IV-2 Amount of Investment and Expense

1. Amount of Investment

(1) Investment in Expansion of Facilities

a. Investment in expansion of distribution system

Annual investment in expansion of distribution system and the investment converted to present value are divided into as below:

- o Distribution substation
- o Subtransmission line
- o High voltage distribution line

And these are computed by electronic computer. Tables IV-5 and IV-6 give the results.

Investment in the far term (10 years) is appreciably greater than the investment in the near term. The reason for this phenomena is that more distribution substations are to be built in the far term and price escalation which is estimated at 8% annually.

b. Investment in expansion of upper stream system

Investment in terminal substation in the metropolitan area, 230 kV transmission line and sub-terminal substations in outskirt of the metropolitan area is given in Table IV-7 and the present value of the investment is given in Table IV-8.

Of this total investment, investment in 230 kV underground transmission line amounts to a sizeable.

c. Investment in expansion of lower stream system

According to growth of demand, investment in expansion of lower stream system will be increased. This investment is given in Tables IV-7 and IV-8.

(2) Policy guided investment

As policy guided investment, an amount for semi-insulated conductor, the same for the near term, has been included, and is shown in Tables IV-7 and IV-8. The amount of this investment is relatively small but can be modified by policy decision.

(3) Investment in renewal of function of facilities

This investment is given in Tables IV-7 and IV-8.

(4) Other investment

Investment of vehicle and testing equipment, etc. is given in Tables IV-9 and IV-10.

(5) Amount of investment

Amount of investment in the 20 years period is given in Tables IV-7 and IV-8. In the far term (last 10 years) the amount of investment is approximately 48,370 million Bahts, and this amount converted into present value is approximately 13,180 million bahts.

Trends of annual investment is shown in Fig. IV-6.

2. Amount of Expense

The amount of expense corresponding to the above mentioned investment is given in Tables IV-9 to IV-12.

Table IV-5 Amount of Investment - Far Term (Detail)

Unit : Million baht

Year	Substation			Transmission line			Distribution line		
	Distribution SS	Upper system	Renewal	Sub-TL	Upper system	Renewal	High voltage DL	Lower system DL	Semi-insulated DL
'82 ~ '91	861	167	1,311	360	563	403	978	7,836	(306) 113
'92 ~ '96	1,256	956	1,309	477	2,679	364	1,467	8,595	(252) 160
'97 ~ 2001	3,570	265	2,174	1,114	794	856	3,484	16,044	(261) 248
'92 ~ 2001	4,826	1,221	3,483	1,591	3,473	1,220	4,951	24,639	(513) 408
TTL	5,687	1,388	4,794	1,952	4,036	1,623	5,929	32,475	(819) 521

SS : Substation, TL : Transmission line, DL : Distribution line

( ) : Semi-insulated conductor length m cct·km

Table IV-6 Present Value of Amount of Investment - Far Term (Detail)

Unit : Million baht

Year	Substation			Transmission line			Distribution line		
	Distribution SS	Upper system	Renewal	Sub-TL	Upper system	Renewal	High voltage DL	Lower system DL	Semi-insulated DL
'82 ~ '91	603	74	806	257	249	246	654	4,830	70
'92 ~ '96	441	334	449	172	928	131	509	2,941	55
'97 ~ 2001	804	72	495	259	215	195	788	3,645	57
'92 ~ 2001	1,245	406	945	431	1,143	326	1,297	6,585	112
TTL	1,848	480	1,751	688	1,392	572	1,950	11,416	182

Table IV-7 Amount of Investment - Far Term

Unit : Million baht

Year	Substation	Transmi-ssion line	Distribution line	Vehicle & equipment	TTL
'82 ∿ '91	2,339	1,326	8,927	880	13,472
'92 ∿ '96	3,521	3,520	10,222	945	18,209
'97 ∿ 2001	6,010	2,764	19,776	1,609	30,159
'92 ∿ 2001	9,530	6,284	29,998	2,555	48,367
TTL	11,869	7,611	38,925	3,435	61,840

Table IV-8 Present Value of Amount of Investment - Far Term

Unit : Million baht

Year	Substation	Transmi-ssion line	Distribution	Vehicle & equipment	TTL
'82 ∿ '91	1,483	752	5,554	538	8,327
'92 ∿ '96	1,224	1,231	3,505	324	6,284
'97 ∿ 2001	1,371	669	4,490	367	6,897
'92 ∿ 2001	2,596	1,900	7,994	691	13,180
TTL	4,079	2,652	13,548	1,228	21,507

