CHAPTER 5

MEA's SHORT- AND LONG-TERM POWER DISTRIBUTION SYSTEM IMPROVEMENT AND EXPANSION PLAN

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5.1 Outline of the Revised 7th Plan

MEA formulated the Revised 7th Plan, and has performed its implementation to cope with the rapid increasing demand.

Brief description of the Revised 7th Plan concerning this Study is as follows:

(1) Terminal Station

Six new terminal stations (Thanontok, Sainoi, Jangwatana, Ratchada, Bangkoknoi and Teparak) are to be constructed with the total capacity of 2,700 MVA, of which Thanontok is to be invested by MEA.

Besides seven existing terminal stations will be boosted by 1,400 MVA and the total increasing capacity will be 4,100 MVA.

(2) Distribution Substation

Forty-two new distribution substations with total capacity of 4,400 MVA will be constructed; 16 existing substations will be boosted by 800 MVA in total, and 22 temporary or small substations will be dismantled resulting in reduction of 1,060 MVA. The total increasing capacity will be 4,140 MVA. In addition, there will be modification of two more existing substations.

(3) Subtransmission Line System

The total length of subtransmission line to be constructed will be 377.7 ckt-km of which 281 ckt-km is overhead line and 96.7 ckt-km is underground cable. Moreover, there will be subtransmission line addition at the total length of 35.3 ckt-km, of which 26.6 ckt-km is overhead line and 8.7 ckt-km is underground cable.

5.2 Progress of Substation Expansion Plan

According to the Revised 7th Plan, most of the substation expansion work has been considerably behind schedule. As a countermeasure to cover power supply, therefore, temporary one-bank substation has been installed in many cases.

Although 12 substations among the 73 projects in total have been commissioned as temporary substations in advance along with rapid increase of power demand, the construction work of many other substations has been by two or three years behind schedule. However, the majority of substations are scheduled to be commissioned by FY 1997 although the commissioning date of five substations is extended to FY 1998.

CHAPTER 6

FORMULATION OF OPTIMUM SHORT- AND LONG-TERM POWER DISTRIBUTION SYSTEM IMPROVEMENT AND EXPANSION PLAN

CHAPTER 6 FORMULATION OF OPTIMUM SHORT- AND LONG-TERM POWER DISTRIBUTION SYSTEM IMPROVEMENT AND EXPANSION PLAN

6.1 General

The followings are the items that the JICA Study Team has specially paid attention to the planning of the future power distribution system in the Metropolitan area.

(1) Reliability.

(2) Capacity of subtransmission networks and substations.

(3) Application of advanced technology to distribution system facilities in the high load density area.

(4) Land acquisition method for distribution substation in downtown area.

(5) Voltage regulation control.

(6) Telecommunication system improvement.

(7) Feasibility of construction of underground subtransmission and distribution lines and substations.

(8) Impact to environment.

The followings are the major improvement and expansion of the power distribution system in this Study.

(1) To promote uprating of 12 kV to 24 kV primary line in distribution area (except in network area).

(2) Expansion of 115 kV subtransmission system.

(3) Introduction of 230 kV subtransmission system into urban area.

6.2 Regional Load Forecast in FY 2016 by the JICA Study Team

(1) Forecast of design load to be used for formulating the distribution substation expansion plan

When calculated from the increase trend of load by FY 2011 since FY 1993 according to the least squares method, the MW and MVA values of non-coincident load for FY 2016 are 17,578 MW and 19,030 MVA, respectively.

The forecast result is presented in Table 6.2-1.

(2) Load forecast for distribution substations by regions

On the basis of the supply areas of distribution substation in FY 2001, therefore, the load blocks have been set by integrating those with similar load characteristics. The results of study are presented in Table 6.2-2 and Fig 6.2-1.

6.3 Long-Term Expansion Plan of Distribution Substations (FY 2016)

(1) Formulation of expansion plan

A method was adopted to calculate the utilization factor in the demand for FY 2016 to be supplied on the basis of equipment for FY 2011 and to study the substations where extension plans are needed.

Countermeasures should be taken for the following substations:

(a) 2-bank configuration substation wherein the utilization factor exceeds 75%.

(b) 3-bank configuration substation wherein the utilization factor exceeds 80%.

(c) (1 x 60 MVA + 1 x 40 MVA) bank configuration substation wherein the utilization factor exceeds 65.0% (excess of 65 MVA).

(d) (1 x 60 MVA + 2 x 40 MVA) bank configuration substation wherein the utilization factor exceeds 79.3% (excess of 111 MVA).

The preferential order of countermeasures is as follows:

i) Switchover to surrounding substation with lighter load through distribution line.

ii) Expansion of bank and/or its capacity.

iii) Construction of new substation.

Table 6.2-1 MEA's Forecast of Maximum Power Demand & 2016's Forecast of Planning Load

		1993	1996	2001	2006	2011	2016
Planning Load							
Coincident Load 12& 24KV (MW)	A	4,080.50	5,266.80	7,664.89	9,969.28	12,645.86	14,874.58
Coincident Load 69&115KV (MW)		401.51	538.90	737.49	827.96	951.83	1,119.08
Total Amount (MW)	B	4,482.01	5,805.70	8,402.38	10,797.24	13,597.69	15,993.66
Percentage A/B (%)		91.04	90.72	91.22	92.33	93.00	93.00
Additional Load (Annual Average)							
12& 24KV (MW)		-	395.43	479.62	460.88	535.32	445.74
69&115KV (MW)		-	45.80	39.72	18.09	24.77	33.45
Total Load (MW)		-	441.23	519.34	478.97	560.09	479.19
Average Increase Rate							
12& 24KV (%)		-	8.88	7.79	5.40	4.87	3.30
69&115KV (%)		-	10.31	6.48	2.34	2.83	3.29
Total Load (%)		-	9.01	7.67	5.14	4.72	3.30
Forecast Load (30minutes Average)							
Total Max. Power Demand (MW)	C	4,346.00	5,723.00	8,290.00	10,653.00	13,416.00	15,780.00
Average Increase (%)		-	9.61	7.69	5.14	4.72	3.30
Ratio	B/C	1.03130	1.01445	1.01356	1.01354	1.01354	1.01354

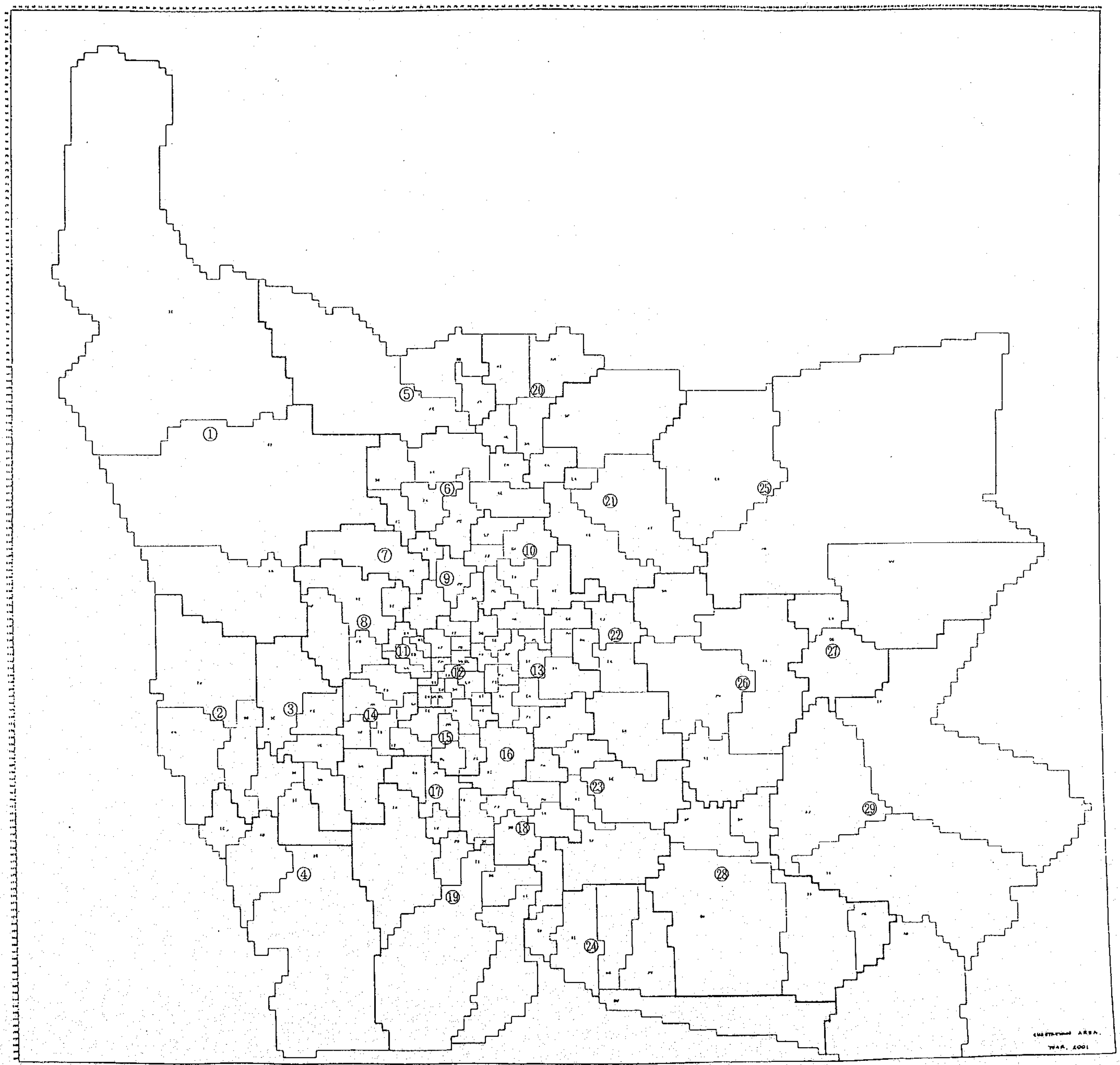
		1993	1996	2001	2006	2011	2016
Planning Load							
Non-Coincident Load 12&24KV (MW)	D	4,831.31	6,217.35	9,063.73	11,783.95	14,944.53	17,578.38
Non-Coincident Load 12&24KV (MVA)	E	5,561.54	6,809.80	9,916.56	12,850.55	16,261.73	19,029.67
Average Increase Rate							
Non-Coincident Load 12&24KV (MW)	%	-	8.77	7.83	5.39	4.87	3.30
Non-Coincident Load 12&24KV (MVA)	%	-	6.98	7.81	5.32	4.82	3.19
Diversity Factor	D/A	1.1840	1.1805	1.1825	1.1820	1.1818	1.1818
Power Factor	D/E	0.8687	0.9130	0.9140	0.9170	0.9190	0.9237

