9.3.3 Study of Distribution Voltage, Conductor Size and Bank Configuration

Studied herein is an optimum system configuration in view of the distribution voltage and conductor size.

When the system configuration is studied based on the distribution voltage and conductor size, the capacity of distribution line shall be changed. This means that where the capacity of distribution line is changed, then the number of distribution lines outgoing from the substation is also changed. Therefore, optimization of system configuration is studied taking into account the number of feeders per one substation and cost of the distribution line downstream of the substation banks.

The distribution voltage is studied regarding 12 kV and 24 kV voltages applied by MEA including 36 kV, a one-rank higher voltage.

The distribution line conductor size is also studied regarding 185 mm² applied by MEA including 240 mm², a one-rank larger conductor size.

The allowable current for the respective conductor sizes listed below is coordinated with that for the underground cable applied by MEA.

Conductor size	Allowable current
Partially insulated conductor	
185 mm²	488 A
240 mm²	600 A
CU. XLPE	
400 mm²	614 A

(1) Study of maximum number of feeders per one substation

For promoting this study, the maximum number of feeders per one bank is studied.

The maximum number of feeders per one bank can generally be obtained from the following formula :

$$N = \frac{P_T \times \alpha \times \gamma}{\sqrt{3} \times V_s \times P_L \times \beta}$$

P_T : Bank capacity (MVA)

P_L : Feeder capacity (kA)

V_S : Feeder voltage (kV)

α : Target utilization factor of bank

β : Target utilization factor of feeder

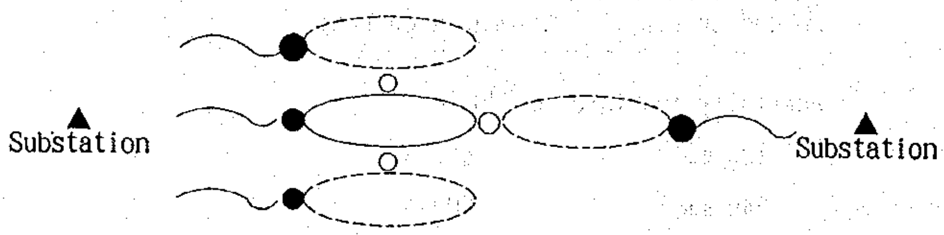
γ : Diversity factor of feeder

N : Number of feeders

The target utilization factor of feeders specified in the planning criteria of MEA is studied.

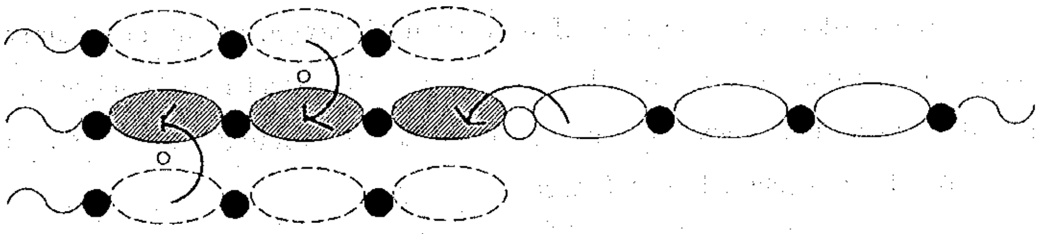
Generally, the target utilization factor of feeders is so set as to provide an allowance for relieving the power system in case any fault has occurred in an adjacent distribution line.

The ideal distribution line system is a "3-division 3-linkage system". Since a distribution line is normally formed in a radial form, it is apparent when considered conceptionally that the simplest distribution line interconnecting method is to interconnect the distribution line with adjacent two distribution lines and one distribution line from the other substation, as shown below.



The target utilization factor in the above system configuration can be obtained from the following formula since an adjacent distribution line in fault is relieved by the three interconnected distribution lines in case any fault has occurred in the adjacent distribution line.

$$\text{Target utilization factor} = \frac{\text{3 sections}}{\text{4 sections}} \times 100 = 75\%$$



Based on the above study conditions, the maximum number of feeders per one bank is obtained by substituting the respective coefficients with the following values:

P_T : 40, 60 and 80 (MVA)

P_L : 0.488 and 0.6 (kA)

V_S : 12, 24 and 36 (kV)

α : 0.8

β : 0.75

γ : 1.1580, 1.1274 and 1.0895

Table 9.3-7 Number of Feeders

(Feeders/Bank)

Diversity Factor	Feeder Voltage	Feeder Capacity 488 A			Feeder Capacity 600 A		
		Bank Capacity			Bank Capacity		
		40 MVA	60 MVA	80 MVA	40 MVA	60 MVA	80 MVA
Residential 1.1580	12 kV	5	8	10	4	6	8
	24 kV	3	4	5	2	3	4
	36 kV	2	3	4	2	2	3
Commercial 1.1274	12 kV	5	8	10	4	6	8
	24 kV	3	4	5	2	3	4
	36 kV	2	3	4	2	2	3
Industrial 1.0895	12 kV	5	7	10	4	6	8
	24 kV	3	4	5	2	3	4
	36 kV	2	3	4	2	2	3

Size of conductor

488 A ; 185sq.mm

600 A ; 240sq.mm

According to the planning criteria of MEA, the standard number of feeders is seven per one bank in case the distribution voltage is 24 kV. This is equivalent to the target utilization factor of feeder which is an order of 40% according to the above calculation formula.

To ensure operation of feeders at a low utilization factor, it seems to be necessary for MEA to increase the number of feeders from a theoretical value. The feeders are operated at a lower utilization factor presumably because it is considered possible to relieve the load by one adjacent distribution circuit where the utilization factor is 50% or less even in case a fault has occurred in a feeder.

In other words, it is predicted inevitable for MEA to operate its distribution line system at such a low utilization factor since the number of switches installed for interconnection between distribution lines and dividing the lines is not enough at present.

(2) Preparation of model of the portion of underground cable section outgoing from distribution substation

Studied herein is the portion of the underground cable section outgoing from distribution substation where the number of feeders per one substation is different.

The portion outgoing from substation may vary in individual cases depending on the road and other conditions around the substation.

Therefore, study models are set and examined under the following conditions:

- Around the substation, a road is assumed to exist per unit mesh of 100 m.
- The substation is assumed to face a wide road.
- Four circuits in maximum shall be raised to a wide road facing the substation.
- The fifth and subsequent circuits be raised successively to the road every 100 m centering on the substation.
- Any overhead line should not be strung across or in parallel with another overhead line.

Based on the above conditions, the relationship between the number of feeders and length of the underground portion outgoing from substation is calculated on a trial basis and the calculation results are presented in Fig. 9.3-5.

(3) Trial calculation of the length of overhead distribution line

Studied herein is the length of overhead distribution line within a supply area of substation.

Since the portion of overhead distribution line is required whenever any power demand exists, this portion is closely related to the power demand conditions regardless of the number of feeders. In this case, a model has also been set and studied.

Setting conditions of the model

- The demand is assumed to exist facing a road.
- A road is assumed to exist per unit mesh of 100 m.
- The overhead distribution line is assumed to be formed on a road per unit mesh of 100 m.
- Any overhead line should not be strung across or in parallel with another overhead line.

The length of overhead distribution line can be obtained from the following formula on a trial basis, where the supply area of distribution line is assumed to be of a square form:

$$L = 2 \times (n \times \ell) \times (n - 1)$$

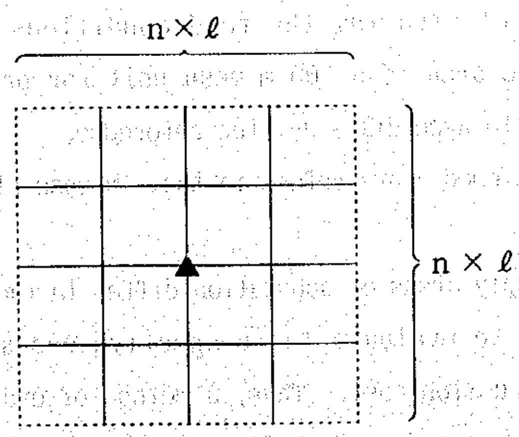
$$= 2 \times \sqrt{S} \times \left(\frac{\sqrt{S}}{\ell} - 1 \right)$$

L : Length of overhead distribution line (km)

ℓ : Road interval (km)

S : Supply area of substation (km^2)

n : Number of blocks



The supply area of a substation is obtained from the following formula:

$$S = \frac{P_T \cdot \alpha}{\sigma}$$

S : Supply area of substation (km²)

P_T : Capacity of substation (MVA)

α : Target utilization factor of substation

σ : Load density (MVA/km²)

Based on the above conditions, the supply area of substation and length of overhead distribution line are calculated based on the load density as a parameter, and the results are presented in Table 9.3-8.

For comparison with actual cost, the value of load density at 80 (MVA/km²) is used from among those in the above table. As explained subsequently in Clause 9.3.4, this load density is roughly equal to that on the Sathorn Street.

Meanwhile, the results of calculating the supply reach of substation on a trial basis is presented in Table 9.3-8 for reference. This calculation is made according to the formula indicated in Item (4) of Clause 6.3.1.

(4) Evaluation of study results

Based on the above conditions, the construction cost of equipment downstream of feeders is calculated on a trial basis according to the respective bank configurations, and the calculation results are presented in Table 9.3-9.

Meanwhile, the results of studying the road conditions around the substation by setting the area to a 200 m mesh unit for preparing the study models are attached to Appendix 9.3-1 for reference.

The construction cost mentioned above refers to that in case all equipment are newly constructed.

Since the capacity and supply areas of substation differ in the respective cases, it is impossible to evaluate the respective cases simply by comparing the total construction cost. Thus, a method of evaluating the respective cases is applied according to the unit cost per kVA in view of the effective output of the substations.

As a result of this study, the following can be concluded:

(a) Distribution voltage

The economically optimum distribution voltage is 24 kV in all of the respective cases because of the following reasons. The number of distribution lines per substation is increased and the construction cost of underground cable for drawing out of distribution line is extraordinarily high where the distribution voltage is 12 kV. When the distribution voltage is increased to 36 kV, the construction cost of the portion of underground cable section can be decreased as the number of distribution lines is decreased, but this cost reduction is offset by the increase of construction cost of the portion of overhead distribution lines.

As a result, the distribution voltage of 24 kV is concluded justifiable. (b) Conductor size

The conductor size of 240 mm² is concluded to be economically advantageous over 185 mm² in all of the respective cases because of the following reasons.

Although the construction cost of overhead distribution line is slightly increased when this conductor size of 240 mm² is adopted, the number of distribution lines per substation is decreased due to increase of transmission capacity, so that the construction cost of the portion of the lines outgoing from the distribution substation can be reduced substantially.

In this study, however, the cost of replacing the existing 185 mm² conductors with 240 mm² conductors is not taken into consideration.

In case the conductor size is to be changed to 240 mm², it is necessary to take into account the construction cost for replacement of conductors. Considering the present situations of most of the distribution facilities of MEA which have been operated at a low utilization factor, whether it is necessary to increase the conductor size of distribution lines even by making new investment is questionable.

When the transmission capacity per circuit is increased, the effect of any fault arising in distribution line can possibly spread over a wide range of the distribution system. It cannot necessarily be said that reckless increase of the transmission capacity is desirable in view of reliability.

When the above situations are taken into account, the distribution line conductor size of 185 mm^2 being adopted at present is evaluated to be sufficient.

(c) Bank configuration

Upon evaluation of distribution line cost per bank kVA on each bank configuration, the following general tendency was obtained in all of the respective cases:

3 × 80 MVA > 3 × 60 MVA > 4 × 40 MVA > 3 × 40 MVA

In other words, the case of 3 x 40 MVA is economically optimum because of the following reasons.

Since economic evaluation is based on the construction cost downstream of the substation feeders, the greater the substation capacity, the larger the number of the circuits outgoing from substation. Therefore, the construction cost of underground cable becomes as much higher.

According to the results of evaluation in view of the configurations of subtransmission line and substation bank described in Clause 9.3.1, the cases of 3 x 60 MVA and 3 x 80 MVA are concluded to be substantially advantageous over the other cases.

However, there is not so much difference between 3 x 60 MVA and 3 x 80 MVA in view of preference.

3 × 40 MVA > 4 × 40 MVA ≫ 3 × 60 MVA, 3 × 80 MVA

When the construction cost downstream of substation feeders is included in the subtransmission line and substation cost to each bank configuration, 3 x 60 MVA is ultimately evaluated to be justifiable.

(d) Conclusion

When the above studies are summarized, the system indicated below is judged to be optimum:

Substation bank configuration : 3 × 60 MVA

No. of feeders per bank : 5 ckts

The number of feeders includes a standby one feeder to cope with standby line in preparation for large scale power demand. Meanwhile, any feeder for power capacitor and station service transformer is not taken into consideration.

Distribution voltage : 24 kV

Conductor size : 185 mm^2

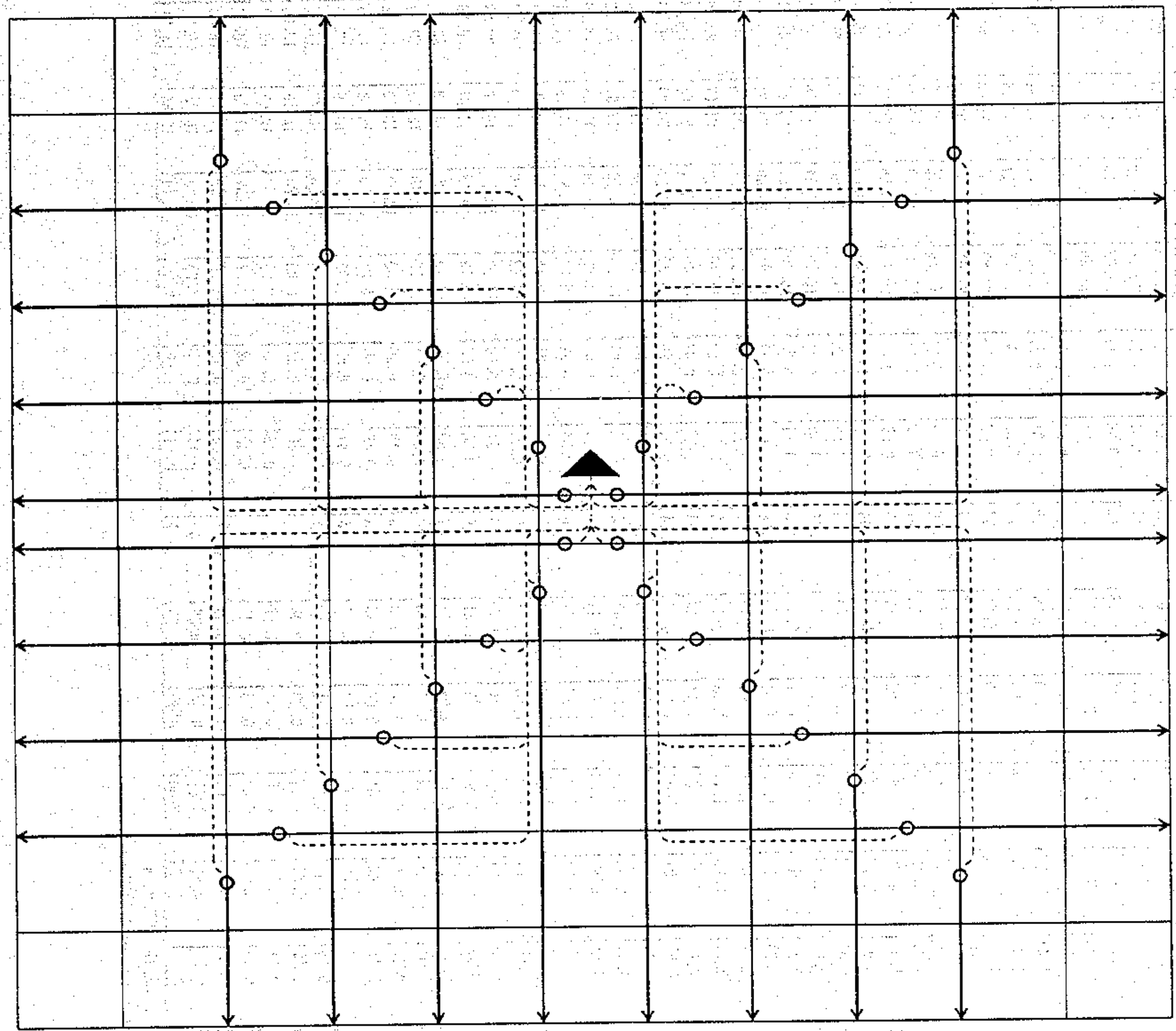


Fig. 9.3-5 Model of Feeder Rising Point

No of Feeder	Length of UG Cable
1	50 m
2	100 m
3	200 m
4	300 m
5	425 m
6	550 m
7	725 m
8	900 m
9	1,125 m
10	1,350 m
11	1,625 m
12	1,900 m
13	2,225 m
14	2,550 m
15	2,925 m
16	3,300 m
17	3,725 m
18	4,150 m
19	4,625 m
20	5,100 m
21	5,625 m
22	6,150 m
23	6,725 m
24	7,300 m
25	7,925 m
26	8,550 m
27	9,225 m
28	9,900 m
29	10,625 m
30	11,350 m
31	12,125 m
32	12,900 m