Fig. Ⅳ-6 Amount of Investment of Each Year

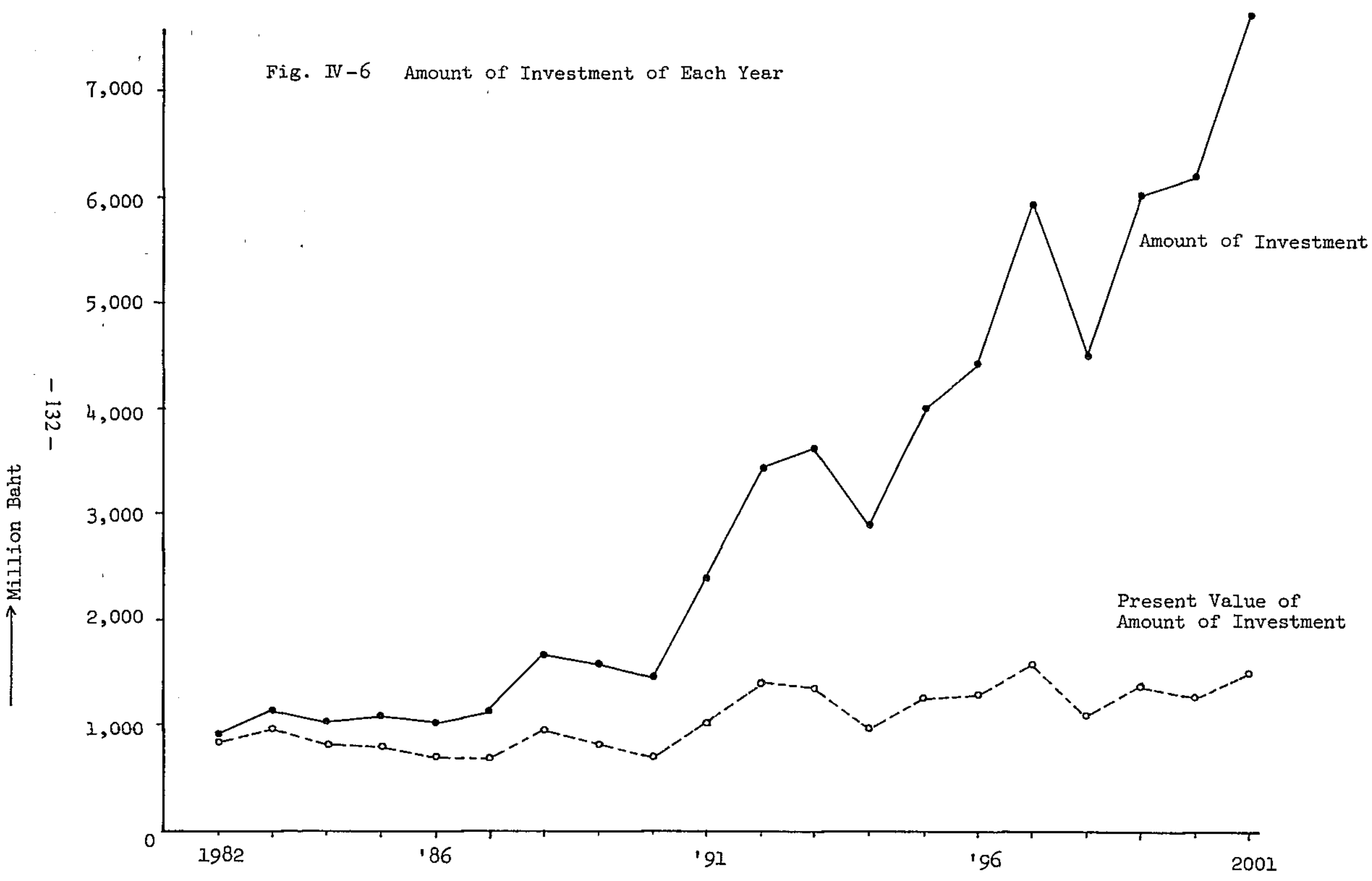


Table IV-9 Amount of Expense - Far Term
(Detail)

Unit : Million baht

	Substation			Transmission line			Distribution line		
	Distri-bution SS	Upper system	Renewal	Sub-TL	Upper system	Renewal	High voltage DL	Lower system DL	Semi-insulated DL
'82 ∿ '91	829	25	936	310	73	246	872	5,807	85
'92 ∿ '96	1,237	559	1,547	446	1,373	423	1,440	9,859	161
'97 ∿2001	3,027	1,049	2,898	977	2,622	812	3,379	19,769	325
'92 ∿2001	4,264	1,608	4,445	1,423	3,995	1,235	4,819	29,628	486
TTL	5,093	1,633	5,381	1,733	4,068	1,481	5,691	35,435	571

Table IV-10 Present Value of Amount of Expense - Far Term
(Detail)

Unit : Million baht

	Substation			Transmission line			Distribution line		
	Distri-bution SS	Upper system	Reneway	Sub-TL	Upper system	Renewal	High voltage DL	Lower system DL	Semi-insulated DL
'82 ∿ '91	487	11	525	183	32	136	510	3,266	48
'92 ∿ '96	420	188	528	153	461	145	487	3,357	55
'97 ∿2001	681	243	659	221	608	184	763	4,483	74
'92 ∿2001	1,101	431	1,187	374	1,069	329	1,250	7,840	129
TTL	1,588	442	1,712	557	1,101	465	1,760	11,106	177

Table IV-11 Amount of Expense - Far Term

Unit : Million baht

Year	Substation	Transmission line	Distribution line	Vehicle & equipment	Distribution loss	TTL
'82 ~ '91	1,790	629	6,764	903	1,044	11,129
'92 ~ '96	3,343	2,242	11,460	1,158	1,342	19,944
'97 ~ 2001	6,974	4,411	23,473	3,014	2,473	40,346
'92 ~ 2001	10,317	6,653	34,933	4,572	3,814	60,290
TTL	12,107	7,282	41,697	5,475	4,858	71,418

Table IV-12 Present Value of Amount of Expense - Far Term

Unit : Million baht

Year	Substation	Transmission line	Distribution line	Vehicle & equipment	Distribution loss	TTL
'82 ~ '91	1,023	351	3,824	506	622	6,325
'92 ~ '96	1,136	759	3,899	531	458	6,783
'97 ~ 2001	1,583	1,013	5,320	685	561	9,162
'92 ~ 2001	2,719	1,772	9,219	1,215	1,019	15,945
TTL	3,742	2,123	13,043	1,721	1,641	22,270

IV-3 Power Flow, Short Circuit Capacity and Reliability Studies

1. Power Flow Studies

Results of calculation of power flow during the period 1996 to 2001 are shown in Figs. IV-7 and IV-8.

The required length of the transmission lines have been restrung with TAAC and therefore, the power flow capacity of each line has been enlarged creating no problem in respect of power flow.

2. Short Circuit Capacity Studies

Figs. IV-9 and IV-10 are impedance maps of the system in 1996 and 2001. Because of the expansion of EGAT's power system, the impedance of the power source side has dropped, and consequently has enlarged the short circuit capacity. There will be 4 terminal substations at which the short circuit capacity on the 69 kV side will exceed 4,000 MVA and almost approach 5,000 MVA. If the short circuit capacity is predicted to exceed 5,000 MVA, it will become necessary to segregate the 69 kV bus and operate the 69 kV system independently. It may also become necessary to study the possibility of raising the impedance of 230 kV/69 kV transformers. Tables IV-13 and IV-14 give the short circuit capacity at the 69 kV side of each terminal substation and each distribution substation.

3. Reliability studies

At the time of 1 bank fault, the average service interruption to customer is 0.635 hour/year. There is no degradation of reliability which means that the facility expansion program has been properly prepared. Table IV-15 gives the power interchange factor of each substation and Table IV-16 gives the interchange factor of each distribution substation.

Average annual service interruption time to customer for outage of distribution feeders are 0.88 H/year-customer (1996) and 0.76 H/year-customer (2001).

