5.5 MEA's Draft Long-Term Plan during FY 1997-2011

Following the Revised 7th Plan, the draft long-term plan during the period FY 1997-2011 has been prepared by MEA. The FY 2011's power system is shown in Fig. 5.5-1 and Fig. 5.5-2. As mentioned in Clause 3.3.1, from the point of view of enhancing the capability of the power supply to cope with the rapid increasing demand in urban area, the 12 kV and 69 kV system will be converted into 24 kV and 115 kV system respectively.

Installed Capacity of Substations until FY 2011

Fiscal Year	1996	2001	2006	2011
Maximum Peak Demand (MW)	5,723	8,290	10,653	13,416
Total Installed Capacity (MVA)				
- Terminal Station	10,685	15,100	19,600	23,100
- Distribution Substation	13,145	17,745	23,360	28,120

Another feature of MEA's draft long-term plan is expansion of 230 kV subtransmission line system into city center as shown in the table below.

Detail of 230 kV Subtransmission Line Expansion Program

Name of Subtransmission Lines	Length (km)	Number of Circuit	Conductor Size (mm^2)	Commissioning Date (Fiscal Year)
South Thonburi - Thanontok	8.6	1 **	2x400/2x1,200	1997
Lardprao - Sanampao *	7.8	2	2x1,200	2000
Bangkapi - Klongtoey *	7.7	2	2x1,200	2002-2006
Bangkok Noi - Thonburi *	10.4	2	2x1,200	2002-2006
Lardprao - Sanampao	7.8	1 **	2x1,200	2002-2006
Bangkok Noi - Thonburi	10.4	1 **	2x1,200	2007-2011

Note: * New terminal station
** Addition of one circuit

The formulation of an optimum long-term plan until FY 2016 has been carried out as is presented in CHAPTER 6 taking the above mentioned MEA's draft long-term plan up to FY 2011 into account.

Incidentally, the load flow diagrams in FY 2011 studied by MEA are shown in Fig. 5.5-3 and Fig. 5.5-4 which are the basis of the study of FY 2016's system planning by the Study Team.

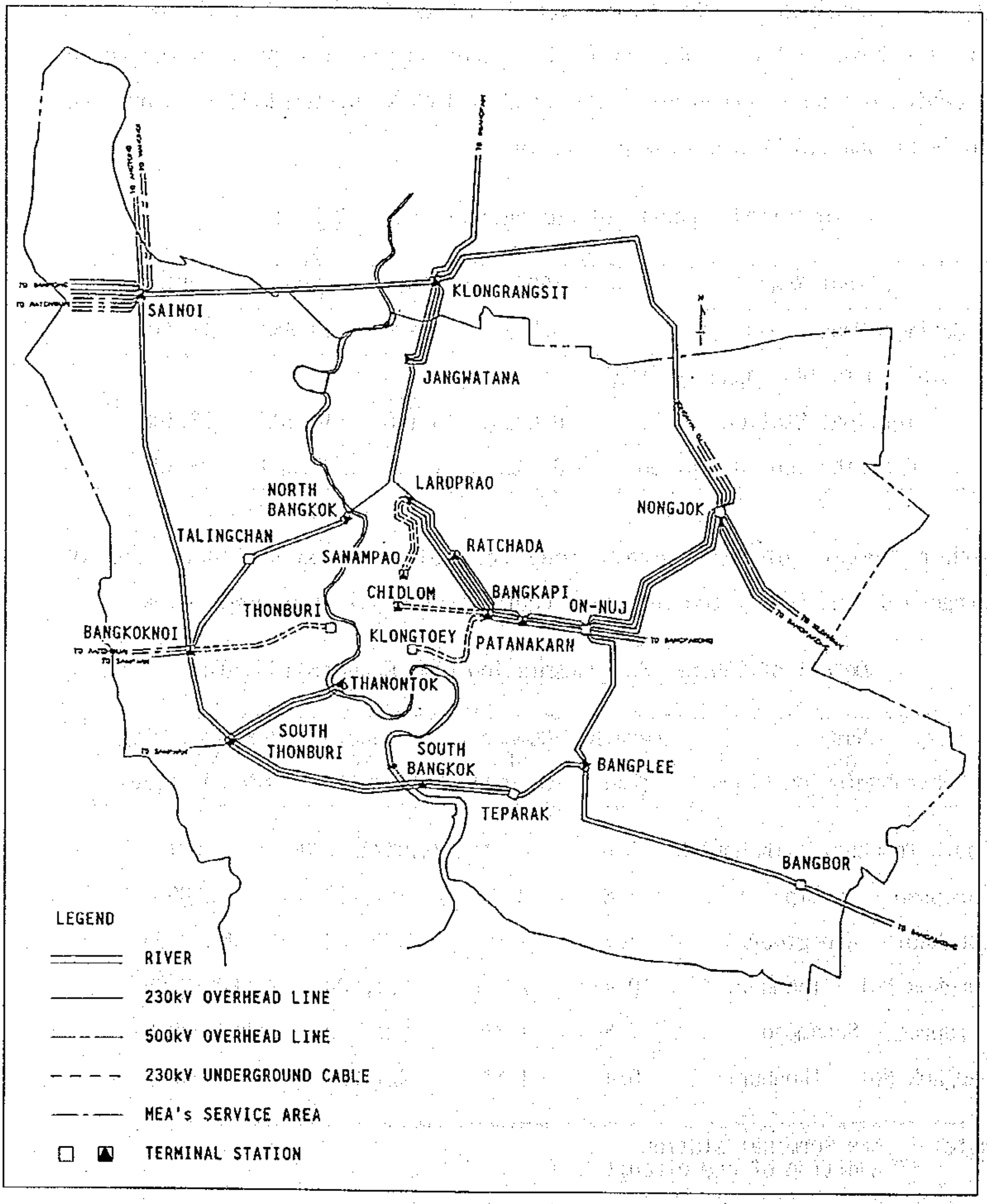

Fig. 5.5-1 230 kV Subtransmission System Route Map in FY 2011
(MEA's Draft Long-Term Plan)

Note: Substation name is abbreviated as shown in attached table.

Fig. 5.5-2 69 kV and 115 kV Subtransmission System Route Map in FY 2011

ABBREVIATION OF SUBSTATION NAME

A		
177	AA	BANGPLA
117	AB	BANGBOR
152	AK	ASOKE
189	AT	SATORNTAI
B		
3	BAT	BANGKAPI
	BBT	BANGBOR
1	BB	BANGBON
8	BC	BANGKRACHAO
16	BD	BANGPOOD
90	BE	BANGKAE
10	BG	BANGNA
120	BH	BANGSHAN
12	BI	BANGPING
11	BJ	BANGNAMJUED
13	BK	BANGPLAKOD
6	BL	BANGKLO
9	BM	BANGMOD
2	BN	BANGCHALONG
7	BOT	BANGKOK NOI
14	BPT	BANGPLEE
5	BR	BANGKHUNPROM
19	BS	BANGSAOTONG
153	BT	BANGBUOTONG
17	BU	BANGPU
155	BW	BANGKAEW
20	BY	BANGYEEKHAN
91	BZ	BANGSON
C		
21	CG	CHALONGKRUNG
22	CK	CHANKASEM
23	CLT	CHIDLOM
D		
122	DD	DINDAENG
24	DM	DONMUANG
E		
94	EB	EKBURI
123	EC	EKACHAI
93	EM	EKAMAI
G		
176	GG	BANGPANG
124	GK	GHOAKLANG
161	GP	KLONGPUME
179	GT	KLONGGRATIAM
175	GY	BANGKRUAY
H		
95	HA	HUAMAK
25	HK	HUAYKWANG
143	HP	SHIMPLEE
154	HS	BANGHUASAE
I		
184	IL	PINKLAO
96	IN	INTAMARA
171	IR	SRINAKARIN
J		
158	JB	JORAKABUO
126	JJ	JATUJAG
118	JK	BANGJAK
97	JR	JANGRON
125	JWT	JANGWATANA
K		
4	KA	BANGKAEN
159	KB	KLONGBANGPI
119	KD	BANGKRADEE
127	KE	KASET
128	KG	KLONGKUM
100	KH	KLONGMAHASAWAD
99	KI	KINGKAEW
27	KJ	KLONGJAN
129	KL	KLONGPRAPA
28	KM	KLONGMAI
31	KN	KLONGSARN
98	KO	KHOTOR
26	KP	KINGPETCH
	KRT	KLONGRANGSIT
162	KR	KRUNGTEPKREETA
30	KS	KLONGSANPASAMIT
32	KTT	KLONGTOEY
34	KU	KRUNAI
L		
160	LA	KLONGNA
101	LB	LARDKRABANG
178	LD	KLONGDAN
180	LG	LUANGPANG
163	LH	LAND&HOUSE
35	LK	LARDPLAKAO
37	LN	LUMPINI
172	LO	THONGLOR
36	LPT	LARDPRAO
181	LS	LUMPAGSHE
M		
40	MA	MAI-AD
42	MB	MINBURI
43	MC	MOCHIT
44	MG	MUANGMAI
121	MI	BANMAI
39	MM	NAHAMEK
38	MN	MAHAISAWAN
41	MS	MAKASAN
130	MU	MITR-UDOM
45	M1	MUANGTHONG1
102	M3	MUANGTHONG3
131	M4	MUANGTHONG4
132	M5	MUANGTHONG5
133	M6	MUANGTHONG6
134	M7	MUANGTHONG7
164	M8	MUANGTHONG8
165	M9	MUANGTHONG9
N		
47	NH	NONGKHAM
182	NI	NIMIMAI
	NJT	NONGJOK
49	NKT	NORTH BANGKOK
135	NL	NANGLERNG
46	NN	NA-NA
168	NP	SANAMPAO
48	NR	NONTHABURI
103	NS	NONSEE
183	NY	NONGYAI
O		
108	OB	SOUTH BANGPLEE
169	OM	SANAMIKOM
	ONT	ON NUCH
170	OS	SONGSUNTISUK
P		
60	PA	PRASANMIT
55	PC	PRACHACHUEN
59	PD	PRAPRADAENG
50	PE	PAKNAM
15	PG	BANGPONGPANG
185	PH	PONGPETCH
53	PI	PHAISINGTO
54	PJ	POOJAO
56	PK	PRAKANONG
137	PL	PLUBPLA
61	PM	PRATHUMWAN
51	PN	PAKNAM
58	PO	PRANNOK
104	PP	PRADIPAT
57	PR	PRAKASA
52	PS	PETCHAKASEM
	PTT	PATANAKARN
186	PT	PUTTAMONTON
156	PY	BANGPLEEYAI
138	PW	PRAWES
R		
66	RC	RUNGPRACHA
	RDT	RATCHADA
107	RG	SAORAHONG
63	RH	RAMKHAMHAENG
92	RI	BEARING
167	RJ	RAJCHAPRAROP
65	RK	ROMKLAO
166	RL	PRARAMKAO
192	RM	TRIMIT
64	RN	RASBURANA
187	RO	RAJCHAKRU
139	RP	PROMPONG
188	RR	RAJDAMRI
62	RT	RAMINTRA
18	RY	BANGRAKYAI
S		
105	SA	SAINAMTIP
106	SB	SANAMBINNAM
29	SC	KLONGSANAMCHAI
71	SD	SAPANDOM
109	SE	SRIEIAM
110	SG	SUANLUANG
142	SH	SATORN
140	SIT	SAINOI
76	SKT	SOUTH BANGKOK
73	SL	SILOM
67	SM	SAILOM
69	SN	SAMSEN
79	SO	SUANSOM
	SPT	SANAMPAO
72	SP	SAPANMAI
68	SR	SAMRONG
70	SS	SANSAB
77	STT	SOUTH THONBURI
80	SU	SUWAWONG
75	SV	SOONVIJAI
144	SW	SRIWIANG
74	SY	SIPRAYA
T		
136	TA	PATANAKARN
84	TBT	THONBURI
148	TC	TROKCHAN
157	TD	BANGTALARD
115	TH	TUNGSONGHONG
147	TI	THA-KWIAN
85	TK	TONGKUNG
190	TLT	TALINGCHAN
191	TM	TIAMRUAMMIT
112	TN	TAIBAN
82	TPT	TEPARAK
114	TR	THONBURIROM
81	TS	TAKSIN
149	TY	TUBYAO
83	TTT	THANONTOK
173	TU	TUNGKRU
113	TW	TAWEEWATTANA
U		
111	UK	SURASAK
W		
86	WB	WANGPETCHABOON
174	WD	WATDEEDOD
33	WG	KLONGWATSING
150	WK	WATKAMPAENG
88	WL	WATIEB
151	WR	WUTTAKART
87	WT	WANGTHONGLANG
146	WW	SUWINTAWONG
Y		
78	YA	SRITHANYA
145	YI	SUANYAI
116	YK	YENARKART
141	YN	SAMYARN
89	YT	YOTHEE

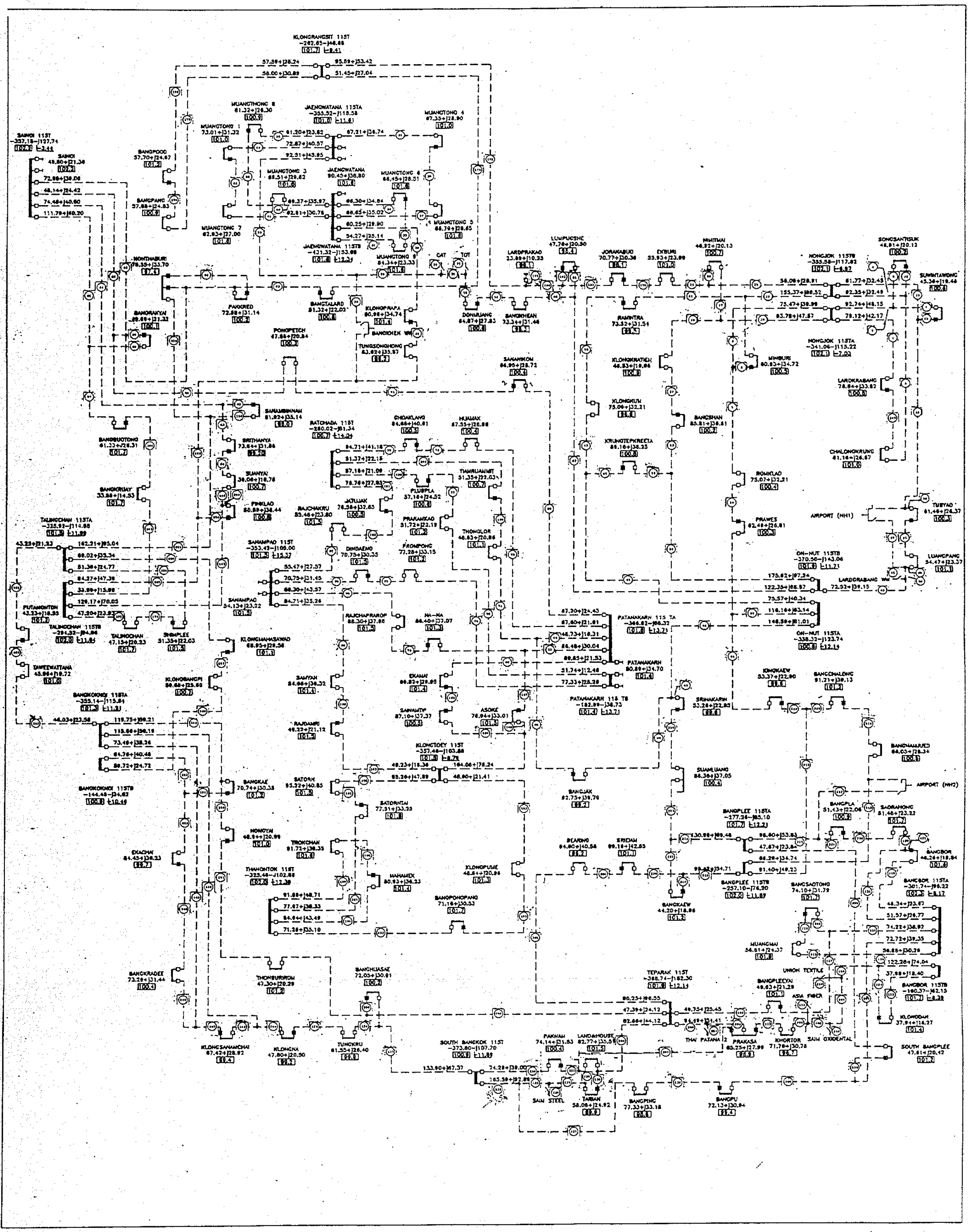

Fig. 5.5-3 Result of MEA's Load Flow Study in FY 2011's System (115 kV)

