i) Method using temporary power supply facilities

Method to prevent service interruptions using provisional power supply facilities

In this method, by-pass lines are temporarily provided using high voltage bypass cables in a work area. Work goes on while power is supplied to customers within the area with the helo of transformer vehicles and low voltage bvoass cables.

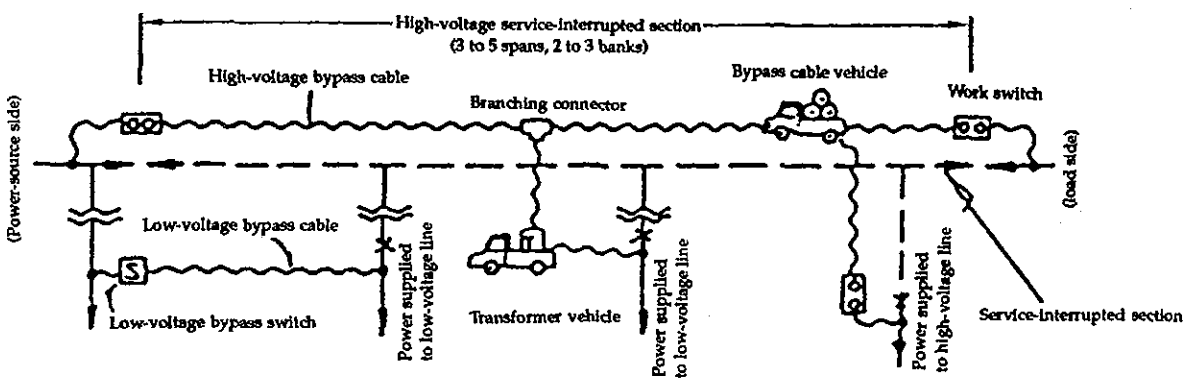
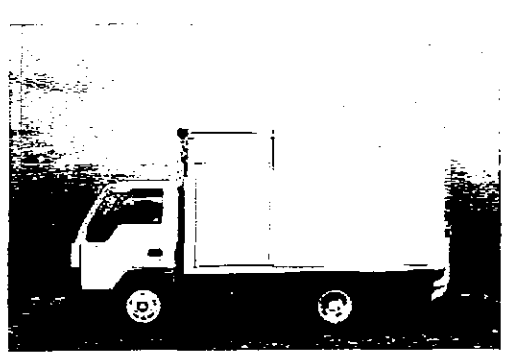


Fig. 2.3 - 2 Method using temporary power supply facilities

[Transformer vehicle]



[By-pass cable vehicle]

(ii) A method using high voltage generator vehicle

This method allows a high voltage generator vehicle to be connected to and separated from a distribution system without any service interruption. The vehicle is used as a temporary power source of a high voltage distribution line.

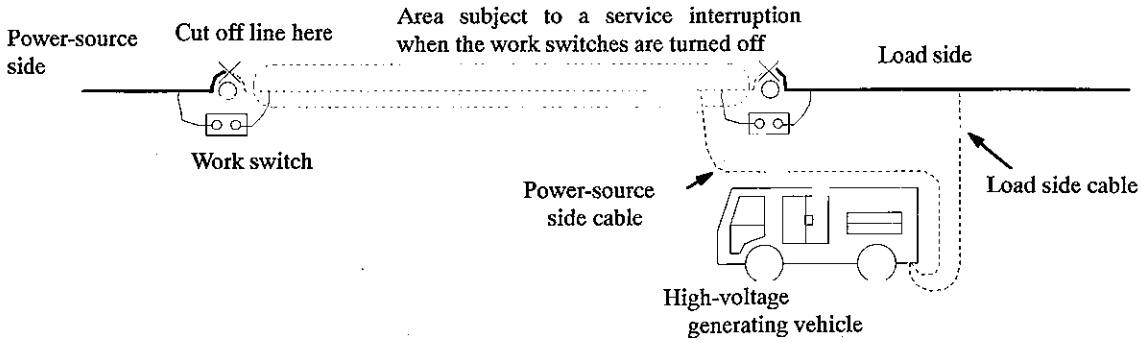
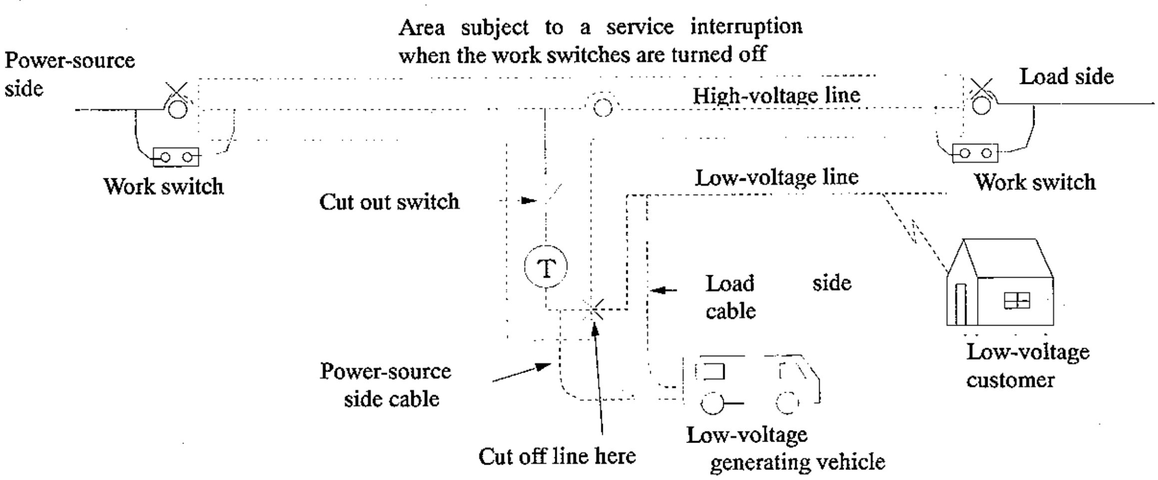
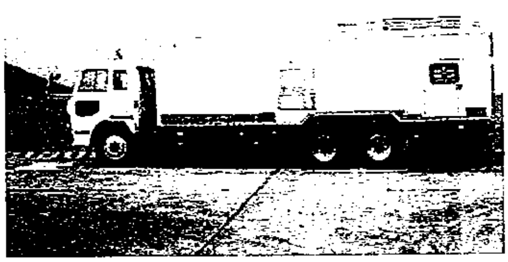


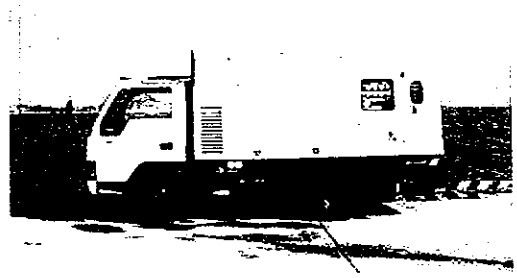
Figure 2.3 - 3 A method using high voltage generator vehicle

(ii) A method using low voltage generator vehicle

This method allows a low voltage generator vehicle to be connected to and separated from a distribution system without any service interruption. The vehicle is used as a temporary power source of loads of a pole transformer in a section of service interruption.







[High voltage generator vehicle] [Low voltage generator vehicle]

Figure 2.3 – 4 A method using low voltage generator vehicle

(c) The method of work performed near hot-lines

This method is used to work on conductors, such as connecting wires, while some conductors are kept live. Dedicated tools are used.

- ✓ Installation of high voltage service wire
- ✓ *Connection and separation of conductors*
- ✓ Connection of a main circuit and a branch wire
- ✓ Moving a conductor
- ✓ Installation and removal of a temporally switch
- ✓ Installation of an arrester
- ✓ Replacement of a clamp cover

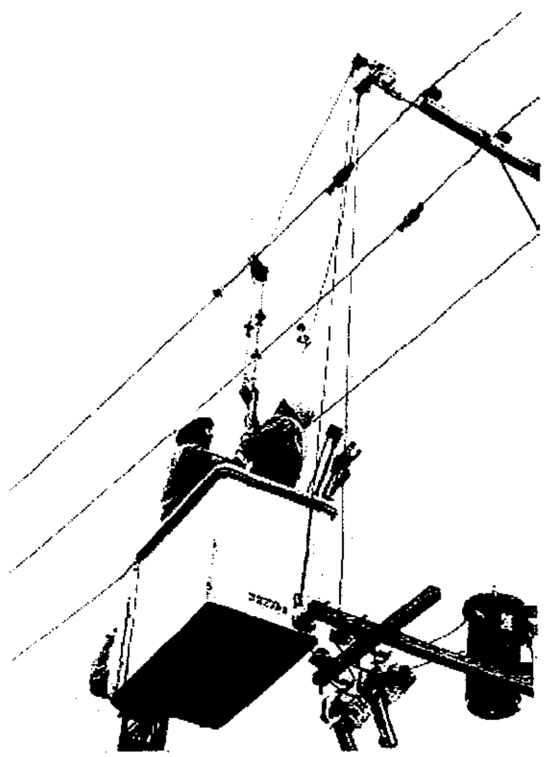


Fig. 2.3 - 5 Method of indirect hot-line work for joining high voltage mains and branch lines together halfway between poles

2.3.2 Voltage Control

Electricity travels through distribution facilities including high voltage lines, pole-mounted transformers, low voltage lines, and service drop wires until it reaches customers. A voltage drop develops across each one of these components. The voltage drop varies constantly due to yearly, seasonal, day-time and night-time load changes.