Table 6.2-2 Block Load of Distribution Substation Planning

No	Block Name	Area (km2)	2001 Load (MVA)	2001 Density (kVA/km2)	2011 Load (MVA)	2011 Density (kVA/km2)	2011 Increase (%)	2016 Load (MVA)	2016 Density (kVA/km2)	2016 Increase (%)	Distribution Substation of Block Area(2001)
1	Sainoi	511.00	150.79	295.09	319.54	625.32	7.80	420.13	822.17	5.63	RY, KH, SI
2	Taweewattana	123.75	368.32	2,976.32	503.76	4,070.79	3.18	532.12	4,299.95	1.10	BB, BO, NH, ST, TW
3	Bangkae	60.50	223.55	3,695.04	456.67	7,548.26	7.40	589.54	9,744.41	5.24	WG, PS, BE, WK
4	Klongsanamchai	148.25	134.46	906.98	258.14	1,741.25	6.74	323.06	2,179.13	4.59	SC, KD, EC
5	Pakkred	116.75	711.06	6,090.45	1,088.80	9,325.91	4.35	1,216.91	10,423.22	2.25	BD, M1, PE, M3, JW, M4, M5, M6, M7
6	Nonthaburi	76.00	377.73	4,970.13	828.75	10,904.61	8.17	1,108.73	14,588.50	5.99	NR, PC, YA, SB, TH, KE, YI
7	North Bangkok	26.25	54.24	2,066.29	71.41	2,720.38	2.79	74.00	2,819.20	0.72	NK
8	Rungpracha	50.00	268.41	5,368.20	485.65	9,713.00	6.11	590.03	11,800.52	3.97	BY, PO, RC, HP
9	Pradipat	25.00	273.14	10,925.60	501.65	20,066.00	6.27	614.04	24,561.76	4.13	SM, SN, BZ, PP
10	Chankasem	45.50	420.53	9,242.42	615.19	13,520.66	3.88	672.04	14,770.02	1.78	CK, LP, MC, WT, IN, JJ
11	Sapandam	9.75	326.15	33,451.28	472.14	48,424.62	3.77	513.07	52,622.26	1.68	BR, SD, WL, NL
12	Chidlom	23.50	1,080.26	45,968.51	1,515.50	64,489.36	3.44	1,621.24	68,989.02	1.36	CL, KP, KT, LN, MS, PM, SL, SY, SU, WB, YT, UK, YN, SH, SW
13	Soonvijai	59.75	1,098.16	18,379.25	1,786.67	29,902.43	4.99	2,058.40	34,450.13	2.87	BA, HK, NN, PI, PK, PA, SS, SV, EM, HA, SA, DD, GK, PL, RP
14	Taksin	44.25	413.86	9,352.77	530.69	11,992.99	2.52	542.78	12,266.31	0.45	BM, KN, MN, TS, TB, WR
15	Thanontok	27.50	449.64	16,350.55	767.39	27,905.09	5.49	905.48	32,926.58	3.36	BL, PG, MM, TT, NS, YK, TC
16	Bangkrachao	18.25	11.55	632.88	28.29	1,550.14	9.37	39.99	2,191.23	7.17	BC
17	Jangron	20.75	164.89	7,946.51	291.93	14,068.92	5.88	350.84	16,908.14	3.74	KU, RN, JR
18	Suanson	43.00	396.97	9,231.86	619.42	14,405.12	4.55	698.86	16,252.60	2.44	MA, PJ, SR, SK, SO, TK, MU
19	Bangplakod	182.00	331.58	1,821.87	473.30	2,600.55	3.62	510.74	2,806.29	1.53	BK, KS, PD, TR, TI
20	Donmuang	58.75	249.37	4,244.60	446.55	7,600.85	6.00	539.72	9,186.64	3.86	KA, DM, KM, MI, KL
21	Lardprao	131.50	218.64	1,662.66	581.36	4,420.99	10.27	856.24	6,511.35	8.05	LK, RT, SP, KG
22	Klongjan	57.50	262.61	4,567.13	427.70	7,438.26	5.00	492.98	8,573.60	2.88	KJ, RH, SG, TA
23	Srieiam	87.25	379.62	4,350.95	587.16	6,729.63	4.46	659.56	7,559.37	2.35	BG, TP, RI, SE, JK
24	Bangping	118.25	481.36	4,070.70	642.07	5,429.77	2.92	669.78	5,664.08	0.85	BI, BU, PN, PR, KO, TN
25	Minburi	435.00	141.91	326.23	331.27	761.54	8.85	457.14	1,050.96	6.65	MB, EB, WY
26	Romklao	152.50	251.29	1,647.80	550.41	3,609.25	8.16	735.74	4,824.54	5.98	RK, KI, BH, PW
27	Chalongkrung	40.00	107.56	2,689.00	187.21	4,680.25	5.70	223.07	5,576.85	3.57	CG, LB
28	South Bangplee	172.50	350.30	2,030.72	512.91	2,973.39	3.89	560.58	3,249.71	1.79	BN, BP, BS, MG, OB
29	Tubyao	393.00	218.61	556.26	380.20	967.43	5.69	452.86	1,152.33	3.56	BJ, RG, AB, TY
30											
	Total	3,258.00	9,916.56	3,043.76	16,261.73	4,991.32	5.07	19,029.67	5,840.91	3.19	

Fig. 6.2-1 Block Area

① Sainoi
② Taweewattana
③ Bangkae
④ Klongsanamchai
⑤ Pakkred
⑥ Nonthaburi
⑦ North Bangkok
⑧ Rungpracha
⑨ Pradipat
⑩ Chankasem
⑪ Sapandam
⑫ Chidlom
⑬ Soonvijai
⑭ Taksin
⑮ Thanontok
⑯ Bangkrachao
⑰ Jangron
⑱ Suansom
⑲ Bangplakod
⑳ Donmuang
㉑ Lardprao
㉒ Klongjan
㉓ Srieiam
㉔ Bangping
㉕ Minburi
㉖ Romklao
㉗ Chalongkrung
㉘ South Bangplee
㉙ Tubyao



The results of comparing the facility states in FY 1996 and those in FY 2016 are listed below:

	FY 1996(A)	FY 2016(B)	B/A
No. of substations	124	192	1.55
No. of banks	257	515	2.00
Capacity (MVA)	11,645	29,240	2.51
Average utilization factor (%)	58.9	65.1	+6.2%
No. of banks per each substation	2.07	2.68	—

For reference, utilization factor of distribution substation in FY 1996 and 2016 is presented in Fig. 6.3-1.

Incidentally, the quantity of equipment to be expanded for twenty (20) years during the period FY 1997-2016 is as listed below:

	Number of Substations	Installed Capacity (MVA)
New	68	10,120
Enlargement	91	6,775
Total	159	16,895