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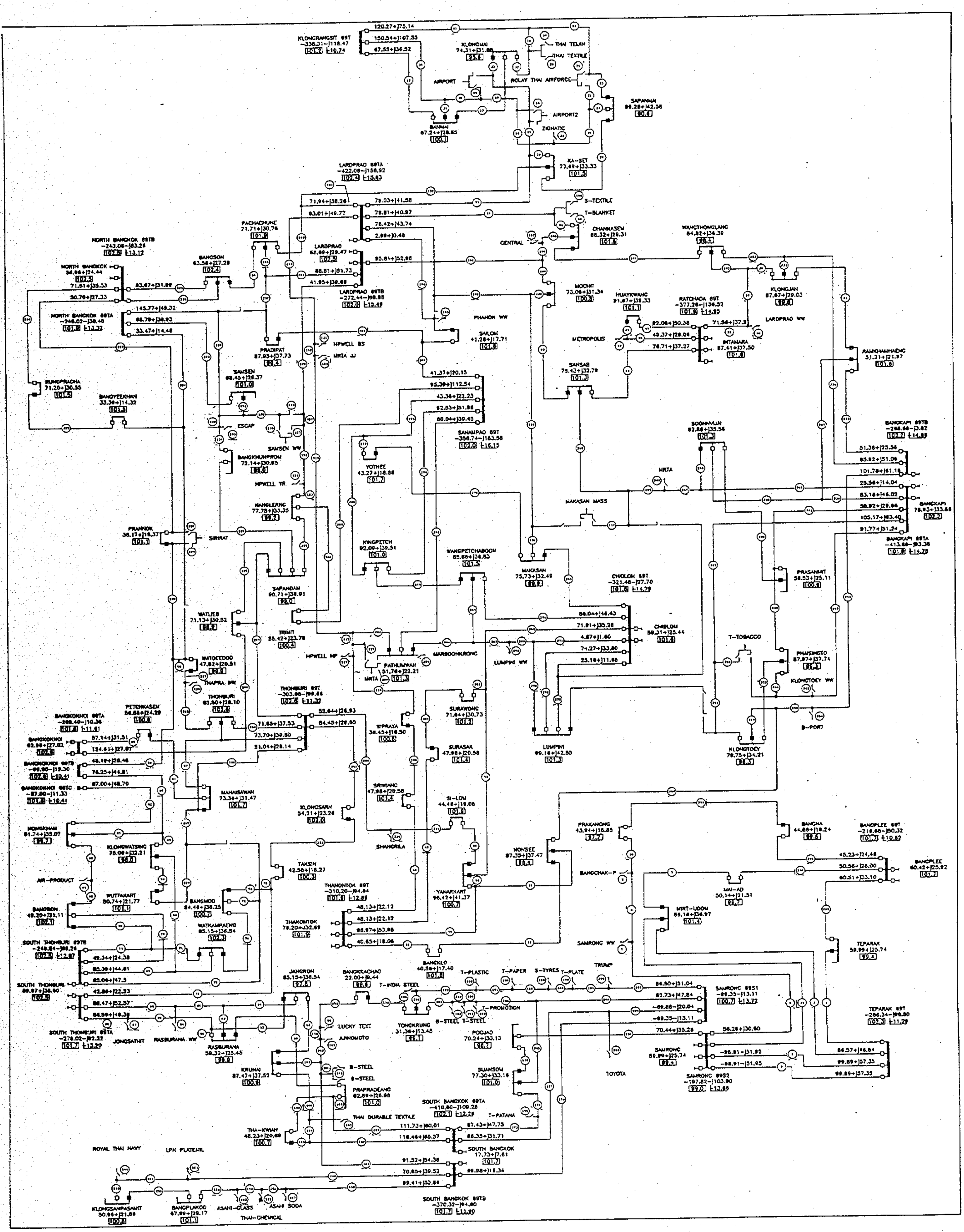
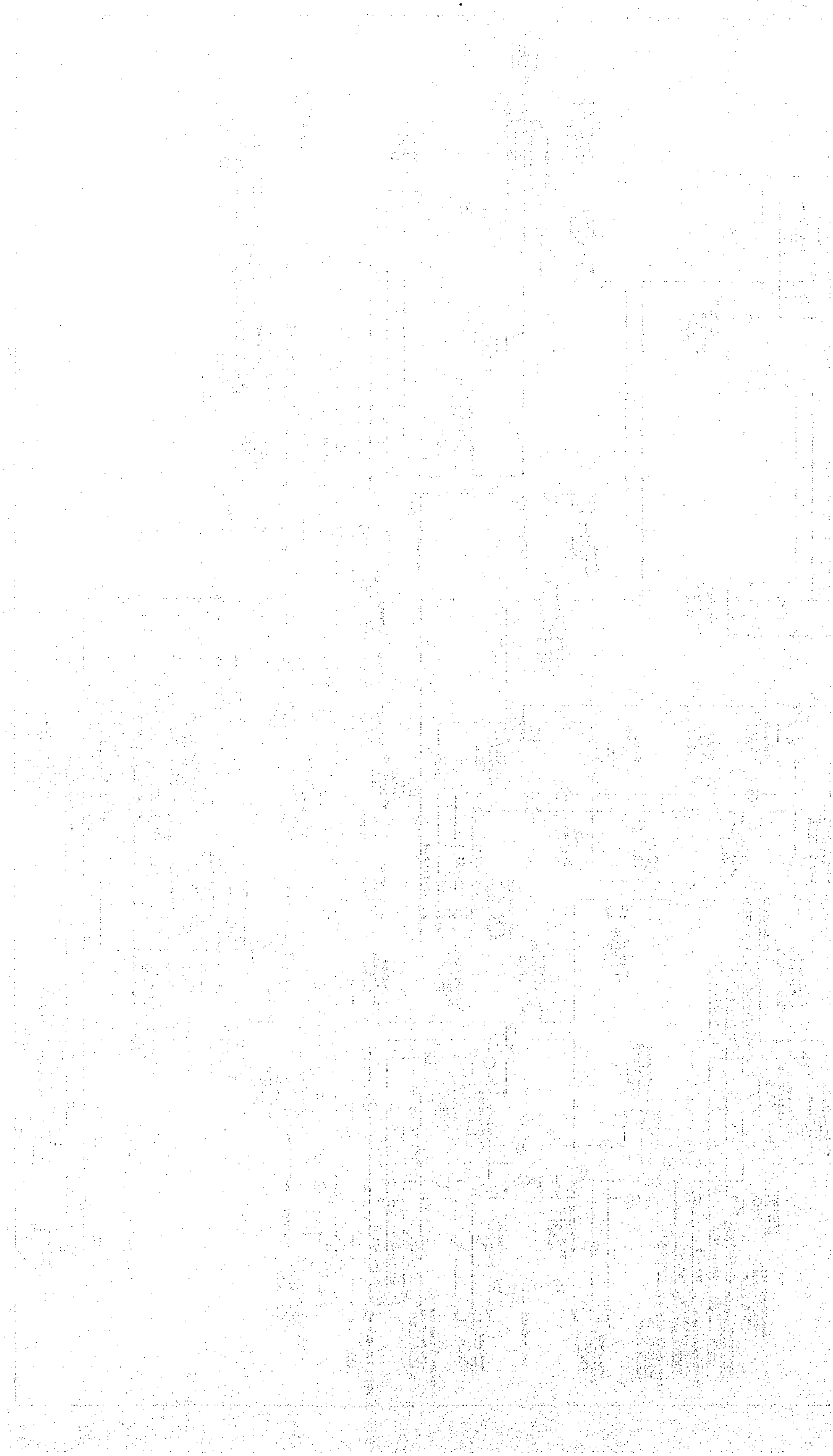
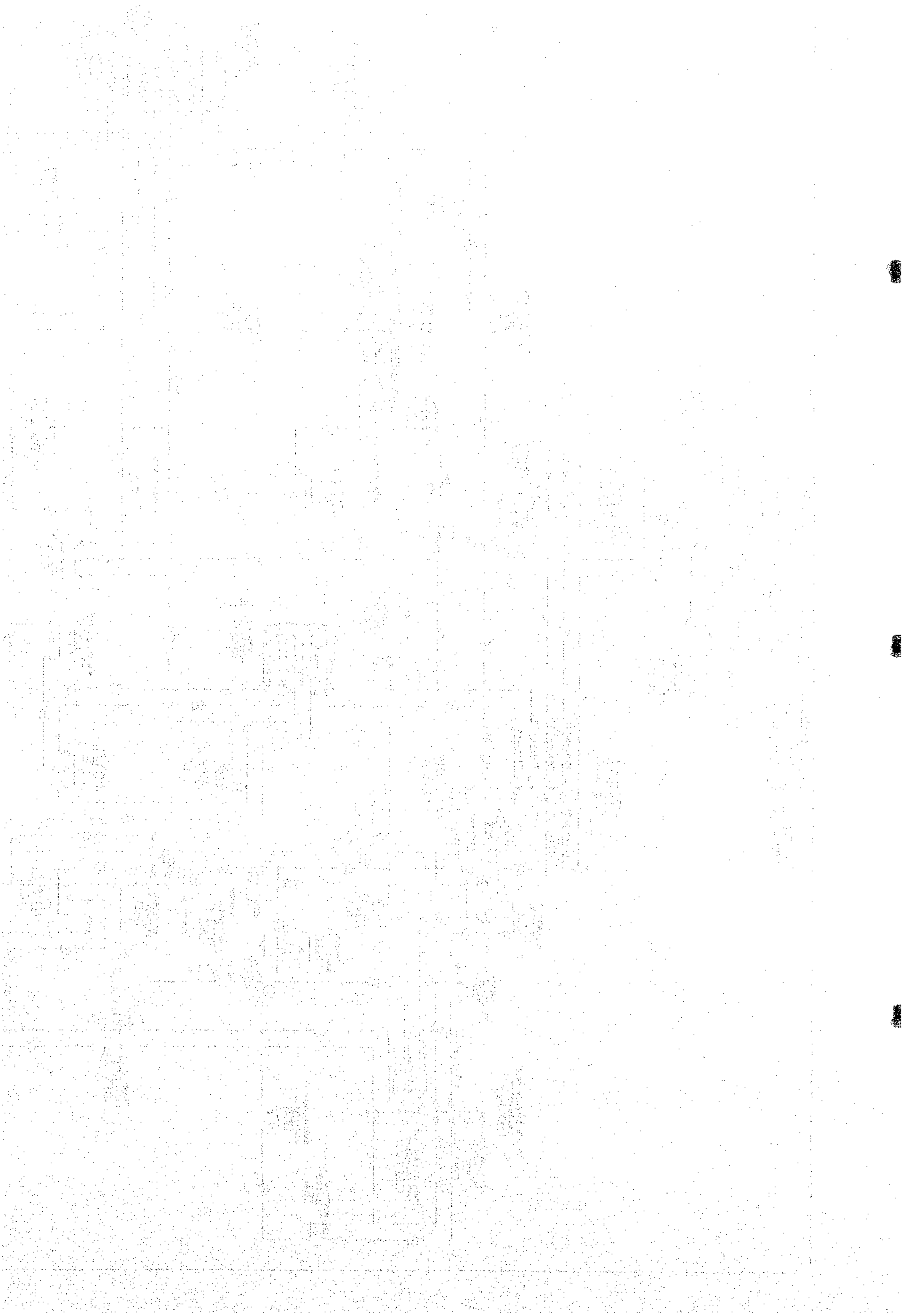


Fig. 5.5-4 Result of MEA's Load Flow Study in FY 2011's System (69 kV)





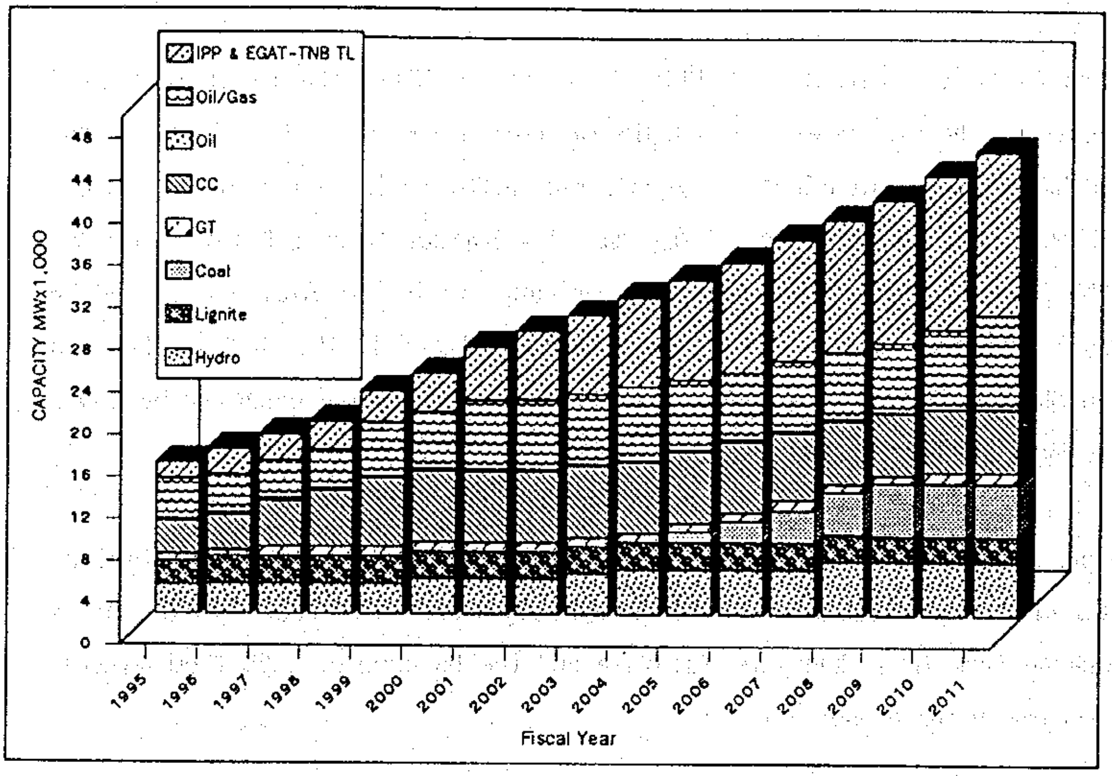
5.6 EGAT's Power Development Plan

According to the latest EGAT PDP 95-01, by FY 2011, the total installed capacity of the system will be 43,918 MW, comprising 5,071 MW (11.5%) hydro; 8,900 MW (20.3%) conventional oil/gas-fired; 5,984 MW (13.6%) combined cycle; 2,475 MW (5.6%) lignite-fired; 5,000 MW (11.4%) imported coal-fired; 1,332 MW (3.0%) peaking gas turbine and power exchange with Malaysia; and 15,156 MW (34.5%) purchased power from private power (included 13,100 MW from IPPs and 2,056 MW from EGCO). The structure of future generating capacity by power plant type is shown in Fig. 5.6-1.

