9.8 Underground Distribution System Facilities

9.8.1 Underground Substation

(1) Generally, the standard substation type to be adopted is an outdoor type substation with the lowest substation construction cost including the cost of subtransmission and distribution lines connected thereto. In the case where it is necessary to construct substation at a site adjacent to an overpopulated urban area or busy street where electric power demand is concentrated, it is not easy to acquire the land for substation and the land price becomes extraordinarily high in such an overpopulated urban area. Moreover, it becomes difficult to construct any outdoor type substation and thereby it becomes essential to adopt the underground substation. However, the construction cost of the underground substation is much higher than that of other types of substations. Prior to adoption of this type, an optimum site should be selected after sufficient overall economic comparative study taking into account the long term system reliability, demand and supply, construction cost of subtransmission and distribution lines as well.

(2) Since the cost of civil, architectural and structural work for constructing underground rooms is very high, the construction cost of underground substation becomes much higher than that of the other type substations. In the case of TEPCO, for example, the building construction cost occupies as much as nearly twice the equipment/installation cost as presented below for reference:

275kV, 2 x 300MVA substation		66kV, 2 x 20MVA substation	
Equipment/installation cost	Construction cost	Equipment/installation Cost	Construction cost
38%	62%	34%	66%

Remarks:

1) The building construction cost refers to the cost of the building occupied by the power company or the portion of the building occupied by the power company according to a partial ownership agreement/contract.
2) The geological conditions largely affecting the building construction

cost are based on the average values in Tokyo.

3) Scale of 275 kV substation: Underground four stories (Total floor area: 16,000 m²)

4) Scale of 66 kV substation: Underground two stories (Total floor area: 700 m²)

On the other hand, the land price for substation around some of the busy streets of Bangkok has risen to be equivalent to the construction cost of substation (excluding the land cost) in maximum. Therefore, it is expected to become economically feasible to adopt underground type substation in the city center of Bangkok in the near future.

Calculation example:

Land price: 125,000(Baht/m²) x 1,320 m² = 165 million Baht

Substation construction cost:

a) Equipment and material cost : 136 million Baht

b) Civil structure & installation cost: 31 million Baht

Total: 167 million Baht

Note: The value of land price for Satorn Substation is quoted as a unit land price, and the substation construction cost is quoted from the standard unit price of 115/24 kV, 2 x 60 MVA substation for FY 1994.

(3) Prior to adopting the underground substation, the following items should be investigated and studied, and the substation be constructed at a site satisfying these various conditions.

- In case it is difficult a space solely for substation construction, but it is possible to acquire a lease or partial ownership of underground rent room of building and under a park, acquire a space sufficient for smooth installation and operation of substation (space for carrying-in and out of equipment, installation and maintenance of cooling and ventilation equipment without trouble). In addition to the above, the following requirements are satisfied:
    - The construction plan of the aboveground portion of office, shopping center or residence building related to room lease or

partial ownership should comply with the construction period and schedule of the substation.

- The contract conditions of the period and scope of rent room and other conditions should be suitable conditions judging from commonsense.

- In case the land price is so high and it is economically advantageous to promote effective utilization of aboveground portion by installing substation under the ground (Example: Offices related to load dispatching, control center, employees' dormitory and welfare facilities of power company).
- It should be possible for the power company to take part in regional redevelopment (for development of demand and reduction of construction cost).
- Others
  - The common interest with the upper building owner should be ensured by construction of substation (Utilization of exhaust heat from substation increase in the rate of building volume to lot).
  - The upper building construction should be free from any opposition or any factor causing legal problem from the surrounding community.
  - To reduce the high underground cable installation cost equivalent to the underground substation construction cost, the substation should be located adjacent to a main road.

(4) Since the construction cost of underground type substation is higher than that of the other substation types, it is essential to reduce the construction cost after sufficiently studying the following items which would affect the construction cost:

- Form of the rights of land and aboveground building (owned, leased, etc.).
- Utilization pattern of upper building (office of the power company, residence, part, hotel, office, etc.).
- Utilization pattern of aboveground portion of lot (large machine hatch position, maintenance space, etc.).
- Restrictions, miscellaneous countermeasures and equipment required

based on the city planning law, building standard law, fire regulations and other laws and regulations.

- Geological conditions (scale of continuous wall, specifications and quantity of piles, etc.).
- Substation connection, number of subtransmission and distribution lines.
- Transformer capacity.
- Breakdown and specifications of equipment (whether or not to adopt GIS and other reduced size equipment in particular).
- Depth of incoming lines, direction and number of circuits of subtransmission and distribution lines connected to underground building.
- Access road for construction work (possibility of access of large scale vehicles and equipment over a long period).
- Location and scale of connecting road.
  (determination of the scale of cable conduit work in addition to the above)
- Cooling tower installation position.
- Protection, monitor and control system.
- Countermeasures for protection from flooding and water leakage.

(5) Since the ground is soft and the ground water level is high in the Bangkok metropolitan area, the design and execution of civil, architectural and structural work for underground room will require extensive and high level knowhow and technology. Therefore, it is impossible to describe the design and construction methods of underground substation in sufficient detail because of limited space of this report. In this report, however, it is recommended to construct a pilot scale underground substation in as early period as possible and accumulate data and information to contribute for dissemination of such an underground type substation in the future.

(6) Presented in Appendix 9.8-1 is an example of layout design in case the underground type is to be adopted for the typical distribution substation (115/24 kV, 3 x 60 MVA) of MEA.

9.8.2 Utility Tunnel

(1) Definition of utility tunnel

The utility tunnel refers to a facility provided under a road by a road manager to accommodate public facilities (cable, gas pipe, water and sewage pipes) by utilities enterprises (telecommunications, electric power, gas, water supply, sewage and other facilities).

(2) Kinds of utility tunnel

The utility tunnel is classified into the following three kinds and its scale varies depending upon its purpose of use.

1) Utility tunnel: It is provided under the car lane of road and used mainly to accommodate trunk lines of public facilities with partition walls (10 m width x 3 m height in general).

2) Cable box system: It is provided under the walkway section of road and used mainly to accommodate public facilities for big consumers within a same space (1.5 m width x 3 m height in general).

3) Common cable box: It is provided under the walkway section of road and used to accommodate the facilities furnished to distribution pole (0.8 m width x 1.5 m height in general).

A concept of utility tunnel is presented in Fig. 9.8-1 and the installation sections by the respective kinds in Fig. 9.8-2.

(3) Objectives of utility tunnel

The major objectives of utility tunnel are to reduce traffic congestion caused by repeated excavation of road by utilities enterprises, promote effective utilization of the space under roads and eliminate disturbances to living environment of the residents along the route.

The other advantages are as follows, for example:

1) Acquisition of walking space by eliminating electric poles.
2) Improvement of urban scenery by eliminating electric poles and wires.
3) Elimination of disturbances to fire fighting activities by eliminating electric poles and wires.
4) Prevention of collapse of electric poles, breaking of wires and other troubles at the time of natural disasters.

(4) Construction of utility tunnel

A utility tunnel is constructed by the road manager according to a utility tunnel construction plan to be formulated by the road manager (It is essential that two public utilities enterprises among such enterprises should apply for participation in the project).

(5) Cost to be born for utility tunnel construction

Any enterprise intending to occupy a part of utility tunnel is required to bear a part of the cost required for construction of such a utility tunnel. The cost to be born is equivalent to the estimated cost required in case of constructing the underground structure independently by the respective enterprises.

(6) Cost to be born for management of utility tunnel

Any person occupying the utility tunnel should bear the cost required for reconstruction, maintenance, repair, restoration from disaster and management of the utility tunnel.

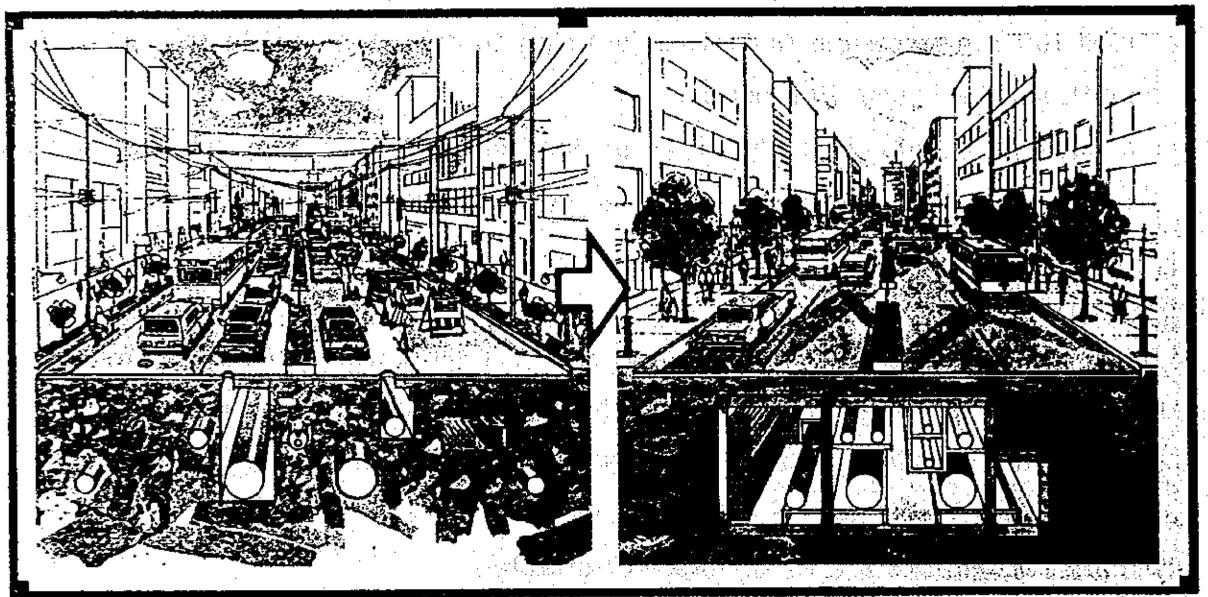
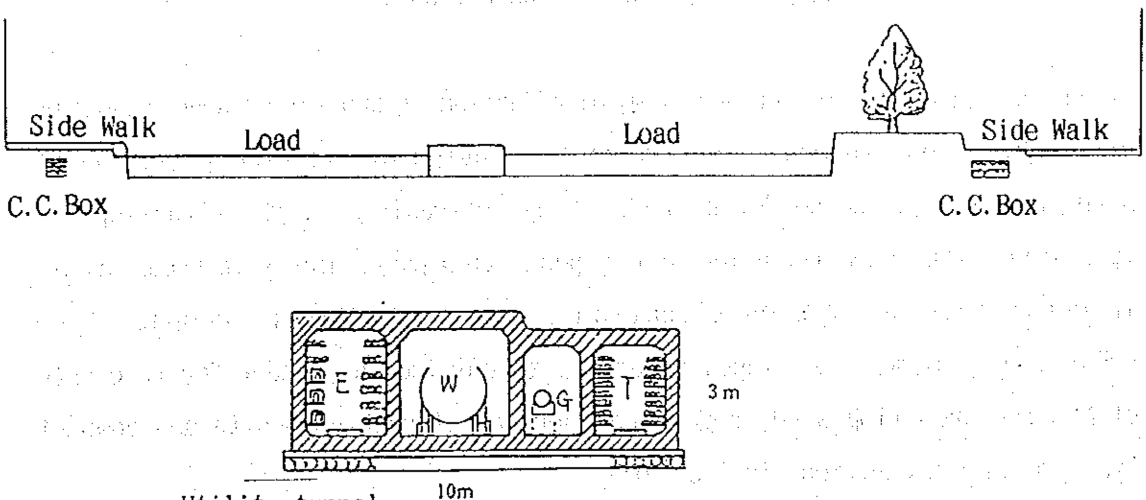
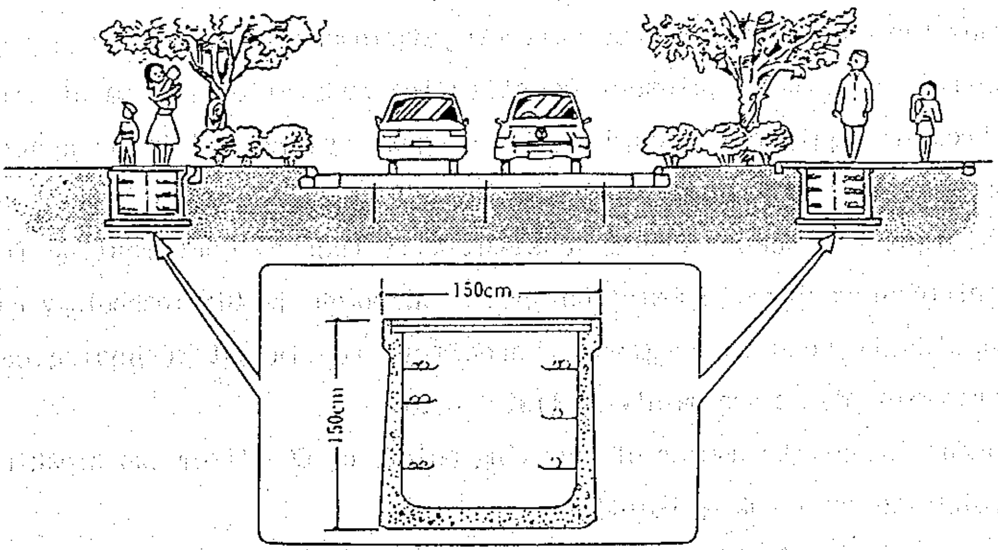