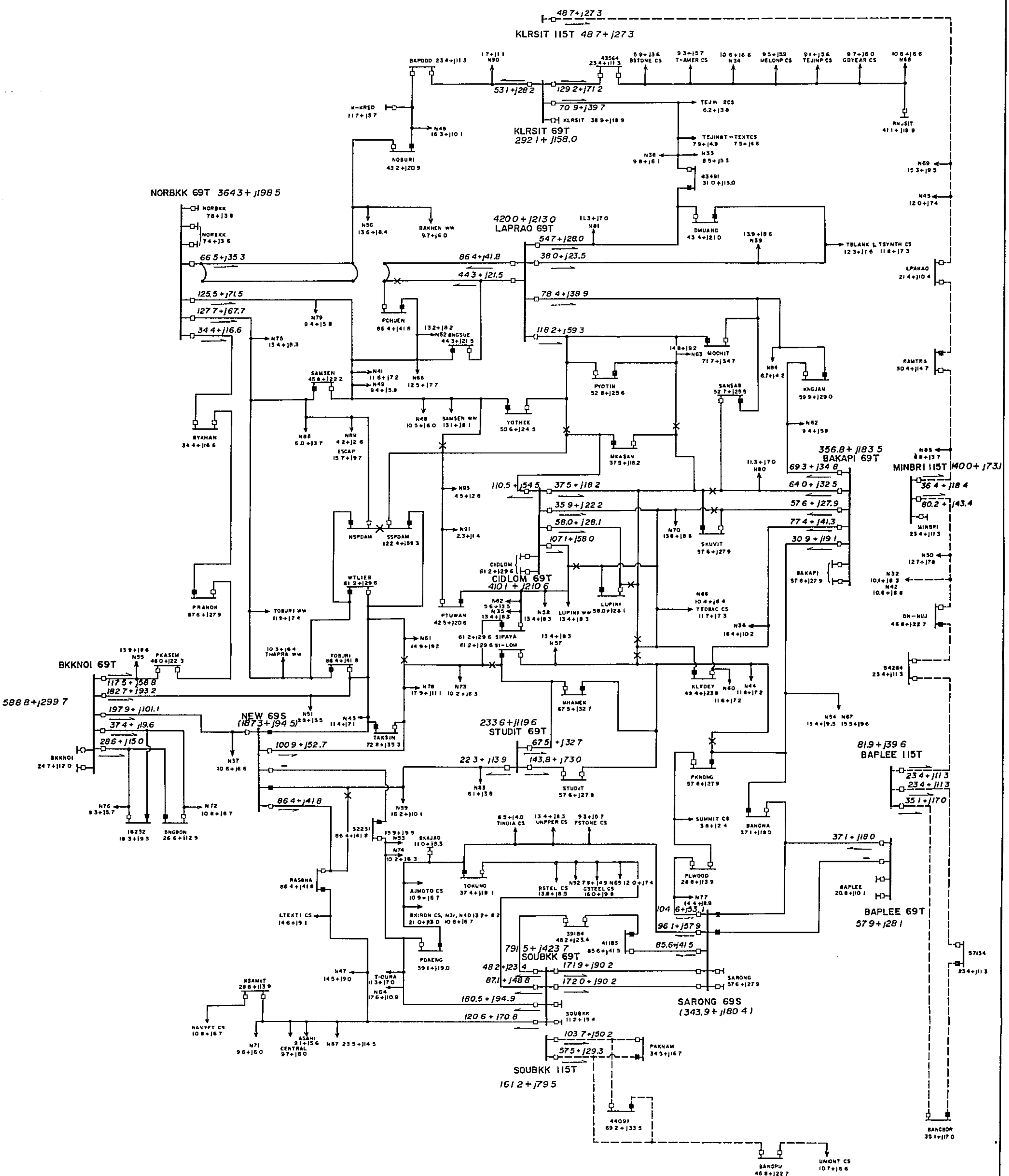


FIG. IV-7

POWER FLOW DIAGRAM YEAR 1996

LEGEND

SYMBOL	DESCRIPTION
■, X	NORMLLY OPEN
□	NORMALLY CLOSE

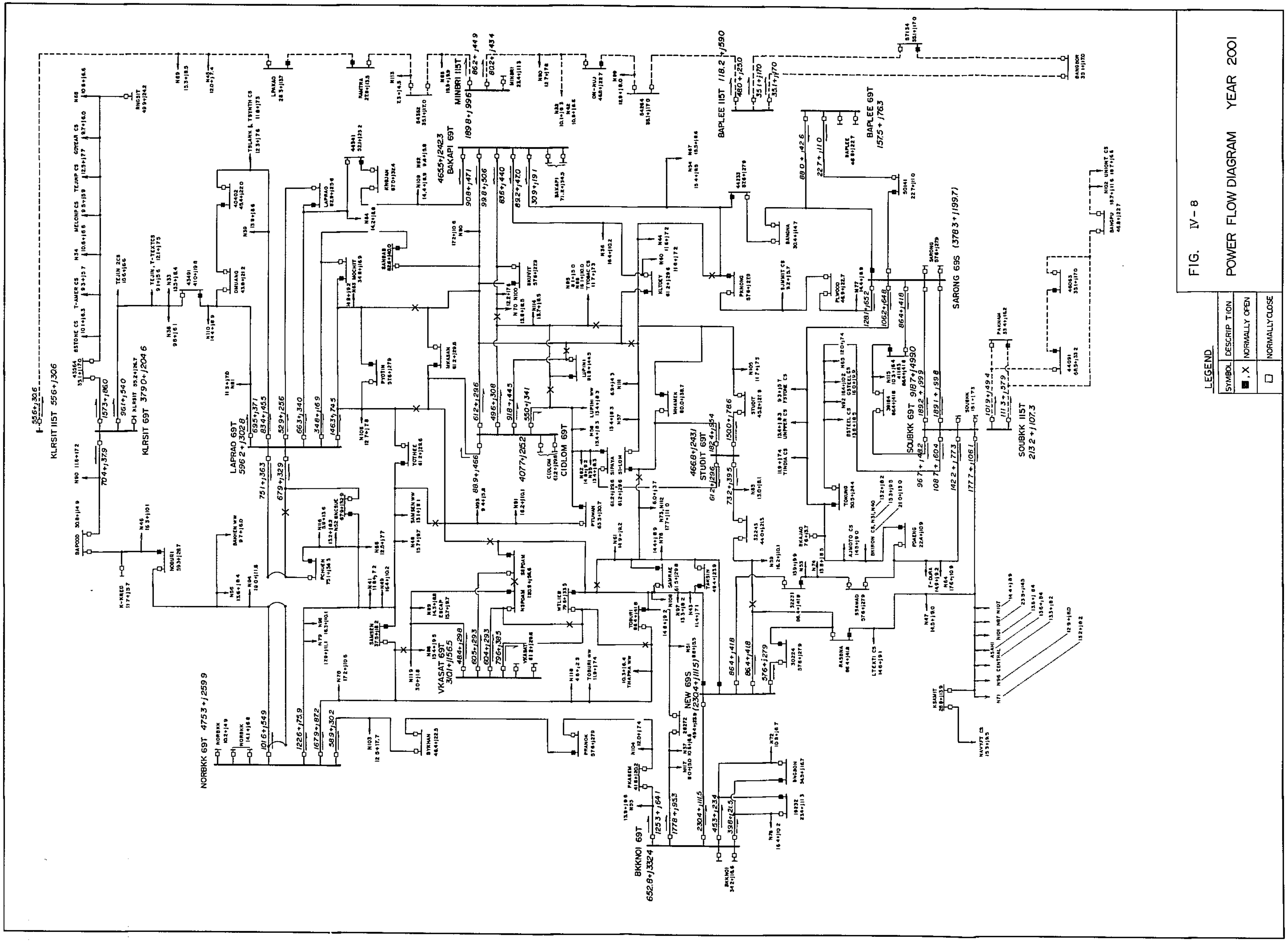


FIG. IV-8
POWER FLOW DIAGRAM YEAR 2001
LEGEND
SYMBOL
DESCRIPTION
NORMALLY OPEN
NORMALLY CLOSE
KLRSIT 115T
KLRSIT 69T
LAPRAO 69T
NORBKK 69T
BAKAPI 69T
MINBRI 115T
BAPLEE 115T
BAPLEE 69T
SARONG 69S
SOUBKK 69T
SOUBKK 115T
CIDLOM 69T
STUDIT 69T
VKASAT 69T
NEW 69S
BKKNOI 69T