The proportion of energy generation in FY 1996 will be 19.5% from lignite, 22.0% from domestic gas, 30.9% from heavy oil, 5.3% from hydro, 19.1% purchased from IPPs, Laos and Malaysia and the balance of 3.2% from peaking gas turbine using diesel oil.

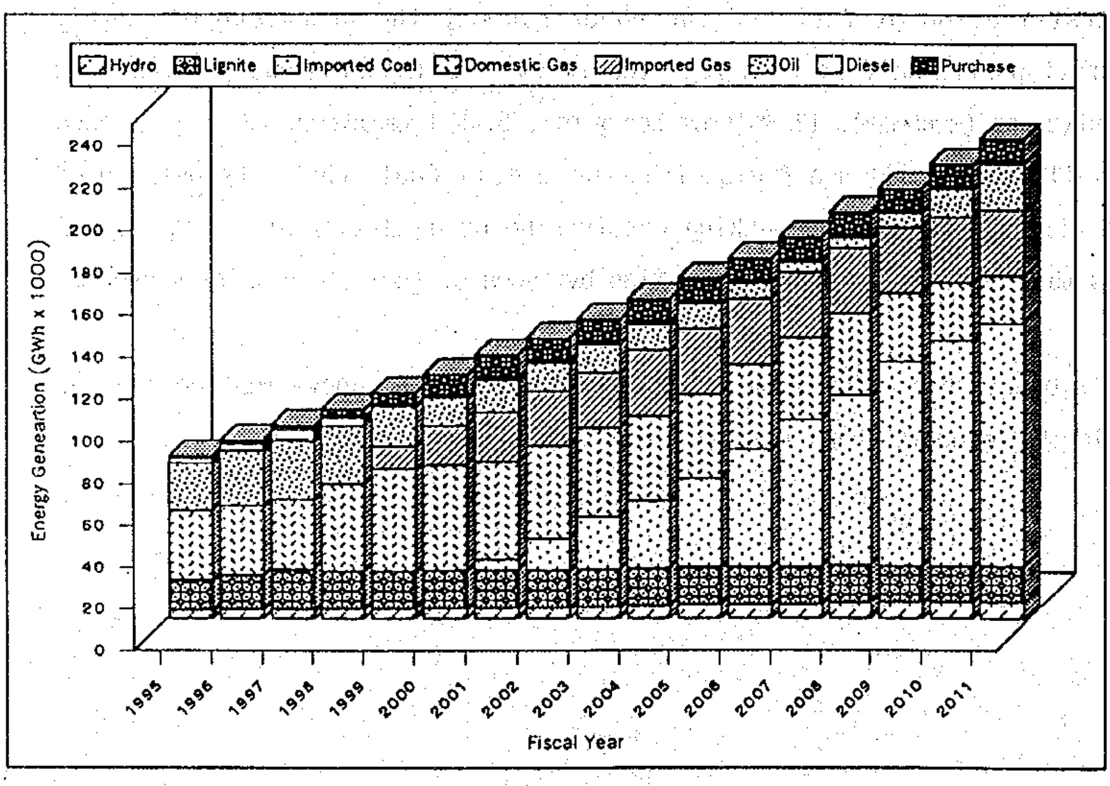
In the long-term profile, total electricity production is expected to reach 228,445 GWh by FY 2011, from 69,651 GWh in FY 1994. In terms of the diversification of fuel and the power source, the breakdown of energy generation will be 7.1% from lignite, 14.4% from imported coal, 10.4% from domestic gas (Myanmar), 12.8% from heavy oil, 3.4% from hydro, 43.5% purchased from IPPs which will use fuels either Gas/LNG/or Coal, while the balance of 0.2% will be produced by peaking gas turbine using diesel oil. Fig. 5.6-2 shows the forecast of energy generation by types of fuel of the EGAT's system.

EGAT's electric power system in future reflecting the above mentioned power development plan is shown in Fig. 5.6-3.



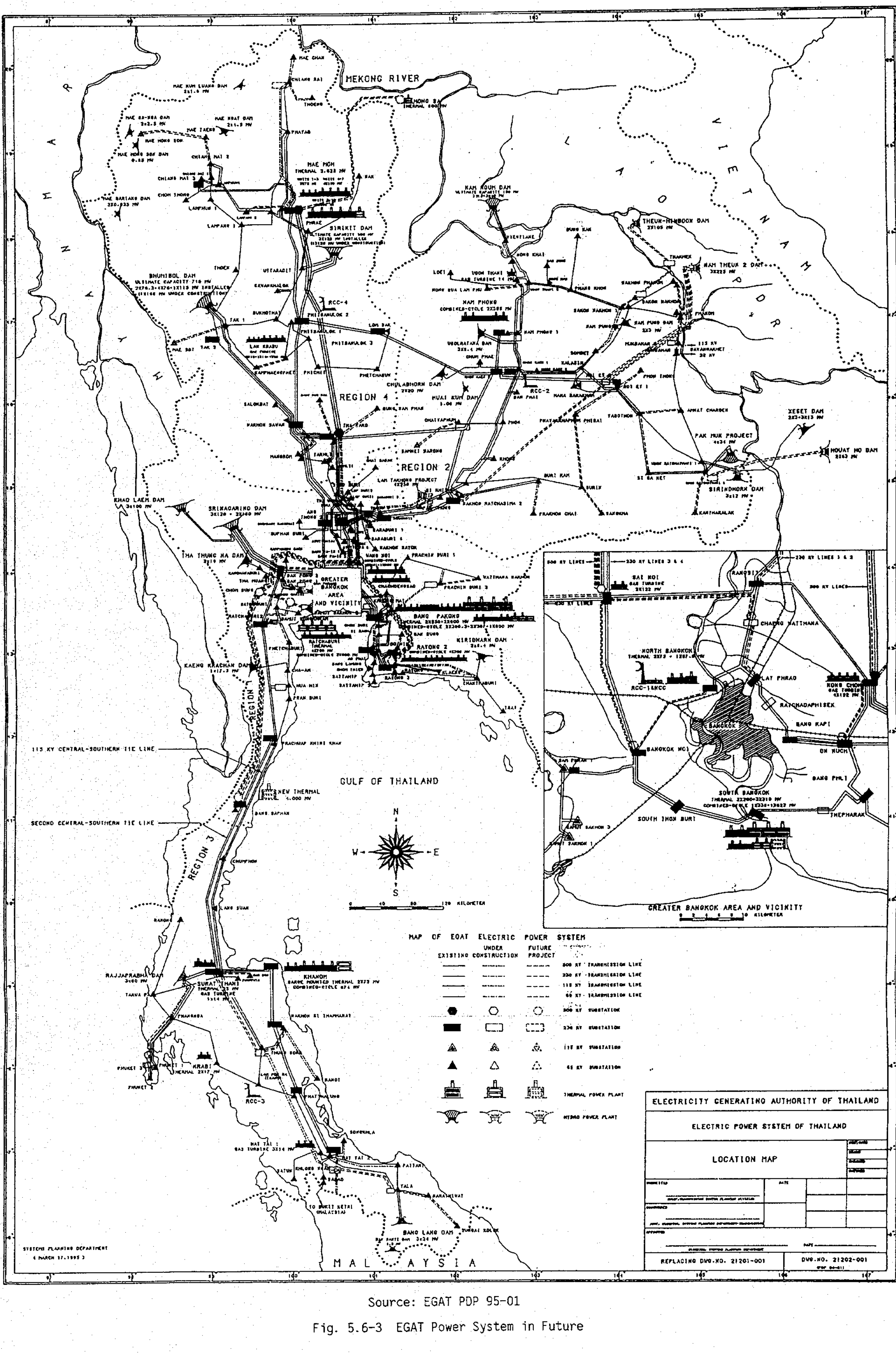
Source: EGAT PDP 95-01

Fig. 5.6-1 Future Trend of Total Generating Capacity



Source: EGAT PDP 95-01

Fig. 5.6-2 Forecast of Energy Generation by Types of Fuel



Source: EGAT PDP 95-01

Fig. 5.6-3 EGAT Power System in Future

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 main objective of this Study is to formulate the optimum power distribution facilities improvement and expansion plan which is designed to meet the power demand growth up to FY 2016, taking into account the problems of the existing power distribution facilities in the Metropolitan area, as discussed in Section 3.3.

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 configurations of power distribution system for the Metropolitan area at each target year during the period of FY 1997-2016, based on the MEA's draft long-term plan up to FY 2011, have been determined. The construction schedules in accordance with the power distribution system configuration of each planned year are also recommended in this Report.

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

6.2.1 Regional Load Forecast by MEA

The regional load distribution based on an overall load forecast is an important factor for formulating power distribution system improvement and expansion plan.

The regional load forecast is developed by MEA based on the following methods:

(1) The overall load values are forecast by dividing the overall load into the 12/24 kV distribution substation load and the 69/115 kV customer's load.

(2) The distribution substation load is forecast by regions based on a 0.5 km x 0.5 km mesh unit using a computer program called "Simulation-Based Load Forecast".

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

The load forecast values were obtained from MEA for individual distribution substations for FY 1993 and every year from FY 1996 to 2001 as well as those of FY 2006 and 2011.

Since appropriate regional load forecast values for FY 2016, a final target fiscal year of this study, were not available from MEA, the JICA Study Team has obtained such load forecast values based on the following methods:

(1) Design load forecast based on MEA's load forecast values

MEA's load forecast value (overall value) for FY 2016 was mean peak values for 30 minutes. Whereas, one-point peak values are used as design load value for formulating a distribution system improvement and expansion plan.

Consequently, the one-point peak values for FY 2016 have been obtained by checking the ratios of one-point peak values to the 30 minutes mean peak values by FY 2011 since FY 1993.

As presented in Table 6.2-1, a series of the ratios of one-point peak values to the 30 minutes mean peak value remain constant at 1.014 for FY 2006 and 2011, although the ratios slightly fluctuate in every fiscal year.

Therefore, a one-point peak value of 15,990 MW for FY 2016 has been obtained from a 30 minutes' mean peak value of 15,780 MW by using the same ratio of 1.014 for FY 2011.

(2) Division of load into 12/24 kV distribution substation load and 69/115 kV customer's load

Now that the overall design load for FY 2016 has been obtained in Item (1) above, the design load is divided into the 12/24 kV distribution substation load and 69/115 kV customer's load.

The 69/115 kV customer's load is affected so largely by the trend of customer's load that it is very difficult to clarify the trend of load for FY 2016.

A little more than 90% of MEA's load is shared by the 12/24 kV distribution substation load as presented in Table 6.2-1. Therefore, the 12/24 kV distribution substation load comprising a base load has been forecast, and after deducting the base load from the overall load, the 69/115 kV customer's load has subsequently been obtained.

The 12/24 kV distribution substation load for FY 2016 has been estimated at 14,870 MW as a result of forecast from the increase trend by FY 2011 since FY 1993 according to the method of least squares.

1,120 MW has therefore been obtained as the 69/115 kV customer's load for FY 2016 by deducting 14,870 MW from the overall load of 15,990 MW.

This share indicates a downward trend as explained below as the share of 69/115 kV customer's demand, which was 8.96% in FY 1993, is forecast at 7.00% respectively for both FY 2011 and FY 2016.

Namely, it generally becomes difficult to clarify the trend of individual loads gradually further in the future, the share of the demand indicates a downward trend.

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

The expansion plan of distribution substations is generally formulated based on the peak load in individual substations, considering that the peak load occurrence time varies in individual substations.

As the rated capacity of distribution substation is expressed by an MVA value, such a value should be used also for design load forecast.

Namely, the load for FY 2016 should be obtained in terms of this MVA value. 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 17,580 MW and 19,030 MVA, respectively.

The above values are evaluated to be justifiable judging from a series of trends, as the diversity factor and power factor are 1.18 and 0.92 respectively in this case.

The above forecast results are presented in Table 6.2-1 and Figs. 6.2-1 and 6.2-2.

(4) Load forecast for distribution substations by regions
For forecasting the regional load for individual distribution substations for FY 2016, there is a method of indiscriminately multiplying the respective substation loads for FY 2011 with the increase rate of overall load.

With this method, it is impossible to reflect the characteristics of regions with high or low increase rate.

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. As a result, the load blocks are divided into 29 blocks in total.

The increase rate of load for 10 years by FY 2011 since FY 2001 has been obtained for each load block, and after indiscriminately deducting the load value so that the load for FY 2016 becomes equal to the overall demand obtained in Item (3) above based on the increase rate, the load and increase rate of each load block for FY 2016 have been determined.

The purpose of obtaining and using the growth rate for 10 years from FY 2001 through FY 2011 is to investigate the trend of regional demand from a long term point of view and thereby exclude short term load fluctuation factors.

The results of study in this paragraph are presented in Table 6.2-2 and Fig. 6.2-3.