Fig. 9.8-1 Concept of utility tunnel

1. Utility Tunnel



2. Cable Box



3. Common Cable Box (C.C.Box)

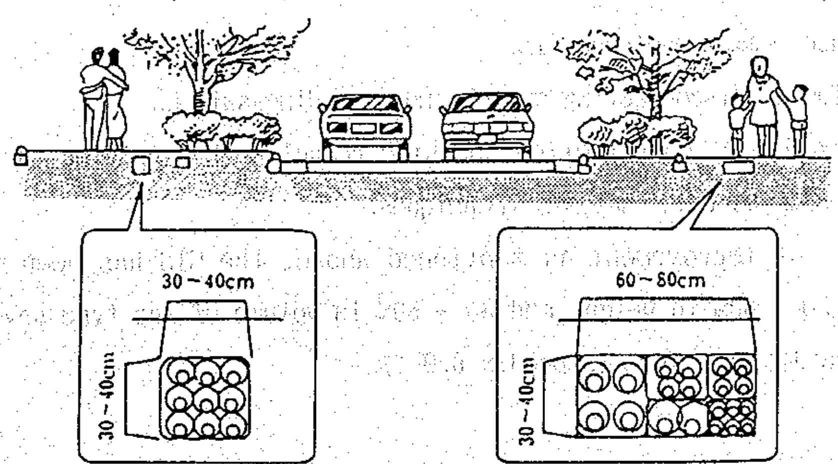


Fig.9.8-2 Installation sections by the respective kinds

9.9 Application of Advanced Technology for Distribution System

9.9.1 Composite and Compact Type Substation Equipment

It has been demanded to further promote reduction of substation space, harmony with ambient environment, improvement of equipment efficiency, saving of maintenance work and so forth, reflecting increasingly tight situations of land along with intensification of overpopulation particularly in urban areas. In consideration of such situations, the composite and compact type substation equipment developed according to outlined hereunder for reference of MEA for promoting study regarding adoption of such composite and compact type substation equipment in the future.

(1) GIS (275 kV or lower voltage)

Among the main transformers, switching equipment, distribution board, control and other equipment constituting substation equipment, the switching equipment occupies the largest volume and floor apace. Subsequent to development of GIS in 1970s, the volume of switching equipment has been reduced substantially thereby contributing for significant saving of substation space. Although the GIS technology has ceaselessly been in progress thereafter, the latest technological improvement points are mainly as listed below:

- Reduction of the number of breaking points of GCB (from two breaking points to one breaking point).
- Improvement of GCB operation system (form pneumatic to hydraulic mechanism).
- Three-phase common enclosed GIS.
- Composition of disconnecting switch and grounding switch.
- Simplification of construction and size reduction by applying various kinds of computerized analysis techniques.

As a result of improvement as mentioned above, the GIS has been made compact to 50 - 60% in weight and 35 - 50% in volume of the type several years to one decade before (Appendix 9.9-1).

(2) 24/12 kV metal clad switchgear

Similarly as in the case of the GIS mentioned above, the metal clad switchgear has been made substantially compact to 80 - 85% in installation space, 60 - 65% in volume and 75 - 80% in weight of the conventional type 12 kV class switchgear along with recent progress and improvement of major technology as mentioned below:

- Adoption of vacuum or gas circuit breaker
- Digitalization and integration of protection and control devices
- Reduction of burden to and downsizing of PT and CT resulting from digitalization of protection and control devices
- Downsizing of circuit breaker, operation mechanism, cable terminal connection section and other component elements
- Combination of molded parts

(3) Power transformer

In the case of oil-filled power transformer, it has also been made possible to substantially reduce the size and weight through remarkable development of new materials and improvement in the insulation and cooling system design technology including electric field and transient voltage analysis technology by using computer. This in turn has contributed particularly for development and improvement of ultra-high voltage and large capacity transformers.

Presented hereunder is an outline of gas insulated transformers applicable for the underground or indoor type substation in case the underground type substation is to be adopted by MEA in the near future.

(a) Various gas insulated transformer systems

i) Dry system

Forced gas circulated system is applied for cooling, however, cooling capacity is limited due to a small specific heat of SF_6 gas. Therefore, this system is applied for distribution transformers. In view of its construction, it can be said that the insulation oil of oil-filled transformer is replaced by SF_6 gas.

ii) Spray system

In the case of this system, the winding is insulated and cooled by spraying a mixture of SF_6 and fluorocarbon ($C_8F_{16}O$) to the winding. Its construction is similar to that of the oil-filled transformer except in case a liquid membrane spraying construction is added. Since the gas pressure is lowered at low temperature, it is limited to increase the voltage. Moreover, it also limited to increase the capacity in view of external cooling surface due condensation cooling characteristic of mixed gases.

iii) Separate system

According to this system, fluorocarbon and SF_6 gas are separated and forcedly circulated to the winding and core for cooling. Since the insulation and cooling functions are therefore separated, it is possible to improve the respective functions and increase the voltage and capacity. This system will be applied mainly for large capacity gas insulated transformers in the future.

(b) Effect of introducing gas insulated transformer

i) Rationalization of layout and reduction of installation space by introducing total gas insulation for transformer including switching equipment (direct coupling of GIS and transformer can be applied).

ii) Since the transformer is non-flammable, it is possible to omit the following equipment and devices which have been installed so far for disaster prevention of oil immersed transformer:

- Transformer room fire extinguisher, waste oil tank, separation for fire prevention and so forth.

iii) Since the conservator for the conventional oil immersed transformer is no longer necessary, it is possible to lower the height of transformer room through reduction of the LTC lifting height.

Note: Although the cost of the gas insulated transformer is still substantially higher than that of the oil immersed transformer, this transformer is considered to become economically applicable in the future when cost reduction mentioned above is taken into consideration.

(c) Application records of various transformer systems in the Metropolitan area of Japan

66 kV-20 MVA transformers (dry system) were installed in distribution substations of electric power companies for the first time in 1988, after 22/66 kV, 10 MVA or smaller capacity transformers had been adopted for private sector's substations for the first time in early 1980s.

Subsequent to adoption of 154 kV - 200 MVA transformers (separate system) in 1989 thereafter, the increasingly widely, and 275 kV - 300 MVA transformers are installed recently in 275 kV underground substations.

Presented in Appendix 9.9-2 are outline comparison between 275 kV - 300 MVA gas insulated transformer and oil immersed transformer with the same ratings.

9.9.2 New Technology for Constructing Underground Transmission Line

(1) Tunneling method

It has become difficult to construct underground transmission line duct facilities by open excavation method on account of increase in the traffic volume in parallel with the progress of urbanization in the central area of Bangkok. As a countermeasure under such situations similar also to those in the central part of Tokyo, the cable accommodation construction work is carried out by the tunneling method in Tokyo as outlined below. The tunneling method is applied as the places where the open excavation method cannot be applied due to various restrictive conditions.

According to this method, a vertical shaft is constructed at first by open excavation method, and then a tunnel is excavated from the lowermost part of the vertical shaft in the intended direction.

Based on the results of geological survey, the most stable stratum is selected as an underground tunnel route. Generally, many tunnels are routed across clay and silt layer as deep as about 6-20 m.

In city area, there are little tunnels routed across rock. Since soft lower soil is generally excavated for tunneling, the shield excavation method and propulsion method are applied widely as a tunnel excavation method.

(a) Shield method

The shield method is a kind of tunnel construction method for poor subsoil. Tunnels are excavated by a tunnel driving machine known as a "shield machine" and are constructed fabricating circular pre-cast members called "segments" that are then bolted.

By the use of the shield method, circular tunnels with diameters of about, ϕ800 mm-ϕ10,000 mm are actually constructed in Japan.

(b) NATM (New Austrian Tunneling Method)

"NATM" frequently used for tunnel driving in mountainous regions is applied to culvert works for underground transmission lines in urban areas in recent years. Culverts with a total length of 2 km up to now have been built using this method in Japan. Conventionally NATM was hardly ever applied to soft ground in urban areas. However, it will tend to be more utilized in culvert construction works in future since geologically good locations can be selected more easily as a result of recent trend towards more deeply located culvert facilities because of underground space overcrowded. However, soft and water-bearing ground is often excavated in urban areas and thus it is necessary to fully examine the measures for handling groundwater and for stabilizing the cutting face when carrying out NATM.

(c) Jacking method

The jacking method is a method of constructing tunnels intruding centrifugal reinforced concrete pipes or steel pipes with attached steel edges at the head pipe, into natural ground from turns in vertical shafts. In this method the soil and sand in pipes are taken away by manpower or by machines.

By the use of this method, it is possible to construct tunnels with a diameter about ϕ600mm÷ϕ3,000 mm, while the limit of construction is about 100 m.

Therefore, this method is generally used in cases where the cut and cover method is difficult to use at crossings of with roads, heavy traffic rail ways, and small rivers, etc.).

(d) TELS (TEPCO Extrude Lining System) method

The TELS method refers to a shield excavation method applying the cast-in-place concrete lining method. According to the conventional shield method, the shop prefabricated reinforced concrete segments are assembled in the shield machine and the tunnel is lined. According to the TELS method, on the other hand, the reinforcing bars and concrete forms are assembled in the shield machine and the tunnel is lined by directly placing concrete without using any segment.

In the case of the conventional shield method, the cost of segments occupied a large portion of the total cost. By adopting a method using no segment, it is possible to substantially reduce the overall tunnel construction cost.

(2) Fault locator

According to the results of investigating actual power facilities, reclosing of the line was reported to be executed even at the time of fault on the underground side of the power system consisting of a mixture of overhead lines and underground cable.

When the reclosing is executed even when a fault has occurred in any underground transmission line, then the fault can possibly spread to the equipment located around the line in fault. Therefore, it is recommended to install fault locators for preventing reclosing at the time of fault on the underground cable side.