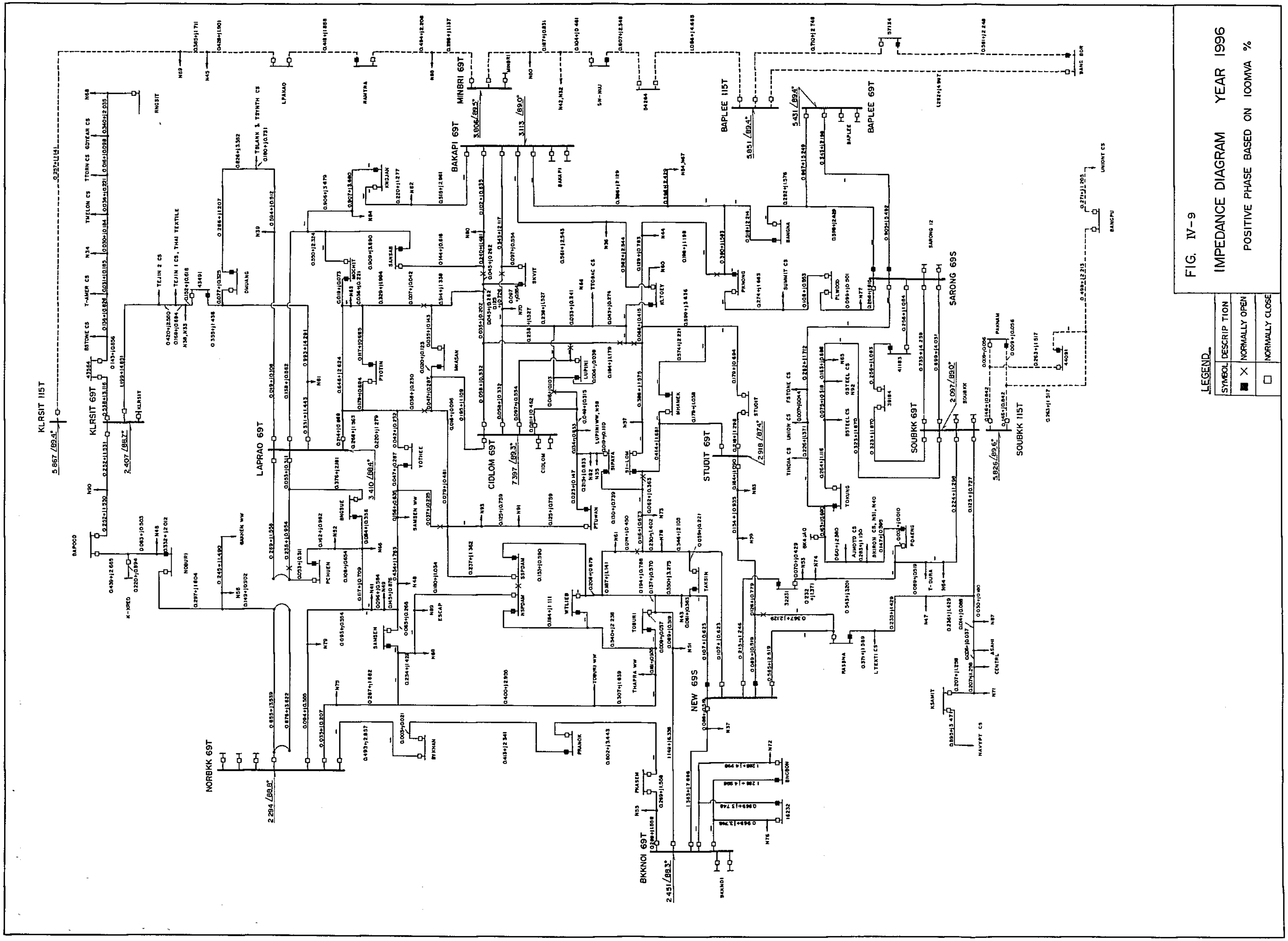


FIG. IV-9
IMPEDANCE DIAGRAM YEAR 1996
POSITIVE PHASE BASED ON 100MVA %

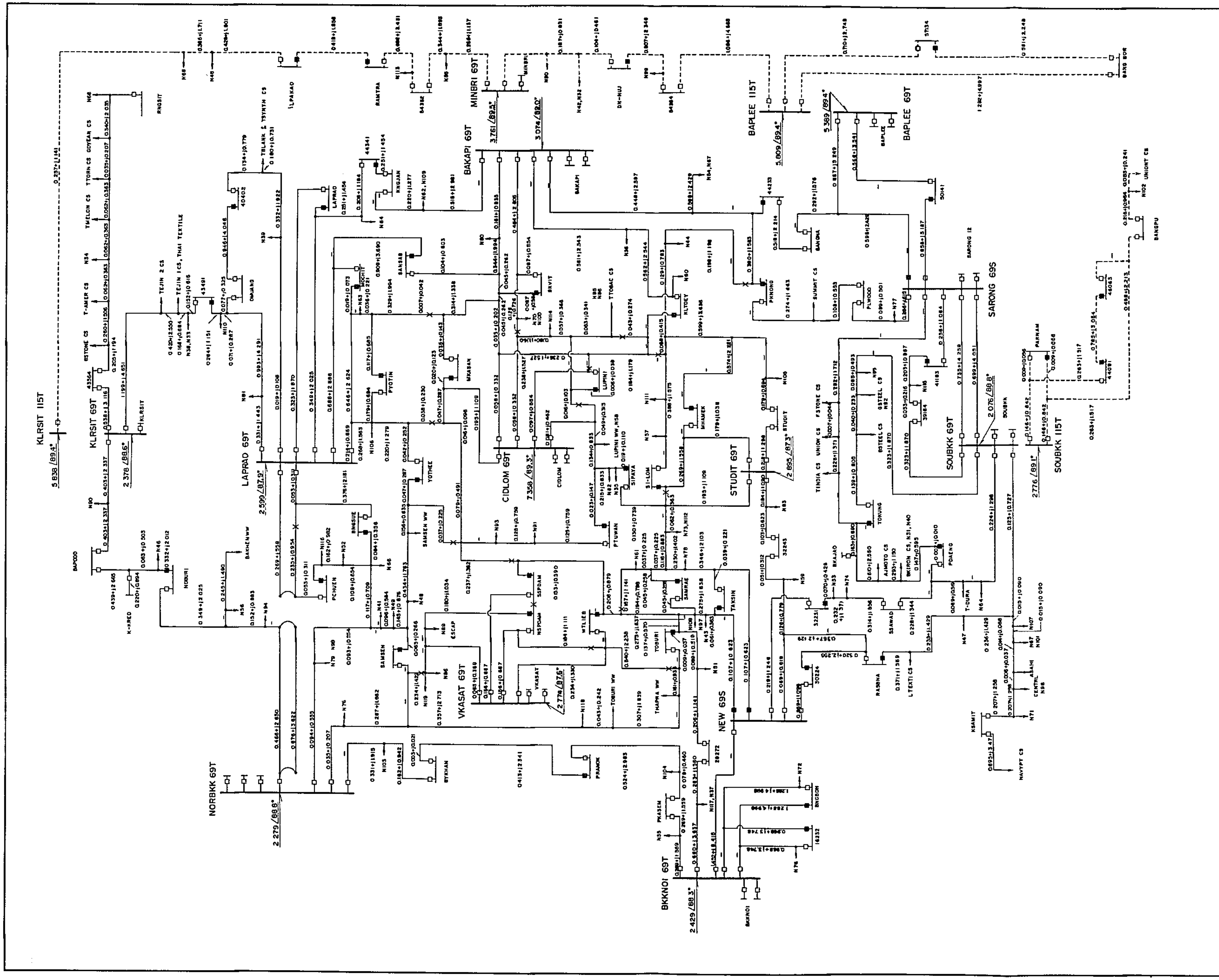


FIG. IV-10

IMPEDANCE DIAGRAM YEAR 2001

POSITIVE PHASE BASED ON 100MVA %

LEGEND

SYMBOL	DESCRIPTION
■ X	NORMALLY OPEN
□	NORMALLY CLOSE

Tabel Ⅳ-13 Fault Level at Terminal Substation - Far Term

Unit : MVA

Substation	'91	'96	2001	Remark
North BKK	4,318	4,360	4,388	
BKK Noi	3,067	4,080	4,116	
S.BKK (69KV)	4,235	4,768	4,818	
" (115KV)	1,710	1,720	3,600	
Bangplee (69KV)	1,830	1,841	1,855	
" (115KV)	1,700	1,710	1,720	
K.Rangsit (69KV)	4,065	4,155	4,205	
" (115KV)	1,690	1,700	1,710	
Lard Prao	2,900	2,930	3,850	
Bangkapi	3,172	3,212	3,253	
Chidlom	1,345	1,352	1,359	
T.Satupradit	—	3,430	3,454	
T.Visutkasat	—	—	3,604	
Minburi	—	2,628	2,659	

(Note) Three phase fault.

Table IV-14 Fault Level at Distribution Substation - Far Term

Unit : MVA

Substation	'91	'96	2001	Remark
North BKK	4,318	4,360	4,388	
Klongkred	1,091	1,097	933	
Bangyeekhan	1,923	1,931	1,936	
Klong Sanpasamit	1,688	1,760	1,767	
Pechkasem	1,561	1,786	1,792	
North BKK	4,318	4,360	4,388	
Prapradaen	2,380	2,538	2,552	
Rasburana	649	738	733	
Thonburi	923	1,060	1,000	
Taksin	750	845	1,035	
Bangkok Noi	3,067	4,080	4,116	
Bangkrajao	1,252	1,240	1,243	
Bangbon	1,195	1,320	1,324	
Pran Nok	1,010	1,100	1,103	
Suksawad	-	-	1,898	
Samray	-	-	1,037	
28272	-	-	1,300	
32231	1,080	1,111	818	
30224	-	-	828	
16232	-	1,591	1,597	
Rangsit	1,014	998	859	
Klong Rangsit	4,065	4,155	4,205	
43564	-	1,800	1,809	
Lumpini	1,251	1,257	1,263	
Makasan	1,056	1,058	1,065	
Sapandam	1,448	1,500	2,725	

(Note) Three phase fault

Fault Level at Distribution Substation - Far Term

Unit : MVA

Substation	'91	'96	2001	Remark
Pathumwan	913	917	920	
Silom	868	938	979	
Watlieb	845	855	2,429	
Yothee	1,340	1,348	1,512	
Bangkapi	3,172	3,212	3,253	
Bangna	809	812	815	
Bangsue	2,217	1,688	1,954	
Donmuang	1,040	1,043	1,138	
Klong Jan	1,189	1,354	1,356	