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

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

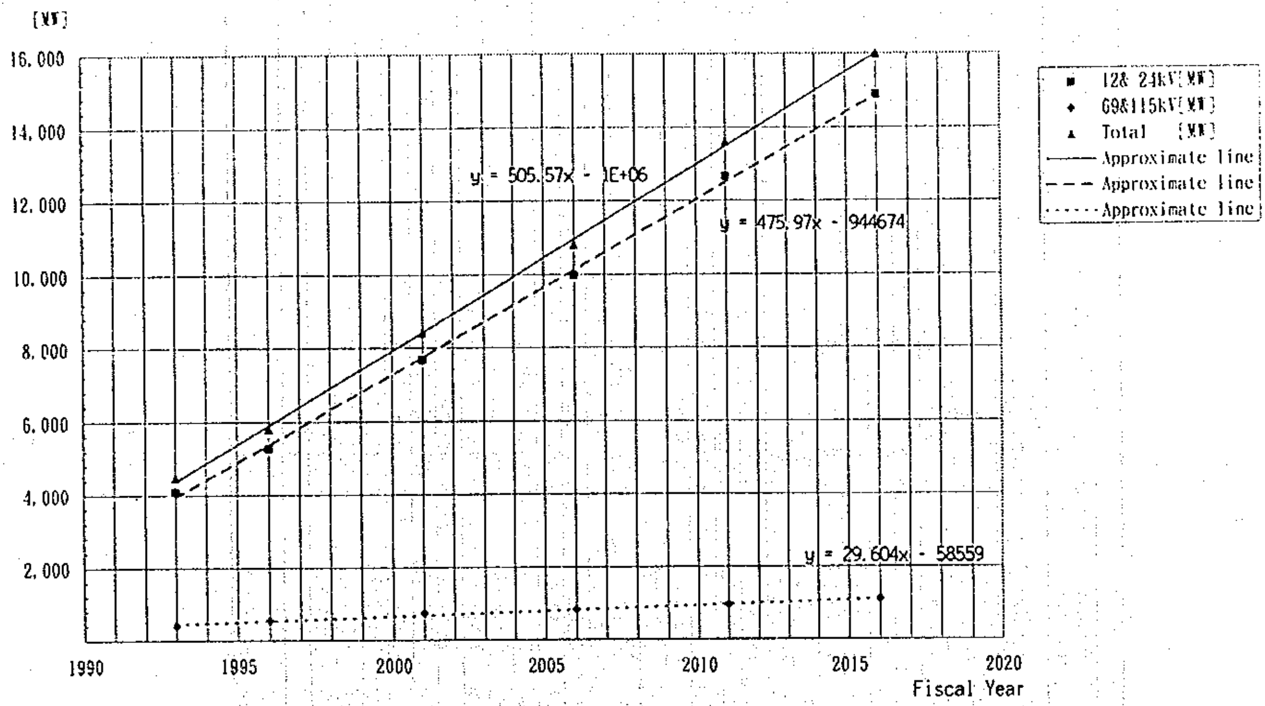


Fig 6.2-1 Planning Load

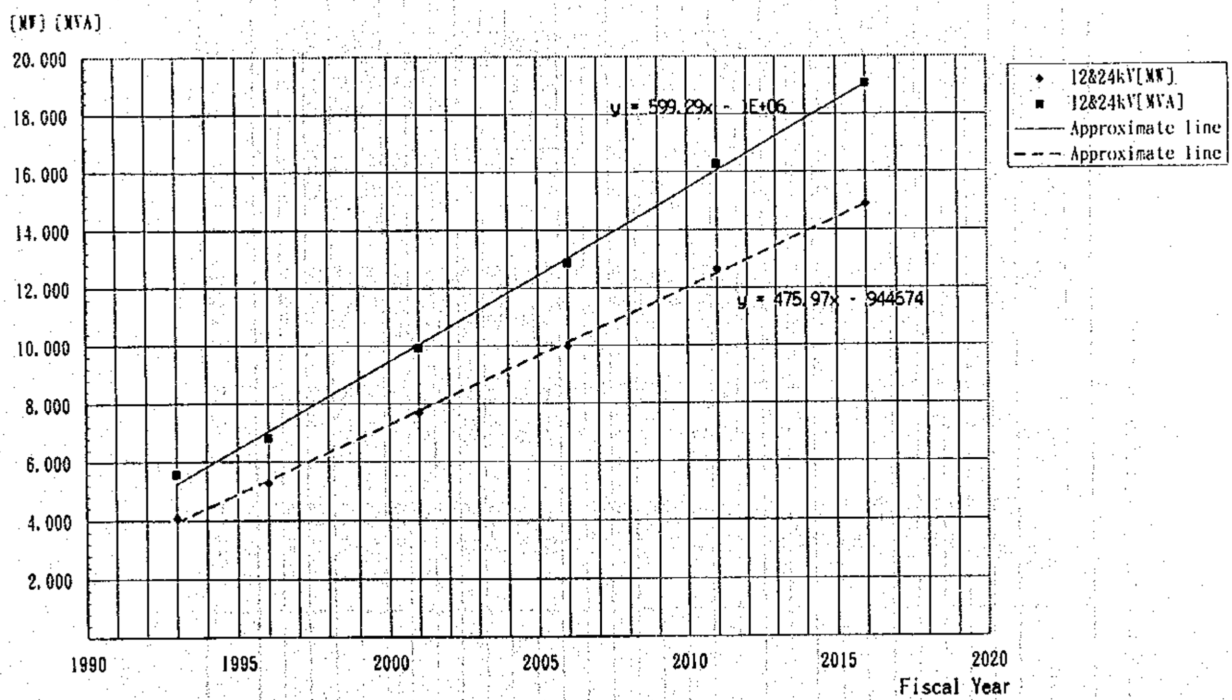


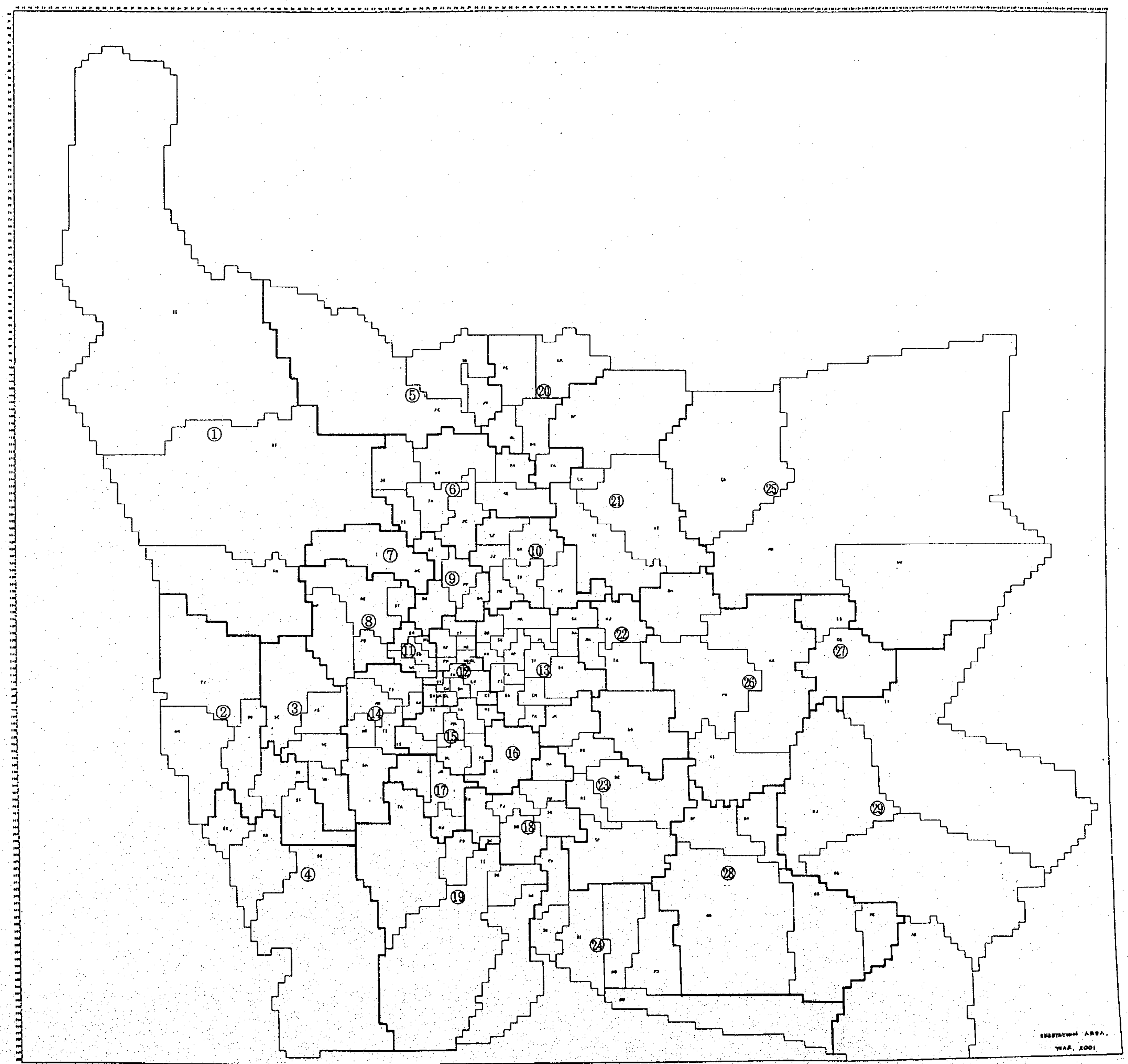
Fig 6.2-2 Distribution Substation Planning Load

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	Suansom	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	1,050.90	6.65	MB, EB, WW
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 6.2-3 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



6.3 Distribution Substation Expansion Plan

6.3.1 Formulation Policy of Distribution Substation Expansion Plan

(1) Distribution voltage

MEA is promoting a voltage boosting project from 12 kV to 24 kV in its supply regions excluding the network supply area around the Royal Palace, and it is concluded justifiable to adopt the distribution voltage according to this Project.

Therefore, the future distribution substation expansion project should basically be carried out based on the above voltage boosting project of MEA.

(2) Standard bank capacity

According to the new basic criteria for power system planning of MEA, the standard bank capacity is specified to be 60 MVA. Generally, an appropriate bank capacity can be obtained from the following equation:

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

P_T : Bank capacity (MVA)

V_s : Feeder voltage (kV)

P_L : Feeder capacity (kA)

β : Target feeder utilization factor

N : Number of feeders

γ : Diversity factor of feeder

α : Target bank utilization factor

The standard bank capacity is given by using the above equation.

Since the target feeder utilization factor is not available from MEA's basic criteria, the average loading current is used with regard to the term $[P_L \times \beta]$.

Sampling study of the diversity factor of feeder has been carried out regarding a typical area as the results are presented in Table 6.3-1.

Table 6.3-1 Diversity Factor of Distribution Feeder

Load Type	Substation	Substation Capacity (MVA)	Substation Maximum Load (MVA)	Distribution Feeder Used (Feeder)	Distribution Feeder Non-coincident Load (MVA)	Diversity Factor	Average
Residential	Bangna	2×40	61.6	10	73.4	1.1916	1.1580
	Nonthaburi	2×20+1×60	58.2	13	71.2	1.2234	
	Prachachuen	1×40+1×60	63.6	12	76.2	1.1981	
	Ramintra	2×60	112.0	8	114.1	1.0188	
Commercial	Chidlom	2×50	74.1	15	85.5	1.1538	1.1274
	Klongtoey	2×40	68.4	12	78.2	1.1433	
	Prathumwan	3×40	91.3	18	97.3	1.0657	
	Silom	2×40	62.7	12	71.9	1.1467	
Industrial	Bangbon	3×40	104.6	18	111.1	1.0621	1.0895
	Prapradaeng	2×40+1×60	101.2	19	116.9	1.1551	
	Prakasa	2×40+1×60	127.4	12	128.5	1.0086	
	Rasburana	3×40	114.1	19	129.2	1.1323	

The results of calculation by substituting the following values into the above respective coefficients are presented in Tables 6.3-2 and 6.3-3.

V_s = 12, 24 (kV)

$P_L \times \beta$ = 0.26 (kA)

N = 5 ～ 7 (Feeders)

γ = 1.1580, 1.1274, 1.0895

α = 0.8

Table 6.3-2 Standard bank capacity (V_s=12 kV)

(MVA)

γ \ N	5 feeders	6 feeders	7 feeders	Load Type
1.1580	29.2	35.0	40.8	Residential
1.1274	30.0	35.9	41.9	Commercial
1.0895	31.0	37.2	43.4	Industrial

Table 6.3-3 Standard bank capacity (V_s=24 kV)

(MVA)

γ \ N	5 feeders	6 feeders	7 feeders	Load Type
1.1580	58.3	70.0	81.7	Residential
1.1274	59.9	71.9	83.9	Commercial
1.0895	62.0	74.4	86.8	Industrial

30-40 MVA is appropriate as a standard capacity for the 12 kV supply area as indicated in Table 6.3-2. It will be necessary to increase the number of feeders or enlarge the load per feeder, where the 60 MVA bank specified in MEA's basic criteria is to be used.

It is deemed difficult to increase the number of feeders per bank from that specified in the present basic criteria since construction of outgoing lines for the portion around substation will become too sophisticated.

Moreover, it is not realistic to increase the load per feeder since it will become necessary to use one rank larger size conductor than that used at present.

When the 60 MVA bank is applied at 12 kV voltage, the load switch with a secondary rated current of roughly 2,900A will become necessary, and since the capacities of secondary switch, bus and cable of the bank should also be increased, it is deemed very difficult to apply the above 60 MVA bank.

Therefore, the 40 MVA bank used so far for the 12 kV supply area shall be applied as a standard bank.

As indicated in Table 6.3-3, 60-80 MVA is appropriate as a standard capacity for the 24 kV supply area, therefore the present standard capacity of 60 MVA according to the basic criteria is appropriate.

Should the bank capacity be changed to 80 MVA under the present situations wherein a large number of 60 MVA banks have already been applied, several types of equipment with capacities of 40, 60 and 80 MVA will be applied in combination. Then, the number of substations with different bank capacity configuration will be increased. Thereby, various problems can possibly be brought about regarding the countermeasures for relieving remaining banks at the time of one bank fault as well as regarding sophistication of physical distribution associated with diversification of equipment and materials.

Therefore, the 60 MVA bank adopted in the basic criteria of MEA shall be adopted as a standard capacity for the 24 kV supply area.

(3) Bank configuration

The 3-bank configuration (3x60 MVA) is a standard configuration according to the basic criteria of MEA.

In the case of 3-bank configuration, the normal target utilization factor is 80%, and the factor at the time of emergency is 120%. In this case, it will be possible to relieve the load by means of the remaining two sound banks without switching over any distribution line even at the time of one bank fault. Thus, this configuration can be highly evaluated in view of reliability.

	BAY 1	BAY 2	BAY 3
Normal:			
Capacity	60 MVA	60 MVA	60 MVA
Load	48 MVA	48 MVA	48 MVA
Utilization Factor	80%	80%	80%
Emergency:			
Load	0 MVA	72 MVA	72 MVA
Utilization Factor	——	120%	120%

Therefore, the 3-bank configuration specified in the basic criteria of MEA shall be adopted as a standard design configuration of substation.
Meanwhile, the substation to be constructed was be installed tentatively in two banks depending on the initial load conditions at the time of commissioning.
Speaking of the target operation during 2-bank configuration, the target utilization factor at 2-bank configuration and that at the time of emergency are 75% and 125% respectively according to the basic criteria of MEA.
When one bank is in fault in this case, roughly 15 MVA of load will remain unrelieved as indicated below, provided that this much load be relieved by distribution line.
Considering that the mean load current to distribution line is roughly 260A, this remaining load is equivalent to 1.4 distribution line feeders. Therefore, switching-over of this much load to distribution line is within a realistically possible range and within a level causing no particular problem in view of reliability as well.

	BAY 1	BAY 2
Normal:		
Capacity	60 MVA	60 MVA
Load	45 MVA	45 MVA
Utilization Factor	75%	75%
Emergency:		
Load	15 MVA	75 MVA
Utilization Factor	——	125%

This bank configuration is not desirable in view of reliability, although supply with one bank may be possible depending on load conditions in some cases. Therefore, any substation shall basically be commissioned at least with 2-bank configuration.