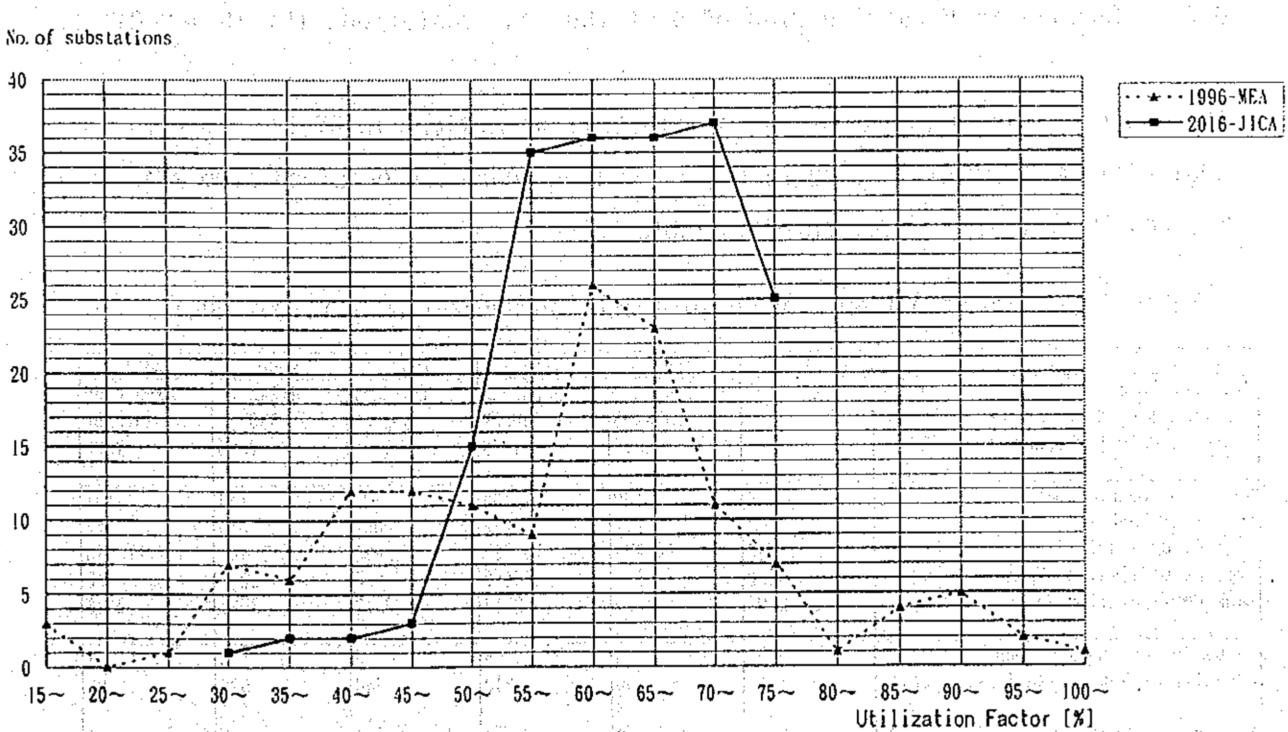


Fig 6.3-1 Distribution Substation Utilization Factor (compare with FY 1996)

6.4 Long-Term Expansion Plan of Distribution Substations (FY 2001-2011)

The long-term plan for distribution substations from FY 2001 through FY 2011 has been determined to be formulated by reviewing the plan formulated by MEA. The result is presented in Table 6.4-1 (including FY 2016 plan).

Table 6.4-1 Construction Plan of Distribution Substation (FY 2001-2011)

		1996	2001	2006	2011	2016
Planning Load	[MVA]	6,856.23	9,916.55	12,850.26	16,262.11	19,029.65
Additional Load	[MVA]	-	3,060.32	2,933.71	3,411.85	2,767.54
Additional Load per annum	[MVA]	-	612.06	586.74	682.37	553.51
Increase Rate per annum	[%]	-	7.66	5.32	4.82	3.19
Number of Substations		124	151	167	182	192
Number of Banks		257	341	404	476	515
Installed Capacity	[MVA]	11,645	17,545	22,340	26,700	29,240
Average Utilization Factor	[%]	58.9	56.5	57.5	60.9	65.1
Bank Configuration Ratio		2.07	2.26	2.42	2.62	2.68
Number of New Substations		-	27	16	15	10
Capacity of New Substations	[MVA]	-	3,000	2,040	2,100	1,320
Number of Expanded Substations		-	46	42	38	28
Expanded Capacity	[MVA]	-	2,540	2,155	2,260	1,220
Increment	[MVA]	-	5,540	4,195	4,360	2,540
Increment per annum	[MVA]	-	1,108	839	872	508

6.5 Short-Term Expansion Plan of Distribution Substations (FY 1997-2001)

The short-term expansion plan for distribution substations in FY 1997 through 2001 will be formulated by reviewing a new five-year plan obtained from MEA. The result of review is presented in Table 6.5-1.

Table 6.5-1 Construction Plan of Distribution Substation (FY 1997-2001)

		1996	1997	1998	1999	2000	2001
Planning Load	[MVA]	6,856.23	7,456.16	8,002.55	8,586.21	9,243.01	9,916.55
Additional Load per annum	[MVA]	-	599.93	546.39	583.66	656.80	673.54
Increase Rate per annum	[%]	-	8.75	7.33	7.29	7.65	7.29
Number of Substations		124	130	135	139	144	151
Number of Banks		257	277	289	302	318	341
Installed Capacity	[MVA]	11,645	12,825	13,585	14,425	15,405	17,545
Average Utilization Factor	[%]	58.9	58.1	58.9	59.5	60.0	56.5
Bank Configuration Ratio		2.07	2.13	2.14	2.17	2.21	2.26
Number of New Substations		-	6	5	4	5	7
Capacity of New Substations	[MVA]	-	300	340	340	580	800
Number of Expanded Substations		-	18	10	8	7	23
Expanded Capacity	[MVA]	-	920	360	360	380	960
Increment	[MVA]	-	1,220	700	700	960	1,760

6.6 Methodology of Subtransmission Line and Terminal Station System Plan

(1) Approach to the subtransmission system planning

First, the study on the basic system configuration at FY 2016 which is the final target in this Study was carried out based on the MEA's draft long-term plan up to FY 2011, taking into account the distribution substation expansion plan at FY 2016 formulated by the JICA Study Team.

After formulating the long-term optimum plan at FY 2016, the study on the optimum subtransmission system plan at each target year during the period of FY 1997-2011 has been carried out by expanding the necessary subtransmission system facilities in chronological order toward the FY 2016's plan.

Power flow analyses and fault current calculation have been carried out to define the necessity for subtransmission system improvement and expansion.

(2) Criteria for the subtransmission system planning

The criteria adopted for the subtransmission system planning in this Study are based on the MEA's planning criteria.

6.7 Subtransmission Line and Terminal Station System Plan (FY 2016)

Fig. 6.7-1 and Fig. 6.7-2 show the system configuration at FY 2016 planned by the JICA Study Team.

(1) Terminal station improvement and expansion

If any of the terminal stations are unable to cope with the increasing load, the following countermeasures should be considered:

- Load reduction by transferring the distribution substations to be supplied from one terminal station to the other.
- Addition of terminal station capacity to be able to supply the increasing load.
- Construction of new terminal station to share load from adjacent terminal stations.