Mahamek	709	2,527	2,536	
Mochit	1,566	1,576	1,805	
Nontaburi	1,454	1,459	1,477	
Plywood	1,608	1,578	1,583	
Prachacuen	2,245	1,889	2,228	
Prakanong	1,246	1,165	1,168	
Samsen	1,931	1,939	1,785	
Samrong	2,452	2,385	2,397	
Sansab	1,691	1,703	1,506	
Satupradit	868	2,364	2,378	
South BKK	4,235	4,768	4,818	
Tangkung	1,560	1,611	1,814	
Bangpood	1,802	1,820	1,407	
Sukhumvit	1,711	1,722	1,547	
Sipraya	999	1,003	2,100	
Chidlom	1,345	1,352	1,359	
Paholyotin	1,510	1,520	1,731	
Klongtoey	1,201	1,207	1,217	
Visutkasat	-	-	3,604	

Fault Level at Distribution Substation - Far Term

Unit : MVA

Substation	'91	'96	2001	Remark
Lardprao	-	-	2,228	
40402	-	-	1,838	
32243	-	-	2,162	
44233	-	-	688	
44341	-	-	1,364	
41183	-	1,887	1,899	
39184	2,355	2,510	2,524	
43491	930	901	904	
Paknam	1,481	1,486	2,718	
Bangpu	955	957	1,350	
Bangplee	1,830	1,841	1,855	
Onnuj	965	1,958	1,975	
Ramintra	792	1,390	970	
Ladplakao	931	936	938	
Minburi	-	2,628	2,659	
Bangbor	912	914	918	
44091	1,216	1,219	1,940	
46063	-	-	1,704	
54264	-	945	949	
54352	-	-	1,466	
50141	-	-	1,117	
57134	-	1,149	1,164	

Table IV-15 Annual Average Time of Interruption - Far Term

Unit : hour

Substation	Annual average time			Remark
	'91	'96	2001	
North BKK	1.04	1.04	1.05	
Klongkred	0.99	0.96	0.91	
Bangyekhan	0.64	0.63	0.63	
Klong Sanpasamit	0.64	0.64	0.64	
Pechkssem	0.64	0.64	0.64	
North BKK	0.63	0.63	0.63	
Prapradaen	0.65	0.64	0.66	
Rasburana	0.63	0.64	0.63	
Thonburi	0.62	0.62	0.62	
Taksin	0.63	0.63	0.63	
Bangkok Noi	0.71	0.70	0.70	
Bangkrajao	0.63	0.63	0.63	
Bangbon	0.66	0.66	0.66	
Pran Nok	0.69	0.64	0.64	
Suksawad			0.64	
Samray			0.62	
28272			0.64	
32231	0.63	0.63	0.64	
30224			0.64	
16232		0.71	0.71	
Rangsit	0.67	0.67	0.67	
Klong Rangsit	0.71	0.71	0.71	
43564		0.66	0.67	
Lumpini	0.56	0.56	0.56	
Makasan	0.56	0.56	0.56	
Sapandam	0.56	0.56	0.56	
Pathumwan	0.56	0.56	0.56	
Silom	0.59	0.58	0.58	
Watlieb	0.56	0.57	0.56	
Yothee	0.59	0.59	0.60	
Bangkapi	0.63	0.63	0.63	