In the case of the type of fault locators used generally in Tokyo, the fault current is monitored by installing a through type current transformer at the bottom of cable head at the interconnecting point of overhead and underground lines. The fault locator is available in two types: namely, an overcurrent detection type and a differential detection type. In other words, it is recommended that the fault information obtained by this fault locator should be transmitted to power source substation and reclosing be locked at the time of fault on the underground cable side.

Moreover, a fault location system using magneto-optical sensor has also been applied based on the states of the arts of advanced technology.

(3) Technology for increasing the capacity

Judging from the growing trend of power demand to the MEA's distribution system, it would become necessary to increase the capacity of transmission lines.

Because of overpopulation, growing demand for preservation of environment and so forth, the share of underground transmission lines to overall distribution systems has been expanded. Under such situations, the measures for increasing the capacity of underground transmission lines are introduced below.

To expand the capacity in the future, it is required to increase the voltage and current. Available particularly for increasing the current are the methods of reducing losses, adopting cooling system, etc.

(a) Reduction of losses

The losses arising when cable is energized include the conductor loss, dielectric loss and sheath loss. By reducing these losses, it is possible to increase the transmission capacity.

1) Reduction of conductor loss

First of all, the AC effective resistance is lowered by increasing the conductor size to reduce the resistance loss. Other available methods include reduction of proximity effect by increasing the separation of phases and reduction of skin effect by adopting insulated individual wire of cable conductor.

2) Reduction of dielectric loss

The dielectric loss occurs in proportion to the product of $\varepsilon \cdot \tan\delta$ of cable insulator. To reduce the dielectric loss, therefore, it is advantageous to apply the cable with less $\varepsilon \cdot \tan\delta$. In the case of incoming line to substation and other short distance cable, the SF_6 gas insulated transmission line conduit which is almost free from the dielectric loss ($\varepsilon = 1$) is applicable.

(b) Cooling system (removal of generated heat)

To obtain as large a transmission capacity of underground transmission line as possible, various countermeasures are taken mainly by adopting large size cable, installing two or more cables per phase and further adopting low loss and large current cable for gas-insulated transmission line conduit. Should it be considered advantageous in view of economy to remove generated heat by applying a cooling system, then adoption of such a cooling system is studied. As major cooling systems are presented in Table 9.9-1, these systems have respectively inherent features.

Therefore, an optimum cooling system should be selected taking into account the kind of cable, cable laying location and system and required transmission capacity.

Table 9.9-1 Typical Types and Features of Cooling Systems

Type	Medium	Object of Cable	Strong Point	Increase rate
Direct (a)Inner	Oil	OF	Effective for substantially increasing the transmission capacity of comparatively short distance line	2
	Water	XLPE		
	Freon gas	OF, XLPE		
(b)Outer	Oil	POF	Effective for substantially increasing the transmission capacity of long distance transmission line	2 -2.5
	Water	Cable in general		
	Air	Tunnel in general	Comparatively easily applicable in case multiple cable are laid	1.2-1.3
Indirect	Water	Cable in general	Comparatively easily applicable for long distance transmission line	1.2-2.0

9.9.3 New Technology for Protection and Control

(1) Digital type protective relay

The digital signal is obtained by splitting voltage and current incorporated in the sampling section at 600 Hz or higher frequency, and such digital signal is processed in a CPU unit and judged whether there is any fault or not in the line or equipment to be protected. The features of this protective relay are as follows:

(a) The round, diamond, leaf and other optional forms of phase-angle characteristics are available.
As such phase characteristics are obtained by executing computer program, the characteristics are free from deterioration with elapse of time. The same can also be applied in the cases of Items (b) and (c) below. Generally, when the operating value of relay is set to a higher sensitivity level, the relay can possibly be maloperated due to heavy power flow. However, the relay of this type makes it possible to obtain a characteristic free from the impact of heavy power flow and set the operating value to a higher sensitivity level.

(b) The operating time of relay (excluding time delay relay) is as short as 10 to 20 msec..
Since this operating time is nearly free from any change due to voltage and current, it is expected to attain high speed actuation regardless of the location of fault point, size of background impedance, intensity of arcing resistance and so forth. Therefore, timely coordination between mutual relays can be attained easily. In addition, it is possible to reduce the gap of setting time between mutual protective relays, and resultantly shorten the operating time of backup protective relays.

(c) Almost no error arises in the operating time of time delay relay.
The time is measured by counting the number of clock pulses which are almost free from any change in oscillation frequency so that the relay is nearly free from error.

(d) The voltage and current waveform as well as the actuation conditions of the respective parts in relay at the time of fault can be reproduced. When a relay has been actuated due to an unknown cause, this function is effective to clarify such a cause similarly as in the case of the recording data with the digital type automatic oscillograph in Item (3) below.

(e) The burden to the digital type protective relay is much smaller than that to the electromagnetic type protective relay.

(f) The relay of this type can be made much smaller in size than the electromagnetic type relay.

(g) Automatic self-diagnosis and normal self-monitor is easily possible. According to the automatic self-diagnosis method, the actuation of relay is diagnosed by inputting a mimic voltage (current) at a certain time interval.

Whereas, the normal self-monitor method is designed to self-monitor disconnection of secondary windings of VT or CT, error output of relay itself, etc. at all times. These functions have made it possible to substantially extend the interval of periodical maintenance and inspection and substantially decrease the number of inspection items.

(2) Digital type fault locator

In case the position of a fault can be located in a short time when any fault has occurred in subtransmission line, it is possible to remedy the fault in a short period. The fault locator is designed to judge the location of fault by measuring the distance to the fault, and the distance is measured based on the theory of distance relay. Since the recently developed fault locator has enabled substantial reduction of size with low burden, such a fault locator is integrated into a digital type protective relay. Consequently, there will be no need to prepare any additional space for installation. Unlike the conventional method applied so far for measuring the distance by measuring the reaching time of pulse to a fault point, the digital type fault locator enables highly accurate measurement of distance in case there is any branch point in subtransmission line or even in case the impedance of subtransmission line varies halfway of the line.

(3) Digital type automatic oscillograph

The digital type automatic oscillograph is installed in substation to record the waveform of voltage and current, actuation of protective relay and circuit breakers at the time of fault in power system, verify abnormal voltage and current as well as abnormal reaction of protective relay and circuit breaker on the occasion of fault arising in the power system. For these purposes, the substation bus voltage, currents in transformers and subtransmission line, and tripping signal from protective relay to circuit breaker are input to the automatic oscillograph. The recent automatic oscillograph consisting mainly of digital type has the following features:

(a) The sampling frequency of as high as 1,600 - 3,200 Hz is used unlike in the case of the digital type protective relay, because of the necessity to reproduce the voltage and current waveform distorted when a fault has occurred in power system.

(b) By using communication line, it is possible to automatically facsimile the recorded voltage and current waveform, tripping signal and other data and print out such data at an optional position.

Presented in the table below is an example of specifications of automatic digital oscillograph: (Price is assumed to be about 600,000 Baht/Set)

Example of specifications of automatic digital oscillograph

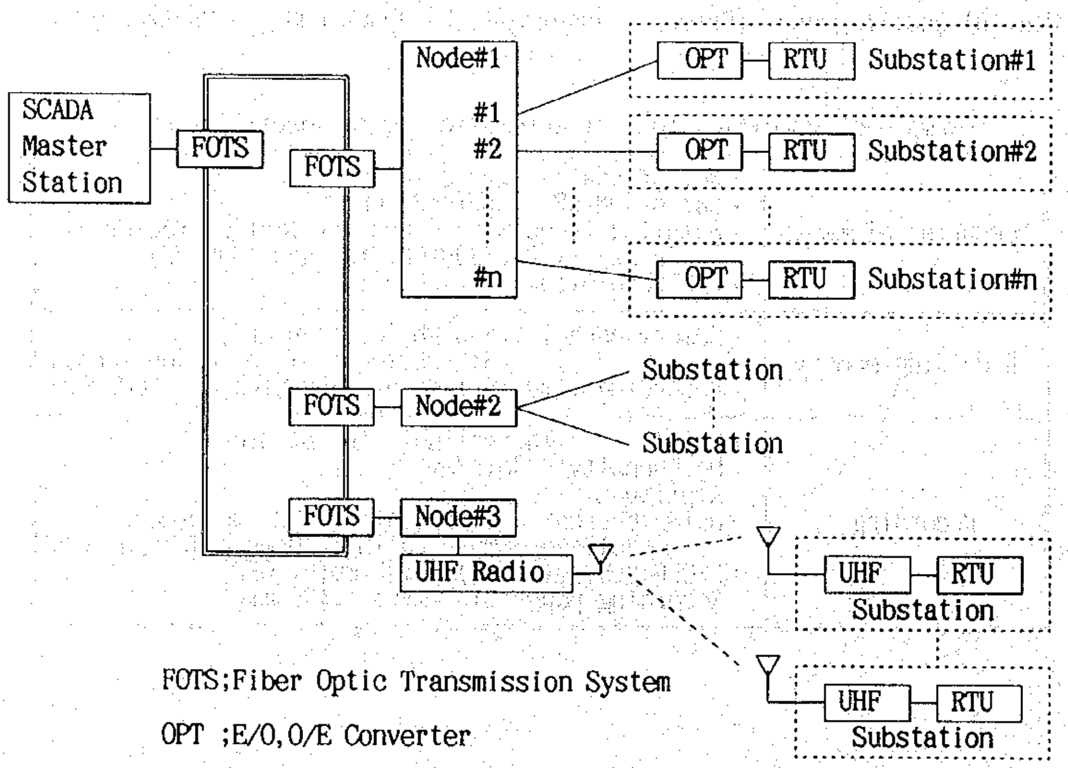
Measuring elements	• No. of analog inputs:16 CH • No. of ON/OFF inputs:32 CH • Sampling frequency : Specify.(Set at factory) 50 Hz---1600,3200/CH(Standard 1600/CH) • A/D resolution :8 bit
Recording memory	• Memory capacity:256 kbytes(standard) (512 kbytes or 1 Mbytes optional) • Recording time :8.1sec(at 256kbytes and 1600/CH)
Recording	• Method :Thermal dot line printer • Dot density:8 dots/mm • Amplitude Analog:Current 5 mmp-p(rating) 32 mmp-p(max.) Voltage 5mmp-p(rating) 10mmp-p(guaranteed) ON/OFF:0.5 mm(at ON) 0.125 mm(at OFF) • Recording paper:216 mm(W) ×100 m(L)

9.9.4 New Technology for Telecommunication Equipment

In the central part of Bangkok, it has become increasingly difficult to acquire radio propagation route as a result of construction of high-rise structures. Presented herein therefore are configuration examples of the SCADA telecommunication circuits using optical fiber cable and video monitor system of substations using optical fiber cable.

(1) Configuration of SCADA telecommunication circuits using optical fiber cable

The configuration in case of forming SCADA telecommunication circuits by using an optical fiber cable network between district offices being planned by MEA is as indicated in the diagram below. In this diagram, the SCADA telecommunication circuits are formed by installing node equipment in the district offices and laying optical fiber cable between the respective node equipment and respective substations (Nodes #1 and #2). In the case of Node #3, moreover, optical fiber cable circuits are formed between the SCADA master station and Node #3, while UHF radio circuits are formed between Node #3 and the respective substations.