On the other hand, it is mandatory that each electric utility maintains its customer terminal voltages within the ranges shown in the right-hand boxes of the following table for the standard voltages shown in the left-hand boxes.

Therefore, electric utilities manage the high and low voltage drops by adjusting the out-going voltage of substations and the tap-changer of the pole transformers.

Table 2.3 - 4 Allowable supply voltage at customers

Standard voltage	Permissible voltage range
100V	101+/- 6V
200V	202+/-20V

(1) Substation-output Voltage Adjustment

(a) Voltage adjustment method

A substation's output voltage is adjusted by means of on-load tap-changing transformers or induction regulators. The "program control method" is standard. However, the "line voltage drop compensation control method" (abbreviated as the LDC method) or a combination of the "LDC method" and the "program control method" is employed to adjust voltages in the cases described in Table 2.3-5.

In addition, voltage adjustments are made manually in unusual cases, for example, at load-interchange time or during a work-related service interruption, or fault-caused service interruption.

Table 2.3 - 5 Substation-output voltage adjustment methods

Adjustment method	Applicable case
LDC method	In cases where the load characteristics of feeders within a given bank are similar to each other
LDC method combined with program control method	In cases where the customer terminal voltage goes out of tolerance in a certain time frame when the LDC method alone is employed and where facilities cannot fully respond to load fluctuations when the program control method alone is adopted.

(i) LDC method

Install resistance and reactance in proportion to impedance of distribution network into circuit of voltage relay.

Making current flow in proportion to load of distribution network into circuit of voltage relay.

Above two things make voltage relay boost sending voltage up to the value equal to descending voltage drop in distribution lines.

Circuit configuration is shown in figure 2.3-6.

(ii) Program control method

In advance, load of every hour of the day must be estimated and sending voltage from substation must be calculated according to every hour's load.

Aiming this voltage, sending voltage is controlled every hour by changing standard voltage of voltage relay.

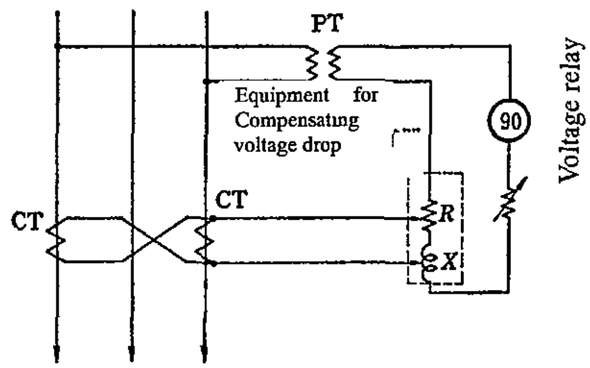


Figure 2.3 - 6 Circuit configuration of voltage relay

(b) Measurement and management of substation output voltages

- ✓ If there is a need to measure and keep track of the output voltage of a substation for voltage-management purposes, recording equipment is installed on the maximum-load and minimum-load days of the year to keep tabs on it around the clock.
- ✓ The quality of the out put voltage of the substation is evaluated by analyzing the results of the above-mentioned voltage measurements and other monthly records such as the "Power station and substation load record" and the "Substation operation log".

(2) Voltage Management of High Voltage Distribution Lines

(a) Permissible voltage drop limit of high voltage distribution lines

The allowable voltage drop limit of high voltage distribution lines being used under normal conditions varies with the type of service area to which they supply power, as shown in the following table.

Table 2.3 - 6 Allowable voltage drop limits by area

Service area type	Allowable voltage drop limit
Cities	300 V
Sub-prefectural area	600 V

(b) Voltage, current, power factor measurement of high voltage distribution lines

When there is a need to conduct measurements for voltage-management purposes due to a change in the distribution system or to significant load changes, these measurements are made at locations shown in the following table.

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Table 2.3 - 7 Measurement locations of voltage, current and power factor

	Measurement locations
Voltage measurements	● At the substation outlet and points where changes were made ● At line terminals, and points before and after SVR
Current measurements	● At major locations such as the substation outlet and branching points
Power-factor measurements	● At required points such as the substation outlet

(c) Determining maximum voltage drop values for high voltage distribution lines

The maximum voltage drop values for high voltage distribution lines are determined by making a comparative study of voltage and current values computed from the following data: yearly maximum voltage drop values calculated from voltage and current measurement results and load currents and distribution facilities characteristics determined from power station and substation load records.

(3) Managing Pole-mounted Transformer Taps

An appropriate tap on a pole-mounted transformer is selected on the basis of a high voltage-line voltage drop value measured under heavy-load conditions. The figures shown in the following table are standard.

Table 2.3 - 8 Managing taps of pole-mounted transformer

High voltage-line voltage drop under heavy load	Pole-mounted transformer taps
160V or lower (6,900V ~ 6,750V)	6,750
160V to 310V (6,740V ~ 6,590V)	6,600
310V to 460V (6,590V ~ 6,440V)	6,450
460V or higher (6,440V or lower)	6,300

Note: The figures in parentheses represent voltage ranges

(4) Voltage Management of Low Voltage Distribution Lines

(a) Allowable voltage drop limit of low voltage distribution lines

Permissible voltage-drop limit values for low voltage lines (including service drop wires) are prescribed as shown in the table below. Voltage controls are implemented to maintain customer terminal voltages within these prescribed tolerance ranges.

If the average voltage drop measured on a low voltage line during any 30-minute period happens to be within the prescribed range (short voltage fluctuations such as flickers are not included), the line is judged to be satisfactory

Table 2.3 – 9 Allowable voltage drop limits

Circuit type	Allowable voltage drop
Lighting circuits (100V circuits)	6 V
Motor circuits (200V circuits)	20 V

(b) Low voltage-line voltage drop management method

To manage low voltage-line voltage drops, the voltage drop values of individual low voltage lines are calculated by the "KWH management" computer system from estimated current values. The values obtained for each transformer are outputted periodically. Those lines whose voltage drops exceed the permissible limits are beefed up.

(c) Supplementary explanation of KWH management:

KWH management is a method for calculating the voltage drop values of low voltage lines and service drop wires. In this method, the maximum load current is first estimated from KWH data by using an equation of the correlation between KWH and maximum current, statistically obtained from the results of lighting-power demand investigations. Then the voltage drops of low voltage lines and service drop wires are calculated from that maximum load current and those lines and wires' impedance values entered into the computer system beforehand.

In the project of physical improvement of distribution network, a formula of kWh-A correlation was calculated as shown below in an attempt.

kWh-A correlation formula

$$\mathbf{Y = 0.0319X^{0.7994}}$$

Y : maximum current of secondary side of distribution transformer (A)

X: Total consumption of all customer in peak month (kWh)

2.3.3 Load Control

(1) Managing Loads of High Voltage Distribution Lines

Managing loads of high voltage distribution lines is done in much the same way that voltage management of high voltage distribution lines is implemented (as discussed in subsection 2.3.2 (2) Voltage Management (Voltage Control) of High Voltage Distribution Lines by keeping tabs on the load currents of individual sections demarcated by switches.

(2) Managing Loads of Pole-mounted Transformers

The load management of pole-mounted transformers is implemented in much the same way that the voltage management of low voltage distribution lines is implemented (as discussed in subsection 2.3.2. (4) Voltage Management of Low Voltage Distribution Lines by keeping tabs on the load current of each transformer's secondary winding using the kWh management system.

Table 2.3 – 10 Overload limits with respect to the rated capacity of a pole-mounted transformer

		Overload limits
Transformers supply to lamp circuits		150%
Transformers supply to lamp and motor circuits	Common use	150%
	Exclusive use	150%
Transformers supply to motor circuits		150%

2.3.4 Operation of Distribution Network

(1) Manipulating Distribution Systems

(a) Commander for manipulating distribution systems

Switching to another distribution system because of a work-related service interruption or throwing switches on or off after recovering from a fault is done under the direction of the commander appointed in advance. Communication among those involved in carrying out the necessary work is also done under the instruction of the commander.