Annual Average Time of Interruption - Far Term

Unit : hour

Substation	Annual average time			Remark
	'91	'96	2001	
Bangna	0.64	0.64	0.64	
Bangsue	0.63	0.63	0.63	
Donmuang	0.64	0.64	0.64	
Klong Jan	0.64	0.64	0.64	
Mahamek	0.63	0.63	0.63	
Mochit	0.63	0.63	0.63	
Nontaburi	0.63	0.64	0.64	
Plywood	0.64	0.64	0.63	
Prachacuen	0.63	0.63	0.63	
Prakanong	0.63	0.63	0.63	
Samsen	0.63	0.63	0.63	
Samrong	0.64	0.65	0.65	
Sansab	0.60	0.60	0.60	
Satupradit	0.63	0.63	0.63	
South BKK	0.67	0.68	0.68	
Tangkung	0.63	0.63	0.63	
Bangpood	0.70	0.71	0.71	
Sukhumvit	0.62	0.62	0.65	
Sipraya	0.56	0.56	0.56	
Chidlom	0.56	0.56	0.56	
Paholyotin	0.63	0.63	0.63	
Klongtoey	0.62	0.62	0.62	
Visutkasat			0.58	
Lardprao			0.63	
40402			0.63	
32243			0.63	
44233			0.63	
44341			0.63	
41183		0.63	0.63	
39184	0.63	0.63	0.63	
43491	0.64	0.64	0.64	

Annual Average Time of Interruption - Far Term

Unit : hour

Substation	Annual average time			Remark
	'91	'96	2001	
Paknam	0.66	0.66	0.63	
Bangpu	0.71	0.71	0.71	
Bangplee	0.73	0.75	0.71	
Onnuj	0.71	0.71	0.71	
Ramintra	0.71	0.71	0.70	
Ladplakao	0.67	0.76	0.76	
Minburi		0.71	0.71	
Bangbor	0.71	0.71	0.71	
44091	0.65	0.66	0.64	
46063			0.71	
54264		0.71	0.71	
54352			0.71	
50141			0.71	
57134		0.71	0.71	
TTL	0.635	0.636	0.636	

Table IV-16 Interchange Factor at 1 Transformer Fault - Far Term

Substation	Interchange factor			Remark
	'91	'96	2001	
North BKK	0.08	0.08	0.08	
Klongkred	0.12	0.14	0.17	
Bangyekhan	1.0	1.0	1.0	
Klong Sanpasamit	1.0	1.0	0.94	
Pechkssem	1.0	1.0	1.0	
North BKK	1.0	1.0	1.0	
Prapradaen	1.0	1.0	1.0	
Rasburana	1.0	1.0	1.0	
Thonburi	1.0	1.0	1.0	
Taksin	1.0	1.0	1.0	
Bangkok Noi	1.0	1.0	1.0	
Bangkrajao	1.0	1.0	1.0	
Bangbon	1.0	1.0	1.0	
Pran Nok	0.46	0.99	1.0	
Suksawad			0.98	
Samray			1.0	
28272			1.0	
32231	1.0	1.0	1.0	
30224			1.0	
16232		1.0	1.0	
Rangsit	1.0	1.0	1.0	
Klong Rangsit	1.0	1.0	1.0	
43564		1.0	1.0	
Lumpini	1.0	1.0	1.0	
Makasan	1.0	1.0	0.97	
Sapandam	1.0	1.0	1.0	
Pathumwan	1.0	1.0	1.0	
Silom	1.0	1.0	1.0	
Watlieb	1.0	0.72	1.0	
Yothee	1.0	1.0	1.0	
Bangkapi	1.0	1.0	1.0	

Interchange Factor at 1 Transformer Fault - Far Term

Substation	Interchange factor			Remark
	'91	'96	2001	
Bangna	1.0	1.0	1.0	
Bangsue	1.0	1.0	1.0	
Donmuang	1.0	1.0	1.0	
Klong Jan	1.0	1.0	1.0	
Mahamek	1.0	1.0	1.0	
Mochit	1.0	1.0	1.0	
Nontaburi	1.0	1.0	1.0	
Plywood	0.93	0.73	1.0	
Prachacuen	0.98	1.0	1.0	
Prakanong	1.0	1.0	1.0	
Samsen	1.0	1.0	1.0	
Samrong	0.84	0.69	0.64	
Sansab	1.0	1.0	1.0	
Satupradit	1.0	0.95	1.0	
South BKK	0.55	0.50	0.46	
Tangkung	1.0	1.0	1.0	
Bangpood	1.0	1.0	1.0	
Sukhumvit	1.0	1.0	1.0	
Sipraya	1.0	1.0	1.0	
Chidlom	1.0	1.0	0.93	
Paholyotin	1.0	1.0	1.0	
Klongtoey	1.0	1.0	0.94	
Visutkasat			1.0	
Lardprao			1.0	
40402			1.0	
32243			1.0	
44233			1.0	
44341			1.0	
41183		1.0	1.0	
39184	1.0	1.0	1.0	
43491	1.0	1.0	1.0	

Interchange Factor at 1 Transformer Fault - Far Term

Substation	Interchange factor			Remark
	'91	'96	2001	
Paknam	1.0	1.0	1.0	
Bangpu	1.0	1.0	1.0	
Bangplee	0.64	0.53	1.0	
Onnuj	1.0	1.0	1.0	
Ramintra	1.0	1.0	1.0	
Ladplakao	0.66	0.31	0.31	
Minburi		1.0	1.0	
Bangbor	1.0	1.0	1.0	
44091	1.0	1.0	1.0	
46063			1.0	
54264		1.0	1.0	
54352			1.0	
50141			1.0	
57134		1.0	1.0	

IV-4 When Load Varies from Projected Load

1. Case Study

In the "MEA Load Forecast for 1982 to 2001" a sensitivity analysis was made for demand when the GDP indicate a plus or minus 10% fluctuation. Results of this sensitivity analysis reveal that in the year 2001, a plus 10% GDP growth will result in +16.6% load growth and a minus 10% GDP growth will result in −14.7% load growth in the MEA system.

In the study of distribution system expansion program when demand variates against projected demand, the above mentioned values were used for 2 case studies.