Finally, the 4-bank configuration (4x40 MVA) is adopted as a bank configuration for the 12 kV supply area according to the basic criteria of MEA.

This is a configuration established by taking into account the reliability of primary transmission line as well. In consideration that high reliability is required as a substation for supply to the important area around the Royal Palace, this bank configuration including the secondary network system is evaluated justifiable.

As described in Item (2) above, 40 MVA is appropriate as a bank capacity in the 12 kV supply area. Where the 3-bank configuration is assumed to be adopted, then the load per one substation is the following one:

$$3 \times 40 \times 0.8 = 96 \text{ MVA}$$

The cost advantage will be lost in the case of 3-bank configuration, when compared with 128 MVA in the case of 4-bank configuration.

Judging from the above conditions, the 4-bank configuration shall be adopted as a design standard for the 12 kV supply area as shown in the basic criteria of MEA.

(4) Supply reach of substation

The supply area, namely, the supply reach of substation is also one of the important factors for promoting a substation expansion project. The supply reach of substation is restricted due either to the limit of supply capacity of substation or the limit of voltage drop in distribution line.

In case of obtaining a supply reach from the supply capacity of substation, that is calculated from the following equation:

$$r = \sqrt{\frac{\sqrt{3} \times V_s \times P_L \times \beta \times N}{\pi \times \sigma \times \gamma}} = \sqrt{\frac{P_T \times \alpha}{\pi \times \sigma}} \quad (\text{km})$$

r : Supply reach of substation (km)

V_s : Feeder voltage (kV)

P_L : Feeder capacity (A)

β : Target feeder utilization factor

N : No. of feeders per substation

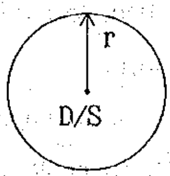
σ : Load density in supply reach (kVA/km^2)

γ : Diversity factor of distribution line

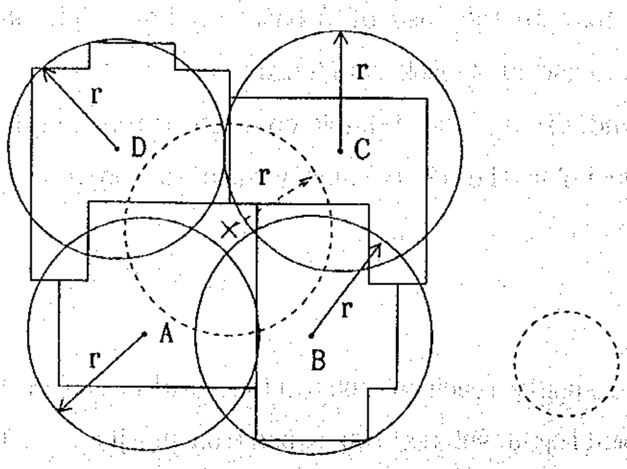
P_T : Bank capacity (MVA)

α : Target bank utilization factor

According to the above equation, a radius of a model circle is obtained where the supply reach of substation is assumed as the circle centering on the substation, provided that the load is distributed uniformly.



This method is used for studying candidate construction sites of substation.



During the First Field Investigation, the substation supply reach maps for FY 2001, 2006 and 2011 were obtained from MEA.

For meeting the request of MEA, it has been judged most desirable to formulate the substation expansion plan on the basis of MEA's plan.

In other words, it has been decided to study the candidate substation construction sites on the basis of MEA's plan. Therefore, the supply reach according to the supply capacity of substation is studied only in case it has become necessary to construct a substation at any site which has not been proposed by MEA.

The supply reach restricted from the lower limit of voltage drop is as listed below according to the basic criteria of MEA:

	12 kV	24 kV	
Normal	900 V	1,800 V	7.5% of service voltage
Emergency	1,200 V	2,400 V	10.0% of service voltage

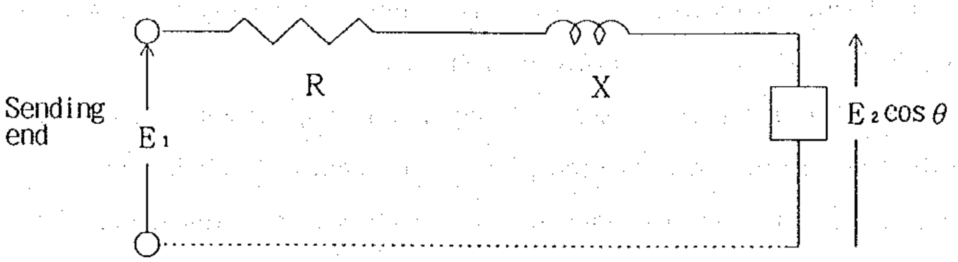
The above MEA's values are deemed justifiable, Judging from the lower limit of voltage drop applied in Japan as presented below for example:

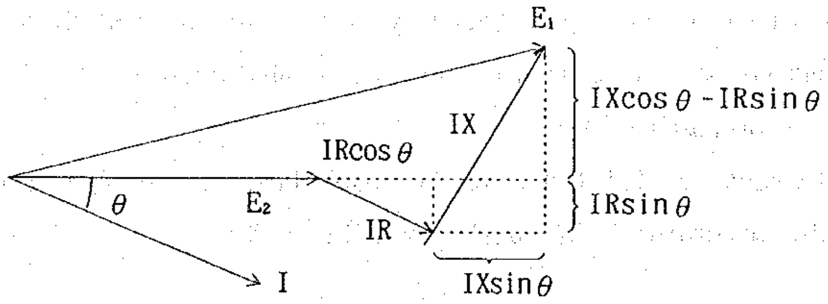
Normal	5-10% of service voltage
Emergency	10-15% of service voltage

When an equivalent resistance is obtained in advance, the voltage drop in distribution line can be calculated easily.

(a) Equivalent resistance

Where one line and imaginary neutral line are picked up as indicated below for calculating the voltage drop in 3-phase AC distribution line, the current is deemed to flow only in the voltage line without considering any impedance since no current flows in the neutral line:





Where the power factor of load is $\cos\theta$ based on the receiving end voltage E_2, then,

$$E_1 = E_2 + I(\cos\theta - j\sin\theta)(R + jX)$$

$$= E_2 + (IR\cos\theta + IX\sin\theta) + j(IX\cos\theta - IR\sin\theta)$$

Even though the terms including 'j' in the above formula are sufficiently large, these terms may be disregarded in calculating an absolute value of E_1 as indicated in the vector diagram.

Actually, therefore, the voltage drop is given from the following equation, in other words, the AC circuit can be considered as if a DC circuit.

$$\varepsilon = I(R\cos\theta + X\sin\theta) \ (V)$$

Meanwhile, $(R\cos\theta + X\sin\theta) = R_e$ (Ω) can be obtained where the conductor size, line constant and power factor of load are available in advance, then the voltage drop can be given from:

$$\varepsilon = I R_e \ (V)$$

In this sense, where $(R\cos\theta + X\sin\theta)$ is an equivalent resistance of the corresponding line, and the value per km is r_e $(= r\cos\theta + x\sin\theta)$, then,

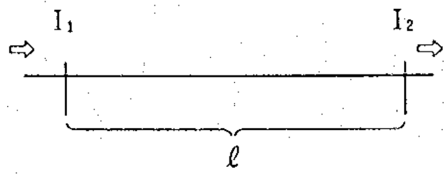
$$\varepsilon = I r_e \ell \ (V) \qquad \ell : \text{Distance (km)}$$

The results of calculating the equivalent resistance are presented in Table 6.3-4.

(b) Voltage drop in distribution line

Where the current flowing to a certain section is I_1 (A) and the outgoing one is I_2 (A), then the three phase AC voltage drop is obtained from:

$$\varepsilon = \sqrt{3}\, r_e\, \ell \times \frac{I_1 + I_2}{2} \quad (V)$$



If there is no load in this section, then,

$$I_1 = I_2$$

and

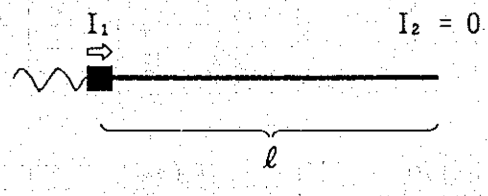
$$\varepsilon = \sqrt{3}\, r_e\, \ell \times I_1 \quad (V)$$

The distance of distribution line, in case the overall voltage drop in distribution line becomes equivalent to the lower limit of voltage drop specified in the basic criteria of MEA, has been calculated on a trial basis. The results are presented in Table 6.3-5 which is recommended to be used as a reference for formulating the substation expansion plan in future.

In other words, the above distance has been calculated where the load is distributed uniformly in the entire distribution lines and where,

$$I_2 = 0$$

and the distance ℓ where the voltage drop becomes the lower limit value of voltage drop has been obtained:



The formulation of substation expansion plan has been prepared without consideration of supply reach of each substation due to the lower limit of voltage drop herein because of the following reasons. Namely, any data was not available pertaining to the load conditions in the distribution lines by regions, and formulation of distribution line expansion plan is out of the scope of this study.

Judging from overall distribution of load, however, the supply reach of each substation is evaluated to be within the lower limit of voltage drop as presented in Table 6.3-5.

Table 6.3-4 Equivalent Resistance

(1)Bare Conductor (Ω/km)

Conductor Size (sq. mm)	Resistance (Ω/km)	Reactance 132.3cm Spacing (Ω/km)	Reactance 124.0cm Spacing (Ω/km)	Equivalent Resistance 132.3cm Spacing Power Factor 0.85	0.90	0.95	Equivalent Resistance 124.0cm Spacing Power Factor 0.85	0.90	0.95
35	1.057	0.388	0.384	1.103	1.120	1.125	1.101	1.119	1.124
70	0.540	0.363	0.359	0.650	0.644	0.626	0.648	0.642	0.625
185	0.201	0.331	0.327	0.345	0.325	0.294	0.343	0.323	0.293

(2)Partially Insulated Conductor (Ω/km)

Conductor Size (sq. mm)	Resistance (Ω/km)	Reactance 132.3cm Spacing (Ω/km)	Reactance 124.0cm Spacing (Ω/km)	Equivalent Resistance 132.3cm Spacing Power Factor 0.85	0.90	0.95	Equivalent Resistance 124.0cm Spacing Power Factor 0.85	0.90	0.95
35	1.057	0.388	0.384	1.103	1.120	1.125	1.101	1.119	1.124
70	0.540	0.363	0.359	0.650	0.644	0.626	0.648	0.642	0.625
185	0.201	0.331	0.327	0.345	0.325	0.294	0.343	0.323	0.293

(3)Spaced Aerial Cable (Ω/km)

Conductor Size (sq. mm)	Resistance (Ω/km)	Reactance 22.86cm Spacing (Ω/km)	Reactance 16.51cm Spacing (Ω/km)	Equivalent Resistance 22.86cm Spacing Power Factor 0.85	0.90	0.95	Equivalent Resistance 16.51cm Spacing Power Factor 0.85	0.90	0.95
35	1.057	0.278	0.257	1.045	1.072	1.091	1.034	1.063	1.084
120	0.305	0.240	0.220	0.386	0.379	0.365	0.375	0.370	0.358
185	0.201	0.226	0.206	0.290	0.279	0.262	0.279	0.271	0.255

Table 6.3-5 Length corresponding to specified voltage drop limit (voltage drop limit in 24kv supply area: 1,800[V])

(1)Bare Conductor (132.3cm Spacing) (km)

Conductor Size (sq. mm)	Load=100[A] Power Factor 0.85	0.90	0.95	Load=200[A] Power Factor 0.85	0.90	0.95	Load=260[A] Power Factor 0.85	0.90	0.95	Load=300[A] Power Factor 0.85	0.90	0.95
35	18.8	18.5	18.4	9.4	9.2	9.2	7.2	7.1	7.1	6.2	6.1	6.1
70	31.9	32.2	33.2	15.9	16.1	16.6	12.2	12.4	12.7	10.6	10.7	11.0
185	60.2	63.9	70.6	30.1	31.9	35.3	23.1	24.5	27.1	20.0	21.3	23.5

(2)Partially Insulated Conductor (132.3cm Spacing) (km)

Conductor Size (sq. mm)	Load=100[A] Power Factor 0.85	0.90	0.95	Load=200[A] Power Factor 0.85	0.90	0.95	Load=260[A] Power Factor 0.85	0.90	0.95	Load=300[A] Power Factor 0.85	0.90	0.95
35	18.8	18.5	18.4	9.4	9.2	9.2	7.2	7.1	7.1	6.2	6.1	6.1
70	31.9	32.2	33.2	15.9	16.1	16.6	12.2	12.4	12.7	10.6	10.7	11.0
185	60.2	63.9	70.6	30.1	31.9	35.3	23.1	24.5	27.1	20.0	21.3	23.5

(3)Spaced Aerial Cable (22.86cm Spacing) (km)

Conductor Size (sq. mm)	Load=100[A] Power Factor 0.85	0.90	0.95	Load=200[A] Power Factor 0.85	0.90	0.95	Load=260[A] Power Factor 0.85	0.90	0.95	Load=300[A] Power Factor 0.85	0.90	0.95
35	19.8	19.3	19.0	9.9	9.6	9.5	7.6	7.4	7.3	6.6	6.4	6.3
120	53.8	54.8	56.9	26.9	27.4	28.4	20.7	21.0	21.9	17.9	18.2	18.9
185	71.6	74.4	79.3	35.8	37.2	39.6	27.5	28.6	30.5	23.8	24.8	26.4

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

Before formulating the long term distribution substation plan, the plan for FY 2016, a final target fiscal year is formulated because of the necessity to clarify an ideal pattern of equipment states to cover the power demand in FY 2016. Where the pattern for FY 2016 has been determined, the plan by FY 2011 since FY 1997 can be formulated only by yearly developing the quantity of equipment matching the sections of demand for the respective fiscal years.

(1) Regional load forecast in FY 2016

The demand data by regions for FY 2016 should initially have been obtained from MEA. However, such demand forecast data by regions for FY 2016 were not available from MEA.

Such being the case, the JICA Study Team carried out load forecast by 29 blocks of areas according to the method described in Clause 6.2.2. The results obtained from this forecast are the demand and increase rate of demand by 29 blocks of areas.

The increase rate of demand has been determined to be used for formulating the plan for FY 2016. In other words, the demand for FY 2016 is calculated by multiplying the increase rate in the respective regions with the demand for the respective substations for FY 2011.

(2) Formulation of expansion plan

A method was adopted to calculate the utilization factor in the demand for FY 2016 is to be supplied on the basis of equipment for FY 2011 and to study the substations where expansion plans are needed. As the equipment states for FY 2011 constituting a basis of this study, the original plan for FY 2011 formulated already by MEA is used because of the following reasons. Namely, it has been concluded possible for meeting the request of MEA to formulate the plan on the basis of MEA's original plan.

The substations required to be extended are following ones:

- 2-bank configuration substation where the utilization factor has exceeded 75% of the target value.

- 3-bank configuration substation where the utilization factor has exceeded 80% of the target value.