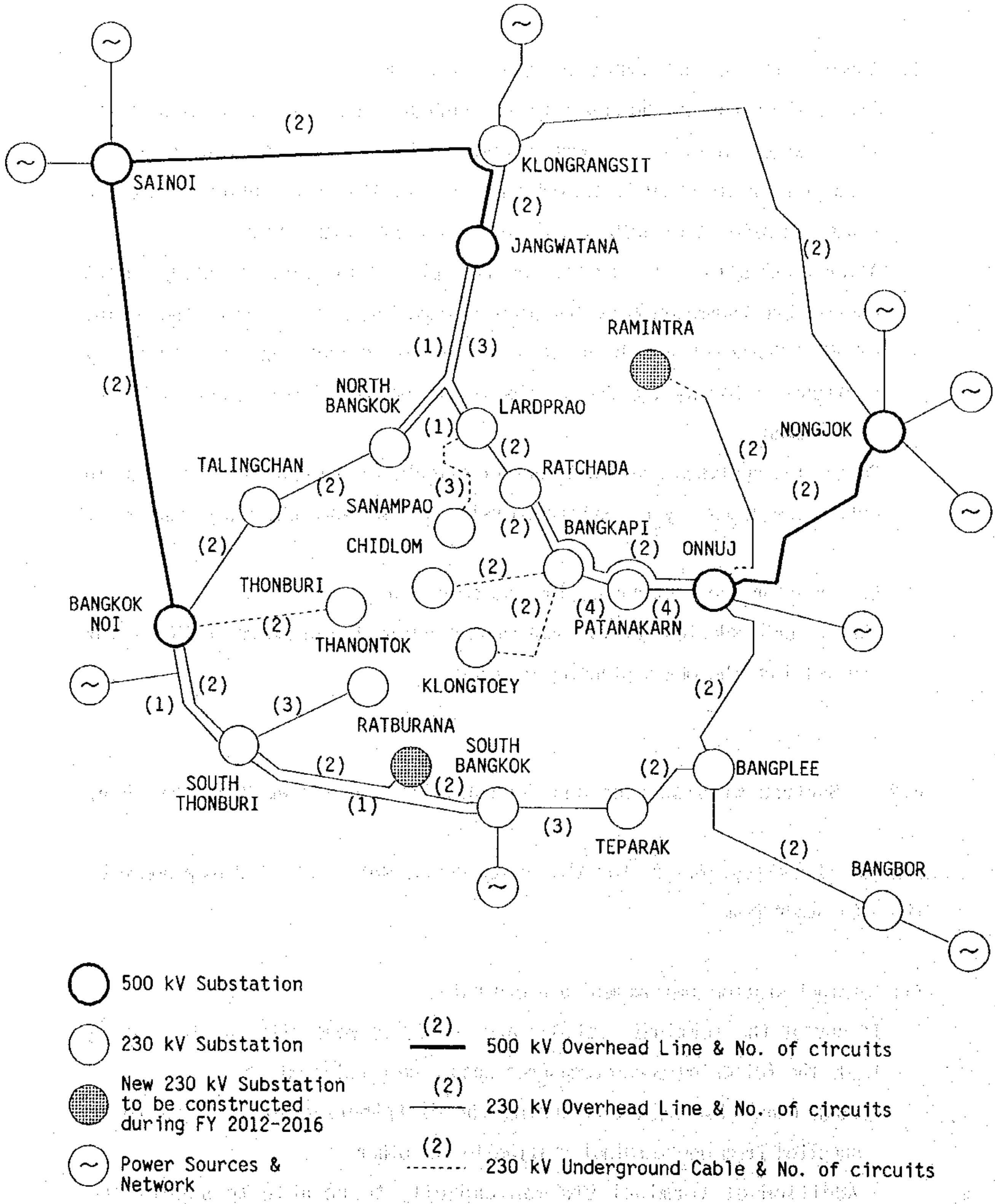
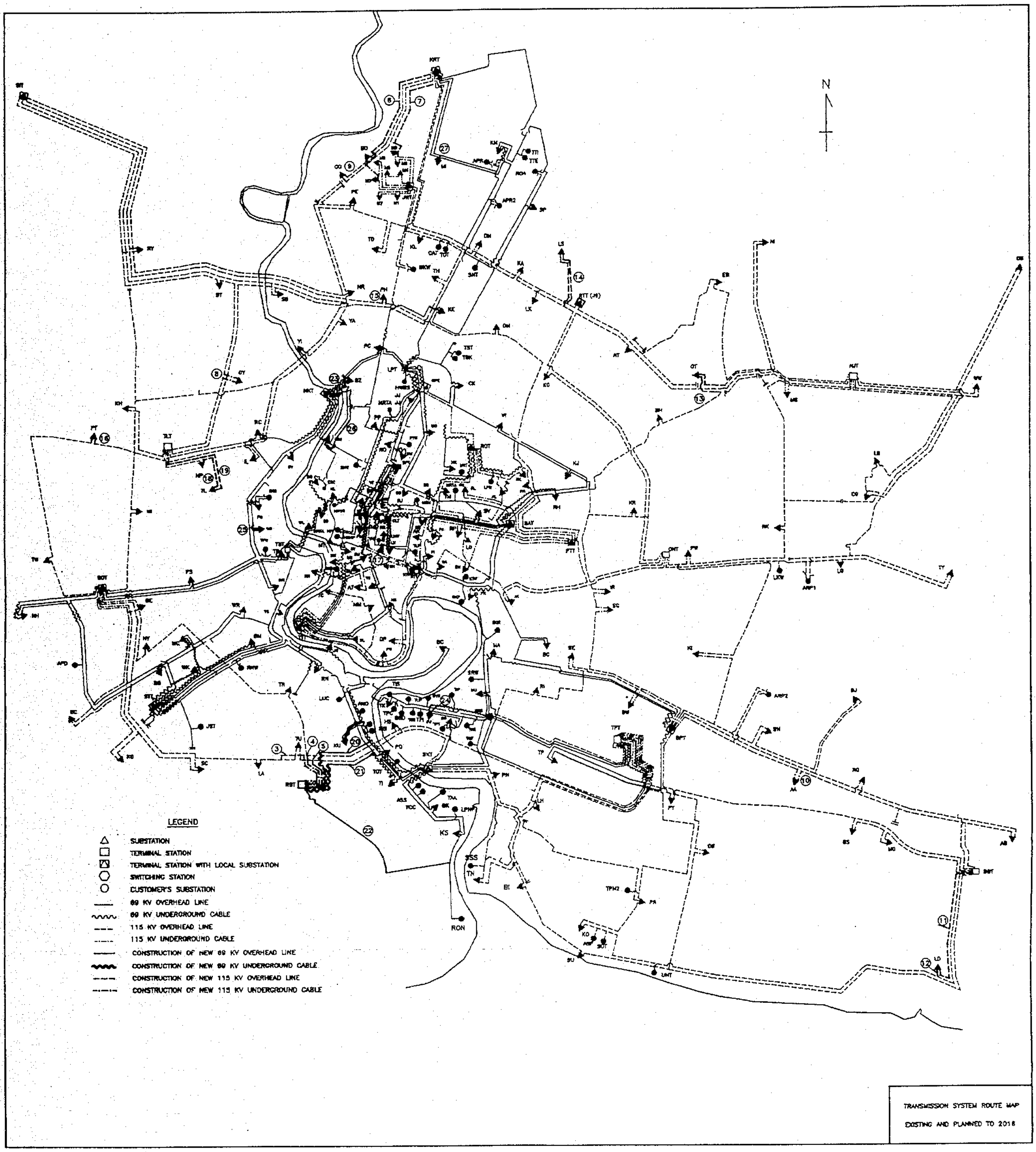


Fig. 6.7-1 230 kV System Configuration at FY 2016



Note: Figures in circle are correspondent with the number of subtransmission line to be constructed during the period of FY 2012-2016 as shown in Table 6.4-2.

Fig.6.7-2 115kV and 69kV System Configuration at FY 2016

The two new terminal stations with total capacity 1,800 MVA will be constructed and 11 existing terminal stations will have capacity added totally 2,900 MVA compared with the JICA plan at FY 2011. The total increasing capacity, therefore, will be 4,700 MVA, of which 1,200 MVA is invested by MEA and 3,500 MVA is invested by EGAT.

The two new terminal stations planned by the JICA Study Team can be summarized as follows:

(a) Construction of a new terminal station as countermeasures against overloading of Nonjok T/S and Onnuj T/S.

The installation of 2 x 300 MVA 230/115 kV transformers are proposed. As one of the candidate sites, a place around Ramintra area will be selected by reason of:

- Located adjacent to the 115 kV subtransmission lines on the secondary side of both the above-mentioned terminal stations.
- Easily interconnected also with the northern terminal stations such as Jangwatana, Lardprao, Klongrangsit, etc.

Incidentally, the new terminal station (hereinafter referred to as " Ramintra T/S") is located outside the EGAT's 230 kV outer ring lines, so that MEA will have to find a plot of land to construct T/S and receive power at 230 kV from EGAT at nearby existing T/S.

(b) Construction of a new terminal station as countermeasures against overloading of South Bangkok T/S.

The installation of two 230/69 kV and two 230/115 kV transformers, each rated 300 MVA, are proposed.

As the 69 kV load at South Bangkok T/S is distributed widely also in the area along the west side of the Chau Phraya River, it is desirable that the new terminal station should be constructed around Ratburana area, located on the west side of the river, by terminating the double circuit of the EGAT's existing three circuit 230 kV South Thonburi - South Bangkok line at the new terminal station (hereinafter referred to as "Ratburana T/S").

(2) Subtransmission line improvement and expansion

According to the subtransmission line expansion plan during the period of FY 2012-2016 formulated by the JICA Study Team, the total length of subtransmission line to be constructed will be 109.3 ckt-km, of which 79.0 ckt-km is overhead line and 30.3 ckt-km is underground cable.

These can be briefly summarized as follows:

(a) Construction of 230 kV double circuit subtransmission line from Onnuj T/S to the new Ramintra T/S, a distance of 19.0 km, of which 13.0 km is overhead line and 6.0 km is underground cable.

(b) Construction of the outgoing 115 kV and 69 kV subtransmission line from the new Ratburana T/S, the total length of 24.7 ckt-km.

(c) Construction of 115 kV subtransmission line to be linked the 11 new distribution substations such as Klongdan D/S, Lumpagshe D/S, etc., the total length of 26.0 ckt-km.

(d) Construction of the incoming 69 kV subtransmission line to be linked distribution substations with the installation of the third transformer such as Samsen D/S, Bangson D/S, etc. to modify the system configuration to "Tapped-tie normally open (3 incomings)", the total length of 6.1 ckt-km.

(e) Construction of 115 kV subtransmission line to transfer the load at Maungthong-3 D/S and Maungthong-9 D/S from Jangwatana T/S to Klongrangsit T/S as countermeasures for the overloading Jangwatana T/S, the total length of 14.5 ckt-km.

6.8 Subtransmission Line and Terminal Station System Plan (FY 1997-2011)

(1) Terminal station improvement and expansion

Table 6.8-1 shows the target for terminal station programme up to FY 2016.

(a) Construction of terminal station

The nine new terminal stations with total capacity 4,800 MVA will be constructed. Among these, the following four terminal stations which are located outside the EGAT's 230 kV outer ring lines will be constructed with the total capacity of 2,400 MVA by MEA's own investment.

FY 1999: Thanontok T/S 230/115 kV, 2x300 MVA

FY 2000: Sanampao T/S 230/115 kV, 1x300 MVA

230/69 kV, 1x300 MVA

FY 2006: Klongtoey T/S 230/115 kV, 2x300 MVA

Thonburi T/S 230/69 kV, 1x300 MVA

(b) Addition of terminal station

The 18 existing terminal stations will have capacity added totally 8,115 MVA. Among these, the following two terminal stations will have capacity added totally 900 MVA by MEA's own investment.

FY 2006: Sanampao T/S 230/69 kV, 1x300 MVA to 2x300 MVA

FY 2011: Sanampao T/S 230/115 kV, 1x300 MVA to 2x300 MVA

Thonburi T/S 230/69 kV, 1x300 MVA to 2x300 MVA

The installed capacity of terminal stations at each target year up to FY 2016 is as shown in Table 6.8-2.

(2) Subtransmission line improvement and expansion

(a) 230 kV subtransmission line

Table 6.8-3 shows the 230 kV subtransmission line system expansion plan.