(b) Isolating trouble spots in a distribution system

In the event of a distribution line failure, it is necessary to isolate the faulty section from healthy sections, which are delimited by section switches. For this reason, a fault-recovery crew must go to the site of the fault without delay and manipulate the section switches there under the instruction of the commander. In addition, the crew members patrol the site to inspect the facilities there and pinpoint the fault.

To speed up the job of locating a fault spot with a minimum of manpower at the time of a successful post-fault circuit re-closure or when there is a high incidence of Vo, equipment that can detect sections momentarily affected by ground faults is installed in strategic places chiefly along long-haul distribution lines cutting through sub-prefectural areas.

(c) Switch manipulation

Manipulating line switches

Except in emergency situations such as fires or electric-shock accidents, line switches should be manipulated under the direction of the commander.

In principle, a single command for a single switch manipulation is the rule.

As a general rule, switches should be manipulated in accordance with the instructions given in the "High voltage switch manipulation instruction manual" when dead-line work is being performed on a distribution system.

(d) Manipulating high voltage customer's section switches

Whenever the need to manipulate a customer's section switch arises, electric utilities or the customer in need of switch manipulation should inform the other party.

And, as a general rule, the switch is actuated by the party who has the need for it. However, this does not apply in emergency situations.

(2) Operating Distribution Systems

(a) Operation under normal conditions

A system of sharing loads at substations using two or more banks is being implemented with the following in mind: optimizing load interchange in the event of a bank failure, equalizing the earth-capacitance values of distribution lines, optimally operating feeder voltage regulators, and enhancing bank utilization factors.

Using the load limit of a single feeder under normal conditions as a basis for judgment, the size of a service area powered by a single feeder is determined with consideration to a feeder's voltage drop, power loss and reserve capacity, along with the reserve capacity of another distribution line with which power can be interchanged if necessary. Some other factors must also be considered.

(b) Load interchange

For smooth load interchange among main transformer banks at a power station or substation or between distribution lines in the event of a failure or while working on distribution facilities, a plan must be prepared in advance. Load interchange should then be implemented according to the plan.

(3) Protective Devices of Distribution Systems

(a) Protective devices used at power stations and substations

Distribution lines devices to prevent overcurrent and ground-fault are employed at power stations and substations to protect distribution lines. In addition, these protection devices are used in conjunction with slow-acting automatic re-closing devices.

The ratings for protective relays must be determined after deliberations by those concerned, such as service offices and power offices, in accordance with the "Standards for Setting Protective Relay Parameters".

(i) Overcurrent protection

To detect short-circuit on distribution lines and to disconnect those faulty distribution lines, an over-current relay (OCRy) has been installed on the outlets of each distribution line. Although induction-type over-current relays were used in the past, they have by now been supplanted by their static counterparts because of the latter's advantages: they are small and require less operator intervention.

Determining the OCRy rating

An overcurrent relay rating is calculated from the maximum load current (Imax) of the distribution system under normal service conditions in which the overcurrent relay is intended to be used. The following equation is used, with consideration, however, to such factors as load characteristics and blind sections.

OCRy rating = (0.9~1.1) x IR

IR=Imax x [1.5 + 1.8/ e (Imax / 100)]

(ii) Ground-fault protection

To detect a possible ground fault on distribution lines and disconnect a faulty distribution line in the event of a ground fault, a directional ground-fault relay (DGRy) is installed on the outlets of each distribution line.

In addition, feeder ground selective relays (FGSRys) are installed on all banks from which three or more feeders are drawn out as a back-up for a DGRy to detect a possible persistent minimal current ground fault.

As with OCRys, conventional electromagnetic-type ground-fault relays (DGRys and OVGRys) are increasingly being supplanted by their static counterparts.

(iii) Re-closing method

Many high voltage distribution-line faults automatically recover after a brief service interruption. For this reason, using an automatic re-closing system in conjunction with automatic faulty-section-detecting equipment makes it possible to automatically isolate a possible faulty section and supply power to healthy sections. Since this automatic re-closing method contributes to the enhanced reliability of distribution lines, the method has been adopted for all distribution lines.

(b) Protective devices for installation along distribution lines

Sections where the short-circuit currents of distribution lines with respect to the preset tap values of overcurrent protective relays used at power stations or substations satisfy the following inequality are regarded as blind sections.

[Single phase short-circuit current] < [CT winding ratio x OCRy's preset tap value] x [Safety factor]

Blind-section breakers (fuse-type or relay-type breakers) are installed to protect these blind sections. However, if installing reactive over-current relays (negative phase over-current relays if blind sections exist only on single-phase line paths) proves more effective, those relays may be installed after deliberations among those concerned.

(c) Protective device for high voltage customers

Protective relays for a high voltage customer's facilities are set to the time constants as their standard breaking times in relation to the time constants of the relays used at the power stations and substations. These time constants are chosen to prevent a fault which has developed on the premises of the customer's high voltage facilities from affecting the distribution lines supplying the facilities.

2.3.5 Distribution Automation Systems

(1) Distribution Automation Systems

(a) History

At our company, since around 1967, we have been using an integrated system called the Substation and Distribution-system Total Operation. It is designed to collectively supervise and regulate our distribution substations and lines from our service offices (station), as an integral part of our automated system-operation system.

We also set up a triple-shift substation and distribution-system control room at each of our service offices in the prefectural capitals to supervise and control the distribution substations powering these prefectural capitals. (For details, refer to Subsection 5-6. "Substation and Distribution-system Total Operation.")

In order to cope with the ever-extending distribution lines and growing convergent traffic in capital cities, we installed remote supervisory and telecontrol equipment on the distribution lines supplying power to prefectural capitals (in the fiscal year 1967). This equipment is designed to actuate a pole-mounted switch by responding to a signal via a dedicated control line. In addition, we installed equipment controlled by distribution line programs, on some of the distribution lines (in the fiscal year 1969). This equipment is designed to sequentially control remote-controlled switches in the event of a fault. We have been using these two kinds of equipment to streamline the operation of our distribution facilities and to quickly repair faults.

In addition, service offices (stations) other than those in the prefectural capitals have also been operating the Substation and Distribution-system Total Operation, along with a time-sequential fault-section selection system. These were installed to enable them to isolate faulty sections in the event of a fault, so that power can be delivered to the other upstream sections still operating soundly.

To satisfy customers demanding higher service reliability in this day and age of a sophisticated information-intensive society, and to cope with the growing number of substations and, extending and converging distribution lines, we began phasing on a new-generation system called the "multi-function remote control system for distribution line switches" in fiscal year 1986. With completion slated for 1991, we had also been making efforts at comprehensively automating our distribution systems largely through the introduction of computer control techniques.

Based on the plan to realize centralization of Substation and Distribution-system in the prefectural capitals, the systems other than those in the prefectural capitals began to be improved in 1998. And those in the prefectural capitals began in 2000 and have been under improvement.

(b) Planning the distribution automation systems

(i) Introducing the multi-function remote control system for distribution line switches

➢ Remote control system for distribution line switches by pulse code signal transmission method.

Efforts were made to increase further the percentage of remote-controlled switches on the distribution lines that power the prefectural capitals (to 50 percent). This was conducted by introducing pulse-code remote control equipment designed to operate on dedicated communication lines introducing before. In addition to the ability to supervise and control pole-mounted switches, the equipment features various other functions and capabilities by virtue of its incorporated signal pulse-coding technology. These include the ability to automatically detect and isolate faulty sections and the ability to gather voltage and current information from places where pole-mounted switches are installed. (See Table 2.3-11 and Figures 2.3-7 and 2.3-8.)

➢ Remote control system for distribution line switches by zero-phase sequence voltage (V0) carrier signal transmission method.

We had decided to introduce a new-generation multi-function remote control system for distribution line switches for installation on distribution lines other than those for powering prefectural capitals. Since the distribution lines involved are long-haul ones, we had decided to employ a distribution line carrier (zero-phase sequence voltage carrier) signal transmission method because of its high cost-performance. We had gradually introduced this method to all distribution lines by fiscal year 1991 (and thus increase the percentage of remote-controlled switches to approximately 30%). (See Table 2.3-12 and Figures 2.3-9 and 2.3-10.)

(ii) Introduction of distribution system automating systems

We had decided to install a minicomputer to control distribution facilities at the four service offices in the prefectural capitals and the six major service offices (which compare favorably with the prefectural ones in scale). Working together with the remote control systems for the distribution line switches and the existing control systems for the substations, the minicomputer forms a system (distribution-system automating system) designed to implement automatic controls in the event of a fault or in the course of work. (See Figure 2.3-11 and Table 2.3-13.)