Table 9.3-8 Supply Area of Substation

Density (MVA/sq. km)	Supply Area (sq. km)				Supply Reach (km)				Total Feeder Length (km)			
	3×40	4×40	3×60	3×80	3×40	4×40	3×60	3×80	3×40	4×40	3×60	3×80
1	96.00	128.00	144.00	192.00	5.53	6.38	6.77	7.82	1,900.80	2,556.90	2,856.00	3,824.37
2	48.00	64.00	72.00	96.00	3.91	4.51	4.79	5.53	956.09	1,264.00	1,425.53	1,900.80
3	32.00	42.67	48.00	64.00	3.19	3.69	3.91	4.51	633.57	849.19	956.09	1,264.00
4	24.00	32.00	36.00	48.00	2.76	3.19	3.39	3.91	470.30	633.57	708.00	956.09
5	19.20	25.60	28.80	38.40	2.47	2.85	3.03	3.50	376.83	505.96	568.86	756.01
6	16.00	21.33	24.00	32.00	2.26	2.61	2.76	3.19	312.00	424.90	470.30	633.57
7	13.71	18.29	20.57	27.43	2.09	2.41	2.56	2.95	274.00	359.24	408.19	544.69
8	12.00	16.00	18.00	24.00	1.95	2.26	2.39	2.76	235.56	312.00	356.38	470.30
9	10.67	14.22	16.00	21.33	1.84	2.13	2.26	2.61	209.06	279.05	312.00	424.90
10	9.60	12.80	14.40	19.20	1.75	2.02	2.14	2.47	185.90	250.44	280.81	376.83
15	6.40	8.53	9.60	12.80	1.43	1.65	1.75	2.02	126.49	169.40	185.90	250.44
20	4.80	6.40	7.20	9.60	1.24	1.43	1.51	1.75	92.02	126.49	139.53	185.90
25	3.84	5.12	5.76	7.68	1.11	1.28	1.35	1.56	74.46	99.56	110.40	149.65
30	3.20	4.27	4.80	6.40	1.01	1.17	1.24	1.43	60.82	82.66	92.02	126.49
35	2.74	3.66	4.11	5.49	0.93	1.08	1.14	1.32	52.97	72.70	81.09	107.78
40	2.40	3.20	3.60	4.80	0.87	1.01	1.07	1.24	46.48	60.82	68.31	92.02
45	2.13	2.84	3.20	4.27	0.82	0.95	1.01	1.17	40.86	53.93	60.82	82.66
50	1.92	2.56	2.88	3.84	0.78	0.90	0.96	1.11	36.03	48.00	54.31	74.46
55	1.75	2.33	2.62	3.49	0.75	0.86	0.91	1.05	34.39	45.79	51.80	67.25
60	1.60	2.13	2.40	3.20	0.71	0.82	0.87	1.01	30.36	40.86	46.48	60.82
65	1.48	1.97	2.22	2.95	0.69	0.79	0.84	0.97	29.20	39.30	41.72	58.40
70	1.37	1.83	2.06	2.74	0.66	0.76	0.81	0.93	25.75	35.17	40.19	52.97
75	1.28	1.71	1.92	2.56	0.64	0.74	0.78	0.90	24.89	34.00	36.03	48.00
80	1.20	1.60	1.80	2.40	0.62	0.71	0.76	0.87	21.91	30.36	34.88	46.48
85	1.13	1.51	1.69	2.26	0.60	0.69	0.73	0.85	21.26	29.49	31.20	45.10
90	1.07	1.42	1.60	2.13	0.58	0.67	0.71	0.82	20.69	26.22	30.36	40.86
95	1.01	1.35	1.52	2.02	0.57	0.65	0.69	0.80	20.10	25.56	29.59	39.80
100	0.96	1.28	1.44	1.92	0.55	0.64	0.68	0.78	17.64	24.89	26.40	36.03
105	0.91	1.22	1.37	1.83	0.54	0.62	0.66	0.76	17.17	24.30	25.75	35.17
110	0.87	1.16	1.31	1.75	0.53	0.61	0.65	0.75	16.79	21.54	25.18	34.39
115	0.83	1.11	1.25	1.67	0.52	0.60	0.63	0.73	16.40	21.07	24.60	31.01
120	0.80	1.07	1.20	1.60	0.50	0.58	0.62	0.71	14.31	20.69	21.91	30.36
125	0.77	1.02	1.15	1.54	0.49	0.57	0.61	0.70	14.04	20.20	21.45	29.78
130	0.74	0.98	1.11	1.48	0.48	0.56	0.59	0.69	13.76	17.82	21.07	29.20
135	0.71	0.95	1.07	1.42	0.48	0.55	0.58	0.67	13.48	17.54	20.69	26.22
140	0.69	0.91	1.03	1.37	0.47	0.54	0.57	0.66	13.29	17.17	20.30	25.75
145	0.66	0.88	0.99	1.32	0.46	0.53	0.56	0.65	13.00	16.89	17.91	25.28
150	0.64	0.85	0.96	1.28	0.45	0.52	0.55	0.64	11.20	16.60	17.64	24.89
155	0.62	0.83	0.93	1.24	0.44	0.51	0.54	0.63	11.02	16.40	17.36	24.50
160	0.60	0.80	0.90	1.20	0.44	0.50	0.54	0.62	10.84	14.31	17.08	21.91
165	0.58	0.78	0.87	1.16	0.43	0.50	0.53	0.61	10.66	14.13	16.79	21.54
170	0.56	0.75	0.85	1.13	0.42	0.49	0.52	0.60	10.48	13.86	16.60	21.26
175	0.55	0.73	0.82	1.10	0.42	0.48	0.51	0.59	10.38	13.67	16.30	20.98
180	0.53	0.71	0.80	1.07	0.41	0.48	0.50	0.58	10.19	13.48	14.31	20.69
185	0.52	0.69	0.78	1.04	0.41	0.47	0.50	0.57	10.10	13.29	14.13	20.40
190	0.51	0.67	0.76	1.01	0.40	0.46	0.49	0.57	10.00	13.10	13.95	20.10
195	0.49	0.66	0.74	0.98	0.40	0.46	0.48	0.56	8.40	13.00	13.76	17.82
200	0.48	0.64	0.72	0.96	0.39	0.45	0.48	0.55	8.31	11.20	13.58	17.64
205	0.47	0.62	0.70	0.94	0.39	0.45	0.47	0.55	8.23	11.02	13.39	17.45
210	0.46	0.61	0.69	0.91	0.38	0.44	0.47	0.54	8.14	10.93	13.29	17.17
215	0.45	0.60	0.67	0.89	0.38	0.44	0.46	0.53	8.05	10.84	13.10	16.98
220	0.44	0.58	0.65	0.87	0.37	0.43	0.46	0.53	7.96	10.66	12.90	16.79
225	0.43	0.57	0.64	0.85	0.37	0.43	0.45	0.52	7.87	10.57	11.20	16.60
230	0.42	0.56	0.63	0.83	0.36	0.42	0.45	0.52	7.78	10.48	11.11	16.40
235	0.41	0.54	0.61	0.82	0.36	0.42	0.44	0.51	7.68	10.29	10.93	16.30
240	0.40	0.53	0.60	0.80	0.36	0.41	0.44	0.50	7.59	10.19	10.84	14.31

Supply Reach : Length of Radius
Feeder Length : Road of 100m Mesh

Table 9.3-9 Cost of Model Case

Size of Conductor (sq.mm)	Bank Configulation	Capacity (MVA)	Maximum Loading (MVA)	Feeder Voltage (kV)	No. of Feeders (ckt)	UG Cable Length (m)	Overhead Length (km)	Unit Cost: Feeder GIS (thousand Baht)	Unit Cost: UG Cable (Baht/m)	Unit Cost: Overhead (Baht/m)	Cost (Thousand Baht): Feeder GIS	Cost (Thousand Baht): UG Cable	Cost (Thousand Baht): Overhead	Cost (Thousand Baht): Total	kVA Cost (Baht/kVA)
185	3×40	120	96	12	3 × 5 = 15	2,925	21.91	8.700	3.960	2.880	18.640	11.580	63.100	93.320	972.1
				24	3 × 3 = 9	1,125	21.91	12.500	4.240	3.060	16.070	4.770	67.040	87.880	915.4
				36	3 × 2 = 6	550	21.91	17.500	5.460	3.230	15.000	3.000	70.770	88.770	924.7
	4×40	160	128	12	4 × 5 = 20	5,100	30.36	8.700	3.960	2.880	24.860	20.200	87.440	132.500	1,035.2
				24	4 × 3 = 12	1,900	30.36	12.500	4.240	3.060	21.430	8.060	92.900	122.390	956.2
				36	4 × 2 = 8	900	30.36	17.500	5.460	3.230	20.000	4.910	98.060	122.970	960.7
	3×60	180	144	12	3 × 8 = 24	7,300	34.88	8.700	3.960	2.880	29.830	28.910	100.450	159.190	1,105.5
				24	3 × 4 = 12	1,900	34.88	12.500	4.240	3.060	21.430	8.060	106.730	136.220	946.0
				36	3 × 3 = 9	1,125	34.88	17.500	5.460	3.230	22.500	6.140	112.660	141.300	981.3
	3×80	240	192	12	3 × 10 = 30	11,350	46.48	8.700	3.960	2.880	37.290	44.950	133.860	216.100	1,125.5
				24	3 × 5 = 15	2,925	46.48	12.500	4.240	3.060	26.790	12.400	142.230	181.420	944.9
				36	3 × 4 = 12	1,900	46.48	17.500	5.460	3.230	30.000	10.370	150.130	190.500	992.2
240	3×40	120	96	12	3 × 4 = 12	1,900	21.91	8.700	3.960	2.920	14.910	7.520	63.980	86.410	900.1
				24	3 × 2 = 6	550	21.91	12.500	4.240	3.100	10.710	2.330	67.920	80.960	843.3
				36	3 × 2 = 6	550	21.91	17.500	5.460	3.270	15.000	3.000	71.650	89.650	933.9
	4×40	160	128	12	4 × 4 = 16	3,300	30.36	8.700	3.960	2.920	19.890	13.070	88.650	121.610	950.1
				24	4 × 2 = 8	900	30.36	12.500	4.240	3.100	14.290	3.820	94.120	112.230	876.8
				36	4 × 2 = 8	900	30.36	17.500	5.460	3.270	20.000	4.910	99.280	124.190	970.2
	3×60	180	144	12	3 × 6 = 18	4,150	34.88	8.700	3.960	2.920	22.370	16.430	101.850	140.650	976.7
				24	3 × 3 = 9	1,125	34.88	12.500	4.240	3.100	16.070	4.770	108.130	128.970	895.6
				36	3 × 2 = 6	550	34.88	17.500	5.460	3.270	15.000	3.000	114.060	132.060	917.1
	3×80	240	192	12	3 × 8 = 24	7,300	46.48	8.700	3.960	2.920	29.830	28.910	135.720	194.460	1,012.8
				24	3 × 4 = 12	1,900	46.48	12.500	4.240	3.100	21.430	8.060	144.090	173.580	904.1
				36	3 × 3 = 9	1,125	46.48	17.500	5.460	3.270	22.500	6.140	151.990	180.630	940.8

9.3.4 Future Plan for Model Districts

The distribution system which should be formed in the model districts in the future is studied herein taking into account the situations of the distribution system in the metropolitan area of Japan.

(1) Sathorn Area

The power demand and its density related to the substations in this model districts and surrounding areas are forecast to become as presented in Table 9.3-10 and Fig. 9.3-6.

This area will become a high density commercial area where large scale high-rise buildings will stand in rows in the future.

The majority of customers are big customers mostly receiving power supply directly from 24 kV lines, while the government agencies including embassies of overseas countries are receiving power supply partly at low voltage.

The Sathorn Street is a single side four-lane road with a width of as much as 3 m, and when the canal between the center of the road is included, the total road width is roughly 60 m.

In this area, a certain extent of walkway width has been acquired, and skyscrapers and other buildings are constructed setting back from sidewalks. Therefore, it would not be impossible to construct overhead transmission line along the street.

Judging from the present situations of the metropolitan area of Japan, however, it is deemed essential to introduce underground transmission facilities in this area for preserving the urban scenery and ensuring the reliability and public securities.

Meanwhile, the road is so wide that it is possible to acquire the space sufficient for installing underground transmission facilities.

Speaking of distribution substations, the space for constructing substations facing the Sathorn Street is still available under present situations. Along with the progress of development in future, however, it will become gradually unavailable to acquire the land under favorable conditions. Moreover, the land price for constructing substations is anticipated to undergo substantial escalation at the same time.

Not only for saving the land cost for constructing a substation in such a area but also for effective utilization of land and space, it is considered advantageous to use a rent room in a high-rise building or purchase a part of the building for construction of substation.

The space ranging from the first to several floors is allocated for parking lots to acquire parking space in many cases of constructing high-rise buildings in Bangkok.

In the case of the metropolitan area of Japan, however, the portion of the first floor of building facing a street allows easy access of customers and is most suitable for stores and so forth. Therefore, this portion is deemed most important. Since lower building floors are frequently allocated for parking in Bangkok, it is deemed sufficiently possible to construct a substation by leasing or purchasing a part of the first floor of building.

Regarding the distribution facilities, the load density is so high that distribution lines are congested in some places of this area. Therefore, underground distribution system should be introduced to preserve the urban scenery and ensure the reliability and public securities similarly as in the case of transmission facilities.

With regard to the power demand configuration, the majority of customers are occupied by high-rise building receiving power supply directly from 24 kV lines. Therefore, the spot network system introduced in the metropolitan area of Japan is suitable to ensure the reliability and efficient operation of distribution lines.

Although the low voltage load is limited to only partial customers, there are a number of foreign embassies, government agencies and other important customers. Therefore, it is deemed desirable to adopt the regular network system adopted also in the metropolitan area of Japan.

The secondary side of both the spot network and regular network systems is connected to a network. Since it is possible to supply load from a sound circuit without limiting the load even when any fault has occurred in one circuit of distribution line in the primary system, these systems offer high supply reliability.

A future conceptional diagram prepared taking into account the above situations is presented in Fig. 9.3-7.

Meanwhile, an example of calculating the capacity of power receiving transformer for spot network system, and an example of water-proof countermeasures in the regular network system are presented respectively in Appendices 9.3-2 and 9.3-3 for reference.

(2) Phahol Yothin Area

The power demand and its density related to the substations in this model area and surrounding areas are presented in Table 9.3-11 and Fig. 9.3-8. This area is a commercial area where comparatively small scale shopping stores are jumbled up close together probably because this area has been developed earlier than the Sathorn area.

Under the present situations, the majority of buildings consist of two or three story shopping stores, and high-rise buildings stand in rows in part of the area. Therefore, low voltage load is observed to share about 70 or 80% of the total load.

It can hardly be considered that all of such low story buildings would be reconstructed to high-rise buildings along with the progress of development in future, and low voltage load is predicted to occupy a substantial share in view of the power demand configuration.

The Phahol Yothin Street is a single side three-lane road including a walkway with a width of roughly 3 m, and when the green belt along the road center is included, the total road width ranges roughly from 40 to 50 m.

Since this area is not predicted to undergo so remarkable an urbanization when compared with the Sathorn area, the power demand for improving the urban scenery is considered to be not so intensive. Therefore, it will be sufficient to introduce overhead transmission line in this area.

Considering that most buildings and other facilities are located very close to the sidewalks, the transmission line route should be relocated to the green belt along the center of road from the existing route along sidewalks or constructed under the ground if possible in view of public safety.

When considered in view of cost reduction, it is considered desirable to introduce overhead transmission system by erecting environmentally-friendly columns along the green belt section as several instances can be seen in Japan. However, the incoming and other sections to substation should inevitably be connected through underground cable.