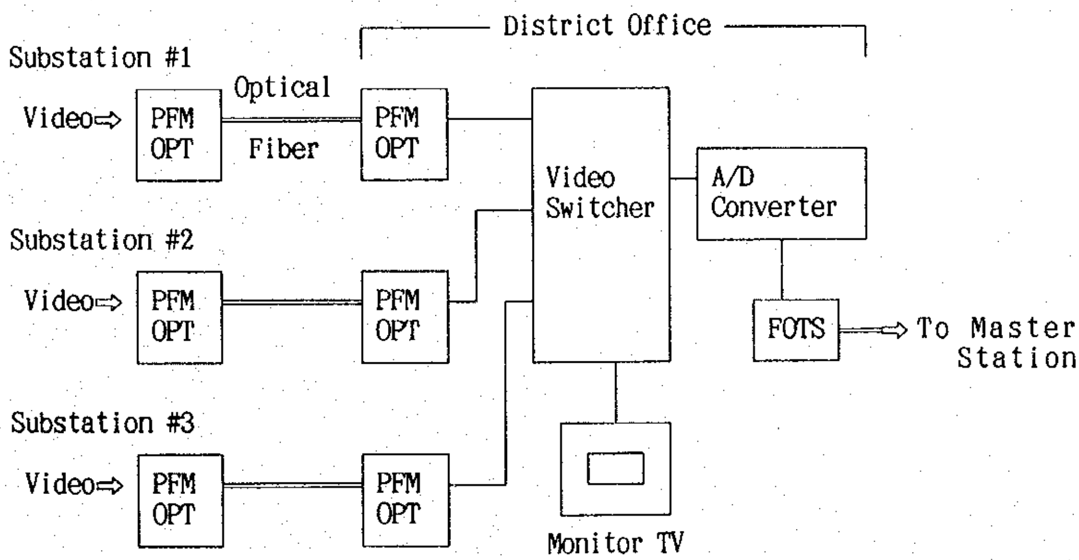


By installing the node equipment as mentioned above, it will become possible to form SCADA telecommunication circuits by combining the optical fiber and UHF radio as appropriate. Meanwhile, it will also be possible to form telephone channels in the case of substation where optical fiber cable is formed.

(2) Video monitor of substation using optical fiber cable

Presented in the diagram below is an example of video monitor system of substation using optical fiber cable. In this case, the video signals between the respective substations and district offices undergo pulse frequency modulation (PFM), and are analog-transmitted through optical fiber cable.

By further installing a video switcher and analog/digital converter at a district office, it will also be possible to video signal of an optional substation to the Chidlom Master Station through optical fiber cable network between district offices.



PFM OPT ; Pulse Frequency Modulation Fiber Optic Transmission Equipment

CHAPTER 10

CONSTRUCTION SCHEDULE AND COST ESTIMATION

CHAPTER 10 CONSTRUCTION SCHEDULE AND COST ESTIMATION

10.1 General

The construction cost has been estimated based on the following conditions. The subtransmission line construction project will, in principle, be carried out by using the equipment and materials including labor force which can be procured in Thailand, while the equipment and materials which can not be procured in the country will be imported from other countries, and the required import duties therefor be added to the construction cost.
Whereas, the construction schedule has been formulated based on the results of calculating the work period according to the past records of required period so far in the country and taking into account the ability of local constructors for subtransmission line construction.

10.2 Construction Schedule

The subtransmission line construction schedule has been prepared on the basis of the past work execution records in Thailand in order that the basic design of relevant structures with the scale described in "SECTION 9. FEASIBILITY DESIGN" will be completed within the scheduled period.

10.2.1 Subtransmission Lines

The subtransmission line construction schedule has been prepared based on the following basic conditions:

(1) Delivery period of materials for subtransmission line
The delivery period of materials for subtransmission line shall be as indicated below provided that the majority of materials be procured in Thailand.

Delivery period of materials for subtransmission line

Items	Origin	Delivery period
Supports and accessories	Domestic	Three (3) months
Insulators and accessories	Domestic	Six (6) months
Conductor and accessories	Domestic	Three (3) months
Cable and accessories	Overseas	Six (6) months
Arrester and accessories	Overseas	Eight (8) months
Others	Domestic	Six (6) months

(2) Efficiency of subtransmission line construction work

The ability of subtransmission line construction work is assumed to be as indicated below provided that the work be carried out by the local constructors.

Efficiency of transmission line construction work

Voltage (kV)	No. of ckt	Type	Support structures	Work efficiency
230	1	Overhead	Concrete pole	2.0 km/month
	2		Concrete pole	1.0 km/month
	1	Underground	Concrete duct	0.15 km/month
	2		Concrete duct	0.13 km/month
115	1	Overhead	Concrete pole	4.5 km/month
	2		Concrete pole	3.0 km/month
	1	Underground	Concrete duct	0.23 km/month
	2		Concrete duct	0.21 km/month
69	1	Overhead	Concrete pole	4.5 km/month
	2		Concrete pole	3.0 km/month
	1	Underground	Concrete duct	0.23 km/month
	2		Concrete duct	0.21 km/month

(3) Construction schedule for the respective years

In consideration of the necessity to complete the respective works by the fiscal years designated in the long-term plan, the construction schedule shall be so formulated as to complete the works by the final scheduled fiscal years while directing efforts for balancing the work volume in the respective fiscal years.

The construction work schedule in the short-term expansion plan is as presented in Table 10.2-1.

(4) Volume of work in the respective fiscal years

The volume of work to be executed in the respective fiscal years are as indicated below:

(a) Volume of work in the respective fiscal years in the short-term plan

(Work Unit : ckt-km)

Items	Type	1997	1998	1999	2000	2001
Total of Subtransmission Line	Overhead	68.1	124.0	98.8	98.8	17.9
	Underground	20.6	9.2	31.2	52.8	13.6
	Total	88.7	133.2	130.0	151.6	31.5
230 kV	Overhead	8.0	0	0	0	0
	Underground	0.6	0	0	15.6	0
	Total	8.6	0	0	15.6	0
115 kV	Overhead	53.4	111.3	94.5	75.6	9.5
	Underground	9.0	4.7	23.5	22.7	11.5
	Total	62.4	116.0	118.0	98.3	21.0
69 kV	Overhead	6.7	12.7	4.3	23.2	8.4
	Underground	11.0	4.5	7.7	14.5	2.1
	Total	17.7	17.2	12.0	37.7	10.5

(b) Volume of work in the respective fiscal years in the long-term plan

(Work Unit : ckt-kmt)

Items	Type	2001	2006	2011	2016	Total
Total of Subtransmission Line	Overhead	407.6	275.6	103.9	79.0	866.1
	Underground	127.4	141.4	46.4	30.1	345.3
	Total	535.0	417.0	150.3	109.1	1211.4
230 kV	Overhead	8.0	0	0	26.0	34.0
	Underground	16.2	44.0	0	12.0	72.2
	Total	24.2	44.0	0	38.0	106.2
115 kV	Overhead	344.3	232.8	89.0	33.4	699.5
	Underground	71.4	67.0	29.6	13.1	181.1
	Total	415.7	299.8	118.6	46.5	880.6
69 kV	Overhead	55.3	42.8	14.9	19.6	132.6
	Underground	39.8	30.4	16.8	5.0	92.0
	Total	95.1	73.2	31.7	24.6	224.6

Table 10.2-1 Construction Work Schedule in Short-term expansion plan

(1/4)

No.	CONSTRUCTION WORKS (From — To)	LENGTH	1997	1998	1999	2000	2001	REMARKS
1	T/S LARDPRAO — T/S SANAMPAO 230 kV、 2 ckt 、 2x1200mm²	15.6km						
2	T/S SOUTH THONBURI — T/S THANONTOK 230 kV、 1 ckt 、 2x400 mm² 2x1200mm²	8.0km 0.6km						
3	T/S RATCHADA — S/S DINDAENG 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	2.0km 5.5km						
4	T/S JANGWATANA — S/S MUANGTHONG 4 115 kV、 1 ckt 、 2x800 mm²	1.0km						
5	T/S THANONTOK — S/S TROKCHAN 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	3.8km 0.8km						
6	LINK S/S KLONGKUM 115 kV、 2 ckt 、 2x400 mm² 2x800 mm²	6.6km 0.4km						
7	S/S SHIMPLEE — THANON #340 115 kV、 1 ckt 、 2x400 mm²	2.5km						
8	T/S NONGJOK — S/S MINBURI 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	7.0km 0.5km						
9	T/S TEPARAK — S/S BANGPING 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	12.2km 3.0km						
10	T/S KLONGRANGSIT — THANON JANGWATANA 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	6.0km 0.2km						
11	T/S ON NUCH — THANON ROMKLAO 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	6.6km 0.8km						
12	T/S BANGKOK NOI — S/S TAWEEWATTANA 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	5.1km 0.3km						
13	S/S TAWEEWATTANA — S/S SHIMPLEE 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	17.8km 0.2km						
14	S/S BANGJAK — THANON SRINAKHARIN 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	5.5km 0.2km						
15	T/S ON NUCH — THANON SRINAKHARIN 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	5.3km 0.8km						
16	T/S ON NUCH — S/S BANGJAK 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	10.8km 1.0km						
17	T/S SAINOI — S/S BANGRAKYAI 115 kV、 1 ckt 、 2x400 mm²	13.5km						
18	S/S SANAMBINNAM — THANON #340 115 kV、 1 ckt 、 2x400 mm²	7.9km						
19	S/S CHALONGKRUNG — THANON LARDKRABANG 115 kV、 1 ckt 、 2x400 mm²	4.8km						
20	S/S TUBYAO — THANON ROMKLAO 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	8.4km 0.2km						

No.	CONSTRUCTION WORKS (From – To)	LENGTH	CONSTRUCTION SCHEDULE IN FISCAL YEAR 1997	1998	1999	2000	2001	REMARKS
21	LINK S/S BNAGKAE 115 kV、 2 ckt 、 2x400 mm² 2x800 mm²	0.6km 2.4km						
22	S/S MINBURI – THANON SUKA PHIBAN 2 115 kV、 1 ckt 、 2x400 mm²	3.6km						
23	THANON SUKA PHIBAN 2– S/S RAMINTRA 115 kV、 1 ckt 、 2x400 mm²	6.2km						
24	S/S SAMYARN – T/S THANONTOK 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	11.3km 4.3km						
25	S/S SUANYAI – THANON #340 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	11.0km 0.4km						
26	S/S SUENYAI – S/S SRITHANYA 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	3.0km 1.0km						
27	T/S THANONTOK – S/S SATORN 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	3.4km 5.0km						
28	LINK S/S TROKCHAN 115 kV、 1 ckt 、 2x800 mm²	0.5km						
29	S/S SATRON – S/S SAMYARN 115 kV、 1 ckt 、 2x800 mm²	3.2km						
30	T/S BANGKOK NOI – S/S BANGKRADEE 115 kV、 1 ckt 、 2x800 mm²	1.5km						
31	THANON EKACHAI – THANON PHRARAM 2 115 kV、 1 ckt 、 2x400 mm²	6.3km						
32	T/S BANGKOK NOI – S/S EKACHAI 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	9.0km 1.5km						
33	LINK S/S TAIBAN 115 kV、 2 ckt 、 2x400 mm² 2x800 mm²	3.8km 0.1km						
34	T/S BNAGBON – THANON BANGNA TRAD 115 kV、 2 ckt 、 2x400 mm² 2x800 mm²	6.0km 0.5km						
35	Interection to S/S BANGNAMJUED – S/S BNAGBON 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	12.0km 0.1km						
36	T/S TEPARAK – THANON PREAK KRASA 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	8.6km 3.0km						
37	T/S SAINOI – S/S THANON RATANATIBET 115 kV、 1 ckt 、 2x400 mm² 2x800 mm²	14.0km 0.5km						
38	T/S SANAMPAO – S/S DINDAENG 115 kV、 1 ckt 、 2x800 mm²	2.7km						
39	LINK S/S MUANGTHONG 6 115 kV、 2 ckt 、 2x800 mm²	2.7km						
40	LINK S/S PRAWES 115 kV、 2 ckt 、 2x800 mm²	0.5km						
41	T/S NONGJOK – S/S EKBURI 115 kV、 2 ckt 、 2x400 mm² 2x800 mm²	16.5km 0.7km						