By introducing this system, it becomes possible to resume in 3 to 4 minutes the supply of power to healthy sections on service interruptions caused by distribution-line faults. It also becomes possible to cope with bank faults in just over 10 minuets and to speedily respond to customer inquiries by giving out information on service interruptions at the windows of the service offices concerned.

Furthermore, sensors were installed at the locations of remote-controlled switches to gather information about distribution-line voltages and currents. Using these sensors, the minicomputer automatically measures voltages and currents at predetermined times and analyzes and predicts voltage and loads. Based on its own processed data, the minicomputer automatically adjusts substation output voltages and optimally allocates loads among feeders in response to load fluctuations to increase the utilization factors of distribution lines and reduce power-distribution loses to a minimum.

(iii) Introduction of a distribution line fault information display system

At service offices not equipped with a minicomputer, a personal computer-based distribution-line fault information display system was installed. The system, designed to display such information as the conditions of the distribution system concerned and the details about a possible fault, is intended to provide those service offices with a means to quickly manipulate the distribution system and speedily respond to customer inquiries in the event of a fault.

Table 2.3 - 11 Major specifications of remote control system by pulse code signal transmission method

Item		Specification
Transmission paths		Dedicates cables
Transmission distance		Approx. 20km in cable length
Signal coding method		Pulse coding method
Signal frequency		1,500 plus and minus 200Hz or 1,200 plus and minus 200Hz
Transmission rate		600 bauds
Number of slaves		
	Number of slaves per master	750 units
	Maximum number of distribution systems per master	15 systems
	Number of slaves per distribution system	30 units
Supervision/control of automatic switches		-Supervising the position of each automatic switch -Controlling the switching of each automatic switch -Detecting a faulty section sectioned off by automatic section switches
Switch-selectable automatic switch functions		-Each automatic switch can be set to function as: -A normally closed switch -A time-delay sequentially-operated switch (Note 1) -A fast-acting switch (Note 2)
Electrical measurement of distribution lines		Voltage and current

Note ;

1 : Following a service interruption, this switch operates with a time lag when power resumes. Its time lag can be set to an arbitrary value within the following range: 5 * N (where N = 1 to 10)

2 : Following a service interruption, this switch operates instantaneously the moment power resumes.

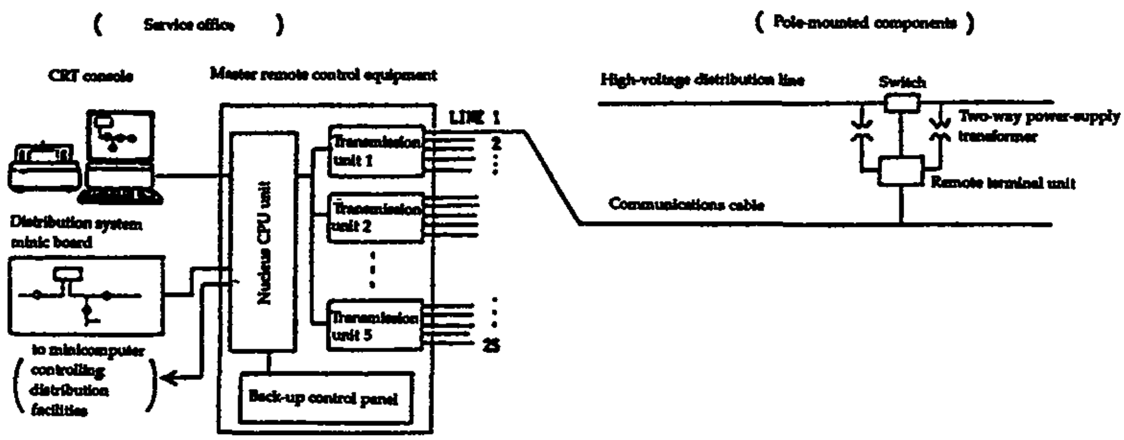
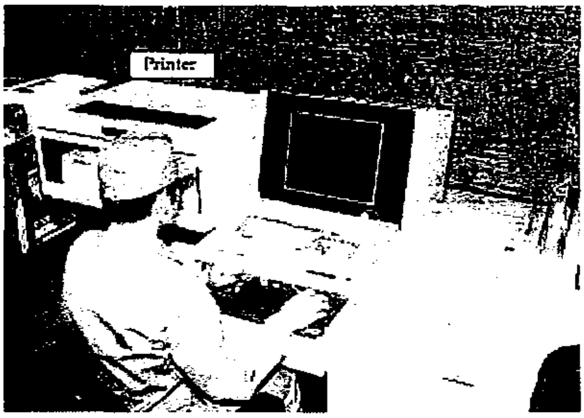
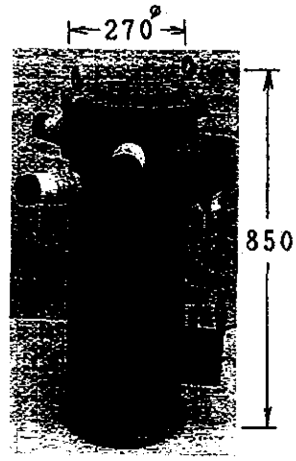


Figure 2.3 - 7 System configuration of pulse code method

(a) CRT console



(c) Two-way power supply trans former



(b) Remote terminal unit mounted on pole

(d) Remote terminal unit

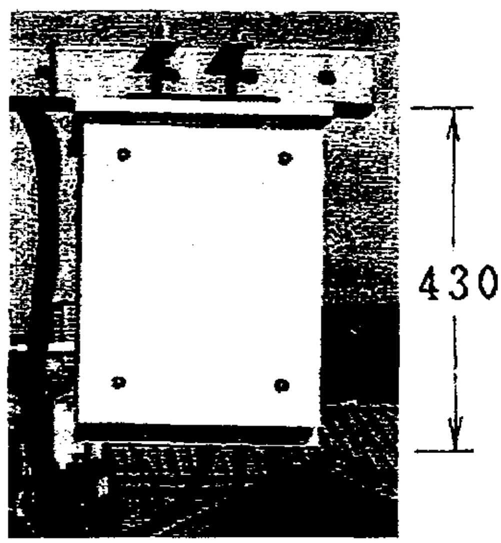


Figure 2.3 - 8 Remote control system by pulse code method

Table 2.3 - 12 Major specifications of remote control system by Vo carrier signal transmission method

Item		Specification
Transmission paths	Service office to substation	Communication cable
	Substation to remote terminal unit	High voltage distribution line
Transmission rate	Service office to substation	300 bauds
	Substation to remote terminal unit	60 bauds
Signal frequencies	Service office to substation	Downward transmission: 1,080+-100Hz Upwards transmission: 1,750+-100Hz
	Substation to remote terminal unit	60 Hz (synchronized to zero-phase voltage)
Signal transmission system		Distribution line carrier system (Vo carrier system)
Number of slaves	Number of slaves per master	1,000 units
	Number of substations	10 substations
	Number of banks	30 banks
Supervision/control of automatic switch		-Supervising the position of each automatic switch -Controlling the on/off switching of each automatic section -Detecting a faulty section sectioned off by automatic section switches. Switch-selectable automatic switch functions
Switch-selectable automatic switch functions		-Each automatic switch can be set to function as: -A normally closed switch -A time-delay sequentially operated switch (Note 1) -A fast-acting switch (Note 2)
Electrical measurement of distribution lines		Voltages and currents at remote terminal units are measured.

Notes 1: Following a service interruption, this switch operates with a certain time lag when power resumes. Its time lag can be set to an arbitrary value within the following range: 5 ¥ N (where N = 1 to 10)

2: Following a service interruption, this switch operates instantaneously the moment power resumes.