Table 6.8-3 230 kV Subtransmission Line System Expansion Plan (FY 1997-2011)

Name of Subtransmission Line	Distance (km)	Circuit (No.)	Conductor Size (mm²)	Commissioning Date (Fiscal Year)
Construction				
1. Lardprao - Sanampao	7.8	2	2x1,200	2000
2. Bangkapi - Klongtoey	7.7	2	2x1,200	2006
3. Bangkoknoi - Thonburi	10.4	2	2x1,200	2006
Addition				
1. South Thonburi - Thanontok	8.0 0.6	1 1	2x400 2x1,200	1997
2. Lardprao - Sanampao	7.8	1	2x1,200	2006

Table 6.8-1 Target for Terminal Station System Program

Name of Terminal Station	System Voltage (kV)	Installation Capacity (MVA)							
		1997	1998	1999	2000	2001	2006	2011	2016
<u>Construction</u>									
1. Onnuj	230-115		2x300						
2. Thanontok *	230-115			2x300					
3. Sanampao *	230-115				1x300				
	230- 69				1x300				
4. Ratchada	230-115				1x300				
5. Bangbor	230-115					1x300			
6. Klongtoey *	230-115						2x300		
7. Patanakarn	230-115						3x300		
8. Talingchan	230-115						2x300		
9. Thonburi *	230- 69						1x300		
10. Ramintra *	230-115								2x300
11. Ratburana	230-115								2x300
	230- 69								2x300
Subtotal		—	600	600	900	300	2,400	—	1,800
<u>Addition</u>									
1. South Thonburi	230- 69	3x200 to 4x200							
2. Klongrangsit	230-115	1x200 to 2x200							
3. Nongjok	230-115	2x200 to 2x200 + 1x300							
4. Teparak	230-115		1x300 to 2x300						
	230- 69		1x300 to 2x300						
5. Jangwatana	230-115		2x300 to 3x300						
6. Sainoi	230-115			1x300 to 2x300					
7. Bangkoknoi	230-115				1x300 to 2x300				
8. Bangkapi	230- 69					4x200 to 2x200 + 2x300			
9. North Bangkok	230- 69					2x200 + 1x285 to 2x200 + 2x300			
10. South Bangkok	230- 69					4x200 to 2x200 + 2x300			
11. Bangplee	230-115						3x200 to 4x200		
12. South Bangkok	230-115						2x200 to 3x200		
13. Jangwatana	230-115						3x300 to 4x300		
14. Bangbor	230-115						1x300 to 2x300		
15. Onnuj	230-115						2x300 to 3x300		

Note: * MEA's Terminal Station

Table 6.8-1 Target for Terminal Station System Program (Cont.)

Name of Terminal Station	System Voltage (kV)	Installation Capacity (MVA)							
		1997	1998	1999	2000	2001	2006	2011	2016
16. Klongrangsit	230- 69						2x200 to 3x200		
17. Lardprao	230- 69						4x200 to 2x200 + 2x300		
18. Sanampao *	230- 69						1x300 to 2x300		
19. Klongrangsit	230-115							2x200 to 3x200	
20. Nonjok	230-115							2x200 + 1x300 to 4x300	
21. Bangkoknoi	230-115							2x300 to 3x300	
22. Bangbor	230-115							2x300 to 3x300	
23. Onnuj	230-115							3x300 to 4x300	
24. Ratchada	230-115							1x300 to 2x300	
25. Sanampao *	230-115							1x300 to 2x300	
26. Talingchan	230-115							2x300 to 3x300	
27. Lardprao	230- 69							2x200 + 2x300 to 4x300	
28. South Bangkok	230- 69							2x200 + 2x300 to 4x300	
29. Thonburi *	230- 69							1x300 to 2x300	
30. Bangplee	230-115								4x200 to 2x200 + 2x300
31. Klongrangsit	230-115								3x200 to 4x200
32. Bangkoknoi	230-115								3x300 to 4x300
33. Sainoi	230-115								2x300 to 3x300
34. Sanampao *	230-115								2x300 to 3x300
35. Klongtoey *	230-115								2x300 to 3x300
36. Patanakarn	230-115								3x300 to 4x300
37. Talingchan	230-115								3x300 to 4x300
38. Bangkapi	230- 69								2x200 + 2x300 to 4x300
39. South Thonburi	230- 69								4x200 to 2x200 + 2x300
40. Ratchada	230- 69								2x300 to 3x300
Subtotal		700	900	300	300	715	2,000	3,200	2,900
Total		700	1,500	900	1,200	1,015	4,400	3,200	4,700

Note: * MEA's Terminal Station

Table 6.8-2 Installed Capacity of Terminal Stations

(Unit: MVA)

Name of Terminal Station	Actual	7th Plan	Planning Period							
	1995	1996	1997	1998	1999	2000	2001	2006	2011	2016
115 kV System										
1. Bangplee	2x200	3x200	3x200	3x200	3x200	3x200	3x200	4x200	4x200	2x200 + 2x300
2. Klongrangsit	2x200	3x200	2x200	2x200	2x200	2x200	2x200	2x200	3x200	4x200
3. Nongjok	1x200	2x200	2x200 + 1x300	2x200 + 1x300	2x200 + 1x300	2x200 + 1x300	2x200 + 1x300	2x200 + 1x300	4x300	4x300
4. South Bangkok	2x200	2x200	2x200	2x200	2x200	2x200	2x200	3x200	3x200	3x200
5. Bangkoknoi	—	1x200	1x300	1x300	1x300	2x300	2x300	2x300	3x300	4x300
6. Jangwatana	—	2x300	2x300	3x300	3x300	3x300	3x300	4x300	4x300	4x300
7. Sainoi	—	1x200	1x300	1x300	2x300	2x300	2x300	2x300	2x300	3x300
8. Teparak	—	1x300	1x300	2x300	2x300	2x300	2x300	2x300	2x300	2x300
9. Bangbor	—	—	—	—	—	—	1x300	2x300	3x300	3x300
10. Onnuj	—	—	—	2x300	2x300	2x300	2x300	3x300	4x300	4x300
11. Ratchada	—	—	—	—	—	1x300	1x300	1x300	2x300	2x300
12. Sanampao *	—	—	—	—	—	1x300	1x300	1x300	2x300	3x300
13. Thanontok *	—	—	—	—	2x300	2x300	2x300	2x300	2x300	2x300
14. Klongtoey *	—	—	—	—	—	—	—	2x300	2x300	3x300
15. Patanakarn	—	—	—	—	—	—	—	3x300	3x300	4x300
16. Talingchan	—	—	—	—	—	—	—	2x300	3x300	4x300
17. Ramintra *	—	—	—	—	—	—	—	—	—	2x300
18. Ratburana	—	—	—	—	—	—	—	—	—	2x300
Subtotal	1,400	3,300	3,600	4,800	5,700	6,600	6,900	10,300	12,800	16,200
69 kV System										
1. Bangkapi	4x200	4x200	4x200	4x200	4x200	4x200	2x200 + 2x300	2x200 + 2x300	2x200 + 2x300	4x300
2. Bangkoknoi	3x200	4x200	4x200	4x200	4x200	4x200	4x200	4x200	4x200	4x200
3. Bangplee	2x200	2x200	2x200	2x200	2x200	2x200	2x200	2x200	2x200	2x200
4. Chidlom *	2x250	2x250	2x250	2x250	2x250	2x250	2x250	2x250	2x250	2x250
5. Klongrangsit	3x200	3x200	2x200	2x200	2x200	2x200	2x200	3x200	3x200	3x200
6. Lardprao	4x200	4x200	4x200	4x200	4x200	4x200	4x200	2x200 + 2x300	4x300	4x300
7. North Bangkok	2x200 + 1x285	2x200 + 1x285	2x200 + 1x285	2x200 + 1x285	2x200 + 1x285	2x200 + 1x285	2x200 + 2x300	2x200 + 2x300	2x200 + 2x300	2x200 + 2x300
8. South Bangkok	4x200	4x200	4x200	4x200	4x200	4x200	2x200 + 2x300	2x200 + 2x300	4x300	4x300
9. South Thonburi	2x200	3x200	4x200	4x200	4x200	4x200	4x200	4x200	4x200	2x200 + 2x300
10. Ratchada	—	2x300	2x300	2x300	2x300	2x300	2x300	2x300	2x300	3x300
11. Teparak	—	1x300	1x300	2x300	2x300	2x300	2x300	2x300	2x300	2x300
12. Thanontok *	—	2x250	2x250	2x250	2x250	2x250	2x250	2x250	2x250	2x250
13. Sanampao *	—	—	—	—	—	1x300	1x300	2x300	2x300	2x300
14. Thonburi *	—	—	—	—	—	—	—	1x300	2x300	2x300
15. Ratburana	—	—	—	—	—	—	—	—	—	2x300
Subtotal	5,585	7,385	7,385	7,685	7,685	7,985	8,700	9,700	10,400	11,700
Total	6,985	10,685	10,985	12,485	13,385	14,585	15,600	20,000	23,200	27,900

Note: * MEA's Terminal Station

(b) 115 kV and 69 kV subtransmission line

Table 6.8-4 shows the 115 kV and 69 kV subtransmission line system expansion plan.

Table 6.8-4 115 kV and 69 kV Subtransmission Line System Expansion Plan (FY 1997-2011)

(Unit: ckt-km)

FY	Overhead Line			Underground Cable		
	115 kV	69 kV	Total	115 kV	69 kV	Total
1997	53.4	6.7	60.1	9.0	11.0	20.0
1998	111.3	12.7	124.0	4.7	4.5	9.2
1999	94.5	4.3	98.8	23.5	7.7	31.2
2000	75.6	23.2	98.8	22.7	14.5	37.2
2001	9.5	8.4	17.9	11.5	2.1	13.6
1997-2001	344.3	55.3	399.6	71.4	39.8	111.2
2006	232.8	42.8	275.6	67.0	30.4	97.4
2011	89.0	14.9	103.9	29.6	16.8	46.4
Total	666.1	113.0	779.1	168.0	87.0	255.0

6.9 Design of Protective Relay System

To attain further high reliability of 230 kV subtransmission line, the following protection system shall be applied under this plan on the basis of two main protection groups and one backup protection group.