	CONSTRUCTION WORKS From — To	LENGTH	CONSTRUCTION SCHEDULE IN FISCAL YEAR 1997	1998	1999	2000	2001	REMARKS
42	LINK S/S RAMINTRA 115 kV 、 1 ckt 、 2x400 mm² 2x800 mm²	1.0km 0.1km						
43	S/S PROMPONG — S/S DINDAENG 115 kV 、 1 ckt 、 2x800 mm²	4.0km						
44	T/S RATCHADA — THANON RATCHAPHISEK 115 kV 、 1 ckt 、 2x800 mm²	3.2km						
45	LINK S/S PATANAKARN 115 kV 、 2 ckt 、 2x800 mm²	0.5km						
46	T/S RATCHADA — S/S PLUBPLA 115 kV 、 1 ckt 、 2x800 mm²	3.6km						
47	S/S PLUBPLA — S/S PROMPONG 115 kV 、 1 ckt 、 2x800 mm²	4.0km						
48	LINK S/S SUWINTAWONG 115 kV 、 2 ckt 、 2x800 mm²	0.5km						
49	LINK S/S BANGKAEN 115 kV 、 1 ckt 、 2x800 mm²	0.1km						
50	THANON JANGWATANA — BANGKHEN WATER WORKS 115 kV 、 1 ckt 、 2x400 mm²	1.4km						
51	T/S JANGWATANA — S/S MUANGTHONG 5 115 kV 、 1 ckt 、 2x800 mm²	1.3km						
52	T/S JANGWATANA — S/S MUANGTHONG 7 115 kV 、 1 ckt 、 2x800 mm²	2.0km						
53	S/S MUANGTHONG 4 — S/S MUANGTHONG 5 115 kV 、 1 ckt 、 2x800 mm²	0.3km						
54	S/S MUANGTHONG 1 — S/S MUANGTHONG 7 115 kV 、 1 ckt 、 2x800 mm²	1.4km						
55	LINK S/S BANGPONGPANG 115 kV 、 2 ckt 、 2x400 mm² 2x800 mm²	2.0km 0.1km						
56	T/S ON NUCH — THANON KINGKAEW — LARDKRABANG 115 kV 、 1 ckt 、 2x400 mm² 2x800 mm²	5.9km 0.8km						
57	LINK S/S NONTHABURI 115 kV 、 1 ckt 、 2x800 mm²	0.1km						
58	THANON ROMKLAO — S/S TUBYAO 115 kV 、 1 ckt 、 2x400 mm² 2x800 mm²	8.4km 0.2km						
59	THANON VIPAVADEE RANGSIT — KLONG PRAPA 115 kV 、 1 ckt 、 2x400 mm²	3.0km						
60	THANON JANGWATANA — THANON NGAM WONG WAN 115 kV 、 1 ckt 、 2x400 mm²	4.5km						
61	T/S JANGWATANA — THANON JANGWATANA 115 kV 、 1 ckt 、 2x400 mm²	1.6km						
62	S/S WATKAMPANK — EKACHAI 69 kV 、 1 ckt 、 2x800 mm²	1.5km						
63	T/S SOUTH THONBURI — S/S BANGMOD 69 kV 、 1 ckt 、 2x800 mm²	6.5km						
64	S/W SAMRONG — S/S POOJAO 69 kV 、 1 ckt 、 2x800 mm²	2.7km						

No.	CONSTRUCTION WORKS (From – To)	LENGTH	CONSTRUCTION SCHEDULE IN FISCAL YEAR 1997	1998	1999	2000	2001	REMARKS
65	LINK S/S THA-KWIAN 69 kV、 2 ckt 、 2x800 mm²	2.4km						
66	T/S THANONTOK – S/S SRIWIANG 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	3.3km 3.2km						
67	S/S SRIWIANG – S/S SIPRAYA 69 kV、 1 ckt 、 2x800 mm²	1.4km						
68	LINK S/S KLONGMAI 69 kV、 1 ckt 、 2x800 mm²	1.0km						
69	LINK S/S WUTTAKART 69 kV、 2 ckt 、 2x400 mm² 2x800 mm²	4.0km 0.5km						
70	T/S SOUTH THONBURI – S/S WATKAMPAENG 69 kV、 1 ckt 、 2x800 mm²	2.6km						
71	T/S TEPARAK – S/W SAMRONG 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	12.0km 2.4km						
72	T/S TEPARAK – THNON SUKHUMVIT 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	10.2km 2.4km						
73	T/S SANAMPAO – THANON PHAHON YOTHIN 69 kV、 1 ckt 、 2x800 mm²	0.3km						
74	T/S SANAMPAO – THANON YOTHEE 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	1.0km 3.0km						
75	T/S SANAMPAO – THANON SRIAYUDTAYA 69 kV、 1 ckt 、 2x800 mm²	2.2km						
76	LINK S/S KINGPETCH 69 kV、 1 ckt 、 2x800 mm²	1.0km						
77	S/S WANGPETCHABOON – INTERSECTION RAJATEVEE 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	1.0km 0.7km						
78	LINK S/S SANSAB 69 kV、 1 ckt 、 2x800 mm²	2.2km						
79	LINK S/S PHAISINGTO 69 kV、 1 ckt 、 2x400 mm²	1.2km						
80	THANON SUKSAWAT – SOI SUANSOM 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	3.7km 0.7km						
81	SOI SUANSOM – THANON SUKHUMUBIT 69 kV、 1 ckt 、 2x400 mm²	1.8km						
82	LINK S/S BANMAI 69 kV、 2 ckt 、 2x400 mm² 2x800 mm²	4.4km 0.1km						
83	S/S THONBURIROM – THANON #340 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	2.8km 0.1km						
84	S/S THONBURIROM – THANON SUKSAWAT 69 kV、 1 ckt 、 2x400 mm² 2x800 mm²	2.7km 0.5km						
85	LINK S/S JATUJAG 69 kV、 2 ckt 、 2x800 mm²	0.5km						

10.2.2 Substation

The construction schedule prepared according to the short and long-term plans for the respective fiscal years (2001, 2006, 2011 and 2016, however, the five years from 1997 through 2001 are the respective fiscal years) presented in chapter 6 can be clarified from the disbursement schedule in Tables 10.5-1 to 10.5-2 presented in Clause 10.5.2. Therefore, any construction schedule chart indicated by a bar chart has not been presented herein.

As is clear from the table below, the average number of distribution substations to be constructed per year and those to be expanded per year are 2 - 5.4 and 5.6 - 9, respectively. The number of substations to be constructed by 2001 is larger than those to be constructed in other years since the number of temporary substations is included. Meanwhile, the primary voltage of the majority of substations to be constructed is 115 kV, the primary voltage of those to be expanded is shared equally by 115 kV and 69 kV.

115 kV & 69 kV Distribution Substation Construction

Ratings	Number of D/S				
	~2001	~2006	~2011	~2016	Total
115 - 24kV, 2 x 60MVA	20	13	9	8	50
115 - 24kV, 3 x 60MVA	0	2	5	2	9
69 - 24/12kV, 2 x 60MVA	6	1	0	0	7
69 - 12kV, 3 x 40MVA	0	0	1	0	1
69 - 12kV, 2 x 40MVA	1	0	0	0	1
Total	27	16	15	10	68

115 kV & 69 kV Distribution Substation Addition/Modification

Ratings	Number of D/S				
	~2001	~2006	~2011	~2016	Total
115 - 24kV, 1 x 60MVA	19	20	21	11	71
115 - 24kV, 2 x 60MVA	7	1	0	1	9
115 - 24kV, 3 x 60MVA	0	1	0	0	1
69 - 24/12kV, 1 x 60MVA	13	15	15	16	59
69 - 24/12kV, 2 x 60MVA	3	3	1	0	7
69 - 24/12kV, 3 x 60MVA	3	0	1	0	4
69 - 24/12kV, 4 x 60MVA	0	1	0	0	1
Total	45	41	38	28	152

230 kV Terminal Station Construction

Ratings	Number of T/S				
	~2001	~2006	~2011	~2016	Total
230 - 115kV, 1 x 300MVA 230 - 115kV, 2 x 300MVA 230 - 115kV, 3 x 300MVA 230 - 69kV, 1 x 300MVA	3(1) 2(1) 0 1(1)	0 2(1) 1 1(1)	0 0 0 0	0 2(1) 0 1	3(0) 6(3) 1(0) 3(2)
Total	6(3)	4(2)	0	3(1)	13(5)

230 kV Terminal Station Addition/Modification

Ratings	Number of T/S				
	~2001	~2006	~2011	~2016	Total
230 - 115kV, 1 x 200MVA 230 - 115kV, 1 x 300MVA 230 - 115kV, 2 x 300MVA 230 - 115kV, 3 x 300MVA 230 - 69kV, 1 x 200MVA 230 - 69kV, 1 x 300MVA 230 - 69kV, 2 x 300MVA	1 5 0 0 1 1 3	2 3 0 0 1 1(1) 1	1 6 1 0 0 1(1) 2	1 6(2) 0 1 0 1 2	5 20(2) 1 1 2 4(2) 8
Total	11	8(1)	11(1)	11(2)	41(4)

Note: Figures in parenthesis are number of Terminal Stations owned by MEA

The MEA's substation construction system consists of the following four types as presented in Table 10.2-2. Due to lack of the number of MEA's engineers, however, an increasing large number of construction projects have been executed in the full-turn key system of Type 4 where the engineering services and construction work are contracted with outside contractors.

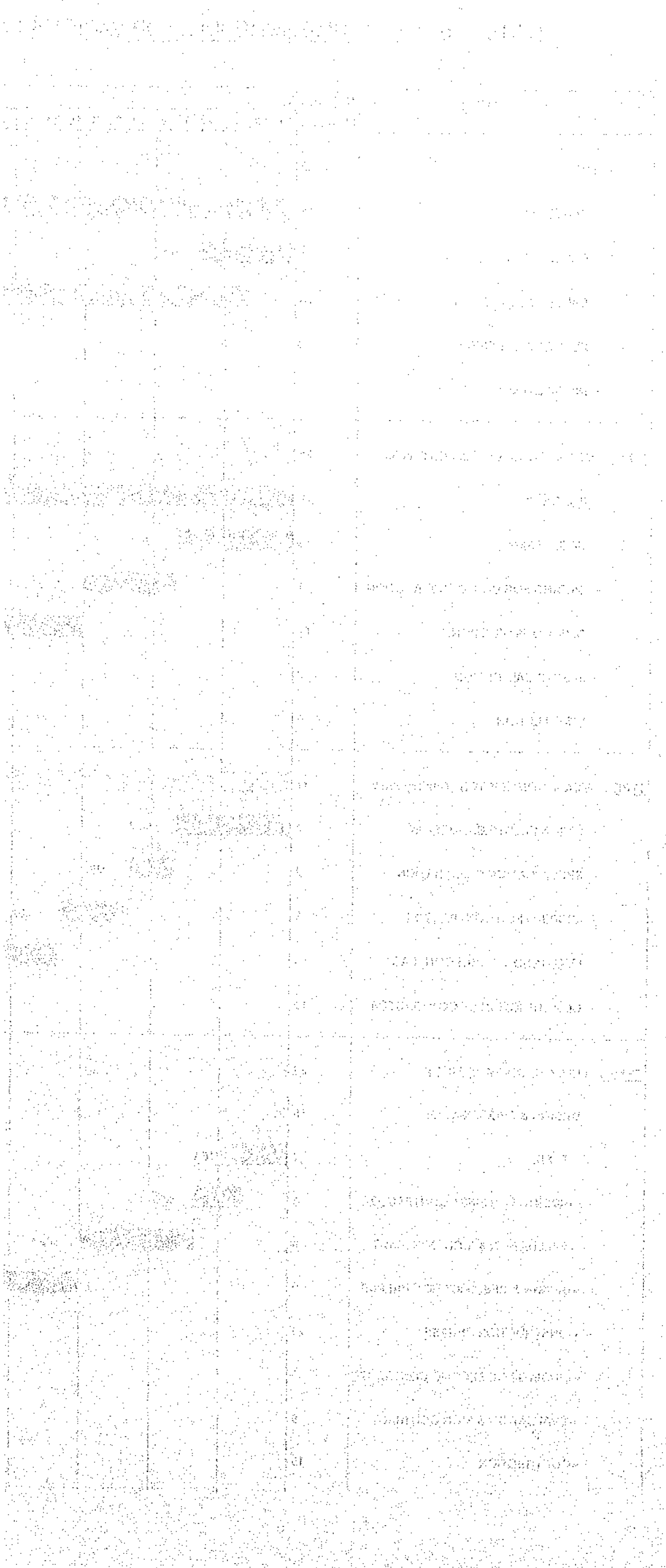
Type	System	Construction period *
Type 1	Design, procurement of materials, installation work, civil work, etc. are all carried out by MEA.	22 months
Type 2	The civil work is contracted to other enterprises, and all of the other works are executed by MEA.	25 months
Type 3	Design and technical specifications are prepared by MEA. Procurement of materials, installation and civil work are contracted toother enterprises.	31 months