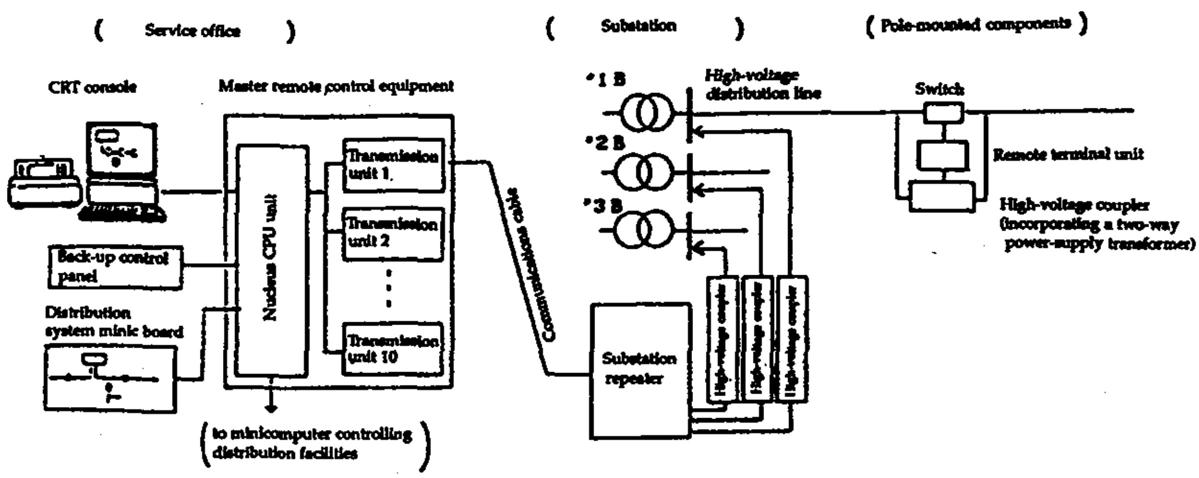
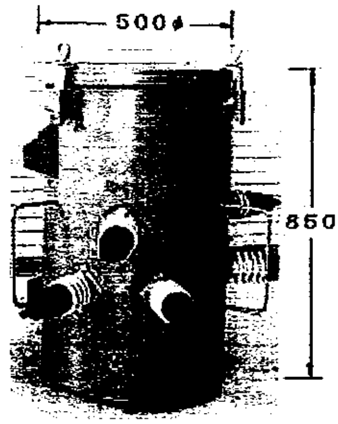


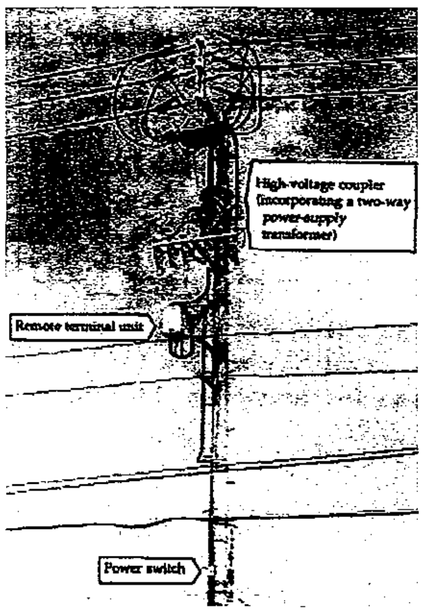
Figure 2.3 - 9 System configuration of Vo carrier method

(a) CRT consol

(c) High-voltage coupler (with a built-in two-way power –supply transformer)



(b) Remote terminal unit mounted on pole



(d) Remote terminal unit

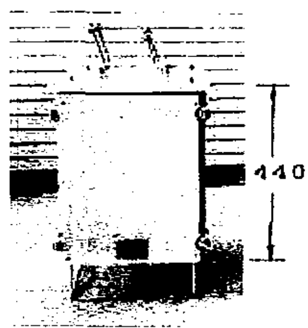
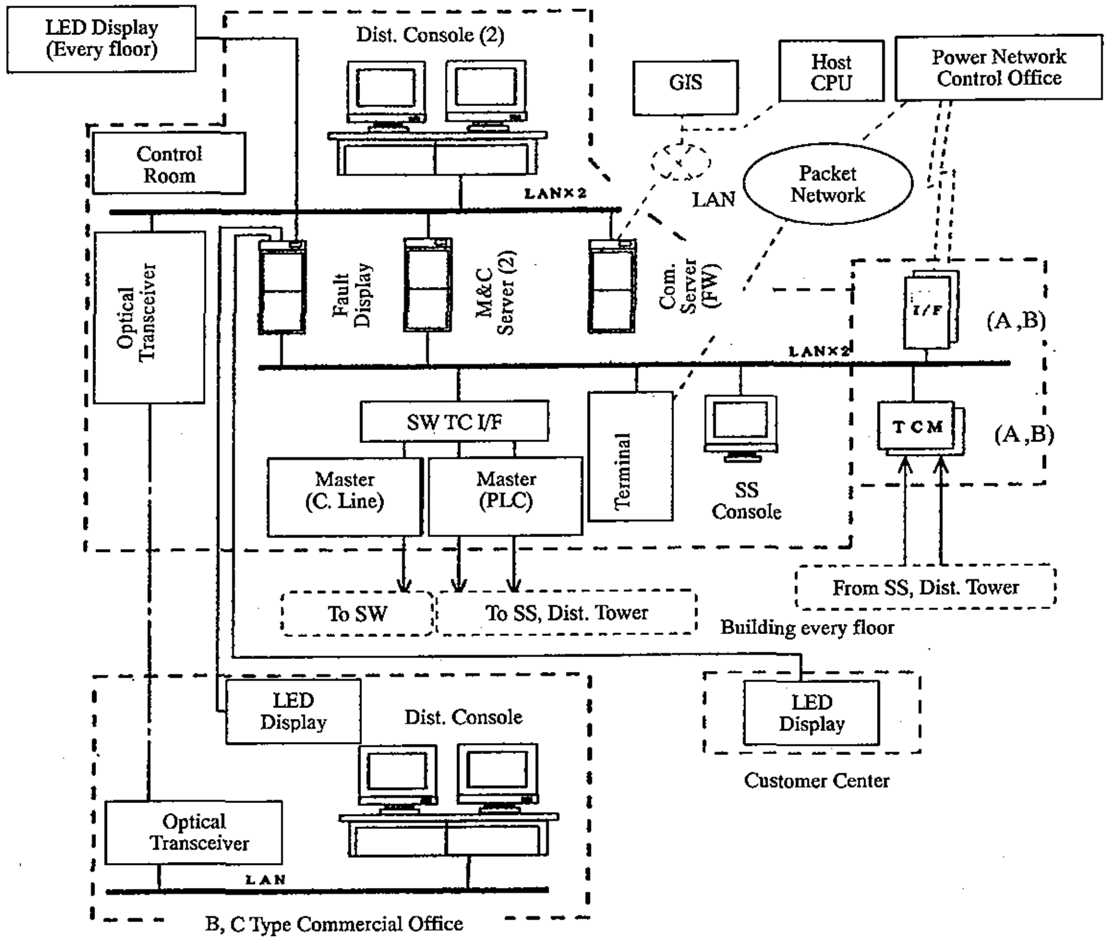


Figure 2.3 - 10 Remote control system by Vo carrier method

(New System Configuration)



(Existing System Configuration)

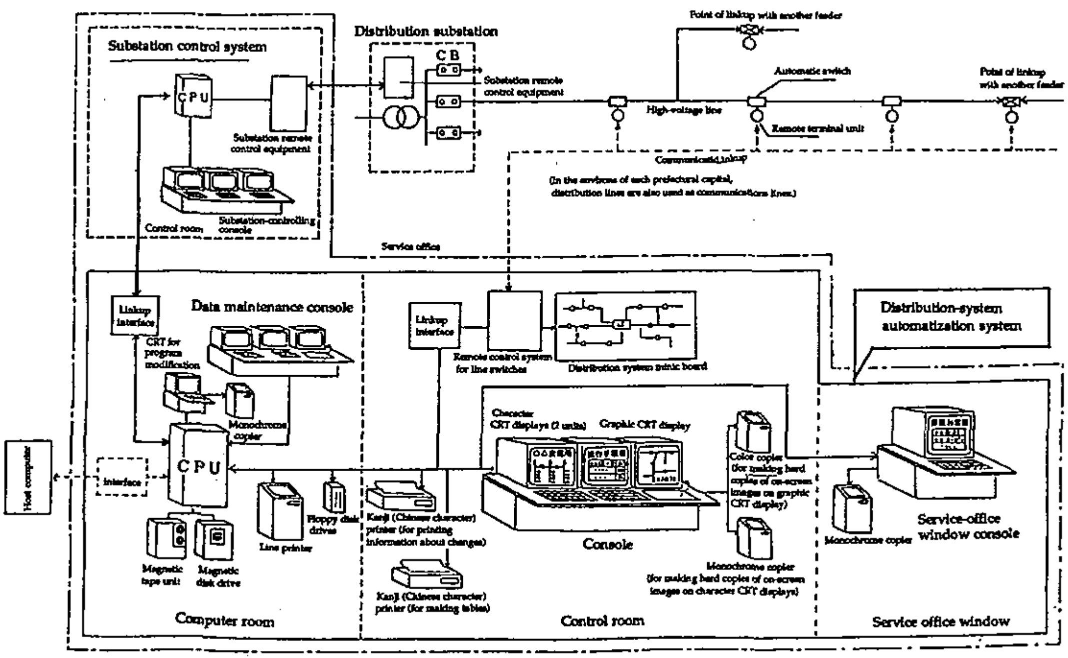


Figure 2.3 - 11 Fundamental configuration of distribution automation system in service offices of prefectural capital