Case 8 – when the distribution load is plus 16.6% of the projected load in 2001 (upper value)
Case 9 – when the distribution load is minus 14.7% of the projected load in 2001 (lower value)

In order to study the facility expansion and investment programs, it is necessary to make the study for each year. Therefore, the upper (B) and lower (C) values of demand shown in Fig. IV-11 were used in the study. The computed upper and lower distribution loads are given in Table IV-17. In the year 2001 the loads are as follow:

upper load – 4,967 MVA
lower load – 3,634 MVA
projected load – 4,260 MVA

2. Facility Expansion Program

Under the conditions of Case 2 in the table below, calculations of distribution system expansion program for variation of loads were made by computer, and the results are given in Tables IV-18 and IV-19. In the year 2001, the number of distribution substations under variation of loads is shown in Table IV-20. In comparison to Case 2, for the other 2 cases there is a plus or minus 8 substations.

Table IV-20 Number and Capacity of Distribution Substations

Year	Case 2	Case 8	Case 9
Number			
1991	57	60	57
2001	76	84	68
Capacity (MVA)			
1991	3,990	4,250	3,990
2004	6,540	7,320	5,460

In the scheduling of construction of distribution substations, using Case 2 as the basis, there would be a plus and minus of approximately 2 years for Case 8 and Case 9. Table IV-21 gives the substations that are required and not required as a result of variation of demand against projected demand.

In Table IV-18, under column "Case 8", 2 distribution substations identified as 33291 and 31304 are to be constructed in the center of the city (Area A) near terminal substations. Therefore, these 2 distribution substations are to be of feeder transformer type.

3. Amount of Investment and Expense

Amount of investment and expense of Case 8 and Case 9 are compared in relation to Case 2, and the results are given in Tables IV-22 to IV-25.

Amount of investment as compared to Case 2 reveal that in Case 8 the investment is approximately 9,290 million Bahts greater (converted to present value – approximately 3,050 million Bahts), and in Case 9 the investment is approximately 8,170 million Bahts less (converted to present value – approximately 2,940 million Bahts).

Fig.Ⅳ-11 DISTRIBUTION LOAD (MVA)

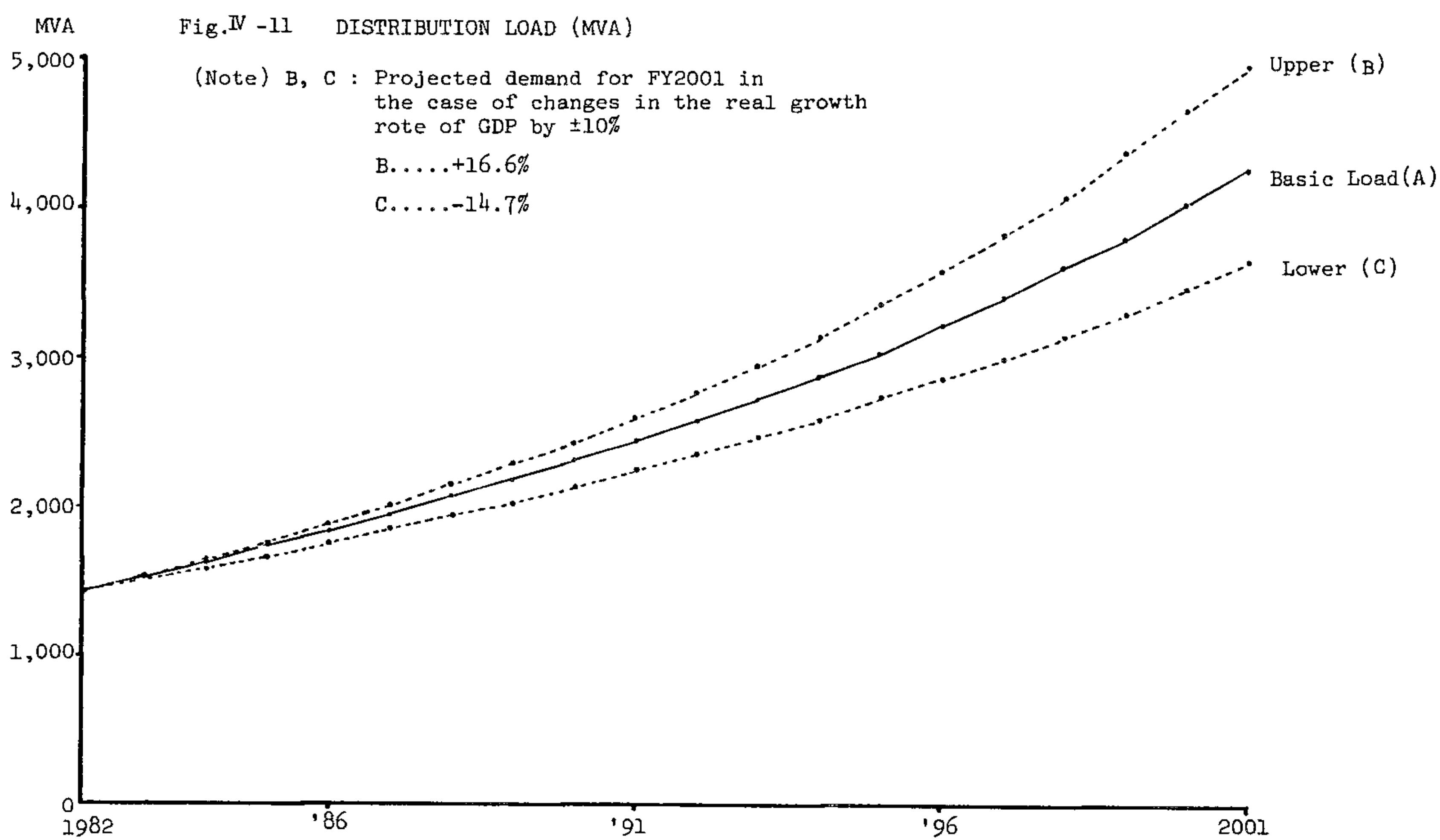


Table IV- 17 Calculation of Upper & Lower Distribution Load

Year	Basic load (MVA) A	Upper load		Lower load	
		(MVA) B	B/A	(MVA) C	C/A
'82	1,449	1,449	1.0	1,449	1.0
'83	1,540	1,546	1.004	1,521	0.988
'84	1,636	1,650	1.009	1,596	0.976
'85	1,737	1,760	1.013	1,675	0.964
'86	1,834	1,878	1.024	1,758	0.959
'87	1,947	2,004	1.029	1,846	0.948
'88	2,064	2,138	1.036	1,937	0.938
'89	2,177	2,281	1.048	2,033	0.934
'90	2,300	2,434	1.058	2,134	0.928
'91	2,432	2,597	1.068	2,240	0.921
'92	2,572	2,771	1.077	2,351	0.914
'93	2,720	2,957	1.087	2,467	0.907
'94	2,877	3,155	1.097	2,590	0.900
'95	3,039	3,366	1.108	2,718	0.894
'96	3,210	3,592	1.119	2,853	0.889
'97	3,396	3,832	1.128	2,994	0.882
'98	3,592	4,089	1.138	3,143	0.875
'99	3,801	4,363	1.148	3,299	0.868
2000	4,024	4,655	1.157	3,462	0.860
2001	4,260	4,967	1.166	3,634	0.853