Meanwhile, the protection systems of 115 kV and 69 kV subtransmission lines, substations, etc. will be determined in accordance with the relevant criteria of MEA with necessary modifications.

Incidentally, the optical fiber should be used as a telecommunication line of the differential relays.

Protective Relay Scheme

Main protection	Group 1 ; Digital current differential scheme
	Group 2 ; Distance relaying scheme
Backup protection	Distance relaying scheme

6.10 Optical Fiber Telecommunication Network

(1) Optical fiber telecommunication network between district offices

A telecommunication network formation plan is being formulated by MEA (Refer to Fig. 6.10-1) for the purpose of forming an optical fiber telecommunication network by 1998 between the Head Office adjacent to the Chidlom T/S and 14 district offices [existing 13 offices including 1 office scheduled to be constructed). As this plan is effective, the MEA is recommended to promote the plan for implementation:

(2) Optical fiber telecommunication network for protection of subtransmission line

The subtransmission lines (230 kV) requiring protection scheduled to be constructed and the commissioning period thereof (fiscal year) are as listed below:

Route	Commissioning FY	Length
1. Lardprao (EGAT)-- Sanampao (MEA)	2000	7.8 km (UG)
2. Bangkapi (EGAT)-- Klongtoey(MEA)	2006	7.7 km (UG)
3. Bangkoknoi(EGAT)-- Thonburi (MEA)	2006	10.4 km (UG)
4. Onnuj (EGAT)-- Ramintra (MEA)	2016	13.0 km (OH)
		6.0 km (UG)

Since underground cable is scheduled to be used under this subtransmission line construction project, application of the power line carrier wave system would be difficult. Therefore, it will be appropriate to form the telecommunication systems for protection of subtransmission line by adopting microwave radio system or optical fiber system. To improve the reliability, the telecommunication line should be of a two-route (diversity) configuration.

6.11 VHF and UHF Telecommunication Network

(1) Trunk radio system

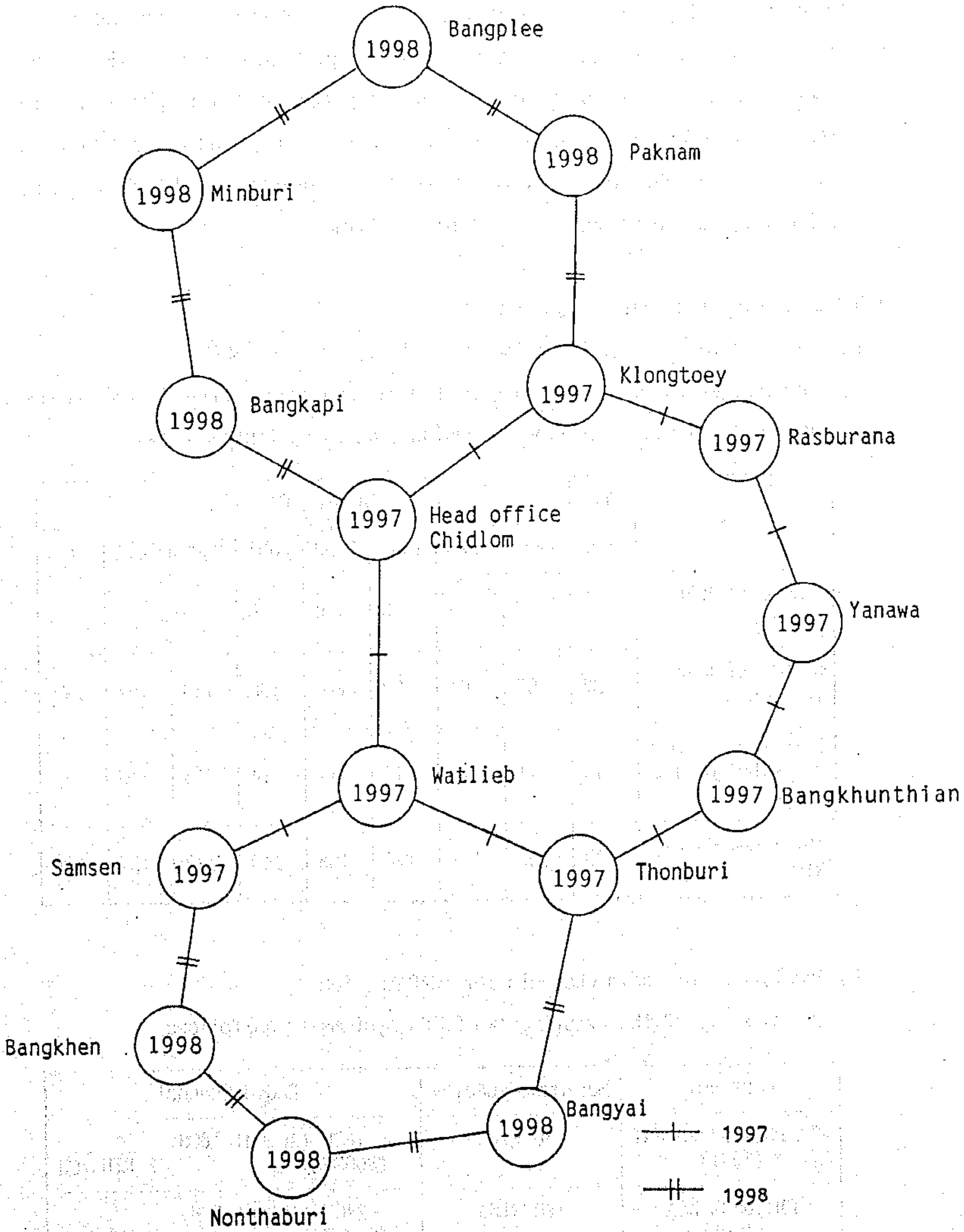


Fig. 6.10-1 MEA Fiber Optic Transmission Configuration Network

At present, the MEA is promoting introduction of a trunk radio system of 800 MHz band, the number of voice channels are 15 [extension to 28 channels is possible in maximum in view of the system]. Thereby, the channel shortage problem in contrast to the number of subscriber units (about 1,800 sets) will be settled after completion of this project. By increasing the number of voice channels (repeater units) in proportion to the increase in the number of subscriber units, the trunk radio system is evaluated to be sufficient to meet the needs of MEA for radio telecommunication network in the future as well.

(2) SCADA telecommunication systems

(a) Installation plan of RTU (Remote Terminal Unit) for SCADA

The number of RTU to be installed in the respective fiscal years according to the substation extension plan is as listed below:

Item	7th	Planning Period							
	1996	1997	1998	1999	2000	2001	2006	2011	2016
Number of RTUs for T/S	6	5	5	5	6	5	5	5	4
Number of RTUs for D/S	82	93	101	109	120	130	149	164	171
Number of common use RTUs for T/S and D/S	10	11	12	12	12	14	18	18	21
Total number of RTUs	98	109	118	126	138	149	172	187	196

(b) Acquisition of radio channels for SCADA system

The capacity of the existing two SCADA systems is as follows:

Contract	Maximum Capacity	Radio Channel
MEA-PSD-207/REPEAT (1981)	80 RTUs	16CH (Actual 16CH) (800MHz) 5 RTUs/CH
PM4-0532-WBA (1991)	120 RTUs	24CH (Actual 8CH) (2.2GHz) 5 RTUs/CH

When the RTU installation plan is taken into account, therefore, the number of existing radio channels (120 RTUs can be accommodated) will be fully occupied in FY 1999. Consequently, it will be required to extend the 2,200 MHz band radio channels by FY 1999.

(c) Countermeasures for preventing radio wave interference with high-rise buildings in the central part of Bangkok

The propagation interference of the SCADA radio channels is predicted to become severe further in the future in proportion to increase in the number of high-rise buildings along with the progress of development in the central part of Bangkok. As the shadow loss per unit shielding area is greater in the case of 2,200 MHz band radio channels than in the case of 800 MHz band radio channels, moreover, the propagation interference due to high-rise buildings will be so much severe.

As a countermeasure, it considered effective to make positive use of optical fiber cable network being planned by MEA at present.

CHAPTER 7

FEASIBILITY DESIGN

CHAPTER 7 FEASIBILITY DESIGN

7.1 Study of Model Districts

7.1.1 Distribution System and Capacity of Distribution Substation

For executing detailed feasibility design, the following model districts have been selected.

- Sathorn Area (High density commercial area)
- Paphol Yothin Area (Commercial area)
- Jomthong Area (Industrial area)

With regard to these model districts, subtransmission lines and distribution substations in the surrounding areas, optimum systems of distribution system and distribution substation are studied on the basis of the following substation capacity as parameters:

- Case 1 : 3 x 40 MVA
- Case 2 : 4 x 40 MVA
- Case 3 : 3 x 60 MVA
- Case 4 : 3 x 80 MVA

(1) Power distribution plan

A study has been carried out and an expansion plan has been formulated regarding the 115 kV and 69 kV system configurations for power supply to distribution substations in the model districts and surrounding areas.

The expansion plan in the respective cases (Case 1 to Case 4) has been formulated on the basis of the subtransmission line expansion plan described in CHAPTER 6, taking into account effective utilization of the existing systems around the respective model districts and surrounding areas. (Case 3 is almost the same as the base plan in CHAPTER 6.)