Type 4	The design and preparation of specifications are contracted with an engineering firm. Then a contractor is selected by bidding, and procurement of materials, installation and civil work are contracted with the contractor on a lump sum basis.	39 months

*Note: The construction period refers to a standard period of time required until completion of substation after commencement of design or arrangement for procurement of materials (commencement of preparation for bidding in the case of Type 4).

Table 10. 2-2 TIME SCHEDULE FOR VARIOUS TYPE OF SUBSTATION CONSTRUCTION

WORK	NUMBER OF MONTHS	MONTH NO. (1–42)
TYPE 1 MEA	22	
- PURCHASE	18	MEA
- CIVIL DESIGN	4	MEA
- CIVIL CONSTRUCTION	16	MEA
- ELECTRICAL DESIGN	2	MEA
- INSTALLATION	4	MEA
TYPE 2 MEA + OTHER UNIT (for CIVIL con.)	25	
- PURCHASE	18	MEA
- CIVIL DESIGN	5	MEA
- BIDDING FOR CIVIL CONSTRUCTION	4	MEA
- CIVIL CONSTRUCTION	12	CONTRACTOR
- ELECTRICAL DESIGN	2	MEA
- INSTALLATION	4	MEA
TYPE 3 MEA + CONTRACTOR (Turnkey Pro.)	31	
- CIVIL & ELECTRICAL DESIGN	5	MEA
- SPECIFICATION PREPARATION	2	MEA
- BIDDING FOR CONTRACTOR	3	MEA
- EVALUATION & SIGN CONTRACT	6	MEA
- CONSTRUCTION BY CONTRACTOR	15	CONTRACTOR
TYPE 4 FULLY TURNKEY PROJECT	39	
- DESIGN & SPECIFICATION	15	
- T.O.R.	2	MEA
-BIDDING FOR FIRST CONTRACTOR	2	MEA
-EVALUATION & SIGN CONTRACT	5	MEA
-DESIGN & SPECIFICATION PREPAR.	6	1st CONTRACTOR
- CONSTRUCTION PHRASE	24	
-BIDDING FOR SECOND CONTRACTO	3	MEA
-EVALUATION & SIGN CONTRACT	6	MEA
-CONTRUCTION	15	2nd CONTRACTOR (Supervising by 1st CONTRACTOR)



10.3 Method of Estimating the Construction Cost

10.3.1 Subtransmission Line Facilities

Based on the basic design in CHAPTER 6, which are prepared for composing optimal power system configuration recommended in CHAPTER 9, all cost required for renovation of subtransmission lines are to be estimated in this clause.

(1) The items of construction cost

The total construction cost of each subtransmission line is broken down into the following:

(a) Overhead subtransmission line

1) Line route survey and soil investigation
2) Right-of-way
3) Preliminary work
4) Tower footing
5) Equipment (supply & installation)
   - Tower bodies
   - Insulator string
   - Conductor
   - Overhead ground wire
   - Line accessories
   - Grounding material
   - Others
6) Miscellaneous expense
7) Engineering & supervision
8) Contingencies
9) Import duties
10) Value added tax

(b) Underground subtransmission line

1) Line route survey and soil investigation
2) Right-of-way

3) Preliminary work

4) Equipment (supply & installation)

- Pipe
- Cable
- Termination
- Splice joint box
- Line accessories
- Others

5) Miscellaneous expense

6) Engineering & supervision

7) Contingencies

8) Import duties

9) Value added tax

Item 1) to 6) of overhead subtransmission line and item 1) to 5) of underground subtransmission line above are categorized in direct cost, and the remainder indirect cost.

(2) Basic calculation method of construction cost

In this case, the construction cost to be allocated is classified largely into the material and construction costs as described below:

(a) Material cost

The material cost shall include the cost of asset utilization and processing at manufacture shop as well as the transportation cost from the manufacture to the material storage yard at the site.

The cost of materials to be imported from any overseas country shall be the CIF price to a port in Bangkok.

(b) Construction cost

The construction cost shall include any cost for topographic survey, land acquisition and utilization, machinery and tools, labor cost and transportation cost to be required for execution of the construction as well as the overhead cost of the contractor taking into account taxes, duties and so forth.

(c) Topographic survey, geological survey and other preliminary work

The cost required for topographic survey, geological survey and other work shall be allocated for executing the preliminary work for basic design of the subtransmission lines.

(d) Miscellaneous work

Any miscellaneous work cost required for execution of the construction shall be allocated.

(e) Land cost

The cost and expenses as required to acquire land in Bangkok shall be allocated.

In addition, the cost and expenses for acquisition of land under subtransmission lines and that for substations as well as those required to miscellaneous proceedings shall be included in the land cost.

(f) Import duties

The import duties required for importing materials from any overseas country shall be allocated.

(g) Value-added taxes

Any value-added tax to be imposed in Thailand shall be allocated.

(h) Engineering and supervising fees

The engineering fees required for preparation of specifications, design of subtransmission lines as well as for supervision of work shall be allocated.

(i) Contingency

The amount of the material cost and construction work cost in excess of the budget for the same shall be allocated in the contingency.

10.3.2 Substation

(1) Breakdown of construction cost

The construction cost of substation is broken down into the following items:

1) Land acquisition cost
2) Land preparation cost
3) Equipment cost
   - Main transformer
   - Primary switching equipment (GIS)
   - Secondary switching equipment (GIS or metal clad switchgear)
   - Station service transformer
   - Power capacitor bank
   - Battery and charger
   - Control and protective relay panels
   - AC/DC distribution board
   - Cable accessories and miscellaneous items
4) Inland transportation cost (including insurance premiums)
5) Installation cost
6) Civil work cost (foundation work, substation building construction and other costs)
7) Engineering and supervisory fees
8) Contingency
9) Import duties
10) Value added tax

The items 1) - 6) and 7) - 10) are respectively classified into the direct and indirect costs. The respective items of indirect cost are defined as follows:

- Engineering and supervisory fees: 7% of direct cost
- Contingency : 10% of direct cost
- Import duties : Amount to be imposed on the respective products
- Value added tax : 7% of a sum of the import duties and direct cost

(2) Basic data of construction cost

1) Acquisition of land

The unit land price is calculated per 1,320 m² of a required standard substation site area as indicated in Table 10.3-1, based on the results of surveying the land price for the candidate construction sites of 27 distribution substations proposed in the 8th Plan (FY 1997 - 2001) now under formulation by MEA.

Table 10.3-1 Land Price for Distribution Substations

No.	SUBSTATION	UNIT LAND PRICE (BAHT/SQ.M)	LAND PRICE (Million Baht)
1	BANMAI	9,583.33	12.650
2	DINDAENG	78,557.95	103.696
3	JATUJAG	* N.A.	-
4	KASET	* N.A.	-
5	KLONGKUM	12,000.00	15.840
6	MUANGTHONG 4	* N.A.	-
7	MUANGTHONG 5	* N.A.	-
8	MUANGTHONG 6	* N.A.	-
9	MUANGTHONG 7	* N.A.	-
10	NANGLERNG	57,077.63	75.342
11	PATANAKARN	56,666.67	74.800
12	PLUBPLA	55,000.00	72.600
13	PRAWES	55,625.00	73.425
14	PROMPONG	82,500.00	108.900
15	SAINOI	7,000.00	9.240
16	SAMYARN	100,000.00	132.000
17	SATORN	125,000.00	165.000
18	SHIMPLEE	26,250.00	34.650
19	SRIWIANG	* N.A.	-
20	SUANYAI	33,750.00	44.550
21	SUWINTAWONG	12,000.00	15.840
22	TAIBAN	15,000.00	19.800
23	THA-KWIAN	15,000.00	19.800
24	TROKCHAN	50,000.00	66.000
25	TUBYAO	10,000.00	13.200
26	WATKAMPAENG	25,329.21	33.435
27	WUTTAKART	15,000.00	19.800

Note: 1. Asterisk(*) means the customer provides land to MEA for constructing substations.

2. N.A. means not available.

Excluding the land for the seven substations offered free of charge for construction from customers, the average unit price of the land for the remaining 20 substations is 42,067 Baht/m².

On the other hand, the land area for the 230 kV terminal station is estimated at 3,250 m² (50m x 65m) referring new GIS substation (Thanontok Terminal Station). Among the five terminal stations scheduled to be constructed by MEA itself, the Thanontok, Thonburi and

Klongtoey Terminal Stations are assumed to be constructed on the land owned by MEA.

Although it is difficult to estimate long term fluctuations of land price, the land price for substation is assumed herein to escalate at an annual rate of 5% since the Ninth Plan (since 2002) based on the above average price level in FY 1995.

2) Land preparation

According to the MEA's method of estimating the substation construction cost, the land preparation cost is to be included in the civil work cost.

3) Equipment

Presented in Tables 10.3-2 - 10.3-6 are lists of the standard unit costs for construction and addition of terminal and distribution substations presented by MEA. Meanwhile, the construction cost described in this report has been obtained by adding yearly price escalation of 2.2% for foreign currency portion and 5% for local currency portion since the cost is based on the price level in FY 1995.

Regarding the rates of import duties to be imposed on imported equipment and materials (foreign currency portion), the following rates presented by MEA are applied:

a) Equipment and materials to which 5% of duty rate is applied:
   - 230 kV power transformer
   - 69, 115 and 230 kV GIS
   - 69 and 115 kV control and metering boards
   - Capacitor bank

b) Equipment and materials to which 10% of duty rate is applied:
   - 69 and 115 kV power transformers
   - Substation pad-mounted transformer

c) Equipment and materials to which 20% of duty rate is applied:
   - 24 kV GIS
   - Miscellaneous equipment
   - Battery
   - AC/DC panel board

4) Inland transportation cost

This cost is calculated based on the standard unit cost list of MEA.

5) Installation cost

This cost is calculated based on the standard unit cost list of MEA.

6) Civil work cost

This cost is calculated based on the standard unit cost list of MEA. In some cases, the values to which the installation cost is also added depending on various lists of standard unit cost are indicated. In addition, the land preparation of new substation site and construction cost of substation building are included in the civil work cost.