Table 2.3 - 13 Specification of main equipment

<table>
<tr><th colspan="2"></th><th colspan="2">New System</th><th colspan="2">Old System (Mini Com.)</th></tr>
<tr><td rowspan="2">Main Equipment</td><td>Computer</td><td>Server for monitor and control
- Main memory: 1024MB
- HD: 54GB
- Speed: 240MHz
(OS: Unix)</td><td>2</td><td>Mini Com.
- Main memory: 16MB
- HD: 800MB
-Speed: 5.6Mips</td><td>1</td></tr>
<tr><td>Console</td><td>CRT (Table x 2sets)
PC (Client)
- Main memory: 3,072MB
- HD : 54.6GB
- Speed: 2.0GHz
(OS : Windows NT)</td><td>4
2</td><td>CRT (Table x 2 sets)</td><td>6</td></tr>
<tr><td rowspan="2">On-line Function</td><td>Alternate Supply Calculation</td><td colspan="2">Alternate supply procedure (2steps) and bank load transfer</td><td colspan="2">Alternate supply procedure (2 steps)</td></tr>
<tr><td>Automatic Alternate Supply Procedure in Fault</td><td colspan="2">Proceed 3 faults at same time</td><td colspan="2">Proceed 1 fault one by one</td></tr>
<tr><td rowspan="2">Maintenance Function</td><td>Revision of System Map</td><td colspan="2">Input data for every SW section on the geographical map</td><td colspan="2">Input data for pole to pole section on town map</td></tr>
<tr><td>Connection with Host Computer</td><td colspan="2">Automatically gather data of new equipment every week and renew automatically
(Be able to renew at a needed time)</td><td colspan="2">Manually revise and renew at a needed time</td></tr>
<tr><td colspan="2">Simulation Function</td><td colspan="2">Remote operation, system configuration, analysis and fault simulation on a mimic system without stop online function</td><td colspan="2">Only fault simulation with stop online function</td></tr>
<tr><td colspan="2">Connection with Business System</td><td colspan="2">Transfer outage information to reception centers and GIS</td><td colspan="2">――――</td></tr>
</table>

(c) Extent of automating

The following tables show how we have made progress in terms of automating as of the end of the fiscal year 2000.

Table 2.3 - 14 Multi-function remote control system for distribution line switches

Item	Number of remote-controlled switches as of the end of FY 2000	Rate of remote control
Prefectural capitals (Pulse-code method)	5,844 units	
Other areas (Vo carrier method)	10,283 units	
Total	16,127 units	33 %

(d) Future direction

As for remote-controlled switch, those will be extended according to the distribution line's expansion. The existing mini computer system of the branch offices in prefectural capitals will be replaced to a open distributed computer system.

Table 2.3 - 15 Outline of distribution automation system (as of the end of 2005)

System	System for Prefectural Capitals		System for Large City	System for Ordinary Area
Number	4		8	15
Transmission Method	Pulse code	V_0 carrier	V_0 carrier	V_0 carrier
Transmission Line	Metallic wire	PLC	PLC	PLC
System Configuration	Operator console (Windows NT PC) x 2 Server for monitor and control (Unix) x 2		EWS x 2	EWS
Main Function	* Automatic remote control - Automatic alternate supply in a fault - Preparing operation manual for remote-control switch * Simulation of a fault * Automatic control of voltage on a distribution feeder at substation		* Automatic entry procedure of fault and working * Simulation of fault	

(2) Other Automatization Systems for Operating Distribution Systems

(a) Introducing compact-type single circuit breakers for large-to –medium-capacity distribution lines

Since around 1965, we have been installing re-closers (some of them are equipped with an answer-back capability) along branch distribution lines for important loads, as well as halfway along long-haul distribution lines to cut off a faulty section before a substation circuit breaker can open the circuit. This means service interruptions can be confined within the smallest number of serious possible in the event of a fault.

We have developed new compact-type circuit breakers intended for installation on large-to-medium-capacity distribution lines. This equipment is capable of breaking a single fault-redden circuit only in the event of a fault, and it recluses the circuit later on. Furthermore, by working together with the new generation's remote distribution-line-switch control system, this equipment makes it possible to monitor the conditions of the distribution lines from the service office. Equipment installation began in fiscal year 1988, and we intend to gradually equip all of our large-to medium-capacity distribution lines with this equipment (By the end of fiscal year 1988, the equipment had been installed on three feeders).

(b) Installing equipment to detect sections with temporary ground faults

In fiscal year 1981, we began installing two or more units of equipment to detect sections with temporary ground faults on each long-haul distribution line running through sub-prefectural areas. This equipment can detect a momentary ground faults in lower reaches of the distribution line and can locally display information about the fault, which should save labor and speed up patrol inspections conducted in the event of a fault (By the end of fiscal 1988, a total of 930 units of the equipment had been installed).

In addition, in fiscal year 1988, we began installing data-transmission equipment designed to work together with the new-generation remote distribution-line-switch control system. This equipment makes it possible to keep tabs on information display on-site in real time at the service office concerned.

(c) Improving voltage regulation by SVRs (automatic voltage regulators)

Since around 1960, we began installing SVRs as a cost-effective means of improving the voltage regulation of long-haul distribution lines running through sub-prefectural areas. In the beginning, we introduced V-connection types, but we came to realize that they were problematic in terms of their ability to protect against ground faults in the distribution lines. For this reason, only star-connection types are currently being used. Standard SVRs are of step-up types featuring five primary taps (6,300 V to 6,900 V) and a secondary voltage rating of 6,900 V (a voltage step-up range of 600 V). In addition, various other kinds of SVRs are being used. These include SVRs featuring step-up ranges wider than 600 V, SVRs with both voltage step-up and step-down capabilities, SVRs with the capability to automatically send power in the opposite direction, and SVRs with the ability to switch over to their predetermined tap in the event of a service interruption, before resuming operation.

2.3.6 Substation and Distribution System Total Operation Network

(1) Distribution Substation Supervision / Control System

The Substation and Distribution System Total Operation Network has been adopted by our company to enable our service offices (stations) to collectively operate the substations (distribution substations or distribution facilities of power station s and substations supervised and controlled by power system control stations) and distribution lines under their aegis with efficiency. The system's methods of operation can be classed under the following categories according to service office types.

(a) At the service offices serving the prefectural capitals

At Substation and Distribution-system operation center, monitor and control one of the following items:

- ✓ Monitoring and control of substation and distribution lines
- ✓ Monitoring and control of distribution equipments at power station or substation and distribution lines (Power transmission system control offices are in charge of monitoring and control for extra high voltage side and the secondary side of main transformer)

(b) At service offices serving ordinary areas

At the branch offices or commercial offices in other than in prefectural capitals, monitor and control one of the following items:

- ✓ Monitoring and control of distribution equipments at power station or substation and distribution lines (Power transmission system control offices are in charge of monitoring and control for extra high voltage side and the secondary side of main transformer)
- ✓ Monitoring and control of substation and distribution lines including the extra high voltage side and the secondary side of main transformer

(2) Jobs Involved in the Substation and Distribution-System Total Operation Network

Jobs performed at each type of service office (station) are discussed below.

The (66kV) facilities on the extra-high voltage side of each substation are under the direction of the power system control station (the Power-System Operation Division).

(a) Service offices serving the prefectural capitals

- ✓ Issuing instructions for dispatching loads and manipulating substation equipment; receiving and conveying information to those who need it
- ✓ Issuing instructions on manipulating distribution facilities (such as instructions to actuate manual or automatic switches installed in series with high voltage distribution lines) and keeping in touch with those concerned
- ✓ Supervising the operating conditions of the substations and distribution lines under their charge and controlling those facilities
- ✓ Conducting daily inspection and maintenance on facilities or equipment installed on the premises of the transmission and distribution network control room under their charge
- ✓ Preparing reference materials related to expanding/improving substation and distribution system control room facilities, and implementing improvements in operating facilities
- ✓ Keeping records and preparing reports

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(b) Serving offices (stations) serving ordinary areas

- ✓ Supervising the operating conditions of each substation
- ✓ Controlling and manipulating the following : Circuit breakers (CBs) and line switches (LSs) on the extra-high voltage side of each substation, CBs on the secondary side of each main transformer bank, and bus-tie CBs
- ✓ Controlling/manipulating distribution-line equipment
- ✓ Running daily inspections on control equipment installed inside the service office (station)
- ✓ Checking the extent of possible damage at the site in the event of a fault at a substation ; helping to take measurements that are required for recovering from fault
- ✓ Conducting daily simple patrol inspections on facilities subject to intermittent supervision/control at each substation
- ✓ Recording the required information about substation-equipment manipulations made under normal service conditions as well as in the event of a fault
- ✓ Cooperating in gathering records on distribution lines
- ✓ Getting in touch with those concerned in the event of a fault
- ✓ (The jobs of supervising/controlling facilities and keeping records at distribution-system control offices and the like are, however, excluded.)