The system configurations used in this study are outlined in Fig. 7.1-1.

(a) Evaluation of the respective cases

The construction cost in the respective cases is as completed in the tables below.

The 3 x 60 MVA and 3 x 80 MVA plans with the smallest number of substations to be constructed are advantageous, since the substation

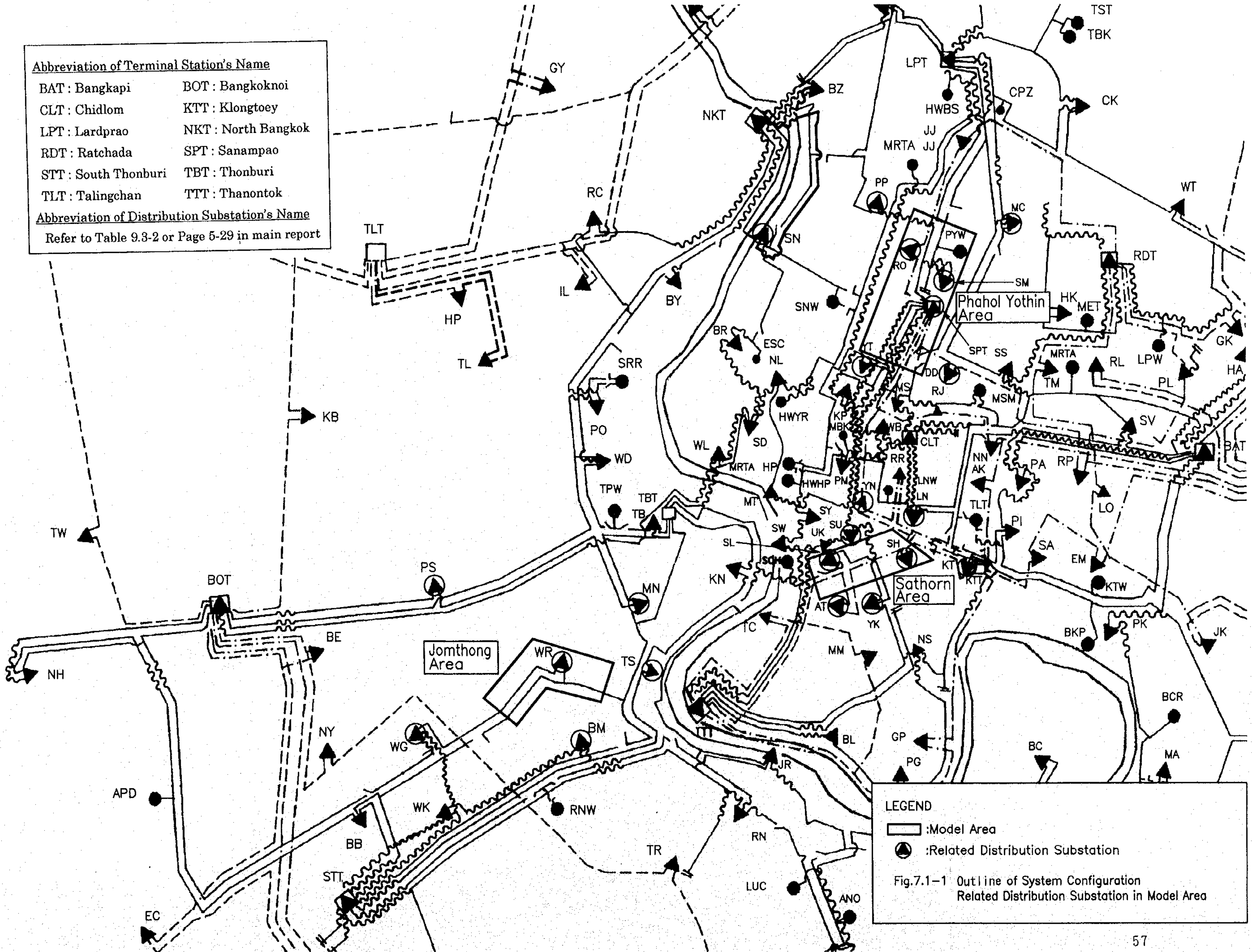
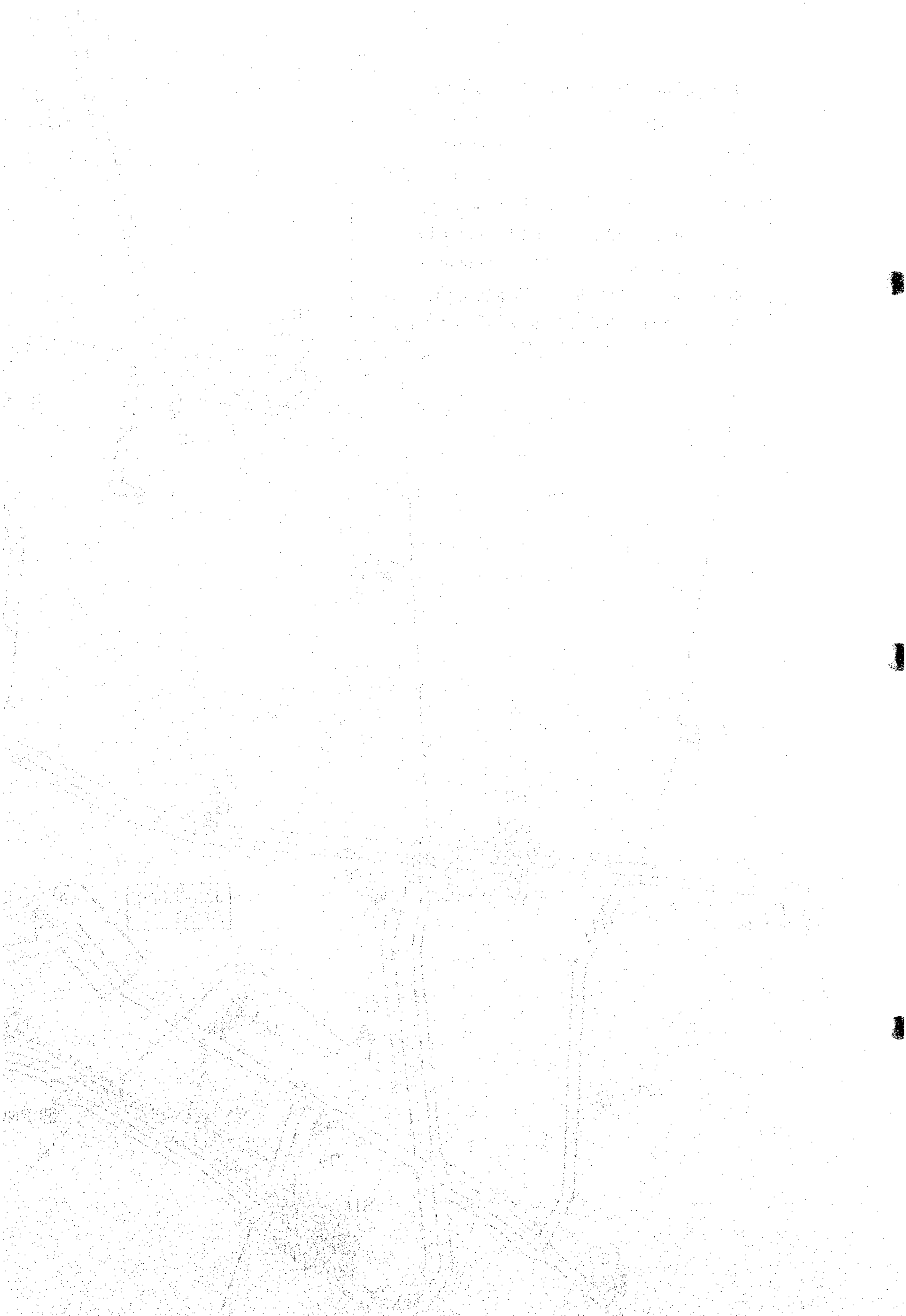


Fig.7.1-1 Outline of System Configuration
Related Distribution Substation in Model Area



construction cost dominates over the other cost when the construction is economically evaluated.

Total Cost (Unit : Million Baht)

Name of Area	Case 1	Case 2	Case 3	Case 4
Sathorn	1,915.8	1,518.1	1,244.7	1,341.6
Phahol Yothin	1,355.2	1,140.0	1,036.2	923.2
Jomthong	799.4	624.8	473.2	457.1
Total	4,050.4	3,282.9	2,754.1	2,721.9

(b) Economic comparison of Cases 3 and 4

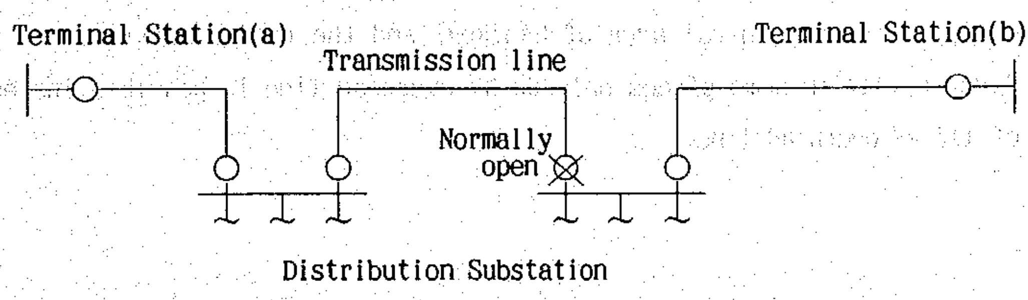
In Cases 3 and 4, the substation capacity to be expanded in the respective model districts is roughly equal. However, while the number of substations to be constructed in Case 4 is slightly lower than in Case 3 so that the substation expansion cost of Case 4 is advantageous over Case 3.