As a part of the countermeasures for easing traffic congestion, however, a "sky train" line has been proposed to be constructed in this area. This sky train line is scheduled to be constructed in the form of elevated bridge near the green belt at the center of road. Therefore, it is practically impossible to construct overhead transmission line along the center of this road. Although there have been some examples of attaching transmission line to the elevated bridge of highway under such similar conditions in Japan, minute adjustments with relevant authorities will be required.

Thus, it will be inevitable to adopt the underground transmission line with a normal duct laying system in this area.

With regard to the distribution substations, as many small scale buildings are closely located, it seems that sufficient space for constructing substations is not available in this area. Judging from the fact that high-rise buildings are constructed by dismantling small scale shopping stores and some of these stores are moved to outskirts in search for a wider space along with the progress of development, however, it is deemed possible to acquire the land for constructing substations.

Moreover, it will also be possible to construct substations by leasing the rooms or acquiring a part of high-rise building.

When the harmony with surrounding environment is taken into consideration, it is deemed preferable to adopt an indoor type substation (wherein all substation equipment are installed indoor) in this area.

Regarding the distribution facilities, as described above regarding the transmission facilities, buildings are located extremely close the sidewalks, the underground distribution system should be adopted for obtaining sufficient separation to buildings and securing public safety as well as for ensuring smooth fire fighting activities at the time of building fire accident.

In this area where the share of customers receiving power supply directly from 24 kV lines is much lower than the Sathorn area and low voltage customers share the majority of load, it is deemed desirable to introduce underground distribution cable of a "4-division 2-linkage system" adopted generally for underground distribution lines in Japan. Therefore, there will be no need to introduce the spot network system.

According to this system, both the 24 kV and low voltage distribution lines will be laid in a duct, while the transformer, switches and other equipment will be installed aboveground. The low voltage system should be interconnected with the low voltage trunk line for preventing long time suspension of power supply at the time of fault in transformer.

A future conceptional diagram prepared taking into account the above situations is presented in Fig. 9.3-9.

Meanwhile, an example of the system configuration of a 24 kV system, wherein the overhead and underground lines coexist, is presented as a special case for reference in Appendix 9.3-4. In addition, an example of the standard system configuration of a low voltage trunk line, and that of equipment layout of an underground distribution system are presented respectively in Appendices 9.3-5 and 9.3-6 for reference.

(3) Jomthong Area

The power demand and its density related to the substations in this model district and surrounding areas are presented in Table 9.3-12 and Fig. 9.3-10.

This area is an industrial area where medium and small scale factories have been located closely since early days. In view of the demand configuration, therefore, low voltage load shares the majority of the total load and 24 kV load is limited to only a part of customers. Moreover, there is no large scale industrial plant receiving power supply directly from 69 kV or 115 kV lines. Such situations are not anticipated to undergo so remarkable change in the future as well.

The street across this area is a single side one-lane road, and the road width including sidewalks is roughly 20 m.

This area is the least urbanized area among the three model districts.

There is no problem for the time being when the conceptional plan is formulated along the extension line of the existing equipment formation.

Therefore, it is sufficient to introduce the following power systems, the overhead transmission line, semi-outdoor type substation being generally constructed at present in urban areas, and 24 kV "3-division 3-linkage system" overhead distribution line.

The 24 kV overhead distribution line of a "3-division 3 linkage system" makes it possible to relieve the section in outage through mutually adjacent distribution lines at the time of fault in the distribution line. Therefore, a switch for dividing the distribution line and that for interconnecting with an adjacent distribution line are installed halfway of the line. Such switches to be installed should preferably be of an integrated three-phase switching mechanism for the purpose of preventing single phase operation to any three-phase load. In the case of Japan, a system of reclosing the substation circuit breakers at the time of trouble in distribution line is adopted together with a system of automatically separating the section downstream of that in fault from the power system. When these systems are adopted together in combination, the reliability of distribution system will be further improved.

In addition, radial type overhead lines, which have been applied at present, will also be applicable for low voltage distribution system in the future.

A future conceptional diagram prepared taking into account the above situations is presented in Fig. 9.3-11.

Meanwhile, an outline of the system introduced in Japan for automatically separating the section of distribution line in fault (time limiting type fault location system) is attached for reference to Appendix 9.3-7.

Table 9.3-10 Power Demand of Sathorn Area

NO	ABB	Substation	2001			2006			2011			2016		
			Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)
32	KT	Klongtoey	1.50	49.16	32.77	1.50	51.51	34.34	2.25	118.50	52.67	2.00	109.63	54.82
37	LN	Lumpini	3.00	121.71	40.57	3.00	125.05	41.68	2.00	132.70	66.35	2.00	136.34	68.17
73	SL	Silom	0.75	48.00	64.00	1.00	55.76	55.76	0.50	57.17	114.34	0.50	61.12	122.24
80	SU	Surawong	0.75	90.19	120.25	0.75	79.38	105.84	0.50	92.13	184.26	0.50	98.48	196.96
116	YK	Yenarkart	3.25	57.98	17.84	4.50	111.46	24.77	3.50	123.99	35.43	2.50	104.46	41.78
141	YN	Samyarn	1.00	54.99	54.99	1.25	79.23	63.38	1.50	129.97	86.65	1.25	116.38	93.10
142	SH	Satorn	2.25	69.02	30.68	1.50	79.04	52.69	2.00	122.45	61.23	2.00	130.90	65.45
189	AT	Satorntai			-			-	0.50	99.68	199.36	0.50	106.55	213.10
		Total	12.50	491.05	39.28	13.50	581.43	43.07	12.75	876.59	68.75	11.25	863.86	76.79

Model District

	2001	2006	2011	2016
Load Density (MVA/sq. km)	44.86	55.39	67.55	79.26

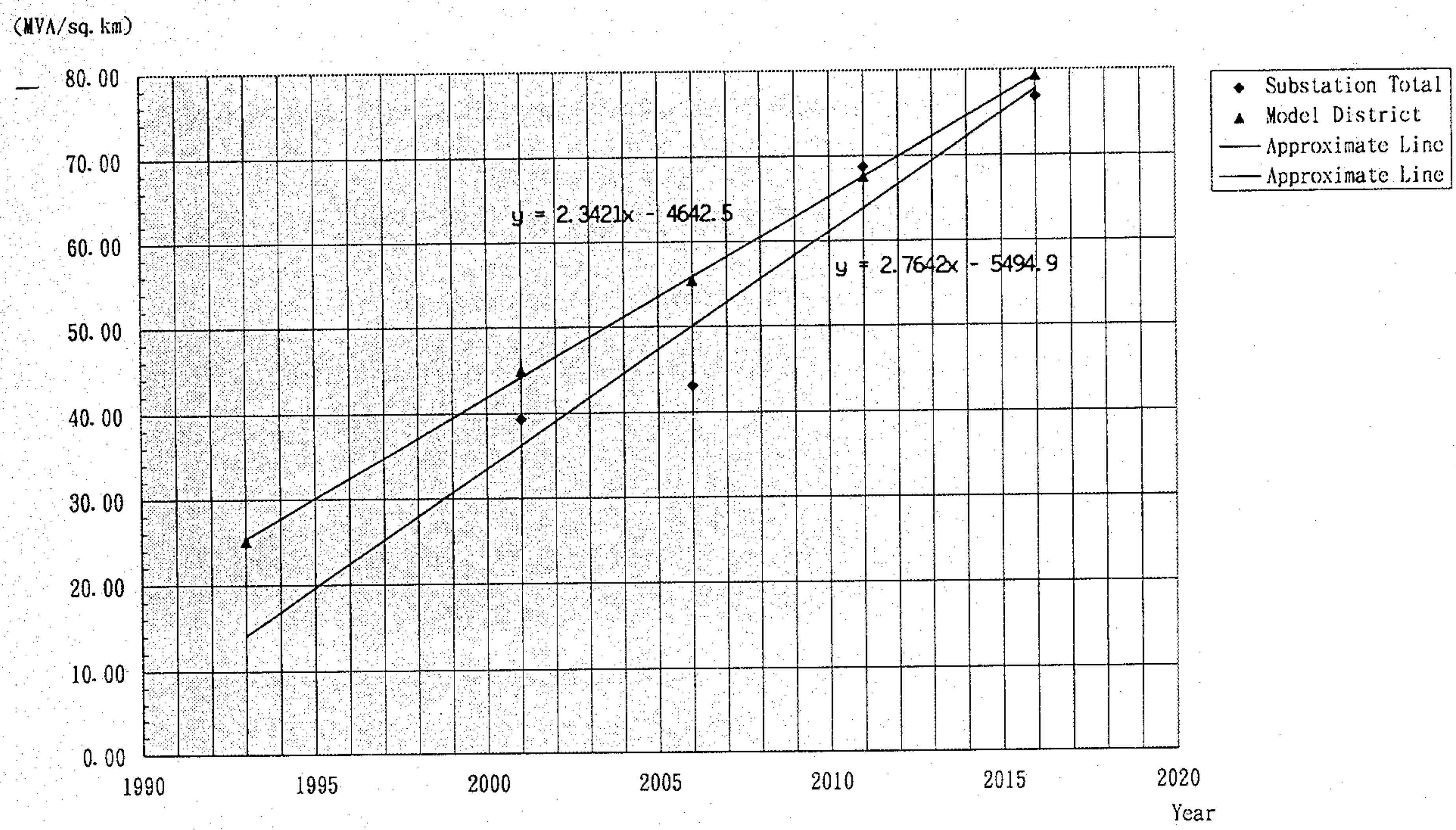


Fig. 9.3-6 Load Density of Sathorn Area

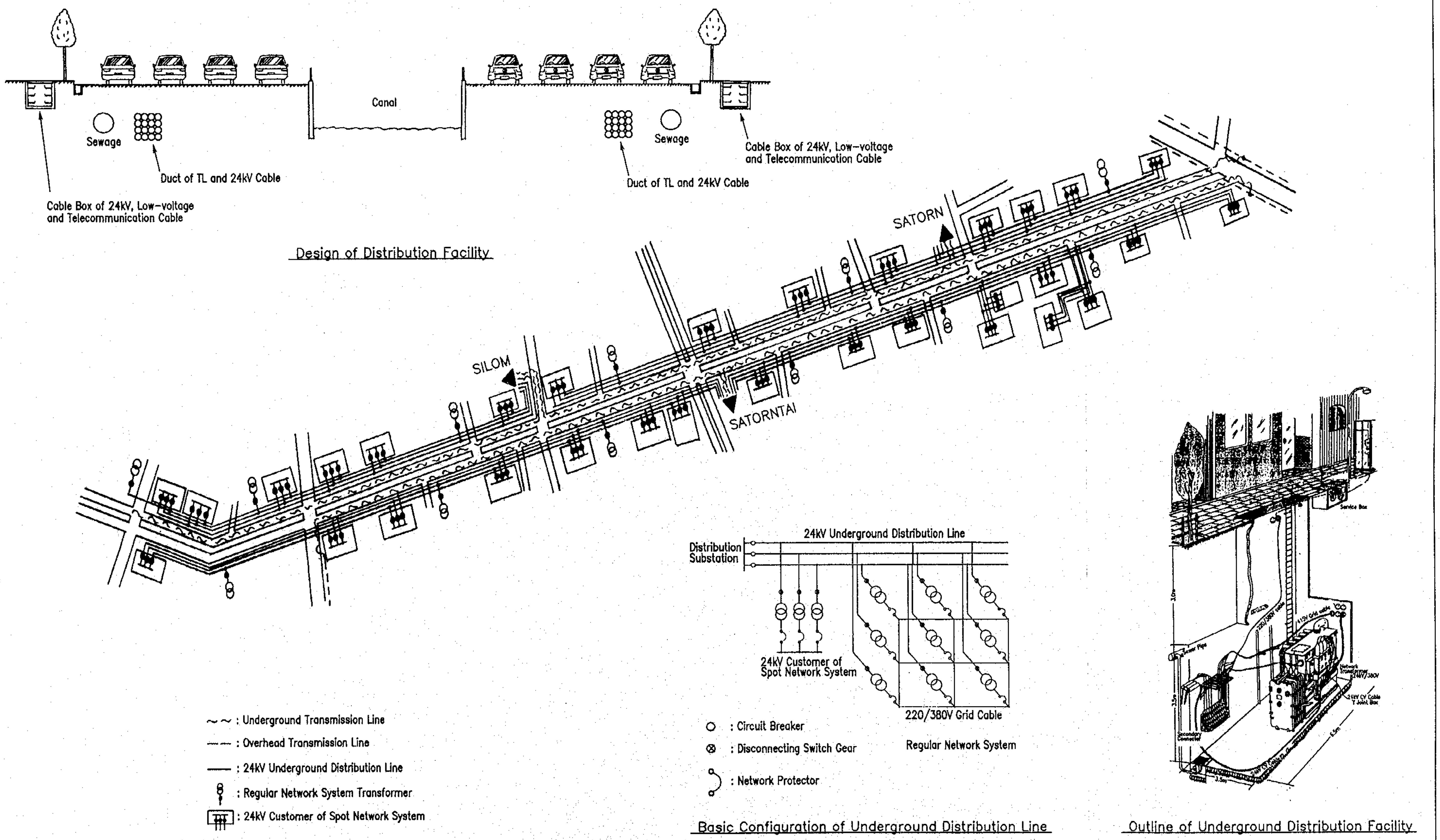


Fig.9.3-7 Future Conceptional Diagram of Sathorn Area

Table 9.3-11 Power Demand of Phahol Yothin Area

No	ABB	Substation	2001			2006			2011			2016		
			Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)
43	MC	Mochit	5.50	84.91	15.44	5.25	75.59	14.40	5.00	93.95	18.79	5.00	102.53	20.51
67	SM	Sailom	5.00	59.34	11.87	3.00	52.26	17.42	2.25	53.09	23.60	2.25	64.94	28.86
69	SN	Samsen	8.25	83.52	10.12	8.25	82.22	9.97	7.00	88.02	12.57	7.00	107.68	15.38
89	YT	Yothee	3.00	57.05	19.02	2.75	54.34	19.76	2.50	55.64	22.26	2.50	59.48	23.79
104	PP	Pradipat	7.00	68.99	9.86	5.75	82.57	14.36	7.00	113.10	16.16	7.00	138.35	19.76
122	DD	Dindaeng	3.50	58.74	16.78	3.50	80.48	22.99	3.50	90.98	25.99	3.50	104.72	29.92
168	NP	Sanampao			-	2.50	82.24	32.90	2.25	69.61	30.94	2.25	85.15	37.84
187	RO	Rajchakru			-			-	1.00	71.35	71.35	1.00	87.28	87.28
		Total	32.25	412.55	12.79	31.00	509.70	16.44	30.50	635.74	20.84	30.50	750.13	24.59

Model District	2001	2006	2011	2016
Load Density (MVA/sq. km)	16.03	21.30	26.70	32.07