The problematical point at the planning stage of expansion is how to ensure the reliability at the time of fault in the largest bank in a substation of a different capacity bank configuration.
According to the basic criteria of MEA, the reliability is attained by setting the target utilization factor as follows as described also in Clause 6.3.1. Formulation policy of distribution substation plan above:

- 2-bank configuration substation
  - Normal: 75%; Emergency: 125%
  - Switchover load through distribution line: max.15 MVA
- 3-bank configuration substation
  - Normal: 80%; Emergency: 120%
  - Switchover load through distribution line: None

Therefore, the standard maximum load to be switched over through distribution line at the time of one bank fault is expected to be 15 MVA in maximum.
As the substations of different capacity bank configuration are in the course of expansion, the substation capacity has not reached a final one. Consequently, it is evaluated justifiable to take into account relief of load by switching over through distribution line even in the case of 3-bank configuration substation with different bank capacities.

(3) Supply reliability for different capacity bank configuration bank
On the basis of this concept, the level of countermeasures required in view of reliability has been studied with regard to the different capacity bank configuration substations.
The following three patterns of different capacity bank substation can be considered:

- 1 x 60 MVA + 1 x 40 MVA
- 1 x 60 MVA + 2 x 40 MVA
- 2 x 60 MVA + 1 x 40 MVA

The bank configuration of (1 x 60 MVA + 1 x 40 MVA) is:

	BAY 1	BAY 2
Normal:		
Capacity	60 MVA	40 MVA
Load	45 MVA	30 MVA
Utilization Factor	75%	75%
Emergency:		
Load	25 MVA	50 MVA
Utilization Factor	—	125%

The remaining load in this case is 25 MVA. Out of this much load, 15 MVA can be switched over through distribution line, but 10 MVA will be left not switched over.

In this case, therefore, the normal load should be lowered by 10 MVA so that the normal load is reduced to 65 MVA in total.

The bank configuration of (1 x 60 MVA + 2 x 40 MVA) is:

	BAY 1	BAY 2	BAY 3
Normal:			
Capacity	60 MVA	40 MVA	40 MVA
Load	48 MVA	32 MVA	32 MVA
Utilization Factor	80%	80%	80%
Emergency:			
Load	16 MVA	48 MVA	48 MVA
Utilization Factor	—	120%	120%

The remaining load in this case is 16 MVA. Out of this load, 15 MVA can be switched over through distribution line, but 1 MVA will be left not switched over.

In this case, therefore, the normal load should be lowered by 1 MVA so that the normal load in this substation is reduced to 111 MVA in total.

The bank configuration of (2 x 60 MVA + 1 x 40 MVA) is:

	BAY 1	BAY 2	BAY 3
Normal:			
Capacity	60 MVA	60 MVA	40 MVA
Load	48 MVA	48 MVA	32 MVA
Utilization Factor	80%	80%	80%
Emergency:			
Load	8 MVA	72 MVA	48 MVA
Utilization Factor	—	120%	120%

In this case, the remaining load of 8 MVA can totally be switched over through distribution line. So that, there will be no particular problem in view of reliability.

When the above study results are summarized, countermeasures should be taken for the following substations:

- 2-bank configuration substation wherein the utilization factor exceeds 75%.
- 3-bank configuration substation wherein the utilization factor exceeds 80%.
- (1 x 60 MVA + 1 x 40 MVA) bank configuration substation wherein the utilization factor exceeds 65.0% (excess of 65 MVA).
- (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 to be taken for effective utilization of existing substation equipment is:

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

ii) Expansion of bank and/or its capacity.

iii) Construction of new substation.

(4) Method of transferring between substations

The load for FY 2016 has been calculated by multiplying the load in the supply area for FY 2011 with the increase rate of load demand by regions. Therefore, the supply area before taking countermeasures in FY 2016 is the same as that in FY 2011. On the basis of the supply area map for FY 2011 obtained by the study team from MEA, the respective areas have been divided in terms of a 0.5 km x 0.5 km mesh, and the load in this mesh unit has further been calculated where the load is distributed uniformly in each substation supply area. Moreover, the load is assumed to be transferred on the basis of this mesh unit. Transfer of load between substations is assumed to be performed freely between all of the supply areas, however, it would be impossible to cross over the Chao Phraya River.

(5) Space of bank expansion

Whether the bank expansion space is available or not has been evaluated based on the following concept:

With regard to the 89 substations constructed by FY 1993, MEA's plan for FY 2011 has been checked. As a results, there is concluded to be no space for extending the substations which are still of a 2-bank configuration.

As the substations installed in and after FY 1994 have been constructed according to the new basic criteria of MEA, 3-bank configuration is concluded to be possible for all of these substations.

It is assumed possible to construct 4 x 40 MVA substations in all of the existing substations in the 12 kV supply area around the Royal Palace. In addition, it is also assumed possible to expand the existing 10, 20, 40 and 50 MVA banks to 60 MVA banks by adopting new technology for compact type equipment and so forth.

(6) Expansion plan for FY 2016

Presented in Table 6.3-6 and Fig. 6.3-1 and Appendix 6.3-1 are the results of formulating a substation expansion and construction plan taking into account the above prerequisite conditions.

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	—

Regarding the equipment states of MEA in FY 1996, the average utilization factor is as low as 58.9%, and number of banks per each substation (bank configuration ratio) is as low as 2.07.

This means that MEA's equipment formation is comprised of slightly excessive equipment.

Generally, the ideal bank configuration ratio is deemed roughly 2.5. In other words, this ratio is intended to attain a marginal capacity to cope with increase of future demand by leaving one 2-bank configuration substation out of two substations. However, the fact that the bank configuration ratio of MEA is low indicates that when should a large demand have newly taken place, a temporary substation with 1-bank configuration has been constructed adjacent to the new demand load instead of expanding the distribution line to supply additional power from an existing substation.

As any distribution substation is closely related to the situations in the supply area, such a substation is affected largely by the trend of load, particularly that of large customers in the area. Consequently the location of substation site would become inappropriate or the equipment capacity may become excessive.

Therefore, it is recommended to improve the utilization factor of substation equipment taking into account the timely appropriate execution period of the such transmission line and distribution substation expansion projects.

For reference, utilization factor of distribution substation in FY 1996 and 2016 is presented in Fig. 6.3-2.

Finally, 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

Table 6.3-6 Expansion of Distribution Substation(compare to MEA Plan for FY 2011)

Substation	Expansion of Installed Capacity [MVA]	Transferring load between substations	
		addition (transferring load from) [MVA]	decrease (transferring load from) [MVA]
Bangkhuprom (BR)			Nanglerng; 10.08
Bangklo (BL)	2×40 to 1×40+1×60		
Bangkrachao (BC)	2×40 to 2×60		
Bangna (BG)	2×40 to 1×40+1×60		
Chalongkrung(CG)			Tubyao; 16.48
Klongsanpasamit (KS)	1×40+1×60 to 2×60		
Lardplakao (LK)	1×60 to 2×60		
Mai-ad (MA)	2×40 to 2×60		
Muangthong 1(M1)			Muangthong7; 21.6
Petchkasem (PS)	1×40+1×60 to 2×60		Wuttakart; 2.14 Watdeedod; 12.84
Poojao (PJ)	3×40 to 2×40+1×60		
Prakanong (PK)	2×40 to 2×60		
Sailom (SM)	2×40 to 1×40+1×60		
Samsen (SN)	3×40 to 2×40+1×60		
Sansab (SS)	2×40+1×60 to 1×40+2×60		
Sapanmai (SP)			Lumpagshe; 47.5
Silom (SL)	2×40 to 1×40+1×60		
South Bankok(SK)	1×40 to 1×60		
Watlieb (WL)	3×40 to 4×40		
Ekburi (EB)	2×60 to 3×60		
Kingkaew (KI)			Prawes; 13.5
Muangthong 3(M3)	2×60 to 3×60	Muangthong 5; 21.6	
Yenarkart (YK)			Klongpume; 41.76
Bangshan (BH)			Klonggratiam; 21.0
Muangthong 4(M4)	2×60 to 3×60	Muangthong 6; 21.6	
Muangthong 5(M5)			Muangthong 3; 21.6
Muangthong 6(M6)			Muangthong 4; 21.6
Muangthong 7(M7)	2×60 to 3×60	Muangthong 1; 21.6	
Nanglerng (NL)	3×40 to 4×40	Bangkhuprom; 10.08	
Prawes (PW)	2×60 to 3×60	Kingkaew; 13.5 Krungtepkreeta; 6.44	
Tubyao (TY)	2×60 to 3×60	Chalongkrung; 16.48 Luangpang; 15.84	
Wuttakart (WR)		Petchkasem; 2.14	
Klongpume (GP)	2×60 to 3×60	Yenarkart; 41.76	
Krungtepkreeta (KR)			Prawes; 6.44 Srinakarin; 24.15
Srinakarin (IR)	2×60 to 3×60	Krungtepkreeta; 24.15	
Watdeeod (WD)	2×60 to 3×60	Petchkasem; 12.84	
Klonggratiam(GT)	2×60 to 3×60	Bangshan; 21.0	
Luangpang (LG)			Tubyao; 15.84
Lumpagshe (LS)	2×60 to 3×60	Sapanma 7; 47.5	

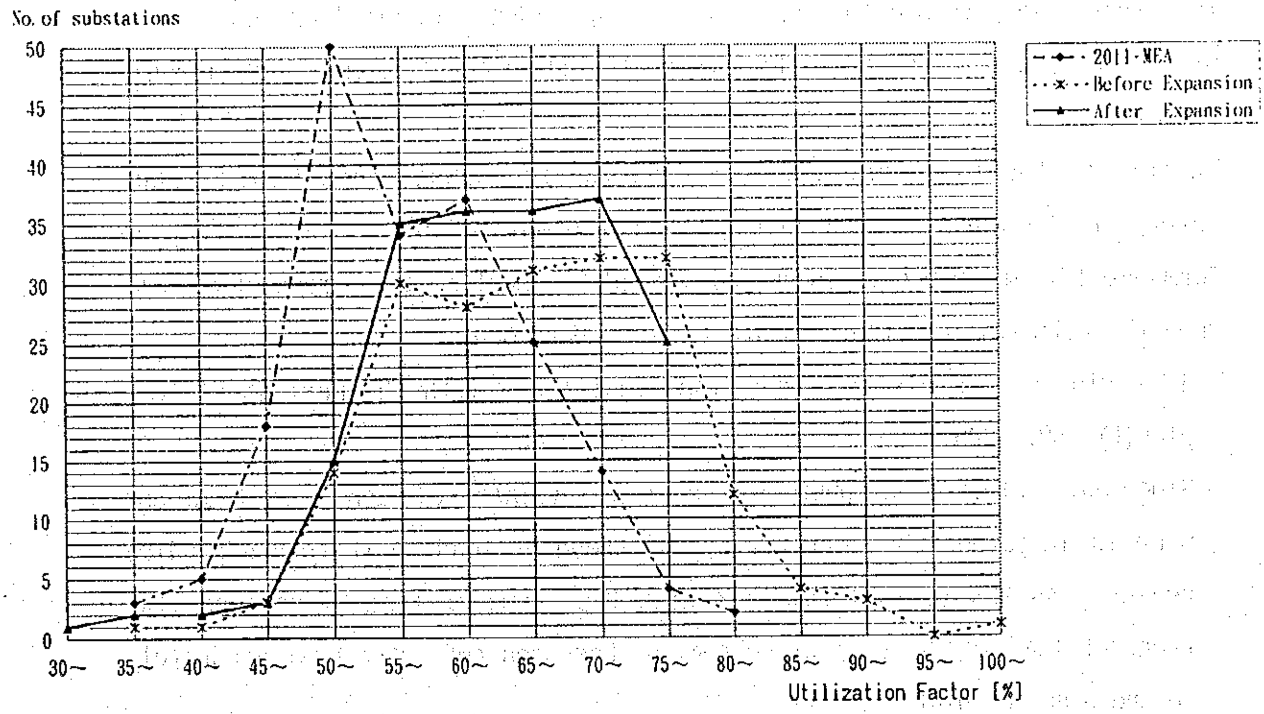


Fig 6.3-1 Distribution Substation Utilization Factor (Planning Year=2016)

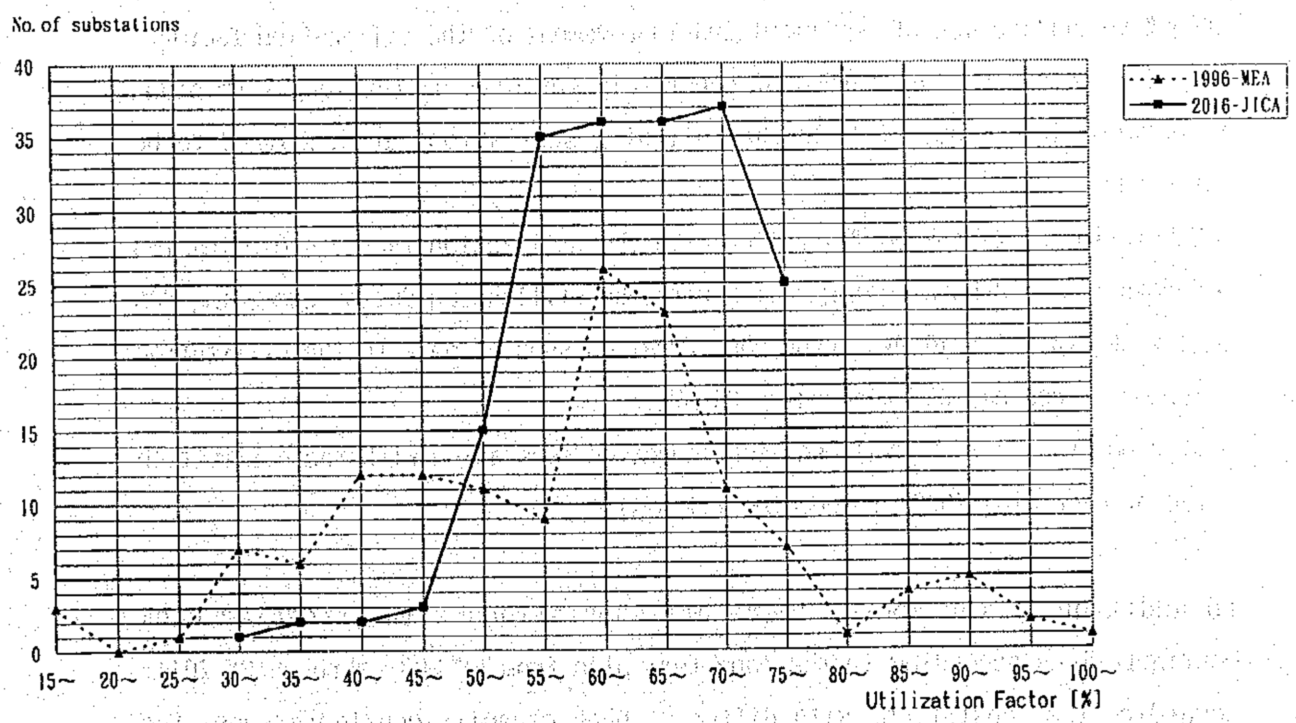


Fig 6.3-2 Distribution Substation Utilization Factor (compare with FY 1996)

6.3.3 Long-Term expansion plan of distribution substations(FY2001～2011)

The study team obtained the load data for individual distribution substations planned by MEA with regard to the regional load forecast from FY 2001 through FY 2011.