7.1.2 Economical Comparison of System Voltages using 115 kV and 69 kV System

The conditions of system configuration and operation, construction cost, economic and other conditions are compared in the cases of adopting 69 kV and 115 kV system configurations.

(1) Configuration of system models

Adopted in this comparison are the distribution substation consisting of three 60 MVA transformer banks and the subtransmission line which is a so-called "tapped-tie normally open".



(2) Comparison between construction cost and annual expenses including transmission loss

As shown in Table 7.1-1(a), in case of underground cable line, the longer the distance between any two distribution substations is than 2.7 km, as a border in terms of construction cost, the more advantageous is the 115 kV system, but the shorter this distance is than this border, the more advantageous is the 69 kV system.

If compared in terms of annual expenses including transmission loss, the border of advantage in distance is roughly 2.0 km. As a sensitivity test, the cost of substation outlet circuit breakers is calculated where the cost on the 115 kV system is assumed to be increased further by 10% (from 11.4 million Baht to 12.54 million Baht). As a result of comparing the construction cost based on this calculation, the border of construction cost is about 3 km, and about 2.3 km when the transmission loss is included, as is presented in Table 7.1-1(b).

In the case of overhead line, the border of line distance becomes longer since the construction cost of subtransmission line becomes relatively lower. As a result of comparing the annual expenses including transmission loss, about 2.1 km is a border distance, as is presented in Table 7.1-1(c).

(3) Results of study

The reinforcement of the 115 kV system is deemed to be the most advantageous in attaining simplification of the system, reduction of the number of subtransmission line circuits, saving of transmission loss and so forth, taking into account the various economic effects incurred from the unit construction costs and the choice between overhead and underground conductors. However, the 69 kV system can not necessarily be disregarded altogether, as the 69 kV network has already been widely equipped in the central area of Bangkok, and the road conditions are so diverse that in some places only 69 kV overhead line is possible instead of 115 kV overhead line.

Table 7.1-1 Cost Comparison Analysis

(a) In case of Underground Cable Line

Unit : Million Baht

Distance of Substations (km)	Construction cost			Annual Expenditure with Line Loss		
	69kV		115kV	69kV		115kV
1.9	3,588.5	<	3,642.5	475.2	<	476.7
2.0	3,636.6	<	3,683.5	481.9	<	482.2
2.1	3,684.6	<	3,724.4	488.7	>	487.6
2.2	3,732.7	<	3,765.4	495.4	>	493.1
2.6	3,924.9	<	3,929.2	522.2	>	515.1
2.7	3,972.0	>	3,970.2	528.9	>	520.6
2.8	4,021.0	>	4,011.2	535.6	>	526.1

(b) In case of 115kV CB cost increased by 10%

Unit : Million Baht

Distance of Substations (km)	Construction cost			Annual Expenditure with Line Loss		
	69kV		115kV	69kV		115kV
2.2	3,732.7	<	3,788.2	495.4	<	496.1
2.3	3,780.7	<	3,829.1	502.1	>	501.6
2.4	3,828.8	<	3,870.1	508.8	>	507.1
2.5	3,876.8	<	3,911.1	515.5	>	512.6
2.9	4,069.1	<	4,074.9	542.3	>	534.5
3.0	4,117.1	>	4,115.9	549.0	>	540.0
3.1	4,165.2	>	4,156.8	555.7	>	545.5
3.2	4,213.2	>	4,197.8	562.4	>	551.0

(c) In case of Overhead Line

Unit : Million Baht

Distance of Substations (km)	Construction cost			Annual Expenditure with Line Loss		
	69kV		115kV	69kV		115kV
2.0	2,835.9	<	2,992.9	398.5	<	399.8
2.1	2,843.9	<	2,999.3	401.0	<	401.2
2.2	2,852.0	<	3,005.8	403.6	>	402.6
2.3	2,860.0	<	3,012.2	406.1	>	403.9
11.0	3,558.2	<	3,572.1	626.6	>	523.4
12.0	3,638.5	>	3,636.4	651.9	>	537.1
13.0	3,718.7	>	3,700.8	677.3	>	550.9
14.0	3,799.0	>	3,765.1	702.6	>	564.6

7.1.3 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.

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

The distribution line conductor size is also studied regarding 185 mm^2 applied by MEA including 240 mm^2, a one-rank larger conductor size.

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

The study results is as shown in Table 7.1-2.

Table 7.1-2 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

(2) Evaluation of study results

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 7.1-3.

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

(a) Distribution voltage

The economically optimum distribution voltage is 24 kV.

Table 7.1-3 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

(b) Conductor size

The conductor size of 240 mm² is economically advantageous over 185 mm² in all of the respective cases.

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 a 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 mm² 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:

$$3 \times 80 \text{ MVA} > 3 \times 60 \text{ MVA} > 4 \times 40 \text{ MVA} > 3 \times 40 \text{ MVA}$$

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

According to the results of evaluation in view of the configurations of subtransmission line and substation bank, the cases of 3 x 60 MVA and 3 x 80 MVA are concluded to be substantially advantageous over the other cases, as described in Clause 7.1.1.

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

$$3 \times 40 \text{ MVA} > 4 \times 40 \text{ MVA} \gg 3 \times 60 \text{ MVA},\ 3 \times 80 \text{ MVA}$$

When the construction cost downstream of substation feeders is included in the subtransmission line and substation 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 x 60 MVA

Number of feeders per bank : 5 circuits

- The number of feeders includes a standby one circuit 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

7.2 Land Acquisition Plan for Subtransmission Line and Substation Facilities

7.2.1 Features and Problematical Points

Although it will be necessary to acquire the land required for subtransmission line and substation facilities as well as the rights pertaining to the land depending upon the natures of required equipment and facilities, it has become increasingly difficult to acquire the land on account of increasing population and complexity of the city area.

(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 adjustments for land utilization are essential in the respective areas along the line route.

(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 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

As the situation of land utilization have become more and more serious along with the progress in urbanization, it has become very difficult to acquire any substation site area requiring a considerably sizable space. In planning land acquisition for substation, 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, especially, 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.

Incidentally, 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 Item (1) 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).

7.2.2 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) Promotion of land acquisition

(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.

(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.

7.3 Underground Distribution System Facilities

7.3.1 Underground Substation

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

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

275 kV, 2x300 MVA Substation		66 kV, 2x20 MVA Substation	
Equipment/Installation Cost	Construction Cost	Equipment/Installation Cost	Construction Cost
38%	62%	34%	66%

Remarks:

1) The building construction cost refers to the cost of the building occupied by the power company or the portion of the building occupied by the power company according to a partial ownership agreement/contract.
2) The geological conditions largely affecting the building construction cost are based on the average values in Tokyo.
3) Scale of 275 kV substation: Underground four stories.

(Total floor area: 16,000 m^2)

4) Scale of 66 kV substation: Underground two stories.

(Total floor area: 700 m^2)

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

Calculation example:

Land price: 125,000(Baht/m^2) x 1,320 m^2 = 165 million Baht

Substation construction cost:

a) Equipment and material cost : 136 million Baht

b) Civil structure & installation cost: 31 million Baht

Total: 167 million Baht

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

7.3.2 Utility Tunnel

(1) Objectives of utility tunnel

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

The other advantages are as follows, for example:

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

(2) Construction of utility tunnel

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

(3) Cost to be born for utility tunnel construction

Any person scheduled to occupy the utility tunnel should bear the amount of investment (estimated in case such a tunnel is constructed independently by himself)among the cost required for constructing the utility tunnel.

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

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

A concept of utility tunnel is presented in Fig. 7.3-1.

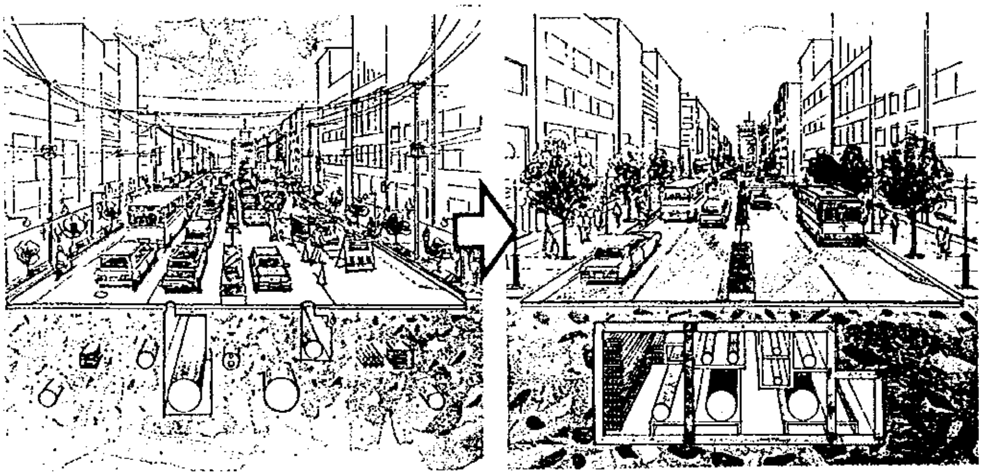


Fig. 7.3-1 Concept of Utility Tunnel