(3) Supervision and Control

Table 2.3 – 16 Type of supervision and control

Type	Definition (Provisions governing power stations and substations)
Continuous remote supervision and control	Technical staff stationed at a substation control center supervises the substation and manipulates its equipment.
Intermittent remote supervision and control	Technical staff goes to a substation control center a predetermined number of times a day and supervises and controls its equipment.
Intermittent supervision and control	Technical staff goes to a substation a predetermined number of times a day to supervise its operation, conduct patrol inspections and manipulate its equipment.
Simplified supervision	Technical staff goes to a substation as required. There, the staff supervises the substation's operation, conducts patrol inspections, and manipulates the equipment.

(4) Implementation Rate (as of the end of fiscal 2000)

(a) Percentage of service offices and stations involved in implementing the substation and distribution system Total operation network

Table 2.3 - 17 Rate of operation in substation and distribution-system (service office and stations)

		Total number of service offices-stations (a)	Number of service offices-stations integrated in Network (b)	Percentage of service offices and stations integrated in Network (b/a)
Service offices in	Prefectural capitals	4	4	100%
	Ordinary areas	39	33	85%
	Total	43	37	86%
Customer center at local office		57	1	2%
Total		100	38	38%

(b) Percentage of power stations and substations integrated in the substation and distribution system total operation network

Table 2.3 - 18 Rate of operation in substation and distribution system (power stations and substations)

	Number of PSSs (a)	Number of PSSs integrated in the Network (b)	Percentage of PSSs integrated in the Network (b/a)
Distribution SS	188	180	100%
Direct-distribution PS	31	22	71%
Total	211	201	96%

(c) Image map of monitoring and control for distribution substation

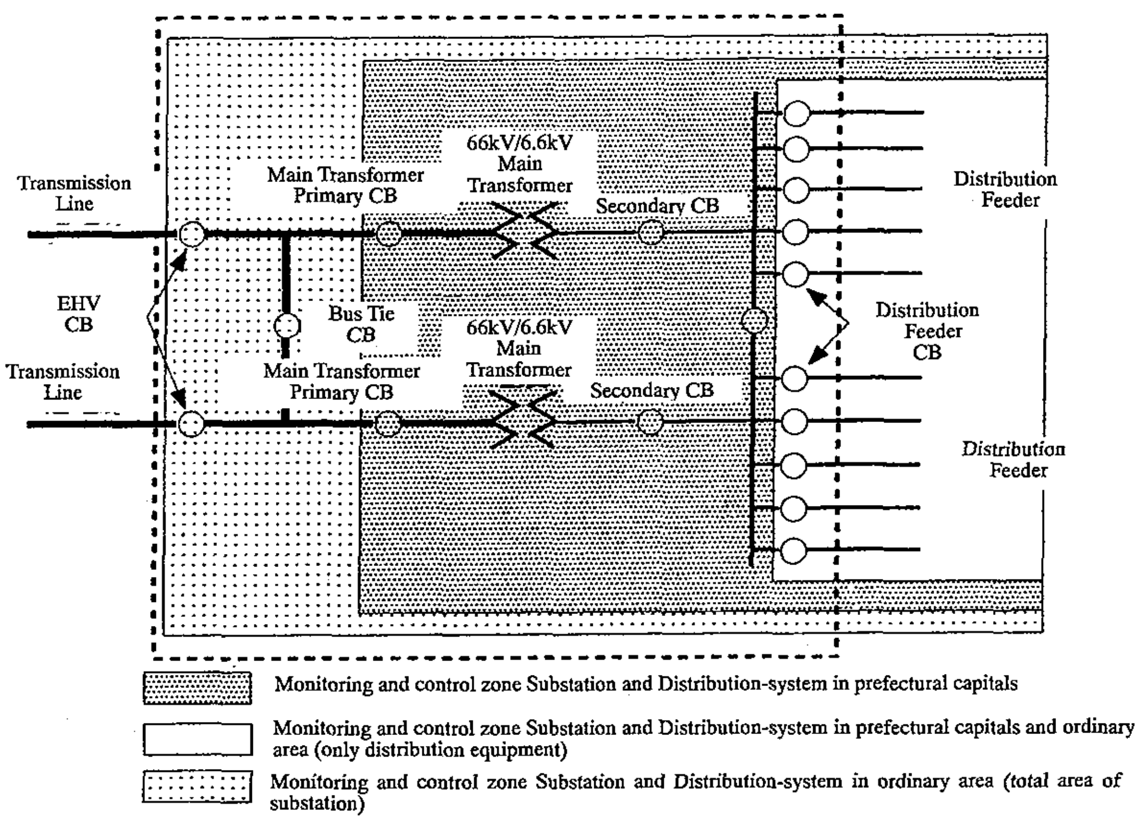

Figure 2.3 - 12 *Chart illustrating the scope supervision and control of distribution substations implemented by different types of service offices*

2.3.7 Patrol, Inspection and Measurement

In order to maintain the capabilities and functions of distribution facilities (including 22 kV distribution facilities) and to prevent interference with other facilities, secure safety, and prevent faults from happening, electric utilities conduct patrol, inspection and measurement as discussed below.

(1) Patrol

(a) Periodic patrol

Periodic patrol is conducted chiefly to make sure that distribution lines, including service drop wires are not being interfered with by neighboring objects, and are maintaining safe distances from those objects. If an irregularity is spotted during a visual inspection from the ground, necessary corrective measures should be taken on the spot, or instructions to remedy the situation should be issued. The areas subject to patrol and the frequency of patrol are determined with consideration to the conditions of the facilities and the characteristics of the areas concerned.

Table 2.3 – 19 Frequencies of periodic patrol (example)

Area type	Frequency
Areas with many environmental changes	Every 2 months
Areas where it is frequently necessary to cut trees	Once or twice a year
Areas other than those listed above	Every 2 years

(b) Ad hoc patrol

An ad hoc patrol is carried out when there is a need to supplement a periodical patrol or after the irregularity has been detected.

Table 2.3 - 20 Frequencies of ad hoc patrol

Inducements to ad hoc patrol inspections	Frequency
Before and after the typhoon season the thunderstorm season and the snow season. After an earthquake.	Whenever needs occur
In the event of a fault ending with a successful re-closure or when there is a high incidence of Vo, an ad hoc inspection is carried out to determine the cause	Whenever needs occur
Carp streamers, festival flags, kites, etc.	Whenever needs occur
To check the condition of protective duct lines and so on	Whenever needs occur
Others	Whenever needs occur

(2) Inspection

Inspection is conducted largely to see whether the functions and capabilities of electrical facilities or equipment are in order. If something is wrong, the necessary corrective measures should be taken on the spot or instructions to remedy it should be issued. Overhead distribution lines, underground distribution lines and automatic equipment are checked periodically as scheduled in the following table.

Table 2.3 – 21 Frequencies and method of inspection

		Frequency	Inspection method
Overhead distribution lines		Every 5 years	● Electrical facilities are visually checked for signs of deterioration and physical damage as well as for interference from other objects in the vicinity. ● Wooden poles are checked by percussion and by sticking them with a probe for signs of decay.
Underground distribution lines		Every 5 years	● Cables, duct lines, and equipment are visually *inspected for signs of deterioration and physical* damage. The environmental conditions along their routes are also checked. ● Manholes are checked for signs of damage, gas or water leakage.
Equipment	Functional inspection	Automatic voltage regulators Every 2 years	● The tap changer and control circuit are checked on the pole to see whether they function properly. ● Visually checked through inspection window
	Precision inspection	Automatic voltage regulators ● That to which ten years or more passed after manufacture, and the number of tap changes amounted to 100,000 times ● That to which the number of tap changes amounted to 200,000 times ● A check result of operation is poor	● Need for an overhaul

(3) *Measurement*

Measurement is conducted on lightning arresters, the secondary windings of transformers and so forth, to determine whether they have appropriate grounding resistance values. Cables are measured to determine whether their insulation resistance is appropriate. Measurement is carried out as scheduled in the following table.