Table 10.3-2 Standard Unit Cost for D/S Construction
1 9 9 4 Price

DESCRIPTION	QUANTITY (Sets)	Million Baht			
		FC	TAX	OTHER LC	TOTAL
D/S Construction, 69-24 kV , 2×60 MVA					
1. 69-12/24 kV POWER TRANSFORMER 36/48/60 MVA OLTC	2	27.273	2.727	–	30.000
2. 69 kV, SF6 GAS INSULATED SWITCHGEAR (2 Incomming/3 transformer bays)	1	42.857	2.143	–	45.000
3. 24 kV SF6 GIS (3 Incomming/21 feeder)	1	25.000	5.000	–	30.000
4. SUBSTATION CAPACITOR BANK & EQUIPMENTS	2	0.545	0.055	–	0.600
5. 23kV, SUBSTATION CAPACITOR BANK & EQUIPMENTS (BANKS)	4	5.714	0.286	–	6.000
6. BATTERY	1	0.667	0.133	–	0.800
7. BATTERY CHARGER	1	0.236	0.064	–	0.300
8. 69 kV, CONTROL & METERING BOARD (2 Incomming/3 Outgoing)	1	3.333	0.167	–	3.500
9. AC & DC PANEL BOARDS	1	0.250	0.050	–	0.300
10. CABLE ACCESSORIES & MISCELLANEOUS ITEMS	LS.	2.083	0.417	–	2.500
11. INSURANCE PREMIUMS & INLAND TRANSPORTATION		–	–	1.000	1.000
12. ENGINEERING SERVICE		–	–	5.000	5.000
13. CIVIL CONSTRUCTION		–	–	25.000	25.000
TOTAL		107.959	11.041	31.000	150.000
D/S Construction, 115-24 kV, 2×60 MVA					
1. 115-24 kV POWER TRANSFORMER 36/48/60 MVA LTC	2	29.091	2.909	–	32.000
2. 115 kV, SF6 GAS INSULATED SWITCHGEAR (2 Incomming/3 transformer bays)	1	57.143	2.857	–	60.000
3. 24 kV SF6 GIS (3 Incomming/21 feeder)	1	25.000	5.000	–	30.000
4. SUBSTATION PAD-MOUNTED TRANSFORMER	2	0.545	0.055	–	0.600
5. 23kV, SUBSTATION CAPACITOR BANK & EQUIPMENTS (BANKS)	4	5.714	0.286	--	6.000
6. BATTERY	1	0.667	0.133	–	0.800
7. BATTERY CHARGER	1	0.236	0.064	–	0.300
8. 115 kV, CONTROL & METERING BOARD (2 Incomming/3 Outgoing)	1	3.333	0.167	–	3.500
9. AC & DC PANEL BOARDS	1	0.250	0.050	–	0.300
10. CABLE ACCESSORIES & MISCELLANEOUS ITEMS	LS.	2.083	0.417	–	2.500
11. INSURANCE PREMIUMS & INLAND TRANSPORTATION		–	–	1.000	1.000
12. ENGINEERING SERVICE		–	–	5.000	5.000
13. CIVIL CONSTRUCTION		–	–	25.000	25.000
TOTAL		124.062	11.937	31.000	167.000

Table 10.3-3 Standard Unit Cost for Temporary S/S Construction

1 9 9 4 Price

DESCRIPTION	QUANTITY (Sets)	Million Baht			
		FC	TAX	OTHER LC	TOTAL
Temporary S/S 69-12/24 kV, 1×60 MVA					
1. 69-12/24 kV POWER TRANSFORMER 36/48/60 MVA	1	13.636	1.364	–	15.000
2. 24 kV, SWITCHGEAR OUTDOOR TYPE(11, 50)	1	5.000	1.000	–	6.000
3. 69 kV SF6 CIRCUIT BREAKER	1	0.909	0.081	–	1.000
4. CONTROL ROOM FOR SUBSTATION	1	–	–	0.180	0.180
5. BATTERY & CHARGER	LS.	0.667	0.133	–	0.800
6. AC & DC PANEL BOARDS	LS.	0.017	0.003	–	0.020
7. CIVIL WORK & INSTALLATION COST		–	–	3.000	3.000
TOTAL		20.229	2.581	3.180	26.000
Temporary S/S 115-24 kV, 1 ×60 MVA					
1. 115-24 kV POWER TRANSFORMER 36/48/60 MVA	1	14.545	1.455	–	16.000
2. 24 kV, SWITCHGEAR OUTDOOR TYPE(11, 50)	1	5.000	1.000	–	6.000
3. 115 kV SF6 CIRCUIT BREAKER	1	0.909	0.091	–	1.000
4. CONTROL ROOM FOR SUBSTATION	1	–	–	0.180	0.180
5. BATTERY & CHARGER	LS.	0.667	0.133	–	0.800
6. AC & DC PANEL BOARDS	LS.	0.017	0.003	–	0.020
7. CIVIL WORK & INSTALLATION COST		–	–	3.000	3.000
TOTAL		21.138	2.682	3.180	27.000

Table 10.3-4 Standard Unit Cost for D/S Addition
1 9 9 4 Price

DESCRIPTION	QUANTITY (Sets)	Million Baht			
		FC	TAX	OTHER LC	TOTAL
Addition D/S 115-24kV, 2×60MVA → 3×60MVA					
1. 115-24 kV, POWER TRANSFORMER 36/48/60 MVA OLTC	1	14.545	1.455	—	16.000
2. CABLE ACCESSORIES & MISCELLANEOUS ITEMS	LS.	1.000	0.200	—	1.200
3. CIVIL WORK & INSTALLATION COST		—	—	0.800	0.800
TOTAL		15.545	1.655	0.800	18.000
Addition D/S 69-12/24kV, 2×60MVA → 3×60MVA					
1. 69-12/24 kV, POWER TRANSFORMER 36/48/60 MVA OLTC	1	13.636	1.364	—	15.000
2. CABLE ACCESSORIES & MISCELLANEOUS ITEMS	LS.	1.000	0.200	—	1.200
3. CIVIL WORK & INSTALLATION COST		—	—	0.800	0.800
TOTAL		14.636	1.564	0.880	17.000

Table 10.3-5 Standard Unit Cost for T/S Construction
1 9 9 4 Price

DESCRIPTION	QUANTITY (Sets)	FC	TAX	OTHER LC	TOTAL
I. 230-115 kV, Indoor T/S 2×300 MVA , EGAT's Transformer (ex:Onnut T/S, Bangbor T/S)					
1. 115 kV, SF6 GAS INSULATED SWITCHGEAR (2I. 2T, 1B, 6L)	1	119.048	5.952	—	125.000
2. 115 kV, CONTROL & METERING BOARD	1	6.667	0.333	—	7.000
3. CABLE & ACCESSORIES	LS.	0.833	0.167	—	1.000
4. S/S MISCELLANEOUS EQUIPMENT	LS.	1.667	0.333	—	2.000
5. CONSTRUCTION & INSTALLATION COST		—	—	35.000	35.000
TOTAL		128.214	6.786	35.000	170.000
II. 230-115 kV , T/S 2×300 MVA , MEA's Transformer (ex:Thanontok T/s)					
1. 230-115 kV, POWER TRANSFORMER	2	66.667	3.333	—	70.000
2. 115 kV, SF6 GAS INSULATED SWITCHGEAR (2I. 2T, 1B, 6L)	1	119.048	5.952	—	125.000
3. 115 kV, CONTROL & METERING BOARD	LS.	6.667	0.333	—	7.000
4. HIGH VOLTAGE CABLE SUPPORT STEEL WORK & CABLE TERMINATOR	LS.	6.667	1.333	—	8.000
5. SUBSTATION MISCELLANEOUS EQUIPMENT		2.500	0.500	—	3.000
6. CONSTRUCTION & INSTALLATION COST		—	—	7.000	7.000
TOTAL		201.549	11.451	7.000	220.000
III. 230-115 kV, T/ S 1×300 MVA , MEA's Transformer 230-69 kV, T/S 1×300 MVA, MEA's Transformer (ex:Sanampao T/S)					
1. 230-115 kV, POWER TRANSFORMER	1	33.333	1.667	—	35.000
2. 230- 69 kV, POWER TRANSFORMER	1	28.571	1.429	—	30.000
3. 230-115 kV, SF6 GAS INSULATED SWITCHGEAR (2 LINEBAY, 4 TRANS, BAY)	1	190.476	9.524	—	200.000
4. 115 kV, SF6 GAS INSULATED SWITCHGEAR (2I. 2T, 1B, 6L)	1	119.048	5.952	—	125.000
5. 69 kV, SF6 GAS INSULATED SWITCHGEAR (2I. 2T, 1B, 6L)	1	95.238	4.762	—	100.000
6. 69 kV, CONTROL & METERING BOARD	LS.}	14.286	0.714	—	15.000
7. 115 kV, CONTROL & METERING BOARD	LS.}				
8. HIGH VOLTAGE CABLE SUPPORT STEEL WORK & CABLE TERMINATOR	LS.	8.333	1.667	—	10.000
9. SUBSTATION MISCELLANEOUS EQUIPMENT	LS.	2.500	0.500	—	3.000
10. CONSTRUCTION & INSTALLATION COST		—	—	52.000	52.000
TOTAL		491.786	26.214	52.000	570.000

Table 10.3-5 (Continued)

DESCRIPTION	QUANTITY (Sets)	FC	TAX	OTHER LC	TOTAL
IV. 230-115 kV, Indoor T/S Addition, EGAT's Transformers -Jangwattana 2×300 to 3×300 MVA					
1. 115 kV, CONTROL & METERING BOARD	1	6.667	0.333	−	7.000
2. CABLE & ACCESSORIES	LS.	0.833	0.167	−	1.000
3. S/S MISCELLANEOUS EQUIPMENT	LS.	1.667	0.333	−	2.000
4. CONSTRUCTION & INSTALLATION COST		−	−	2.000	2.000
TOTAL		9.167	0.833	2.000	12.000
V. 230-115 kV, Indoor T/S Addition, EGAT's Transformers -Jangwattana 3×300 to 4×300 MVA					
1. CABLE & ACCESSORIES	LS.	0.833	0.167	−	1.000
2. S/S MISCELLANEOUS EQUIPMENT	LS.	1.667	0.333	−	2.000
3. INSTALLATION COST		−	−	2.000	2.000
TOTAL		2.500	0.500	2.000	5.000

Note. 1. For Item Nos. I and II, the construction of T/S and Installation of 69 kV GIS, 69 kV Control & Metering Board have already been included the MEA 7th plan.

2. For Item No. IV, the construction of T/S and installation of 115 kV GIS have already been included in the MEA 7th plan.