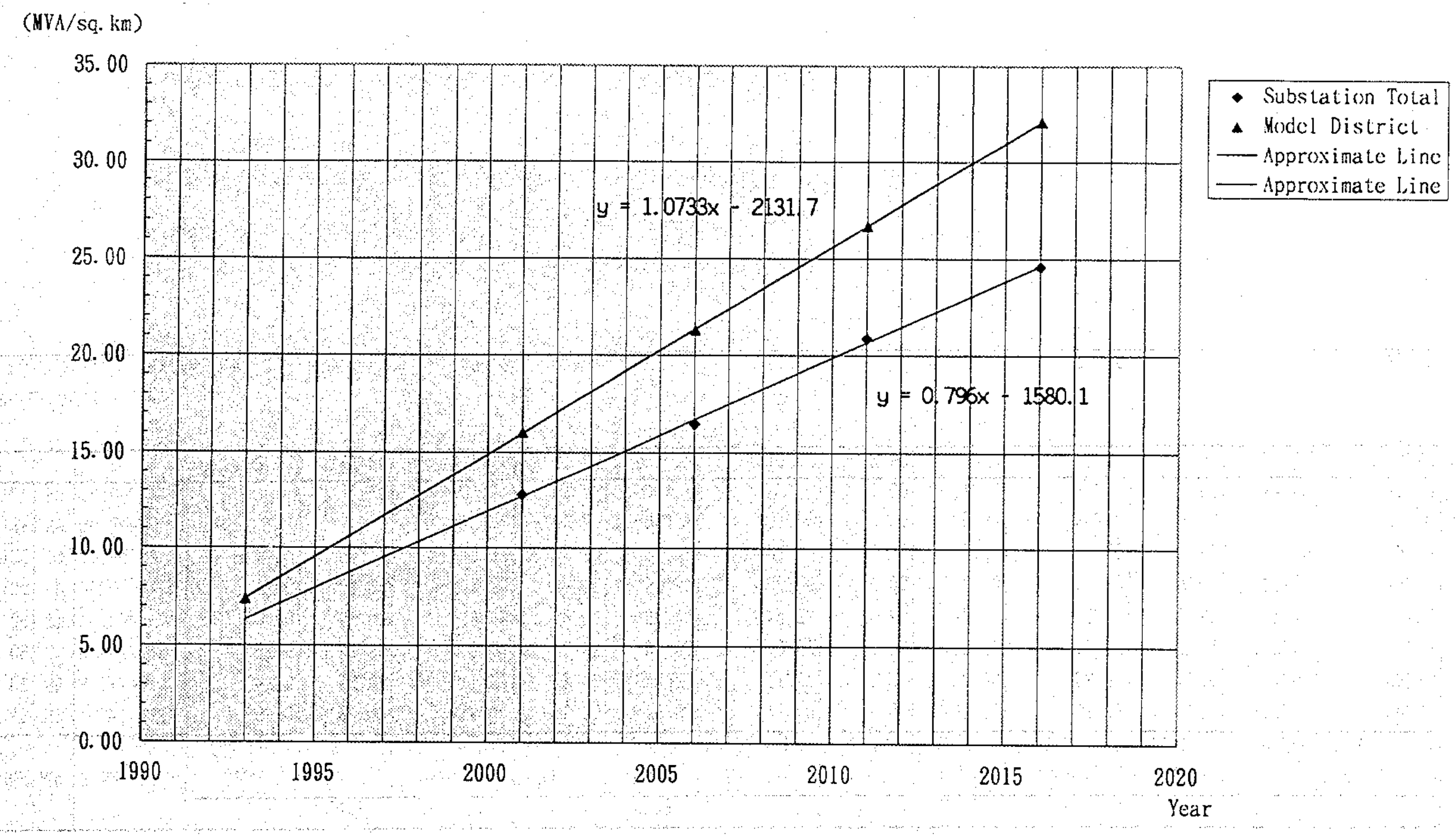
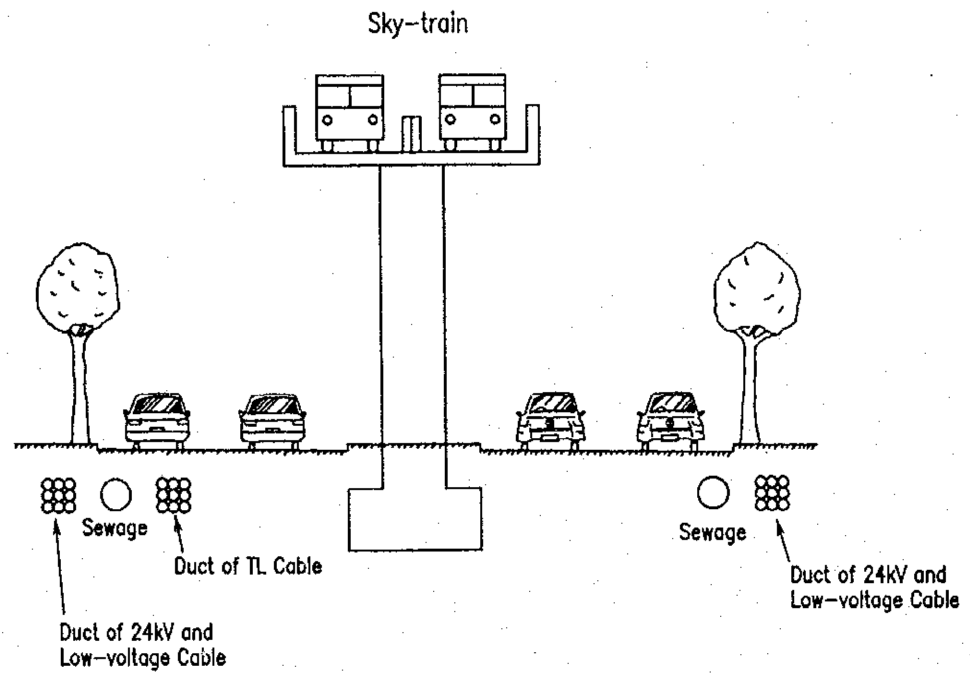
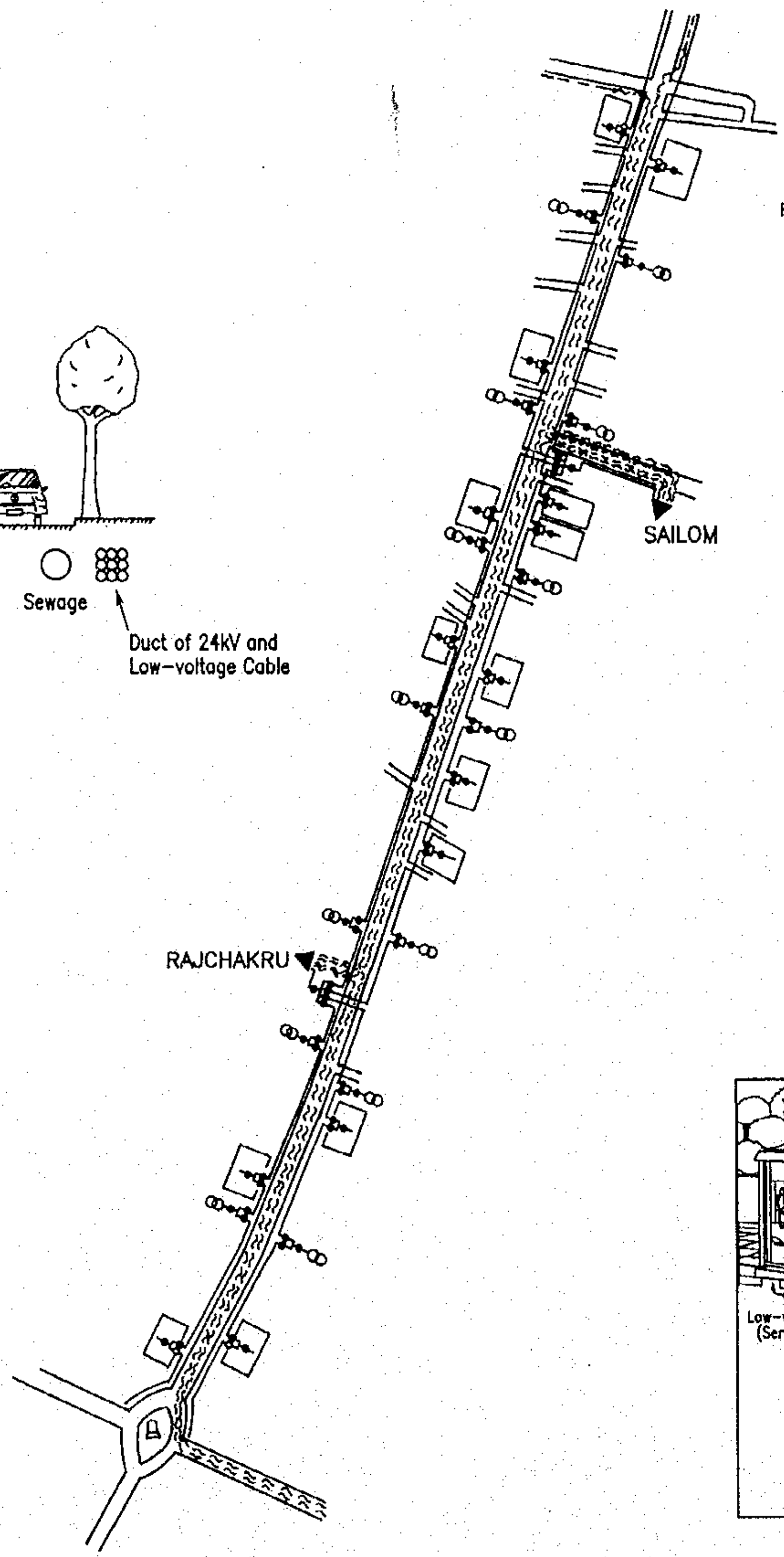


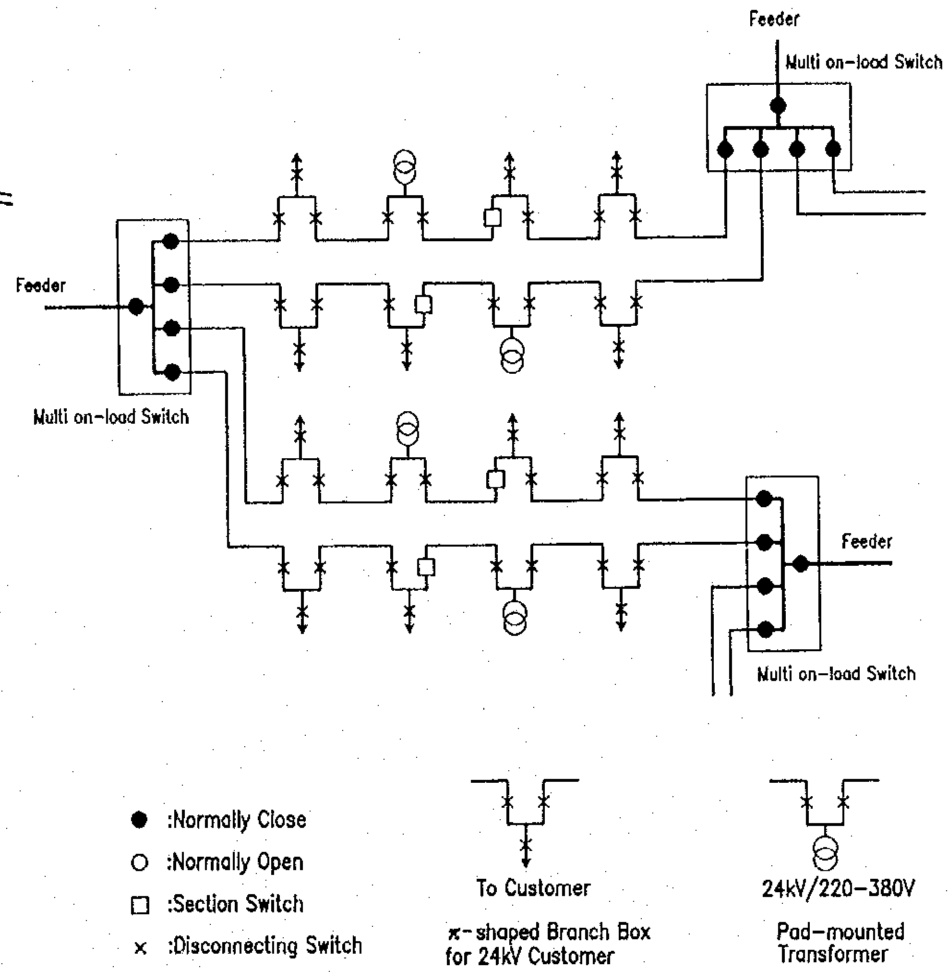
Fig. 9.3-8 Load Density of Phahol Yothin Area



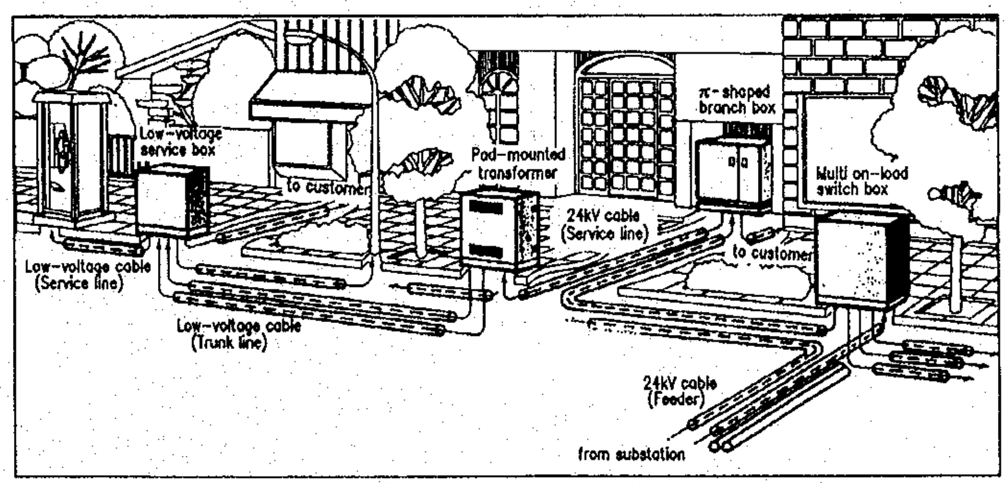
Design of Distribution Facility



~~ : Underground Transmission Line
-- : Overhead Transmission Line
—— : 24kV Underground Distribution Line
: Multi on-load Switch
: Pad-mounted Transformer
: π-shaped Branch Box
: 24kV Direct Receiving Customer



Basic Configuration of Underground Distribution Line



Outline of Underground Distribution System

Fig.9.3-9 Future Conceptional Diagram of Phahol Yothin Area

Table 9.3-12 Power Demand of Jomthong Area

No	ABB	Substation	2001			2006			2011			2016		
			Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)	Area (sq. km)	Load (MVA)	Density (MVA/sq. km)
9	BM	Bangmod	16.00	92.24	5.77	16.00	98.98	6.19	7.00	108.65	15.52	7.00	111.03	15.86
33	WG	Klongwatsing	9.75	55.89	5.73	9.75	72.71	7.46	8.25	98.22	11.91	8.00	124.56	15.57
38	MN	Mahaisawan	8.50	80.27	9.44	8.50	76.05	8.95	9.00	94.34	10.48	9.00	96.40	10.71
52	PS	Petchkasem	10.00	55.09	5.51	11.00	57.04	5.19	9.75	64.82	6.65	9.25	79.33	8.58
81	TS	Taksin	5.00	48.48	9.70	5.00	54.24	10.85	3.50	54.76	15.65	3.50	55.95	15.99
151	WR	Wuttakart	4.75	43.11	9.08	4.75	56.83	11.96	5.25	65.25	12.43	5.50	68.81	12.51
		Total	54.00	375.08	6.95	55.00	415.85	7.56	42.75	486.04	11.37	42.25	536.08	12.69

Model District	2001	2006	2011	2016
Load Density (MVA/sq.km)	15.11	20.73	26.18	31.68