Therefore, 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 since it is judged possible to best meet the request of MEA when the following requirements are taken into account:

- It would be possible to ensure the consistency with the next short-term plan(FY 1997～2001).
- Since any distribution substation is closely related to each local load, any plan is affected substantially by the trend of load in the corresponding region. As MEA is most familiar with the trend of load by regions, the trend of load in the respective regions has been reflected most accurately in the plan formulated by MEA.

As described also in Clause 6.3.2, the equipment seems to be slightly excessive according to the plan of MEA.

Therefore, MEA's plan has been reviewed preferentially in for ensuring effective utilization of equipment and improvement of the utilization factor.

Now, let us explain the method of concretely formulating the long term plan.

As described in clause 6.3.2, the following substations are required to be extended:

- Substation of 2-bank configuration with the utilization factor exceeding 75%
- Substation of 3-bank configuration with the utilization factor exceeding 80%
- (1 x 60 MVA + 1 x 40 MVA) bank configuration substation with the utilization factor exceeding 65% (exceeding 65 MVA)
- (1 x 60 MVA + 2 x 40 MVA) bank configuration substation with the utilization factor exceeding 79.3% (exceeding 111 MVA)

In addition to the above, there are substations with irregular bank configurations according to the long term plan from FY 2001 through FY 2011. Regarding the substations with different bank capacity configurations, the countermeasures required for reliability level are also studied based on a similar concept in Clause 6.3.2.

The following three patterns of different capacity bank configurations can be considered:

a) 1 x 40 MVA + 2 x 20 MVA

b) 2 x 60 MVA + 1 x 20 MVA

c) 1 x 40 MVA + 2 x 22.4 MVA

a) In case (1 x 40 MVA + 2 x 20 MVA) bank configuration:

	BAY 1	BAY 2	BAY 3
Normal:			
Capacity	40 MVA	20 MVA	20 MVA
Load	32 MVA	16 MVA	16 MVA
Utilization Factor	80%	80%	80%
Emergency:			
Load	16 MVA	24 MVA	24 MVA
Utilization Factor	—	120%	120%

In this case, as much as 16 MVA remains as a residual load. Since 15 MVA out of this residual load can be switched over through distribution line, the remainder of 1 MVA is left over without being switched over.

In this case, therefore, the substation should be operated while normally lowering the load by 1 MVA. In other words, the normal load of this substation should be 63 MVA.

b) In case (1 x 20 MVA + 2 x 60 MVA) bank configuration:

	BAY 1	BAY 2	BAY 3
Normal:			
Capacity	60 MVA	60 MVA	20 MVA
Load	48 MVA	48 MVA	16 MVA
Utilization Factor	80%	80%	80%
Emergency:			
Load	16 MVA	72 MVA	24 MVA
Utilization Factor	—	120%	120%

In this case, as much as 16 MVA remains as a residual load. Since 15 MVA out of this residual load can be switched over through distribution line, the remainder of 1 MVA is left over without being switched over.

In this case, therefore, the substation should be operated while normally lowering the load by 1 MVA. In other words, the normal load of this substation should be 111 MVA.

c) In case (2 x 22.4 MVA + 1 x 40 MVA) bank configuration:

	BAY 1	BAY 2	BAY 3
Normal:			
Capacity	40 MVA	22.4 MVA	22.4 MVA
Load	32 MVA	17.92 MVA	17.92 MVA
Utilization Factor	80%	80%	80%
Emergency:			
Load	14.08 MVA	26.88 MVA	26.88 MVA
Utilization Factor	—	120%	120%

Since all of as much as 14.08 MVA of residual load can totally be switched over through distribution line in this case, there would not be any particular problem in reliability.

In conclusion, the following countermeasures should be taken additionally in the following cases:

- (1 x 40 MVA + 2 x 20 MVA) bank configuration substation with the utilization factor exceeding 78.8% (exceeding 63 MVA)
- (2 x 60 MVA + 1 x 20 MVA) bank configuration substation with the utilization factor exceeding 79.3% (exceeding 111 MVA)

Therefore, the countermeasures should be taken according to the following priority order similarly as described in Clause 6.3.2:

i) Switching of excessive load over to surrounding substation with lighter load through distribution line.

ii) Extension of banks and bank capacity.

iii) Construction of substations.

The design utilization factors of many substations proposed to be constructed according to MEA's plan are low. Therefore, the study team has formulated the long term plan for reducing the number of substations with a utilization factor of less than 40% to improve the utilization factor of substation equipment.

The method of transferring load between substations have been studied according to the method described in Clause 6.3.2.

Meanwhile, the plan for FY 2001 has been formulated provided that there would be some areas with dual distribution system voltages of 12 kV and 24 kV in consideration that the distribution line voltage boosting project from 12 kV to 24 kV is now under implementation.

Therefore, the load transfer plan has been formulated according to the following conditions, provided that transfer of load optionally between all substations would be impossible:

- Transfer of load should be performed preferentially between the substations with a same voltage.
- Any load should not be transferred from 24 kV area to 12 kV area.
- Transfer of load from 12 kV area to 24 kV area is evaluated possible after boosting the existing 12 kV distribution voltage to 24 kV.

Based on the above prerequisite conditions, a substation construction plan has been formulated as indicated in Table 6.3-7. In addition, the plans for the respective fiscal years are presented in Table 6.3-8, Figs. 6.3-3, 6.3-4, 6.3-5 and 6.3-6, and Appendix 6.3-2. (including FY 2016 plan)

Table 6.3-7 Construct Plan of Distribution Substation

		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

The design utilization factor of 56.5% and bank configuration ratio of 2.2583 proposed for FY 2001 are much lower than those in the plans for the other fiscal years.

It should be particularly noted that the utilization factor in as many as eighteen substations is lower than 40%. This is because the voltage boosting project to 24 kV will be under implementation halfway in FY 2001, thus load transferring between mutual substations would be impossible.

The following substations, which are located in 12 kV area isolated from other distribution areas, have problem in view of reliability since it is impossible to back up these substations from other substations at the time of one bank fault and other major emergency:

- Srithanya (YA)
- Thonburi (TB)

Nonetheless, such situations are deemed inevitable during the course of implementing the distribution system voltage boosting project from 12 kV to 24 kV.

Table 6.3-8 Target for Distribution Substation System Program

(1／7)

Description	Installation Capacity [MVA]			
	2001 (from 1996)	2006	2011	2016
Construction of Substation				
Taiban (TN)	2×60			
Banmai (MI)	2×60			
Dindaeng (DD)	2×(40)			
Jatujag (JJ)	2×60			
Kaset (KE)	2×60			
Klongkum (KG)	2×60			
Muangthong 4 (M4)	2×60			
Muangthong 5 (M5)	2×60			
Muangthong 6 (M6)	2×60			
Muangthong 7 (M7)	2×60			
Nanglerng (NL)	2×40			
Patanakarn (TA)	2×60			
Plubpla (PL)	2×60			
Prawes (PW)	2×60			
Prompong (RP)	2×60			
Sainoi (SI)	2×60			
Samyarn (YN)	2×(40)			
Satorn (SH)	2×60			
Shimplee (HP)	2×60			
Sriwiang (SW)	2×(40)			
Suanyai (YI)	2×60			
Suwintawong (WW)	2×60			
Tha-kwian (TI)	2×(40)			
Trokchan (TC)	2×(40)			
Tubyao (TY)	2×60			
Watkampaeng (WK)	2×60			

Table 6.3-8 Target for Distribution Substation System Program (2／7)

Description	Installation Capacity [MVA]			
	2001 (from 1996)	2006	2011	2016
Wuttakart (WR)	2×60			
Asoke (AK)		2×60		
Banghuasae (HS)		2×60		
Bangkaew (BW)		2×60		
Bangtalard (TD)		2×60		
Jorakabuo (JB)		3×60		
Klongna (LA)		2×60		
Land & House (LH)		2×60		
Muangthong 8 (M8)		2×60		
Muangthong 9 (M9)		2×60		
Praramkao (RL)		2×60		
Rajchaprarop (RJ)		3×60		
Sanampao (NP)		2×60		
Sananikom (OM)		2×60		
Songsunikom (OS)		2×60		
Srinakarin (IR)		2×60		
Watdeedod (WD)		2×60		
Bangbuotong (BT)			3×60	
Bangpleeyai (PY)			2×60	
Klongbangpi (KB)			3×60	
Klongpume (GP)			2×60	
Krungtepkreeta (KR)			3×60	
Thonglor (LO)			2×60	
Tungkru (TU)			2×60	
Luangpang (LG)			2×60	
Nimitmai (NI)			2×60	
Nongyai (NY)			2×60	

Table 6.3-8 Target for Distribution Substation System Program (3/7)

Description	Installation Capacity [MVA]			
	2001 (from 1996)	2006	2011	2016
Pinklao (IL)			3×60	
Rajchakru (RU)			2×60	
Satorntai (AT)			3×60	
Tiamruammit (TM)			2×60	
Trimit (RM)			3×40	
Bangkruay (GY)				2×60
Bangpang (GG)				2×60
Bangpla (AA)				2×60
Klongdan (LD)				2×60
Klonggratiam (GT)				3×60
Lumpagshe (LS)				3×60
Pongpetch (PH)				2×60
Puttamonton (PT)				2×60
Rajdamri (RR)				2×60
Talingchan (TL)				2×60
<u>Addition of Substation</u>				
Bangchalong (BN)	1×60 to 2×60	2×60 to 3×60		
Bangkapi (BA)		2×40+ 1×60 to 1×40+ 2×60		
Bangkhaen (KA)	1×60 to 2×60	2×60 to 3×60		
Bangklo (BL)				2×40 to 1×40+ 1×60
Bangkok noi (BO)	2×40 to 1×40+ 1×60	1×40+ 1×60 to 1×40+ 2×60		
Bangkrachao (BC)		2×10 to 1×60	1×60 to 2×60	
Bangmod (BM)	2×(40) to 2×(40)+ 1×60			
Bangna (BG)				2×40 to 1×40+ 1×60
Bangping (BI)			2×60 to 3×60	

Table 6.3-8 Target for Distribution Substation System Program (4/7)

Description	Installation Capacity (MVA)			
	2001 (from 1996)	2006	2011	2016
Bangpongpang (PG)	1×40+ 1×60 to 2×60	2×60 to 3×60		
Bangpood (BD)		2×60 to 3×60		
Bangpu (BU)		2×40 to 3×60		
Bangsaotong (BS)		1×60 to 2×60	2×60 to 3×60	
Chalongkrung (CG)		1×60 to 2×60		
Chidlom (CL)		2×50 to 2×60		
Donmuang (DM)	2×40+ 1×60 to 2×60	2×60 to 3×60		
Huaykwang (HK)	2×60 to 3×60			
Klongmai (KM)	1×40 to 2×60		2×60 to 3×60	
Klongsanamchai (SC)	1×40 to 1×40+ 1×60	1×40+ 1×60 to 2×60		2×60 to 3×60
Klongsanpasamit (KS)		2×20+ 1×40 to 1×40+ 1×60		1×40+ 1×60 to 2×60
Klongsarn (KN)			2×40 to 2×60	
Klongtoey (KT)			2×40 to 3×60	
Klongwatsing (WG)			2×60 to 3×60	
Krunai (KU)		1×40+ 1×(40) to 2×60	2×60 to 3×60	
Lardplakao (LK)				1×60 to 2×60
Lardprao (LP)	2×20 to 2×(40)+ 1×60			
Lumpini (LN)	4×40 to 3×40+ 1×60			
Mahamek (MM)	2×40+ 1×(40) to 3×60			
Mai-ad (MA)			2×40 to 1×40+ 1×60	1×40+ 1×60 to 2×60
Makasan (MS)	2×40 to 2×40+ 1×60			
Minburi (MB)		2×60 to 3×60		
Muangthong 1 (M1)	1×60 to 2×60			
Na-na (NN)		1×(40)+ 2×60 to 3×60		
Nongkham (NH)	1×40+ 1×60 to 2×60	2×60 to 3×60		
Nonthaburi (NR)	2×20+ 1×40 to 2×60	2×60 to 3×60		
Pakkred (PE)	2×40+ 1×60 to 3×60			

Table 6.3-8 Target for Distribution Substation System Program (5／7)

Description	Installation Capacity [MVA]			
	2001 (from 1996)	2006	2011	2016
Paknam (PN)	2×40 to 2×60	2×60 to 3×60		
Petchkasem (PS)		2×22.4+ 1×40 to 1×40+ 1×60		1×40+ 1×60 to 2×60
Phaisingto (PI)	1×40+ 2×60 to 3×60	3×60 to 4×60		
Poojao (PJ)				3×40 to 2×40+ 1×60
Prachachuen (PC)	2×40 to 1×40+ 1×60		1×40+ 1×60 to 1×40+ 2×60	
Prakanong (PK)				2×40 to 2×60
Ramintra (RT)		2×60 to 3×60		
Romklao (RK)			2×60 to 3×60	
Sailom (SM)				2×40 to 1×40+ 1×60
Samrong (SR)	2×40+ 1×60 to 3×60			
Samsen (SN)				3×40 to 2×40+ 1×60
Sansab (SS)		3×40 to 2×40+ 1×60		2×40+ 1×60 to 1×40+ 2×60
Sapanmai (SP)		2×60 to 3×60		
Silom (SL)				2×40 to 1×40+ 1×60
South Bangkok (SK)	2×20 to 1×60			
South Thonburi (ST)		2×60 to 3×60		
Srithanya (YA)		1×(40) to 2×60	2×60 to 3×60	
Suansom (SO)	2×40 to 2×60		2×60 to 3×60	
Surawong (SU)	3×40 to 1×40+ 2×60	1×40+ 2×60 to 3×60		
Thanontok (TT)	1×40 to 2×60		2×60 to 3×60	
Wangpetchaboon (WB)	2×40 to 3×60			
Watlieb (WL)				3×40 to 4×40
Bangkae (BE)	1×40 to 1×(40)+ 1×60	1×(40)+ 1×60 to 3×60		
Bangson (BZ)	1×(40) to 2 ×60			2×60 to 3×60
Bearing (RI)	1×60 to 2×60		2×60 to 3×60	
Ekamai (EM)	1×(40) to 1×(40)+ 2×60			
Ekburi (EB)	1×60 to 2×60			2×60 to 3×60

Table 6.3-8 Target for Distribution Substation System Program (6/7)