(a) Grounding resistance measurement

Measurement is taken with an earth resistance tester. If a transformer is connected to an overhead common ground wire, it is cut off from this overhead ground wire first, and the *grounding resistance values of its grounding electrodes are determined one by one. Then, the* transformer's combined grounding resistance value is calculated from the measurement results.

Table 2.3 - 22 Frequencies of grounding resistance measurement and their limits

Classification of distribution facilities	Frequency	Limit
Lightning arresters	Every 5 years	30 ohms
The outer casings of high voltage equipment mounted on poles assembled with steel pipes, panzer masts (assembled with steel strips), composite concrete poles, and steel towers		10 ohms

(b) Measuring Cable insulation Resistance

High voltage cables are subjected to DC-withstand voltage tests to measure their leakage currents. Their insulation resistance values are then calculated from the measurement results.

For low voltage cables, a 500V megohmmeter is used to measure the insulation resistance between their conductors as well as between their conductors and the ground.

Table 2.3 - 23 Frequencies of measuring cable insulation resistance

Cable type		Frequency
High voltage cables	Equipment in which always and opposite direction power transmission is impossible	Every 5 to 15 years
	Equipment in which always and opposite direction power transmission is possible	Whenever needs occur
Low voltage cables (underground)		Whenever needs occur

(4) Measures to be Taken if an Irregularity Is Spotted

If an irregularity is spotted in the course of a patrol inspection, a checkup, or a measurement, it is dealt with as discussed below.

- If remedying a spotted irregularity falls into the category of individual work as defined in the "Distribution-Facilities Work Safety Standards," and if the patrol inspection crew who spotted the irregularity considers that they can fix it right on the spot with their own equipment, *it should be fixed by them immediately.*
- If an irregularity cannot be remedied on the spot or if a stop-gap measure was taken previously to fix it temporarily, a work slip is issued.
- In places like construction sites where there are safety hazards, appropriate safety measures are taken - for example, "Danger" or "Off Limits" signs are put up.
- Repair work slips are issued for those wooden poles that fail to measure up to the safety factors shown in the following table.

Table 2.3 - 24 Safety factors of wooden poles

Type	High voltage line wooden poles	Low voltage line wooden poles
• Wooden poles which need safety enhancement specially • Wooden poles with long-span work • Wooden poles shared by telecommunication	1.5	1.5
Others	1.3	1.2

(5) Managing Patrol, Inspection, Measurement and Repair

(a) Planning patrol, inspection, and measurement

While deciding upon patrol and inspection, measurement plans at the beginning of a fiscal year, the number of plans is inputted to a preservation management system.

(b) Keeping track of individual patrol inspections, checkups and measurement projects

The progress of the above plan is kept track of with respect to the total project count by entering the number of individual patrol inspections, checkups and measurement projects executed so far into the distribution-facilities maintenance management system.

(c) Keeping track of individual repair projects

Immediately after discovering a poor part, after it designs repair, it creates a managed ledger and manages the repair situation of a poor part.

Irregularities are classified into the following categories in order of repair priority.

Table 2.3 - 25 Repair priority of irregularities

Priority classification	Judgment criteria	Example cases
Top priority	Those irregularities highly likely to fatally electrocute or cause injuries from electric shocks, fires or faults grave enough to cause power interruption if left unfixed and are therefore in need of urgent repair.	- A live electrical wire touching a building - Height of electrical wire from ground is insufficient - A damaged high voltage insulator or bushing - A support in danger of falling to the ground because of a hole dug very nearby - A dropping stay wire that has come off of its joint
High priority	Those irregularities caused by interference from foreign objects that are either too close to the electrical facilities or that have somehow gotten into the facilities that need to be attended to within a month.	- Distribution lines strung too close to a tree. - Facilities whose grounding resistance is too high - Wooden poles with insufficient safety factors - Damaged low voltage insulators
Low priority	High priority irregularities that have received stop-gap measures; irregularities inside electrical facilities or equipment in need of remedial attention within a year.	- Wooden poles with attached reinforcing metal parts - Equipments housings that are extremely rusty

2.3.8 Customer Services

Electrical facilities installed on customer premises are divided into those to be managed by qualified electrical-facilities engineers (such as non-utility electrical facilities) and others. When it comes to the latter (called customer facilities), it is dictated by the Electric Industry Law that electric power companies must inform their customers whenever repairs or modifications to customer facilities are necessary.

(1) Completion Survey

When a customer installs new electrical facilities or equipment or modifies or repairs a portion of his facilities or equipment, a completion survey is conducted on the whole or a portion of the facilities. A survey includes measuring the insulation resistance of interior wiring and the grounding resistance of grounding-type receptacles and inspecting interior wiring and load equipment visually.

(2) Periodic Survey

Periodic surveys are conducted on existing customer facilities. A periodic survey consists of measuring the insulation resistance of interior wiring and inspecting electrical wiring and equipment visually.

The ordinary customers, such as a residence and a store---------------- Every 4years

The specific customers, such as a pool, a public bathhouse, a school, and a hospital--- Once a year

(3) Re-Survey

If an irregularity is spotted during a survey of a customer's facilities, the cause of the irregularity is traced, and we ask the customer to make the necessary repairs on the facilities to eliminate the cause. After the repairs have been done, a re-survey is conducted on the facility in much the same fashion as the initial survey.

(4) Recommending Safe Electrical Wiring to Customers

The company has established guidelines called the "Recommended Safe Electrical Wiring Standards" so customers can use their interior wiring safely and efficiently. If any inadequacy is detected in the interior wiring of a customer's facilities, the inadequacy is made known to the customer so that customer will hopefully make appropriate repairs.

(5) The Measure for Technical Ssupport activities

In order to have the customer be further satisfied, technical support activities are promoted vigorously.

(a) The outline of the activities

In order for an electric utility to have electricity successfully bought by the customers, it is important to strengthen confidence in each other.

- ✓ For this reason, the solution services for the large customers are developed positively.
- ✓ The main flow of technical support activities is as follows:
- ✓ Employees of an electric power company visit a large quantity customer.
- ✓ They grasp troubles or difficulties the customer faces.
- ✓ The company examine whether it can provide solutions to the problems.
- ✓ The company proposes solution services for solving the customer's problems.
- ✓ As for the case of a charged menu, the customer, a group company, etc. conclude an individual contract for the service.

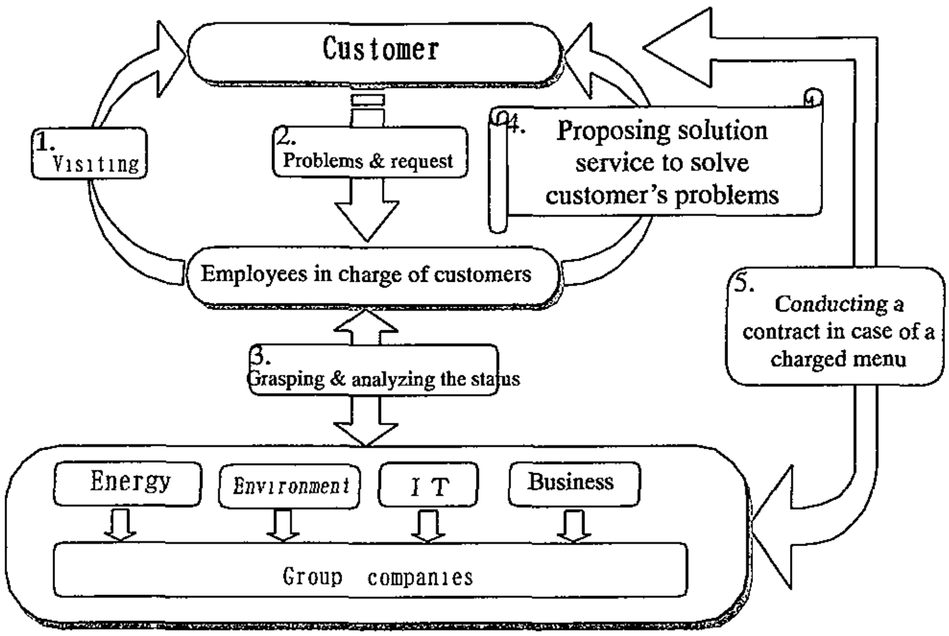

Figure 2.3 - 13 The main flow of technical support activities

(b) The contents of consulting

The main contents of consulting are as follows.

- ✓ Consulting about installation of UPS (uninterruptible power supply) so that inverter application apparatuses or computers of customers do not stop due to instantaneous voltage degradation, which occurs, for example, at the time of a lightning.
- ✓ Energy-saving consulting including proposals of more efficient use of energy.
- ✓ Degradation diagnosis of equipment of the customer.