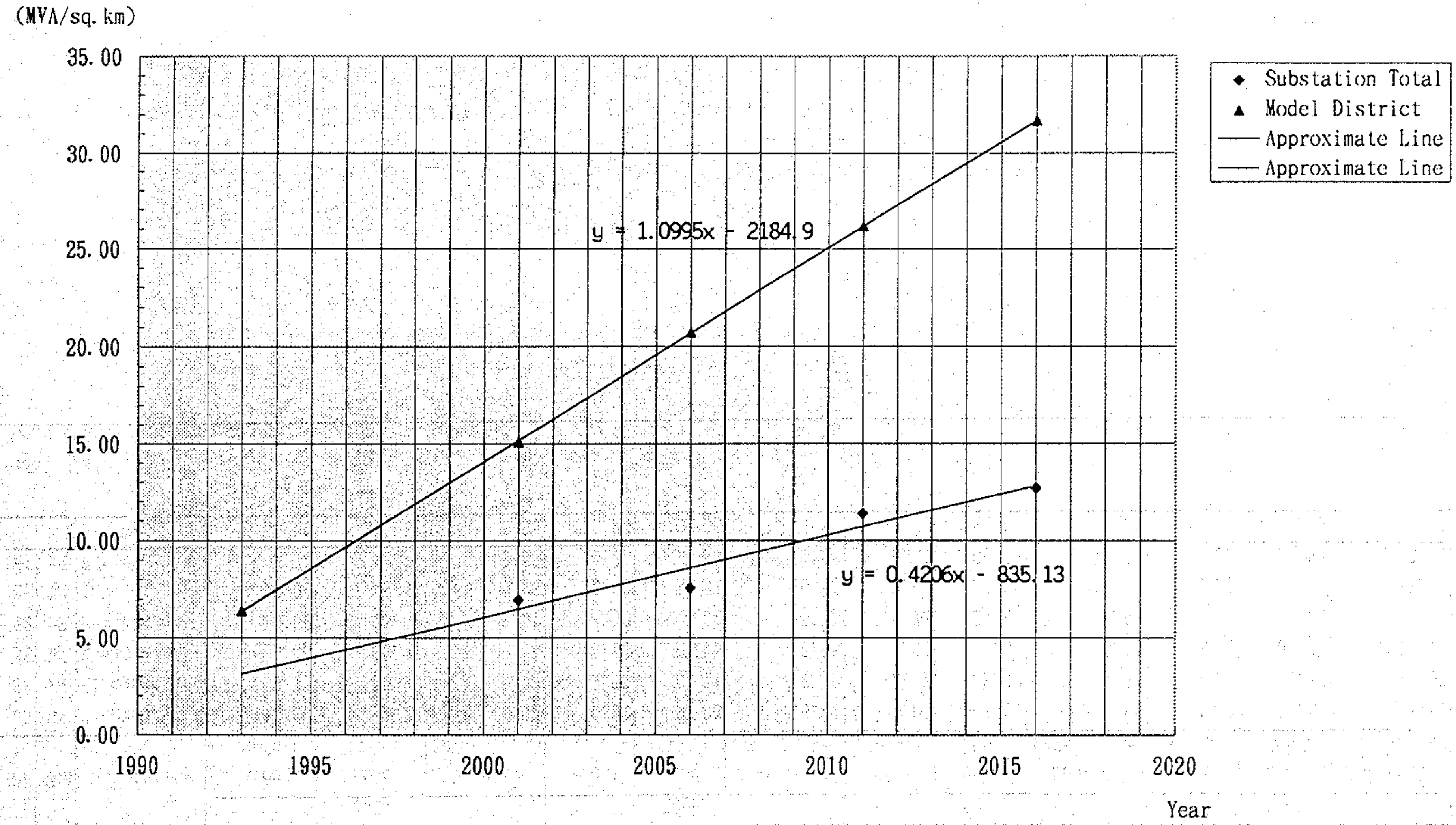
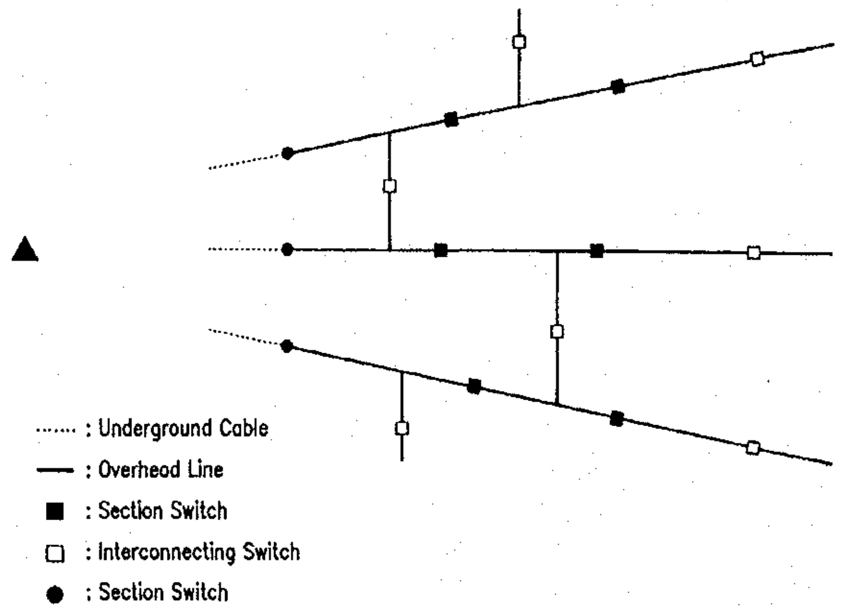
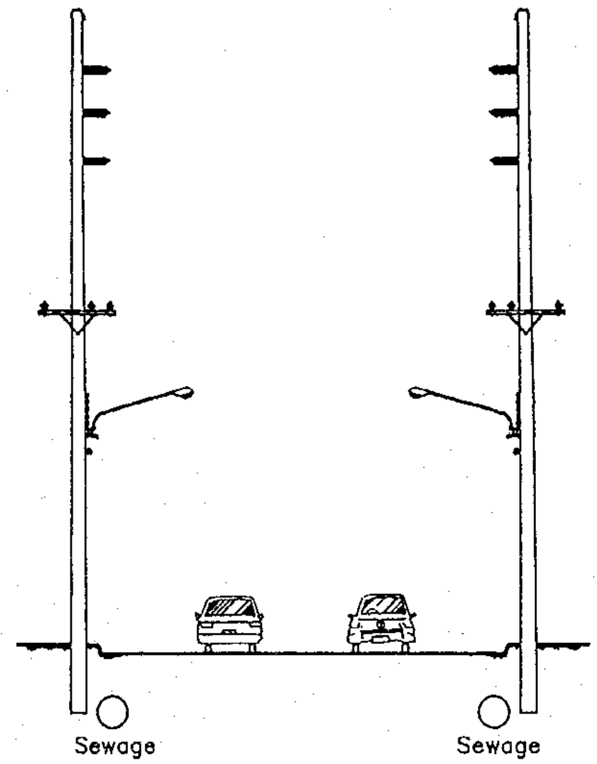


Fig. 9.3-10 Load Density of Jomthong Area



Basic Configuration of Distribution Line



Design of Distribution Facility

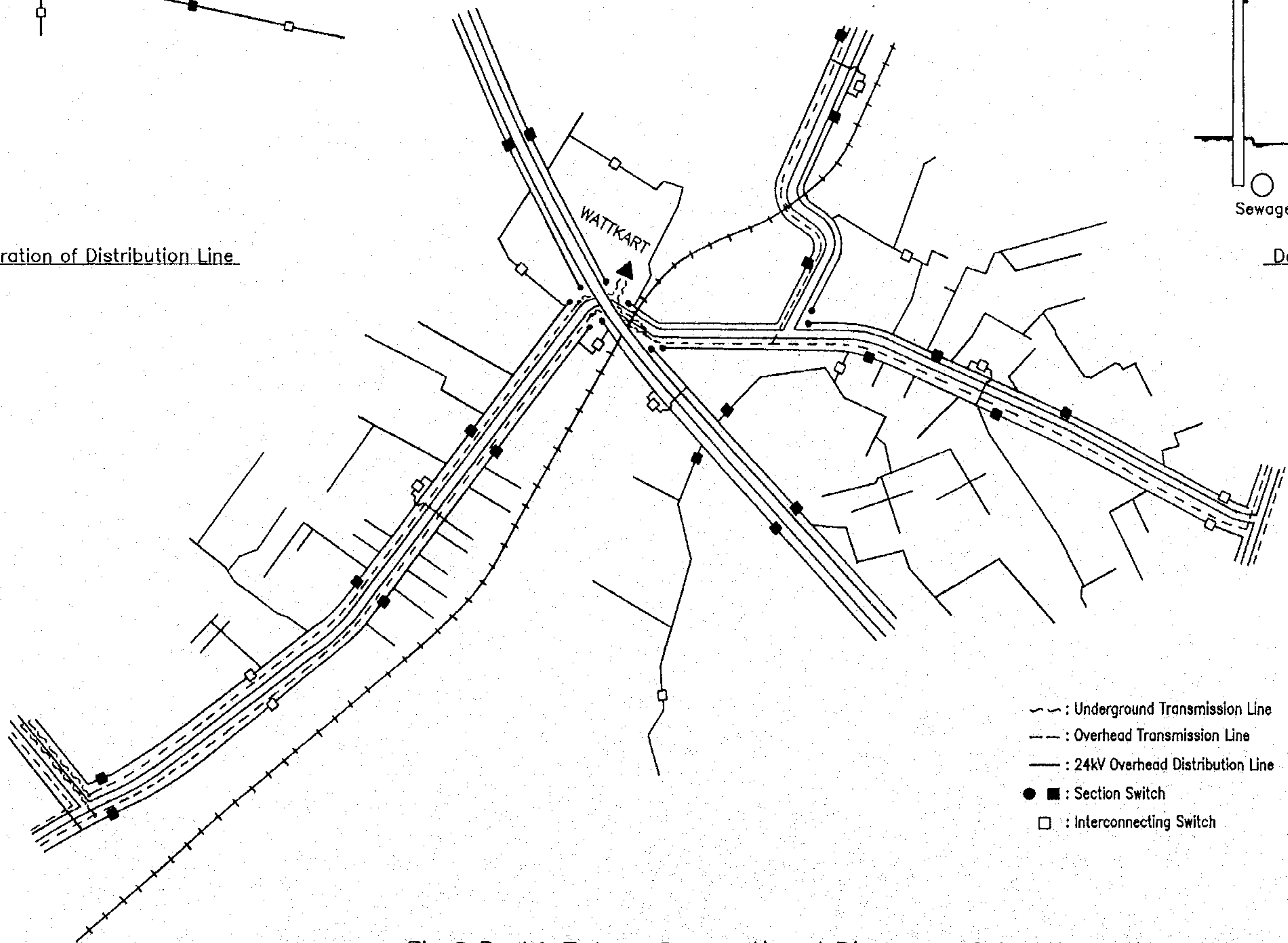


Fig.9.3–11 Future Conceptional Diagram of Jomthong Area

9.4 Overhead Subtransmission Line Facilities

9.4.1 Selection of Overhead Subtransmission Line Route

(1) Future expansion plan of subtransmission line

The scale of the construction and expansion plan of subtransmission facilities have been expanded rapidly in the Metropolitan area of Thailand where the power demand has been growing rapidly along with remarkable economic development and improvement of the people's living standard. To meet such rapidly growing power demand, a construction and expansion plan of subtransmission facilities has been formulated in Section 6.4 for ensuring required power with reliability. In accordance with the above plan, the overhead subtransmission lines were designed.

(2) Selection of subtransmission line route

The Study Team investigated the situations of the existing subtransmission line routes, since it will constitute a basis of future design of the existing subtransmission facilities in the Metropolitan area to clarify the situations of such facilities.

Then, the subtransmission line routes for the future project were selected taking into account the following items:

a) The impact of the route upon environment should be minimized.

b) The route should be balanced with the social environment.

c) Coordination with various kinds of regional development projects should be ensured.

d) Technical coordination should be ensured.

e) The route should allow such a system configuration as to obtain optimum electric power system.

f) The route should be provided along local roads and meet the required topographic conditions.

g) Whether expansion of existing lines is possible or not should be studied, and an alternative route be also studied depending upon the situations.

When selecting the routes of subtransmission lines under the power distribution system improvement and expansion plan in the Metropolitan area, it is necessary to take into account the growth of power demand and load centers in accordance with the expansion plans for the respective fiscal years.

However, it has become more and more difficult since the past several years to acquire the land under subtransmission lines resulting from economic and regional development, improvement of living standard and so forth. Thereby, it has become nearly impossible to construct new subtransmission lines.

Consequently, expansion and improvement of overhead subtransmission line will be carried out by making use of the space under existing subtransmission lines and side walks as far as practicable.

(3) Prerequisite conditions for selecting subtransmission line route

The routes of subtransmission lines to the Metropolitan area shall be selected taking into account the following prerequisite conditions:

a) Increase of transmission capacity to the Metropolitan area

The number of circuits and conductors should be increased to meet the increase of transmission capacity to the Metropolitan area.

b) Difficulty to acquire land for new routes (impossible particularly in the 230 kV loop system)

Countermeasures shall be taken to make effective use of the routes of existing subtransmission lines wherever possible.

c) It should be taken into account to adopt underground cable, for the subtransmission lines to the Metropolitan area.

d) Reduction of short-circuit current in the respective substations

The 230 kV subtransmission system in the Metropolitan area shall be so designed as to reduce short-circuit current in the respective substations.

(4) Transmission capacity of multiple circuits (N-circuits)

The transmission capacity of multiple circuits (N-circuits) refers to that of two or more circuits with N-1 times of transmission capacity per circuit.

Voltage	Number of conductors (AAC)	Transmission capacity of multiple circuits (N-circuits) (MVA)			Remarks
		1 ckt	2 ckt	4 ckt	
230 kV	400 mm² X 2	(0) 673	(673) 1,346	(2,019) 2,692	( ):In case of N-1
115 kV	400 mm² X 1	(0) 168	(168) 336	(504) 672	
	400 mm² X 2	(0) 337	(337) 674	(1,011) 1,348	
69 kV	400 mm² X 1	(0) 101	(101) 202	(303) 404	
	400 mm² X 2	(0) 202	(202) 404	(606) 808	

(5) Selection of the respective subtransmission line routes

The routes of the respective subtransmission lines according to power distribution system improvement and expansion plan in the Metropolitan area shall be selected as follows:

a) Route of 115 kV overhead subtransmission line (To be selected by using the side walk or canal side)

b) Route of 69 kV overhead subtransmission line (To be selected by using the side walk or canal side)

9.4.2 Basic Design

(1) Basic design of overhead subtransmission line

The basic design of the subtransmission lines under this plan shall be carried out taking into account the following requirements.

The construction, expansion and improvement work of subtransmission lines in the Metropolitan area shall be so planned as to minimize the changes of existing facilities as far as practicable in accordance with the standards and criteria being applied at present in Thailand.

The basic design for expansion and improvement of subtransmission lines including future plan shall be carried out so as to be applicable to the sections of power system in the respective FY years of 1997, 2001, 2006 and 2011.

Should it be clarified difficult to construct any subtransmission line along a new route in the future as a result of executing site survey, then expansion or improvement of existing subtransmission lines (increase in the number of circuits or conductors) shall be studied.

The basic design shall be carried out by studying adoption of narrow phase-to-phase interval tower or underground cable system in case it is impossible to increase the space under any subtransmission line.

The basic design shall be executed taking into account the following items as it will be required to increase the voltage, or the number of circuits or conductors in the expansion section of existing subtransmission line:

a) Expansion to 230 kV× 2 ckt or 4 ckt

b) Expansion to combination of 115 kV and 69 kV × 2 ckt each

c) Expansion to 69 kV× 2 ckt (4 ckt) or multiple conductors

(2) Service voltage of overhead subtransmission line

The system voltages of 230, 115 and 69 kV being used by MEA at present are applicable to international codes and standards. Therefore, the service voltages of the subtransmission lines to be applied under this project shall be as follows:

Major subtransmission lines	Voltage (kV)
Trunk subtransmission line	230
General subtransmission line	115 or 69

(3) Number of circuits to be applied for overhead subtransmission lines

The largest number of circuits adopted by MEA at present is two circuits in the cases of both 69 kV and 230 kV (underground cable), while one or two circuits share roughly half the 115 kV system.

As it has become more and more difficult to acquire the land along with remarkable progress of economic and regional development in the Metropolitan area for the past several years, the scale of subtransmission lines should be expanded by increasing the number of circuits and/or conductors. Therefore, it is recommended to adopt the following number of circuits while making utmost use of the land under existing subtransmission lines:

Present	Future
230 kV× 2 ckt	230 kV× 4 ckt
115 kV× 1 ckt	115 kV× 2 ckt
69 kV× 2 ckt	115 kV× 2 ckt

(4) Number of conductors used in overhead subtransmission line

The distance of the subtransmission lines under this plan is comparatively short (5-10 km), and since the subtransmission capacity is determined according to the thermal capacity of conductor, the following number of conductors is recommended, provided that the subtransmission capacity be acquired by increasing the number of conductors.

Since corona noise, radio interference and other problems occur in the case of single conductor, the surface potential gradient shall be reduced.

Cross section of conductor	No. of conductors
400 mm^2 AAC	2 and 4 conductors
600 mm^2 AAC	2 and 4 conductors
800 mm^2 AAC	1 conductor

(5) Supporting structures of overhead subtransmission line

In consideration of increase in the design load because of the necessity to increase the number of conductors per circuit, the self-standing type concrete pole or steel tower is recommended to be applied as a supporting structure of the overhead subtransmission line to be constructed or expanded under this plan. The basic design of supporting structure is presented in Fig. 9.4-1.

The steel tower with an X-section member should be applied, in case a combination of material with angle material is insufficient in strength. An optimum aboveground level of the subtransmission line conductor shall be selected taking into account the ambient environment since such a level is determined according to the electric field intensity.

In some cases where it is impossible to expand any subtransmission line by using the space under the existing subtransmission line, adoption of a steel pole type with a narrow phase-to-phase interval pole should be applied.

(6) Insulator string

To save the space under subtransmission line by minimizing the rolling range of conductor, adoption of insulator string (V-string or tension insulator string) shall be studied.

The insulators, to be used for the subtransmission lines under this plan will be installed under existing subtransmission line in many cases. To reduce rolling range of conductor, therefore, adoption of the V-type suspension insulator or combination of the tension insulator string and jumper rolling-preventive type suspension insulator should be taken into account because of narrow phase-to-phase interval.

Although any arcing horn or shield ring has not been furnished to many insulators of existing subtransmission lines of MEA, the insulators of the subtransmission lines to be constructed in the future shall be of a construction wherein the arcing horn or shield ring can be provided thereto to ensure immediate removal of faulty arc at the time of lightning attack to subtransmission line and lower the fault ratio of the system.