Description	Installation Capacity [MVA]			
	2001 (from 1996)	2006	2011	2016
Huamak (HA)		1×60 to 2×60		2×60 to 3×60
Intamara (IN)		2×60 to 3×60		
Jangrom (JR)		1×(40) to 2×60	2×60 to 3×60	
Khotor (KO)	1×60 to 3×60			
Klongmahasawad (KH)			2×60 to 3×60	
Lardkrabang (LB)			2×60 to 3×60	
Muangthong 3 (M3)	1×60 to 2×60			2×60 to 3×60
Nonsee (NS)			2×60 to 3×60	
Pradipat (PP)			2×60 to 3×60	
Sainamtip (SA)	1×60 to 3×60			
Sanambinnam (SB)		2×60 to 3×60		
Saorahong (RG)		1×60 to 2×60		
South Bangplee (OB)	1×60 to 2×60			
Srieiam (SE)	2×60 to 3×60			
Surasak (UK)	1×(40) to 2×60			
Taweewattana (TW)	1×60 to 2×60			
Thonburirom (TR)	1×(40) to 2×(40)			
Tungsonghong (TH)			2×60 to 3×60	
Yenarkart (YK)		2×60 to 3 ×60		
Bangbor (AB)	1×60 to 2×60			
Bangjak (JK)	1×(40) to 1×(40)+1×60	1×(40)+1×60 to 3×60		
Bangkradee (KD)			2×60 to 3×60	
Bangshan (BH)	1×60 to 2×60		2×60 to 3×60	
Banmai (MI)				2×60 to 3×60
Dindaeng (DD)			2×60 to 3×60	
Ekachai (EC)	1×(40) to 2×60		2×60 to 3×60	
Ghoaklang (GK)	1×60 to 2×60	2×60 to 3×60		

Table 6.3-8 Target for Distribution Substation System Program (7／7)

Description	Installation Capacity [MVA]			
	2001 (from 1996)	2006	2011	2016
Jangwatana (JW)	1×60 to 2×60	2×60 to 3×60		
Jatujag (JJ)			2×60 to 3×60	
Kaset (KE)			2×60 to 3×60	
Klongkum (KG)			2×60 to 3×60	
Klongprapa (KL)	1×60 to 2×60		2×60 to 3×60	
Mitr-udom (MU)		1×40 to 2×60	2×60 to 3×60	
Muangthong 4 (M4)				2×60 to 3×60
Muangthong 7 (M7)				2×60 to 3×60
Nanglerng (NL)		2×40 to 3×40		3×40 to 4×40
Patanakarn (TA)		2×60 to 3×60		
Prawes (PW)				2×60 to 3×60
Prompong (RP)			2×60 to 3×60	
Samyarn (YN)			2×60 to 3×60	
Satorn (SH)			2×60 to 3×60	
Shimplee (HP)			2×60 to 3×60	
Trokchan (TC)		2×(40) to 3×60		
Tubyao (TY)				2×60 to 3×60
Watkampaeng (WK)			2×60 to 3×60	
Asoke (AK)			2×60 to 3×60	
Banghuasae (HS)			2×60 to 3×60	
Klongpume (GP)				2×60 to 3×60
Land & House (LH)			2×60 to 3×60	
Sananikom (DM)				2×60 to 3×60
Srinakarin (IR)				2×60 to 3×60
Watdeedod (WD)				2×60 to 3×60

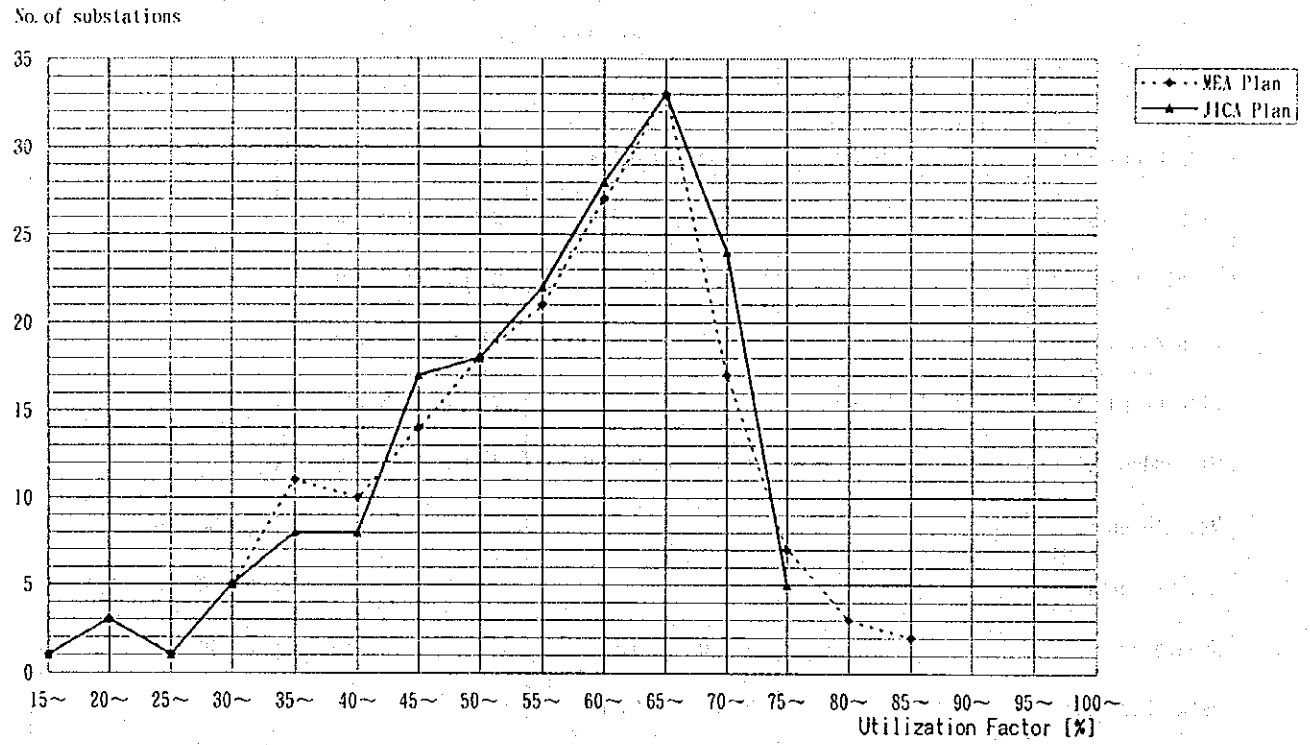


Fig 6.3-3 Distribution Substation Utilization Factor (Planning Year=2001)

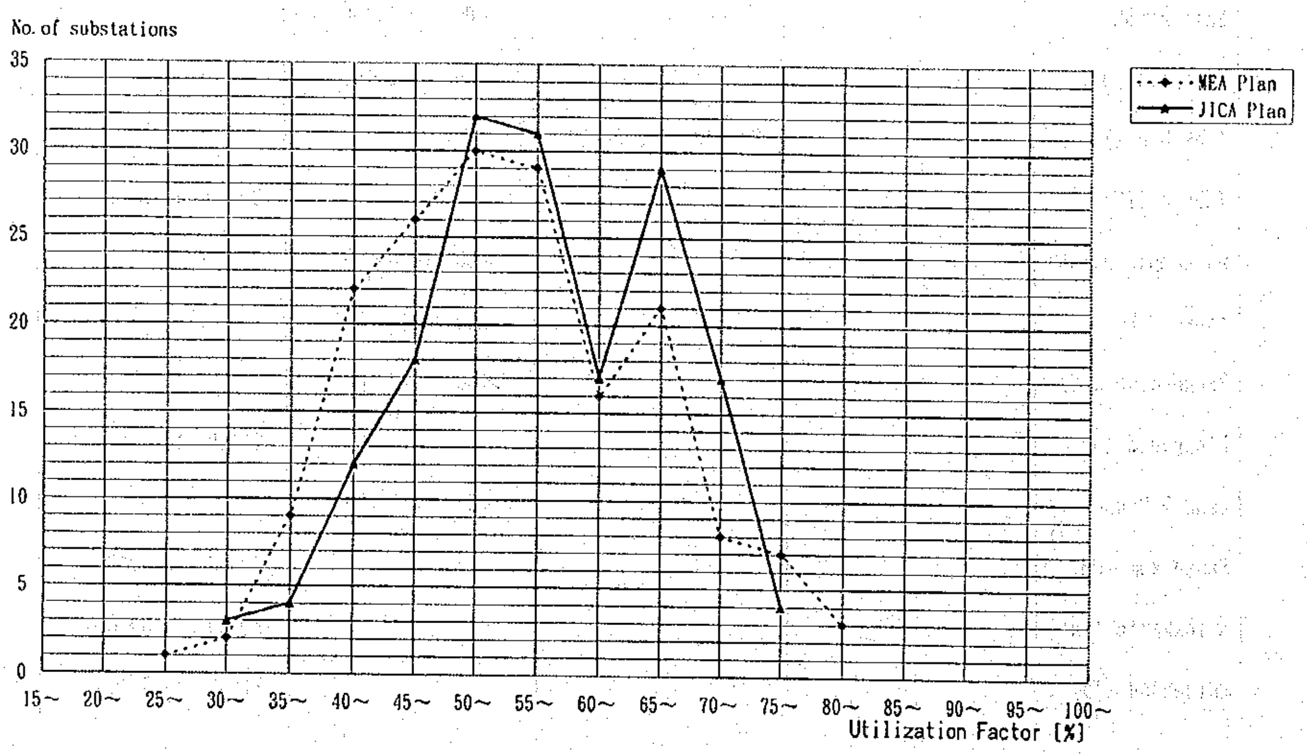


Fig 6.3-4 Distribution Substation Utilization Factor (Planning Year=2006)

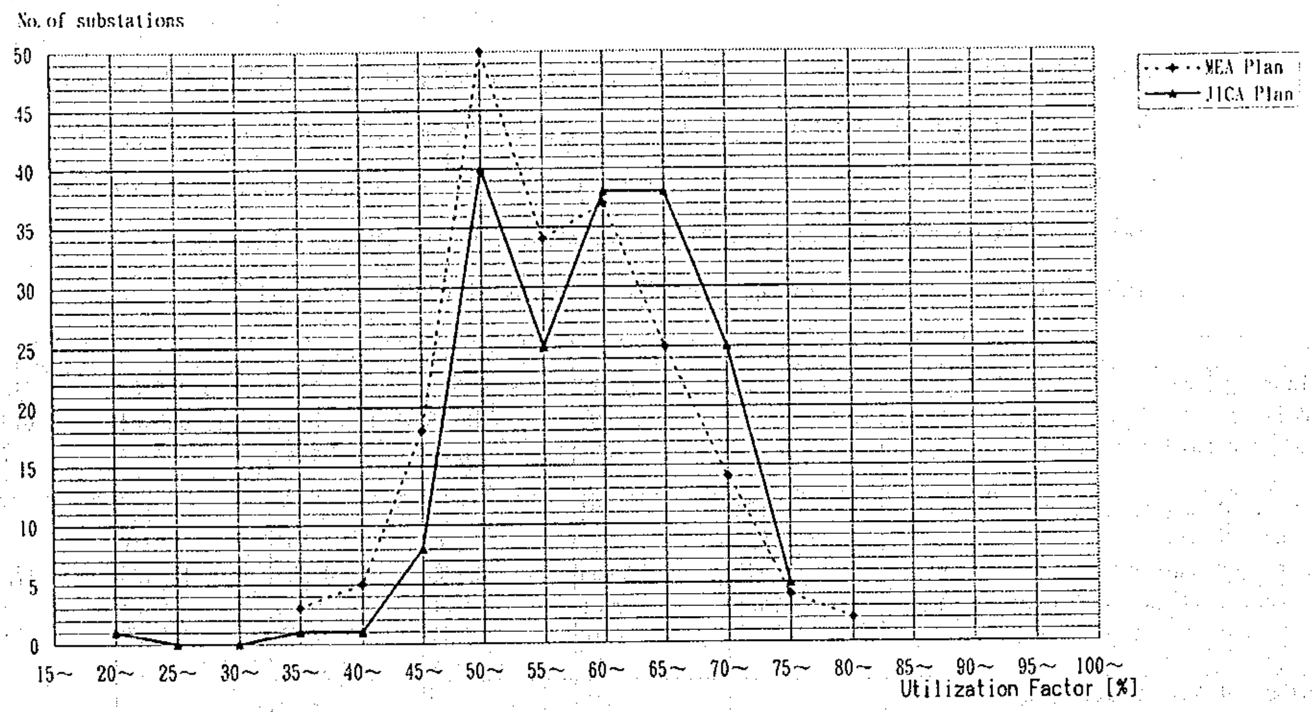


Fig 6.3-5 Distribution Substation Utilization Factor (Planning Year=2011)

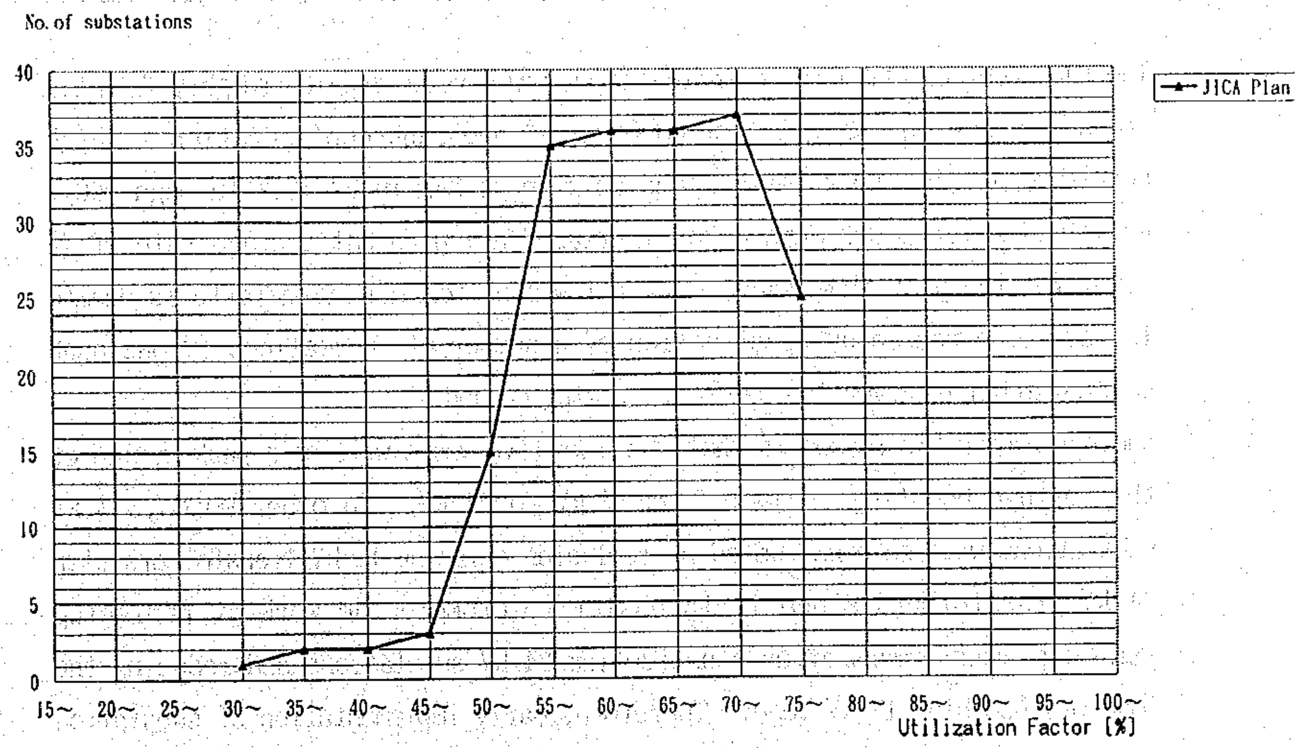


Fig 6.3-6 Distribution Substation Utilization Factor (Planning Year=2016)