3. For Item No.V, the control board has already been included in the addition of Jangwatana T/S in 1998

Table 10.3-6 Standard Unit Cost for T/S Addition
1 9 9 4 Price

DESCRIPTION	QUANTITY (Sets)	FC	TAX	OTHER LC	TOTAL
I. 230-69 kV, Indoor T/S Addition, EGAT's Transformers					
-South Thonburi 3×200 to 4×200 MVA					
1. CABLE & ACCESSORIES	LS.	0.833	0.167	–	1.000
2. S/S MISCELLANEOUS EQUIPMENT	LS.	1.667	0.333	–	2.000
3. INSTALLATION COST		–	–	2.000	2.000
TOTAL		2.500	0.500	2.000	5.000
II. Bargkoknoi indoor T/S Addition, EGAT's Transformers					
-230-115 kV, 1 ×300 to 2×300 MVA					
Teparak Indoor T/S Addition, EGAT's Transformers					
-230-115 kV, 1 ×300 to 2×300 MVA					
-230- 69 kV, 1 ×300 to 2×300 MVA					
1. CABLE & ACCESSORIES	LS.	0.833	0.167	–	1.000
2. S/S MISCELLANEOUS EQUIPMENT	LS.	1.667	0.333	–	2.000
3. CONSTRUCTION & INSTALLATION COST		–	–	2.000	2.000
TOTAL		2.500	0.500	2.000	5.000
III. 230-115 kV, Outdoor T/S Addition, EGAT's Transformers					
-Klong Rangsit 1×200 to 2×200 MVA					
-Nong Jok 2×200 to 2×200 + 1×300 MVA					
-Sai Noi 1×300 to 2×300 MVA					
1. 123 kV, CB, 2000A, 31.5 kA	3 sets	4.545	0.455	–	5.000
2. 123 kV, CT, Outdoor 1000-2000/5/5/5 A	3	2.727	0.273	–	3.000
3. 123 kV, 2000 A Motor Operate Disconnecting Switch	4	1.364	0.136	–	1.500
4. 123 kV, Control Board		4.762	0.238	–	5.000
5. S/S MISCELLANEOUS EQUIPMENT	LS.	2.917	0.583	–	3.500
6. CONSTRUCTION & INSTALLATION COST		–	–	5.000	5.000
TOTAL		16.315	1.685	5.000	23.000

10.4 Rates of Taxes and Other Expenses

10.4.1 Taxes

The rates of the respective taxes shall be as described below:

(1) Import duties

The rates of the import duties to be imposed to the materials imported from overseas countries shall be as follows:

Tower (pole) materials and arm accessories	: 35%
Conductor, wire earth and accessories	: 35%
Insulators and accessories	: 35%
Cable and accessories	: 10%

(2) Value-added taxes

The rate of value-added taxes shall be 7%.

10.4.2 Rates of the Other Cost and Expenses

The rates of the other cost and expenses shall be as follows:

(1) Rate of miscellaneous work cost : 5% of the direct cost

(2) Rate of engineering and supervision fees : 7% of the direct cost

(3) Contingency rate : 10% of the direct cost

(4) Escalation rate :

The yearly price escalation rates are assumed to be 5% for the local currency portion and 2.2% for the foreign current portion, and these escalation rates will be taken into account for financial analysis.

(5) Foreign exchange rate

The exchange rate of the local currency to US. dollar shall be US$1 = 25.0 Baht.

10.4.3 Material Transportation Cost

The transportation cost (on the basis of the level in 1994) of the respective materials in Thailand shall be as follows:

(1) Weight limit of road traffic

According to the road regulations of Thailand, the limit of maximum weight of load shall be as follows:

National road or major road : 20 tons

Other roads : 14 tons

(2) Standard of maximum carrying size

Standard of maximum carrying size of Thailand shall be as follows:

Maximum width : 3.0 m (Low Bed Trailer : 3.0 m)

Maximum length : 4.0 m (Low Bed Trailer : 10.0 m)

Maximum height : 2.7 m (Low Bed Trailer : 3.0 m)

(3) Transportation cost

Transportation cost of Express Transportation Organization of Thailand shall be as follows:

Transportation cost (Baht)

Distance of transportation	6-Wheel Truck		10-Wheel Truck		Remarks
	5tons Car	per 1ton	10tons Car	per 1ton	
0 ~ 10	500	100	650	65	
10 ~ 15	620	125	810	80	
15 ~ 20	720	145	930	95	
20 ~ 25	830	165	1,070	105	
25 ~ 30	840	170	1,210	120	
30 ~ 35	1,050	210	1,340	135	
35 ~ 40	1,150	230	1,470	150	
40 ~ 60	1,310	260	1,670	165	

Transportation cost of large-sized trailer (Thai Baht)

Distance of Transportation	15tons Car	per 1ton	Remarks
1 ～ 3	1,500	100	
3 ～ 26	2,000	135	
26 ～ 50	2,500	165	

10.5 Construction Cost and Expenditure

The construction cost of the respective works are as indicated below:

(1) Construction cost

The construction cost in this studies is as indicated below:

Items	Construction cost (Million Baht)		
	Foreign currency	Local currency	Total
Subtransmission Line	10,033	7,169	17,202
Substation	22,606	15,310	37,916
Telecommunication	397	283	680
Total ( ) : Million US$	33,036 (1,321)	22,762 (911)	55,798 (2,232)

(2) Construction cost in the short-term plan

The construction cost in the respective fiscal years are as indicated below:

Construction cost in the short-term plan (Unit: Million Baht)

Items		1997	1998	1999	2000	2001
Subtransmission Line	F.C.	338.96	187.24	484.19	1,810.75	196.96
	L.C.	362.24	405.00	513.41	1,090.35	144.42
	Subtotal	701.20	592.24	997.60	2,901.10	341.38
Substation	F.C.	2,637.70	1,418.87	1,576.61	2,253.61	1,517.77
	L.C.	1,929.62	842.82	988.32	1,565.53	1,064.71
	Subtotal	4,567.32	2,261.69	2,564.93	3,819.14	2,582.48
Telecommunication	F.C.	43.04	35.52	30.10	45.14	43.04
	L.C.	30.65	25.30	21.38	32.07	30.65
	Subtotal	73.69	60.82	51.48	77.21	73.69
Total	F.C.	3,019.70	1,641.63	2,090.90	4,109.50	1,757.77
	L.C.	2,322.51	1,273.12	1,523.11	2,687.95	1,239.78
	Total	5,342.21	2,914.75	3,614.01	6,797.45	2,997.55

(3) Construction cost in the long-term plan

The construction cost in the respective fiscal years are as indicated below:

Construction cost in the long-term plan (Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Period from the last	5	5	5	5	20
Subtransmission line	5,533.5	8,261.9	1,348.4	2,058.6	17,202.4
Substation	15,795.6	9,773.2	6,701.6	5,646.3	37,916.7
Telecommunication	336.9	169.6	96.5	76.6	679.6
Total	21,666.0	18,204.7	8,146.5	7,781.5	55,798.7
Annual investment	4,333.2	3,640.9	1,629.3	1,556.3	2,789.9

10.5.1 Subtransmission Line Facility

The amount of construction cost (on the basis of the price level in FY 1995) in the respective fiscal years are as indicated below:
The exchange rate is 25.0 Baht per U.S.Dollar.

Amount of construction cost for subtransmission line facilities

Planned year	1997～2001	2002～2006	2007～2011	2012～2016	Total
Period from the last year	5	5	5	5	20
Amount of construction cost (Million Baht)	5,533.5	8,261.9	1,348.4	2,058.6	17,202.4
Annual investment (Million Baht)	1,106.7	1,652.4	269.7	411.7	860.1

The total transmission line cost accounts for 17.2 billion Baht (688.1 million US$) in price level in 1995, of which 49.8% (8.6 billion Baht) is for 230 kV subtransmission lines, 37.2% (6.4 billion Baht) for 115 kV subtransmission lines and the remaining (13.0%) for 69 kV subtransmission lines, as can be understood from the following tables.
In the type of facility, the construction costs for overhead subtransmission lines share 16.8% (2.9 billion Baht) and those costs for underground subtransmission lines share 83.2% (14.3 billion Baht).

The average investment ranging from 0.3 to 2.9 billion baht (10.8 to 116.0 million US$) per, annum expressed in price level in 1995, is necessary for construction and renovation of transmission lines.
The construction cost of the respective subtransmission line are as presented in Appendix 10.5-1.

(1) Construction cost of the respective voltage

The construction cost of the respective voltage for subtransmission line are as indicated below:

(a) Amount of construction cost for subtransmission line facilities

1) Amount of construction cost for subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	5,533.5	8,261.9	1,348.4	2,058.6	17,202.4
Foreign currency	3,018.1	5,058.7	683.4	1,273.0	10,033.2
Local currency	2,515.4	3,203.2	665.0	785.6	7,169.2

2) Amount of construction cost for overhead subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	1,299.7	970.6	343.1	270.9	2,884.3
Foreign currency	246.4	172.7	64.5	52.8	536.4
Local currency	1,053.3	797.9	278.6	218.1	2,347.9

3) Amount of construction cost for underground subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	4,233.7	7,290.4	1,005.3	1,787.7	14,317.1
Foreign currency	2,771.6	4,886.1	619.0	1,220.2	9,496.9
Local currency	1,462.1	2,404.3	386.3	567.5	4,820.2

(b) Construction cost for 230 kV transmission line facilities

1) Construction cost for 230 kV transmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	1,918.7	5,161.8	0.0	1,485.1	8,565.6
Foreign currency	1,319.5	3,567.6	0.0	993.5	5,880.6
Local currency	599.2	1,594.2	0.0	491.6	2,685.0

2) Construction cost for 230 kV overhead transmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	35.4	0.0	0.0	93.4	128.8
Foreign currency	6.0	0.0	0.0	20.5	26.5
Local currency	29.4	0.0	0.0	72.9	102.3

3) Construction cost for 230 kV underground transmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	1,883.3	5,161.8	0.0	1,391.7	8,436.8
Foreign currency	1,313.5	3,567.6	0.0	973.0	5,854.1
Local currency	569.8	1,594.2	0.0	418.7	2,582.7

(c) Construction cost for 115 kV subtransmission line facilities

1) Construction cost for 115 kV subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	2,685.0	2,347.6	962.2	403.9	6,398.7
Foreign currency	1,205.5	1,103.8	474.4	206.2	2,989.9
Local currency	1,479.5	1,243.8	487.8	197.7	3,408.8

2) Construction cost for 115 kV overhead subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	1,105.0	827.6	293.3	112.0	2,337.9
Foreign currency	211.0	148.1	55.9	21.0	436.0
Local currency	894.0	679.5	237.4	91.0	1,901.9

3) Construction cost for 115 kV underground subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	1,580.0	1,520.0	668.9	291.9	4,060.8
Foreign currency	994.5	955.7	418.5	185.2	2,553.9
Local currency	585.5	564.3	250.4	106.7	1,506.9

(d) Construction cost for 69 kV subtransmission line facilities

1) Construction cost for 69 kV subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	929.7	751.6	386.2	169.6	2,237.1
Foreign currency	493.0	387.4	209.1	73.3	1,162.8
Local currency	436.7	364.2	177.1	96.3	1,074.3

2) Construction cost for 69 kV overhead subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	159.3	143.0	49.8	65.5	417.6
Foreign currency	29.4	24.6	8.6	11.3	73.9
Local currency	129.9	118.4	41.2	54.2	343.7

3) Construction cost for 69 kV underground subtransmission line facilities

(Unit: Million Baht)

Planned year	2001	2006	2011	2016	Total
Total cost	770.4	608.6	336.4	104.1	1,819.5
Foreign currency	463.6	362.8	200.5	62.0	1,088.9
Local currency	306.8	245.8	135.9	42.1	730.6

(2) Construction cost in the respective fiscal years

The construction cost in the respective fiscal years for subtransmission line are as indicated below:

(Unit: Million Baht)

Planned year	Construction cost in the respective fiscal years			Remarks
	Foreign currency	Local currency	Total cost	
1997	338.96	362.24	701.20	
1998	187.24	405.00	592.24	
1999	484.19	513.41	997.60	
2000	1,810.75	1,090.35	2,901.10	
2001	196.96	144.42	341.38	
2002				
2003				
2004	1,011.75/year (2002–2006)	640.64/year	1,652.39/year	
2005				
2006				
2007				
2008				
2009	136.67/year (2007–2011)	133.00/year	269.67/year	
2010				
2011				
2012				
2013				
2014	224.60/year (2012–2016)	157.12/year	411.72/year	
2015				
2016				
Total	10,033.23	7,169.19	17,202.42	