(7) Types of pole foundation for subtransmission line

The subtransmission lines under this plan are routed generally along the areas where the ground is soft so that there is a danger of differential depression of steel tower. Therefore, the construction of any steel tower foundation shall be made free from any danger in view of the strength by using the pile foundation.

At the location where the reaction of pole foundation is intensive, moreover, a combination of pile and mat foundations should be applied. The pile being adopted at present by MEA is concrete pile. Since the reaction of foundation is intensified, the cast-in-place concrete pile should be adopted, and the diameter and quantity of piles be determined according to the reaction of the pole foundation. The basic configuration of concrete pole and tower foundation is presented in Fig. 9.4-2.

(8) Conductor

The type of conductor is generally selected according to optimum electric power system design, therefore, an optimum type should be determined taking into account the necessity to increase the number of conductors to two or four.

Meanwhile, the standard conductor for the subtransmission lines of MEA is AAC 800 mm^2 (2×400 mm^2 all aluminum strands). However, the conductor type will be reviewed when the electric power system plan has been finalized.

An optimum conductor type should be selected taking into account the following conditions:

a) The required subtransmission capacity (allowable thermal current) should be satisfied.

b) Maximum potential gradient of conductor.

c) Corona noise level.

d) Mechanical strength and characteristics of conductor.

e) The conductor should be free from adverse effect of corrosion and vibration.

(9) In case any land under existing subtransmission line is not available

In such a case, adoption of underground cable should be studied.

(10)Study of environmental impact

With the reinforcement and expansion of ultrahigh voltage subtransmission line network toward higher voltage and greater capacity, the subtransmission line facilities are predicted to cause an impact upon the surrounding environment. Therefore, the countermeasures for protecting the surrounding environment should be studied sufficiently in advance with regard to the following items:

a) Prevention of electrostatic and electromagnetic induction interference.

b) Investigation of TV receiving conditions.

c) Investigation of radio receiving conditions.

d) Investigation of wind noise.

(11)Survey around the areas along the subtransmission line routes

As the conditions of the area along a subtransmission line route will largely affect maintenance and management of subtransmission line facilities, as well as easiness and cost of the construction work, such conditions should be investigated and studied sufficiently in advance with regard to the following items:

a) Topographical and geological conditions (fault, soft ground, river crossing, etc.).

b) Climatic conditions (wind velocity, salt and dust contamination, lightning attack and so forth).

(12)Countermeasures preventing impacts of subtransmission line upon environment

With regard to the impacts of subtransmission line upon the surrounding environment, the following countermeasures should be taken after sufficient study particularly for preventing the impact of electric field intensity upon human body, problems due to wind, corona noise and so forth.

1) Electric field intensity

The aboveground level of subtransmission line should be determined so that the electric field intensity becomes not higher than 50 V/cm.

2) Corona noise

To prevent corona noise arising from subtransmission line, the number of conductors should be increased or the corona shield ring, be mounted on the insulator strings.

The surface potential gradient of conductor shall be made not more than 15 V/cm.

3) Wind noise

The wind noise preventive countermeasures should be taken by mounting a wind noise preventive spiral rod on the subtransmission line to prevent the wind noise arising when the conductor of subtransmission line comes into contact with wind.

4) Others

Sufficient countermeasures should be taken for preserving the scenery in any specified area by using a special tower matching the environment where the environment can possibly be worsened due to the shape of subtransmission line.

(13) Compensation for the land under subtransmission

Compensations for the land under subtransmission line is provided at present by MEA as indicated below, and such compensations should also be studied if possible in the area where urbanization is expected:

Scope of land	Scope of compensation	
	Present compensation	Future compensation
Steel pole site	Compensation for only land	Compensation for only land
Land under T/L	No compensation	Temporary compensation (% of land price) or compensation for leased land (every 3-5 years)

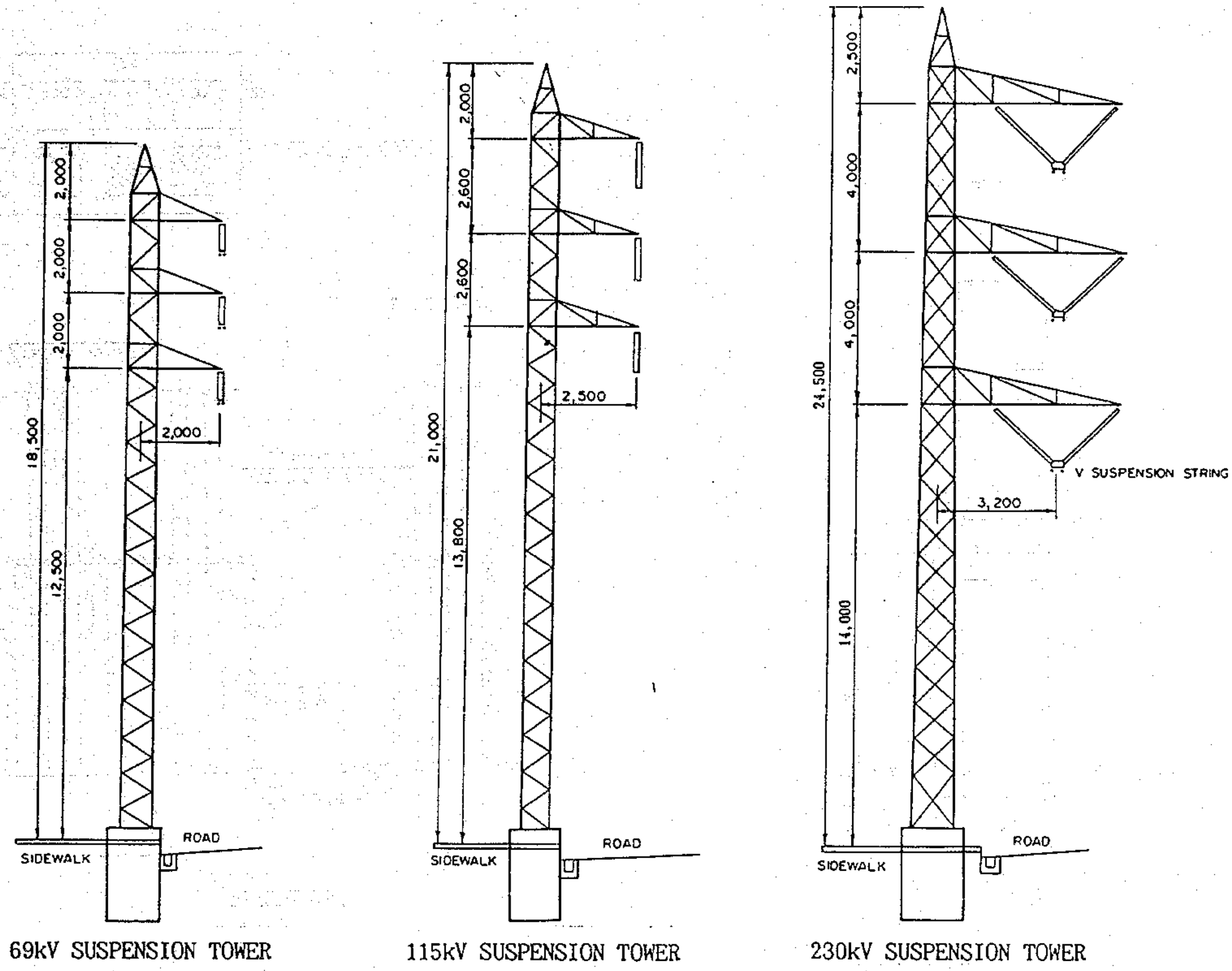


Fig. 9. 4-1 PRINCIPAL DIMENSION OF SINGLE CIRCUIT STEEL POLE

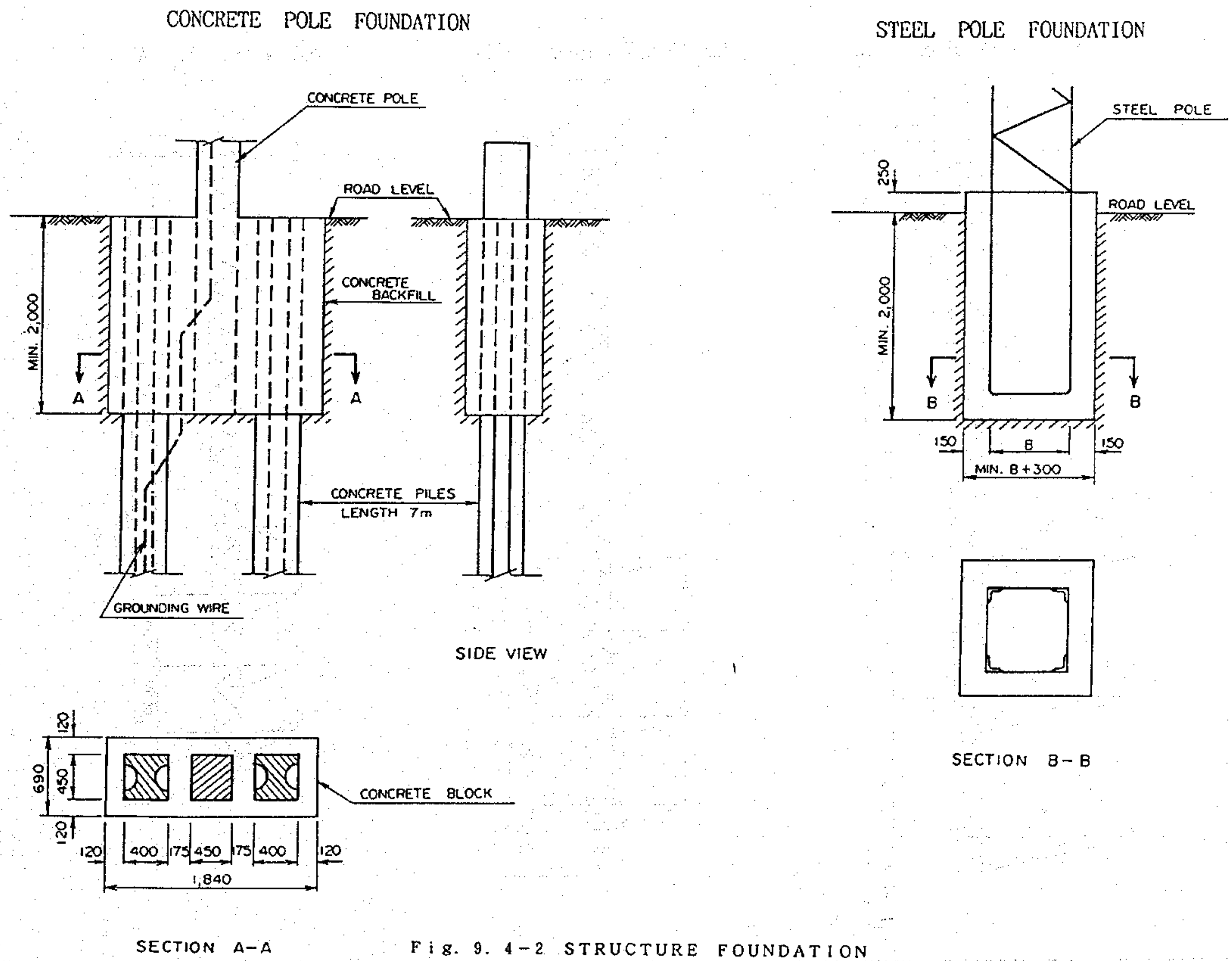


Fig. 9. 4-2 STRUCTURE FOUNDATION

9.5 Underground Subtransmission Line Facilities

9.5.1 Selection of Underground Subtransmission Line Route

(1) Future plan of underground subtransmission lines

The existing underground subtransmission lines in the present supply area of MEA have been applied partially in many cases where sufficient clearance or land is not available. However, it has become more and more difficult to construct overhead subtransmission lines in proportion to the progress of urbanization along with economic growth and improvement of living standard in the Metropolitan area. Thereby, it would become increasingly important to adopt underground subtransmission lines as a future supply system to the Metropolitan area in consideration of incessantly growing importance to adopt such underground line system for preservation of urban scenic beauty as well.

(2) Survey and investigation of miscellaneous conditions along the routes

Prior to determining the underground subtransmission line routes, it is essential to investigate miscellaneous conditions and problems along the routes including urban development projects and projects of other enterprises. Since there can possibly be various important problems which might cause delay in the construction schedule, unpredictable damage to existing facilities, sufficient survey and investigations should be carried out regarding the following items in advance:

(a) Investigation of urban development projects and projects of other enterprises

(b) Investigation and topographic survey of existing buried facilities

The locations of any existing buried and on-the-road facilities shall be confirmed based on relevant records and by field survey.

(c) Survey of traffic volume

The traffic volume shall be surveyed to confirm the possibility of traffic restriction, availability of alternative detour routes, etc. in addition to the types and number of vehicles, as the traffic conditions will be affected seriously by the line construction work.

(d) Investigation and study of environmental impacts

The work should be carried out while sufficiently paying attention to the noise and vibration due to the work as well as preservation of environment, considering that most of the underground subtransmission line construction work will be carried out on and under roads. The investigation items of environmental impacts can be classified largely into the following three items:

1) Investigation of living environment

Actual situations of the people's life in the relevant areas should be investigated to confirm the composition of residents, living standard and conditions, belief and will of the people.

2) Investigation of social environment

The configuration and actual situations of miscellaneous functions for maintaining the living environment should be investigated to confirm the population density, areas for specified use, schools, hospitals, high-rise buildings and other facilities.

3) Investigation of natural environment

The natural world constituting the entire environment should be investigated to confirm the topography, ground water, water quality. In the case of large scale construction, the adjacent well and pond can possibly be affected adversely by reduction of ground water level, cutoff of water vein, change of water quality and so forth following the progress of excavation work. Therefore, the natural environment shall be investigated sufficiently to confirm existence and depth of well, pond and underground floors of building including the depth, water level and quality and utilization conditions within the range of environmental impact assessment study in advance.

(e) Geological survey

The geological survey is highly important for determining the work execution methods to ensure safe and exact execution of design and construction of structures. This survey shall therefore be carried out to obtain detailed information of ground without any omission as required design and execution of construction work while sufficiently taking into account the diversity of this survey.

(3) Selection of underground subtransmission line routes

The routes of the underground subtransmission lines shall be selected based on the results of route survey taking into account the following requirements and conditions:

(a) Future system configuration and distribution of load

(b) Effective utilization of public land

(c) Harmony with regional environment

1) Coordination with miscellaneous plans related to land utilization in the relevant area

2) Requests on safety, public interferences (electromagnetic induction interference, etc.), preservation of urban scenery as well as coordination with local community

3) Legal restrictions pertaining to road and land utilization

(d) Impacts upon flooding, salt contamination, fire accident, landslide, ground settlement and other disasters

(e) Easiness and safety in view of construction and maintenance of subtransmission lines

(f) Reduction of construction cost

(g) Reduction of subtransmission loss and maintenance cost

(h) Interconnection with and effective utilization of existing lines

(i) Effect of multiple cable laying upon subtransmission capacity

(j) Execution of disaster preventive countermeasures

(k) Effective utilization of land owned by MEA

(4) Selection of the respective subtransmission line routes

The respective subtransmission line routes shall concretely be selected under car lane or side-walk. In addition adoption of bridge cross-linking and other systems as required around canal and river crossing sections shall be studied.

9.5.2 Basic Design

(1) Outline of basic design

The 69 kV and 115 kV underground subtransmission lines shall be designed according to the standards and planning criteria being applied by MEA. The 230 kV lines shall be designed based on the past design records and those in Japan, as such standards and criteria of the 230 kV lines are not available from MEA.

That the construction cost of underground subtransmission lines is generally much higher than that of overhead lines. The underground subtransmission system should preferably be adopted only in the following cases:

(a) In case construction of overhead system subtransmission lines is impossible or extremely difficult because of legal restrictions or restrictions due to land situations.

(b) In case the underground subtransmission system is advantageous over the overhead system as a whole in view of harmony with surrounding environment, cost and other factors.

(2) Service voltage

The service voltages shall be as follows in compliance with those of the existing overhead subtransmission lines:

Line categories	Voltage (kV)
Trunk subtransmission line	230
General subtransmission line	115 or 69

(3) Number of circuits to be applied

The number of circuits being adopted at present by MEA is two circuits similarly in many cases of overhead lines.

The subtransmission capacity per circuit tends to be increased in compliance with the increase of demand in the Metropolitan area. The following standard number of circuits should be applied in the future:

Voltage (kV)	No. of circuits
230	3 (1 cable per phase)
115 or 69	double (2 cable per phase)

(4) Transmission capacity

In case of designing underground subtransmission lines, the subtransmission capacity per circuit shall, in principle, be determined according to the standards indicated in the table below:

Service voltage	Subtransmission capacity	Concept
230 kV (a)	267 MVA/ckt	The power of one [250 MVA x 4 bank] substation shall be transmitted through three circuits.
230 kV (b)	320 MVA/ckt	The power of one [300 MVA x 4 bank] substation shall be transmitted through three circuits.
115 kV	288 MVA/ckt	The power of two [60 MVA x 3 bank] substations shall be transmitted through one circuit.
69 kV	192 MVA/ckt	The power of two [40 MVA x 3 bank] substations shall be transmitted through one circuit.

The subtransmission capacity of multiple circuits shall be determined based on "N-1 times" of the subtransmission capacity per circuit in case of multiple circuit subtransmission.

Voltage (kV)	Number of conductors	Transmission capacity of multiple circuits (N-circuits) (MVA)		
		1 ckt	2 ckt	3 ckt
230	1,200mm² X 1	(0) 320	(320) 640	(640) 960
115	800mm² X 2	(0) 288	(288) 576	(576) 864
69	800mm² X 2	(0) 192	(192) 384	(384) 576

Note 1) Numerical value in a parenthesis is shown the subtransmission capacity of multiple circuits

2) This table shows the subtransmission capacity in duct bank

(5) Cable duct facilities

The cable duct facilities are generally classified into those indicated below.

Duct facilities
- Direct burying system
- Duct system
- Tunnel system

According to the actual situations of MEA's facilities, the lines which can be accommodated per route are two circuits of power source subtransmission lines (2 cables per phase) and eight circuits of distribution lines, the number of cable ducts is roughly twenty-four. Judging from these situations, the cable duct system should basically be applied in ordinary places. However, it should be studied to apply the tunnel system around the outlet of substation and other places where power source subtransmission and distribution lines are concentrated.

Under the present situations in the Metropolitan area, it would be very difficult to construct the cable duct facilities based on open-cut method continuously on a twenty-four hour basis due to the chronicle traffic congestion. When nighttime execution of work is taken into account, it will be possible to execute construction of the cable duct by open excavation in the majority of the district. Therefore, the cable duct facilities for cable laying have been planned to be carried out basically according to the open-cut method.

As a cable duct type, wherein asbestos concrete conduits are totally banded, has been selected taking into account reduction of the cost.

The cable duct burying position cannot be determined indiscriminately because of the requirements to ensure coordination with the conditions of existing buried facilities/materials and the facilities embedding plans of other utility enterprises. In the light of the fact that many water supply pipes, telephone lines and other facilities have been buried under sidewalks according to the results of site survey, any cable duct shall, in principle, be accommodated under sidewalks under this plan.

(6) Manhole

The installation interval of manholes under this plan shall be as indicated in the table below in view of the present situations of power facilities in Thailand:

Service voltage	Manhole installation interval
230 kV	500 m
115 kV	200 m
69 kV	200 m

(7) Kinds of cable

In the case of the voltage ranging from 69 kV to 230 kV, the following three kinds of cables are widely applied:

a) Cross-linked polyethylene cable (XLPE cable)

b) Oil-filled paper-insulated cable (OF cable)

c) Pipe type oil-filled paper-insulated cable (POF cable)

The OF cable and POF cable have so far been applied for most of the 230 kV class power systems. The XLPE cable has also come to be applied for 275 kV class long distance lines in Japan reflecting the recent trend of technology. The XLPE cable uses no oil so that this cable requires no oil feed tank and much less auxiliaries than the OF cable. The XLPE cable is more environmentally friendly than the other cables, and this cable shall be, in principle, applied to all of the voltage classes under this plan.

(8) Terminal joint system

The air or gas insulation system shall be applied for terminal connection depending on the actual situations of substation facilities, conditions of branch sections and so forth.

The terminal joint for 230kV XLPE cable is shown in Appendix 9.5-1.

(9) Intermediate connecting system

Two kinds of extrusion molded type and prefabricated type connection sections are used in Japan for the intermediate connection section of 230 kV class system. The prefabricated type connection section shall be applied under this plan, since the extrusion molded type connection section does not allow easy connection work and the work schedule tends to become longer.

The features of the respective connecting systems are as presented below:

Extrusion molded type joint (EMJ)

In the case of the extrusion molded joint section (EMJ), the form of the joint section is obtained with a die at the site, and after molding an insulator by pressure-filling polyethylene resin into the form using an extrusion molding machine, a cross-linked polyethylene resin pipe is attached. Then, the form is cross-linked by heating and pressurizing (to reinforce the linkage of polyethylene molecule). In view of using the same material as that of the cable insulator, the joint section of this type is featured as follows:

- Excellent in dielectric strength.
- The joint section can be down-sized.
- A clean working environment and sophisticated skills are required for molding the insulator at the work site.
- In the case of three-phase joint section, a peered of about twenty days is required for assembly since the assembly and fabrication work should be carried out individually according to sophisticated work schedules.

The extrusion molded type joint is shown in Appendix 9.5-2.

Prefabricated joint (PJ)

In the case of prefabricated joint section (PJ), insulator parts are shop-fabricated in advance and assembled at the work site. Therefore, this PJ section has the following advantages over the EMJ section:

- There is no need to execute the work continuously on a twenty-four hour basis.
- Quality control is easy as the portion of field work is small.
- Short in assembly period.
- It is easy to promote automation and mechanization of connection work.

The prefabricated joint is shown in Appendix 9.5-3.

9.6 Substation

9.6.1 Selection of Substation Sites

The following conditions shall be taken into consideration to make substation sites appropriate from a long-term point of view.

(a) Substation location for subtransmission system and supply area (to be located load center in the future)

(b) Easiness in drawing out work of incoming and outgoing lines including easiness in cable duct construction (to be faced a wide road)

- The candidate locations of new substation planned by MEA have been reviewed and selected taking into consideration the above items for this plan. While the terminal station sites for FY 2016 plan have been selected as described in Clause 6.4.2.

  Moreover, the followings shall be taken into account when the substation sites are concretely selected.

(c) Selection of type considering regional environment, topography and acquisition of necessary site area and capacity to be consistent with selected type of substation

(d) Effective public and company land use, leased room use

(e) Various disasters effect of flood damage, salt and dust damage, fire, land slide, ground subsidence, etc.

(f) Convenience of operation and maintenance

(g) Difficulties in carrying facilities

(h) Difficulties in building foundations against heavy weight

(i) Land value including site construction cost and difficulties and period of land acquisition

(j) Harmony with regional environment

- Adjustment to various development plans concerned with regional land use
- Request for environment, safety, urban beauty
- Legal restriction on land

(k) Proper or improper place for worker to inhabit

9.6.2 Basic Design

(1) Types of substation

Generally, the type of substation is selected taking into account the regional situations, land conditions, economic and other factors. The present planning criteria of MEA uniformly adopts a semi-outdoor type, in which power transformers are installed outdoor and other major equipment are installed indoor. However, it will be required to promote study for adopting underground and indoor types (rent room) in overpopulated areas in the future as described in Clause 3.3.3, considering the increase in the difficulties to acquire the land due to escalation of land price along with overpopulation expected to be intensified on urban area in the future as well as countermeasures for protection of environment and so forth.

In the areas on the outskirts of city center, on the other hand, adoption of compact type substation should also be considered depending on the local situations. Thereby, it is recommended to adopt three types as future standard substation types by adding the two types, namely, the underground (or indoor type) and outdoor type in addition to the present standard semi-outdoor type. Presented in Appendix 9.6-1 is an installation example of compact outdoor type substation on the outskirts of the Tokyo metropolitan area in Japan.

(2) Connection system

The substation connection system should comprehensively be studied particularly taking into account the following requirement items so as to attain a maximum degree of functions as a power system by mutual connection between the respective equipment constituting a substation as well as between substation equipment and transmission line or distribution line:

- Safe and exact daily operation and maintenance should be ensured.
- The connection system should be made as simple as possible to attain a maximum degree of the performance.
- It should be made possible to minimize the range of the impact of any trouble and perform immediate load switching and operation.

- The entire power system should be free from any substantial impact when any equipment has been shut down.
- Easy execution of future expansion and modification work should be ensured.
- Reasonable construction cost should be ensured.

(a) Primary transmission line

1) Terminal substation

The terminal substation should be connected to three circuits in a radial form according to the planning criteria of MEA.

2) Distribution substation

The connection system of the distribution substation should be designed according to the planning criteria of MEA. As it becomes more and more difficult to acquire the land for substation, however, it is deemed to become essential to further reduce the size of substation building. Although the transformer primary circuit GIS should be further reduced in size, it is difficult substantially to reduce its size with the present equipment configuration. Therefore, it is recommended to eliminate the primary circuit breakers from the incoming lines when highly reliable underground subtransmission lines are entirely installed in the urban area in the future. Adoption of transfer trip protection sysytem is indispensable in this case, and for that purpose, establishment of a well maintained communication network becomes a primary condition.

(b) Secondary outgoing lines

The connection system of secondary outgoing lines should be designed according to the planning criteria of MEA.

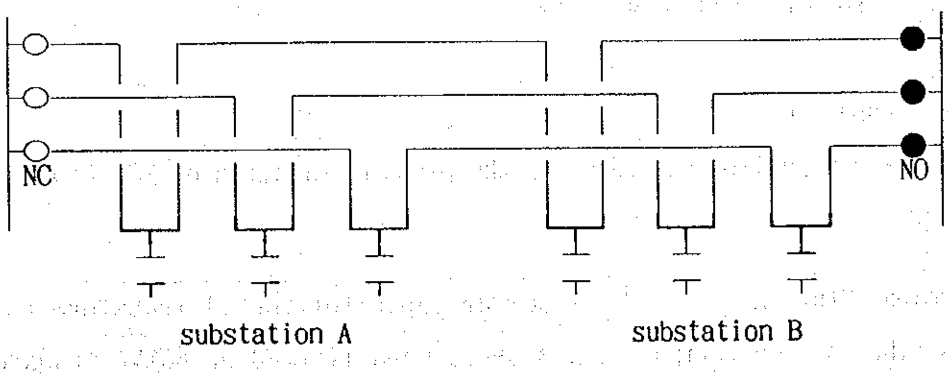
(c) Bus

1) 69 kV or higher voltage bus

A double main bus 1-bus tie system shall be applied for the 69 kV or higher voltage bus according to the planning criteria of MEA. The distribution substation bus system should be applied the single bus system in future because of the reasons described in Item (a) above, and the concept of such bus system configurations is presented in the diagrams below:

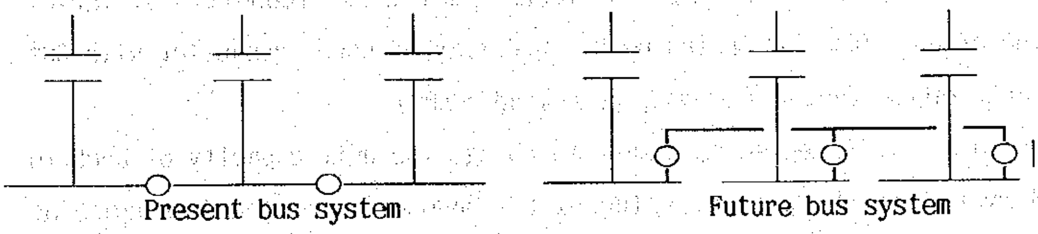
<Single Bus System of Distribution Substation>

(Application example of TEPCO)



2) 24/12 kV bus

The connection system between buses for the 24/12 kV bus shall be applied according to the planning criteria of MEA. However, the bus system lacks in reliability and easiness of operation and maintenance. Accordingly, it should preferably be changed to the following system in the future:



(3) Voltage, capacity of transformer and number of banks for distribution substation

Based on the results of study in Section 9.3, the following values should be applied to the voltage, capacity of transformer and number of transformer banks:

(a) Voltage

1) Primary voltage : Although 115 kV will be applied preferentially, 69 kV will be applied wherever advantageous to apply 69 kV.

2) Secondary voltage : 24 kV

(b) Capacity of transformer : 60 MVA

(c) Number of transformers : 3 banks (at final stage)

(4) Number of outgoing circuits

Based on the results of study in Section 9.3, the number of outgoing feeders should be of 5 circuits.

(5) Power capacitor

The power capacitor according to the planning criteria of MEA is as listed below:

Terminal Station	1 x 30Mvar Capacitor/200MVA Transformer
Distribution Substation	2 x 3.6Mvar Capacitor/40 or 60MVA Transformer

When inappropriate power factor (hereinafter referred to as "pf") of the MEA's distribution system (84.84% according to actual records in September 1994) under present situations is taken into consideration, however, it is deemed necessary to review the planning criteria of MEA for power capacitor. As a result of trial calculation, the capacity of power capacitor required for distribution substation is 13.6 Mvar (for 40 MVA) - 18.1 Mvar (for 60 MVA) per one transformer bank. (conditions: Target value of pf = 95%, pf including 2 x 3.6 Mvar of power capacitor with 60% of utilization factor = 84.84%, peak load = 80%)

Therefore, it is deemed necessary to change the unit capacity of bank to 4.8 Mvar from the present value of 3.6 Mvar. Where the impedance of distribution system is 4.5% (10 MVA base), the allowable voltage fluctuation is 2% or less and the unit capacity is 4.8 Mvar, the required capacity of power capacitor becomes 14.4 Mvar (3 x 4.8 Mvar). When considered similarly, it will be necessary to expand the power capacitors also for terminal station. Consequently, it is recommended to install power capacitors according to the criteria presented below:

Terminal Station	2 x 30Mvar Capacitor/200MVA Transformer
	3 x 30Mvar Capacitor/300MVA Transformer
Distribution Substation	3 x 4.8Mvar Capacitor/40 or 60MVA Transformer

Incidentally, the power capacitors having about 30% of transformer capacity are generally installed in TEPCO.

(6) Protection, monitor and control

Basically, the protection, monitor and control equipment will be designed according to the planning criteria of MEA, those for the 230 kV or higher voltage are recommended to be as described below:

(a) The main protection system should consist of two lines, and one digital type differential relay be applied tentatively for the main protective relay 1 and one distance relay for the main protective relay 2. In the future, however, the differential relay should be applied for both main protective relays 1 and 2. Meanwhile, the optical fiber should be used as a subtransmission line of the differential relays.

(b) The backup protection system should tentatively be consist of one line (sequence), and extended to two lines in the future. The distance relay should be applied as a protective relay.

(7) Disaster prevention

Every substation equipment should be designed according to the basic design concept that any trouble in transformers does not cause any danger to the public and other substation equipment. The strength of transformer tank should withstand any trouble in transformer failure, and be designed so that any insulation oil should not be dispersed around the transformer in the case where troubles has occurred (installation of oil exhaust pipe, oil collector tank and so forth).

(8) Environment

(a) Countermeasures for preventing vibration and noise

When the official vibration and noise control regulations are established, the countermeasures should be taken to satisfy the said control regulations. However, the following countermeasures can be taken into consideration:

- Adoption of low noise type transformer.
- Application of sound insulation wall.
- Promotion of indoor installation of all the substation equipment and application of underground type substation.
- Sufficient separation to the site boundary.
- Application of rubber vibration insulator.

Reference: Standard noise and vibration levels in Japan

In Japan, the noise and vibration levels of power plant and substation are regulated within the ranges listed in the table below based on the values at the boundary of the sites. These regulations are set forth by prefectural governors, majors of cities, towns and villages.

(a) Noise level

i) Area required to be kept particularly calm

Daytime	Morning & Evening	Nighttime
45 ～ 50 phon	40 ～ 45 phon	40 ～ 45 phon

ii) Area required to be kept calm

Daytime	Morning & Evening	Nighttime
50 ～ 60 phon	45 ～ 50 phon	40 ～ 50 phon

iii) Combined residential, commercial and industrial area

Daytime	Morning & Evening	Nighttime
60 ～ 65 phon	55 ～ 65 phon	50 ～ 55 phon

iv) Industrial area

Daytime	Morning & Evening	Nighttime
65 ～ 70 phon	60 ～ 70 phon	55 ～ 65 phon

(b) Vibration level

i) Area required to be calm or particularly calm

Daytime	Nighttime
60 ～ 65 dB	55 ～ 60 dB

ii) Combined residential, commercial and industrial area including industrial area

Daytime	Nighttime
65 ～ 70 dB	60 ～ 65 dB

9.7 Land Acquisition Plan for Subtransmission Line and Substation Facilities

9.7.1 Features and Problematical Points

Acquisition of land and the rights pertaining to the land is necessary for subtransmission line and substation facilities according to the natures of required equipment and facilities, but it becomes increasingly difficult to acquire the land as overpopulation of cities advances.
Acquisition of land does not simply mean purchase of land, but includes settlement of various rights including easement, surface rights, right of lease and so forth for using the land. In a wider sense, moreover, acquisition of land has an extremely wide range of contents and sometimes includes the compensation for housing which can no longer be used due to preparation of land by reclamation; compensation for the loss of trees which should be felled; and that for the losses of agricultural crops, fishes, shells and so forth which can no longer been obtained. Acquisition of land requiring such a wide range of sophisticated proceedings is featured and raises various problematical points, depending respectively upon the characteristics of the power source, subtransmission line, substation, distribution and other respective equipment and facilities, patterns of the rights pertaining to the required land, local situations around the relevant land and other conditions. The features and problems about acquisition of land according to examples of subtransmission line and substation are described below:

(1) Overhead subtransmission line

As overhead subtransmission line connects the fixed power sources and the load center (substations), the line is affected specifically by the areas along the route. Since the total Bangkok area is included in the function zone of metropolis and a wide range of urbanization is in progress, proper adjustment for land utilization are essential in the respective areas along the line route.
The various plans affecting location of line route are also extremely diversified in both quantity and categories. These plans include those for

city development, road construction, land readjustment and improvement, housing and industrial estate land preparation and other projects as well as large scale urban residence development and other projects undertaken by private developers.

(2) Underground subtransmission line

As the majority of underground subtransmission lines are laid in the spaces under roads, every road manager tends to strengthen the regulations for the occupancy of such spaces reflecting ever-growing social interests in the recent road environment, worsened due to traffic congestion, noise, vibration and so forth resulting from construction work. Therefore, it has become more and more difficult to use the roads, which are valuable urban spaces.

Consequently, it has become necessary to promote reasonable formation of power distribution system after adjustment regarding the work period, method, arrangement, etc. with other enterprises occupying the road spaces for telephone line, gas pipeline, water works, etc. while ensuring smooth road traffic.

(3) Substation

It has become very difficult to acquire any substation site area requiring a considerably sizable space, as the situation of land utilization have become more and more serious along with the progress in urbanization.

The scale of a substation is determined according to its purpose of use ranging from ultra-high voltage and large capacity one connected directly to power source to the one for distributing power directly to customers. In every case, a sizable one lot of space is required, and it should be possible to construct incoming and outgoing lines from and to subtransmission and distribution lines. In the case of distribution substation, it should be located in a load center in view of its function, and similarly as in the case of subtransmission line, the construction work is affected largely by urban redevelopment, disaster preventive public work, park gardening and other miscellaneous projects. Therefore, it is essential to promote adjustment for land utilization as described previously.

Meanwhile, the following five patterns can be considered as those of settling the rights for constructing substation in a public underground space.

- In case there is a building above the space: Partial ownership
- Same as above: Room lease
- In case there is no such building: Partial ownership (settling of surface rights)
- Same as above: Partial ownership (no settling of surface rights)
- Same as above: Room lease (land lease)

Considering substations are permanent facilities, the right of partial ownership and the surface rights are preferable for the power utilities, a room lease system is adopted in some cases where it is difficult to acquire such rights as a result of negotiations with land owner. However, it is advantageous to lease a room or land from economics viewpoint in some cases where there is almost no possibility to construct a building above ground in the future when the substation site area is located in the space under public park and so forth.

9.7.2 Method of Promoting Land Acquisition

(1) Basic concept of land acquisition

As the job of land acquisition is that of negotiations with the third parties for acquiring the space for equipment and facilities, this job is directly related to business operation of the utility. Therefore, land acquisition should be promoted based on the following items of basic concept:

(a) Prior to formulating short and long-term plans, survey should be carried out sufficiently regarding the development trend, development projects, laws and regulations for land utilization and other items, and the results of such survey be reflected to the short and long-term plans after sufficient discussions and coordination with the sectors in charge of planning and work execution.

(b) Through close communication and coordination with local public bodies and relevant administrative agencies, sufficient understanding and cooperation should be obtained regarding the subtransmission line and substation construction plans.

(c) Based on the results of formulating a land acquisition plan in accordance with the plans, the land and the right related thereto should be acquired from a true land owner after concluding a contract with the owner.

(d) When the property right among the land and right related thereto has been acquired, the right should be registered.

(2) Study of the plan

(a) Prior to adjustment of preliminary short and long-term plans, study should be carried out regarding the following items pertaining to the suitability of the location for site and route, work period, approximate amount of land acquisition budget and so forth after receiving a request for study for new important project items from the planning sector.

1) Study on the suitability of location for site and route

Overall study should be carried out regarding the suitability of the location for site and route including the following items:

- Consistency with laws and regulations pertaining to land utilization
  Whether installation of subtransmission line and substation is subject to legal restrictions or not whether adjustment is possible or not.
- Consistency with land utilization plan of any other enterprise
  In the case where the MEA's plan is contradictory to any concrete land utilization plan or development plan of any other enterprise, the execution period and necessity of any countermeasure should be studied to attain the consistency with the plan of the other enterprise.

2) Study of work period

A reasonable work schedule/period should be formulated taking into account the situations of the land, schedules for land acquisition and expropriation, work execution schedules and so forth.

(b) An advance acquisition of land according to the short and long-term plans should be judged without missing the opportunity taking into account the increase in difficulty to acquire the land in the following areas where the subtransmission line and substation construction is scheduled to be started within 5 years or to be commissioned within 10 years after land acquisition.

- Land in existing urban area.
- Land in the area where urban or regional development project is being executed or under planning.
- Land in the area where the land place is excavated substantially.
- Land in the area subject to other particular situations.

(3) Preparation for land acquisition

(a) Primary study

Primary study should be carried out regarding the " individual work plans to be formulated in the next fiscal year or next thereto" among the short and long-term plans, and the results thereof be summarized. After sufficiently clarifying the relationship between the equipment formation and other works taking into account the countermeasures for power supply to meet the recent demand, the contents of the work plan should be discussed and studied with the sectors in charge of equipment formation and construction work based on the above study results.

(b) Formation of land acquisition policy

Based on the results of the study and discussions mentioned above, a land acquisition policy should be prepared individually regarding the proposed route, major schedule, total budget (land cost) and so forth, and a reasonable work plan be formulated by reflecting the following items to the work plan:

- Location, route and approximate space area of the land scheduled to be acquired.
- Compensation policy (form of right, scope of compensation, etc.).
- Land acquisition schedule.
- Estimated amount of total expenditure and budget for land acquisition.- Method of land acquisition (Necessity of agent for land acquisition). (c) Secondary study

- For promoting formulation of reasonable land acquisition plan and ensuring smooth land acquisition, the secondary study (detailed study) should be carried out with regard to each project for which the land acquisition plan and work execution plan have been formulated, and the study results be summarized.
- Should it become necessary to change the route and other work execution plans as a result of the secondary study, the said plans should be changed after discussions with the sectors in charge of the planning and work execution.

(d) Formulation of land acquisition plan

On the base of the results of secondary study, individual land acquisition plans including the following items should be prepared:

- Location, route and area of land scheduled to be acquired.
- Form of right.
- Contents of compensation.
  - Scope.
  - Whether it is possible or not to construct any structure under the line.
- Land acquisition schedule.
- Total amount of expenditure and budget for land acquisition.
- Basic items pertaining to contract.
- Work compensation execution plan and entrustment plan therefor.

(4) Execution of land acquisition

(a) Coordination and cooperation with the relevant sectors

Land acquisition should be carried out in close coordination and cooperation with the relevant sectors to ensure completion of the work within the scheduled period.

(b) Explanation of the project

To obtain understanding on the construction project from land owner and others by publicly announcing the project, the contents of the projects, should be explained to the relevant local public body, administrative agency, land owner and people around the project site.

(c) Negotiations for understanding of site survey

To carry out geological and topographical survey as required to determine the location and range of equipment installation, understanding should be obtained from the land owner regarding "entry to the site" for the survey and "witness of the site" for confirming the border of the land.

(d) Topographical survey of the land

After prior arrangement with the land owner, topographical survey of the land and confirmation of border should be carried out while being directly witnessed by the sector in charge of land acquisition, and efforts be directed for confirming precise conditions of the site, disposition of the land owner, local characters and so forth.

(e) Acquisition of land

The land and the right related thereto to be used for equipment installation should be acquired from a true land owner through appropriate compensation according to the equipment construction plan and land acquisition plan.

1) Land for substation, tower and other sites

Ownerships, surface rights and other property rights should be acquired as regards the land for substation, tower and other sites, and in case it is impossible to obtain such rights, the rights of lease should be acquired.

2) Land under subtransmission line

The easement, rights of lease, rights of use and lease, and other rights should be acquired in the case of the land under subtransmission line. In the areas, where the rights of land are expected to be frequently transferred, particularly where urbanization is planned efforts should be directed for acquiring the easement and other rights related to the land.

Note: In Japan, special measures are taken in the taxation system of Japan to reduce the burden of tax imposed to the profit from transfer of land, etc. in the case where the land owner or other person performs transfer of land, settlement of rights pertaining to the land and so forth in connection with acquisition of land and for installation of subtransmission line, substation and other facilities.

Since these special taxation measures are also effective for facilitating smooth acquisition of land, it is recommended to study application of this system if such a system has not been established in Bangkok.

(f) Contracting

1) When a consent of the land owner has been obtained regarding acquisition of the land and the rights related thereto, a contract should be concluded taking into account the following points:
   - Whether the person is a true land owner and entitled to conclude the contract or not.
   - Whether any other right has been settled regarding the land or not.

2) The contract for acquiring the land and the rights related thereto should in principle be completed not later than the commencement period of the construction work.

(g) Registration

Registration should be carried out for transfer of the ownership, settlement of easement, surface and other rights, when the easement, surface rights and so forth have been settled subsequent to acquisition of the ownership along with installation of substation equipment.

(5) Land acquisition schedule control

After adjustment with the sectors in charge of equipment planning and work execution, the land acquisition plan should be formulated while sufficiently reflecting the situations of the land area, and the land acquisition schedule for individual works be controlled as described below:

(a) Confirmation of the progress of land acquisition and study of countermeasures for solving difficult problems

The negotiation method with land owner and other countermeasures should be studied to ensure commissioning of equipment on schedule, after confirming the latest progress of land acquisition and clarifying difficult positions, opposing land owner and other situations.

(b) Study on whether it is possible or not to start the work

Overall countermeasures including change of work method and schedule should be taken through cooperation with the sectors in charge of construction management and work execution, after studying on whether it is possible or not to start the work with the sector in charge of land acquisition.

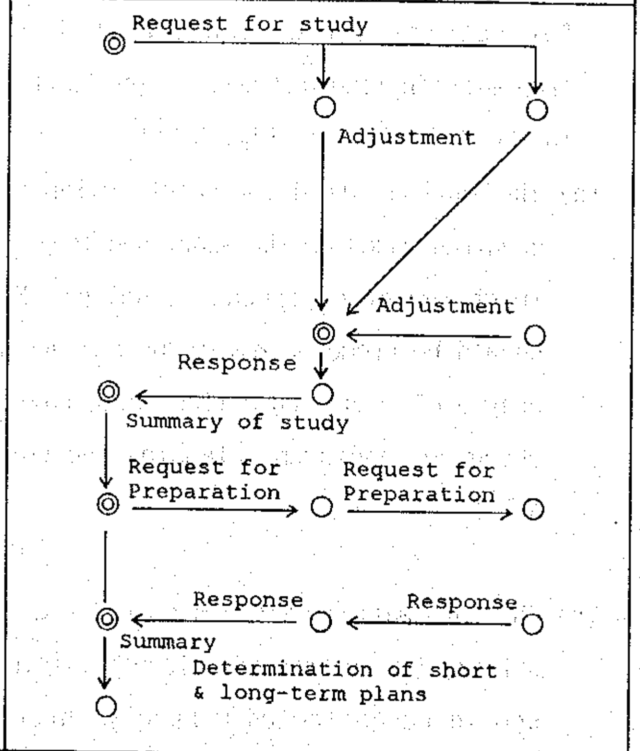
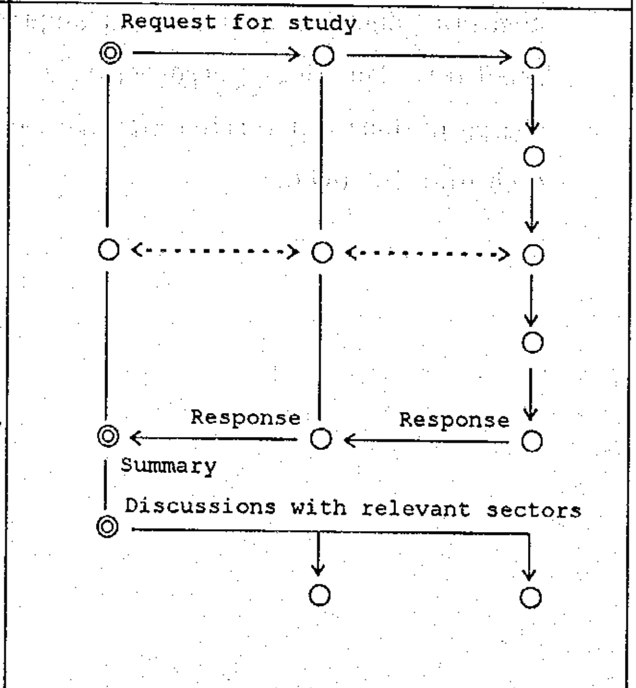
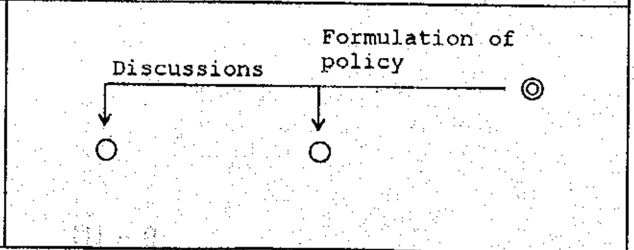
(6) Summary

Described so far in this clause are the basic concept and standard methods for acquiring the land (including the rights) required for the transmission line and substation facilities. The process is as presented in the flow chart in Fig. 9.7-1.

(a) The land required for construction of such power facilities should be acquired based on the short and long-term plans formulated by the sector in charge of equipment planning. More concretely, land acquisition should be promoted mainly by and under responsibility of the sector in charge of land acquisition while having discussions with the sectors in charge of equipment planning and work execution as indicated in Fig. 9.7-1.

(b) The information pertaining to the situations of land including the land utilization, urban redevelopment, main road construction and other plans should be collected minutely through daily activities. Moreover, negotiations for actual land acquisition should also be promoted smoothly. For these purposes, it is desirable to appoint the staff in charge of land acquisition also not only in the head office but also in each district office.

Fig. 9.7-1 Flow of Equipment Planning and Land Acquisition Planning

Main Process	Execution Items	Sectors in charge of: Equipment planning / Work execution / Land acquisition
Short & long term plans	Study of projects in short & long-term plans Study of the necessity of prior acquisition of land Preparation of short & long-term draft plans and data	
Fist study	Confirmation of project to be studied Confirmation of proposed candidate routes Field reconnaissance Desk study in office Investigation by relevant administrative agency Discussion on work plan (main items) of individual projects based on the results of the First Study	
Formulation of policy for land acquisition for individual projects	Formulation of land acquisition policy for individual projects	

Main Process	Execution Items	Sectors in charge of		
		Equipment planning	Work execution	Land acquisition
Formulation of individual work execution plans	Preparation of relative data for formulating individual work execution plans	◎ Request for Preparation → ◎ ← Response Summary ↓ ◎ Formulation →	○ Request for Preparation → ↓ ○ ← Response Discussion ↓ ○	○ ↓ ○ ↓ ○
Second Study	Investigation by company and relevant administrative agency and study of rights Summary of the results of the Second Study		○ ← Communication and adjustment →	◎ ↓ ○
Formulation of land acquisition plans for individual projects	Formulation of individual land acquisition plans	Discussions ↓ ○	↓ ○	Formulation of plans ◎
Preparation of documents for obtaining approval for execution of individual work	Communication on the progress and other situations of land acquisition Preparation of relative data for preparing documents for obtaining work execution approval	○ ← Discussions	◎ ← Communication ↓ ◎ Request for preparation → ◎ ← Response Summary ↓ ◎ Preparation →	○ ○ ↓ ○ ○

◎: Major sector in charge