(Note) $B = 1.449 \times 1.067^n$

$C = 1.449 \times 1.0496^n$

Values of "n" are as follows :

	'82,	'83,	'84,	'85,	'86,	'87,	'88,	'89,	. . . . .	2001
n =	0,	1,	2,	3,	4,	5,	6,	7,		19

Table Ⅳ-18 Distribution Substation Expansion Program - Far Term (Case 8)

Unit : No. x MVA

Bloc No.	Substation	Capacity in 1991	Expansion			Capacity in 2001
			'92 ∿ '96	'97 ∿ 2001	TTL	
10	North BKK	1x40				1x40
	Klongkred	1x20				1x20
20	Bangyekhan	2x40				2x40
	Klong Sanpsamit	2x20				2x20
	Pechkasem	1x40 2x20				1x40 2x20
	North BKK	2x20				2x20
	Prapradaen	2x40				2x40
	Rasburana	2x40	+1x40		+1x40	3x40
	Thonburi	3x40				3x40
	Taksin	2x40	+1x40		+1x40	3x40
	Bangkok Noi	1x40 2x20				1x40 2x20
	Bangkrajao	2x10				2x10
	Bangbon	2x40				2x40
	Pran Nok	1x40	+2x40		+2x40	3x40
	Suksawad			new 2x40	+2x40	2x40
	Samray		new 2x40	+1x40	+3x40	3x40
	28272			new 3x40	+3x40	3x40
	32231	2x40	+1x40		+1x40	3x40
	30224			new 3x40	+3x40	3x40
	16264			new 2x20	+2x20	2x20
	16232		new 2x20		+2x20	2x20
30	Rangsit	2x40		+1x40	+1x40	3x40
	Klong Ransit	2x40	+1x40		+1x40	3x40
	43564	2x20		+1x20	+1x20	3x20
40	Lumpini	2x40		+1x40	+1x40	3x40
	Makasan	2x40		+1x40	+1x40	3x40
	Sapandam	4x40				4x40
	Pathumwan	2x40		+1x40	+1x40	3x40
	Silom	2x40				2x40
	Watlieb	2x40		+1x40	+1x40	3x40

Distribution Substation Expansion Program - Far Term (Case 8)

Unit : No. x MVA

Bloc No.	Substation	Capacity in 1991	Expansion			Capacity in 2001
			'92 ∿ '96	'97 ∿ 2001	TTL	
40	Yothee	2x40				2x40
	Bangkapi	2x40	+1x40		+1x40	3x40
	Bangna	2x40				2x40
	Bangsue	1x10	+2x40 -1x10	+1x40	+3x40 -1x10	3x40
	Donmuang	2x40				2x40
	Klong Jan	2x40	+1x40		+1x40	3x40
	Mahamek	3x40				3x40
	Mochit	2x40	+1x40		+1x40	3x40
	Nontaburi	1x40 1x20	+2x40 -1x20		+2x40 -1x20	3x40
	Plywood	1x20	+1x40	+1x40 -1x20	+2x40 -1x20	2x40
	Prachacuen	2x40	+1x40		+1x40	3x40
	Prakanong	2x40				2x40
	Samsen	2x40				2x40
	Samrong	2x40				2x40
	Sansab	2x40		+1x40	+1x40	3x40
	Satupradit	2x40	+1x40		+1x40	3x40
	South BKK	1x20		+2x40 -1x20	+2x40 -1x20	2x40
	Tangkung	2x40		+1x40	+1x40	3x40
	Bangpood	2x20		+1x20	+1x20	3x20
	Sukhumvit	2x40				2x40
	Sipraya	2x40				2x40
	Chidlom	2x40				2x40
	Paholyotin	2x40				2x40
	Klongtoey	2x40				2x40
	Visutkasat		new 2x40		+2x40	2x40
	Lardprao			new 2x40	+2x40	2x40
	Setsiri			new 2x40	+2x40	2x40
	33291			new 2x40	+2x40	2x40
	31304			new 2x40	+2x40	2x40
	40402			new 2x40	+2x40	2x40
	32243			new 2x40	+2x40	2x40
	44233			new 2x40	+2x40	2x40
	44341		new 2x40	+1x40	+3x40	3x40

Distribution Substation Expansion Program - Far Term (Case 8)

Unit : No. x MVA

Bloc No.	Substation	Capacity in 1991	Expansion			Capacity in 2001
			'92 ∿ '96	'97 ∿ 2001	TTL	
40	40263			new 2x40	+2x40	2x40
	41183	2x40	+1x40		+1x40	3x40
	39184	2x40	+1x40		+1x40	3x40
	43491	2x40		+1x40	+1x40	3x40
50	Paknam	2x40				2x40
	Bangpu	2x40				2x40
	Bangplee	1x40		+1x40	+1x40	2x40
	Onnuj	2x40				2x40
	Ramintra	2x40				2x40
	Ladplakao	1x40				1x40
	Bangping			new 2x40	+2x40	2x40
	Minburi		new 2x20	+1x20	+3x20	3x20
	Bangbor	3x20				3x20
	44091	2x40	+1x40		+1x40	3x40
	46063			new 3x20	+3x20	3x20
	54264	2x20	+1x20		+1x20	3x20
	54352			new 2x20	+2x20	2x20
	51221			new 2x20	+2x20	2x20
	50141		new 2x20	+1x20	+3x20	3x20
	57134		new 3x20		+3x20	3x20
	67042			new 2x20	+2x20	2x20
	Number of Substation	60	+7	+17	+24	84
	Total Capacity (MVA)	4,250	'96 5,420	2001 7,320		7,320
	Total Load (MVA)	2,597	'96 3,625	2001 4,968		4,967
	Utilizing factor (%)	61.1	'96 66.9	2001 67.9		67.9

Table IV- 19 Distribution Substation Expansion Program - Far Term (Case 9)

Unit : No. x MVA

Bloc No.	Substation	Capacity in 1991	Expansion '92 ∿ '96	Expansion '97 ∿ 2001	Expansion TTL	Capacity in 2001
10	North BKK	1x40				1x40
	Klongkred	1x20				1x20
20	Bangyekhan	2x40				2x40
	Klong Sanpsamit	2x20				2x20
	Pechkasem	1x40 2x20				1x40 2x20
	North BKK	2x20				2x20
	Prapradaen	2x40				2x40
	Rasburana	2x40	+1x40		+1x40	3x40
	Thonburi	2x40	+1x40		+1x40	3x40
	Taksin	2x40		+1x40	+1x40	3x40
	Bangkok Noi	1x40 2x20				1x40 2x20
	Bangkrajao	2x10				2x10
	Bangbon	2x40				2x40
	Pran Nok	1x40	+1x40		+1x40	2x40
	Samray			new 2x40	+2x40	2x40
	32231	2x40		+1x40	+1x40	3x40
	16232			new 2x20	+2x20	2x20
30	Rangsit	2x40				2x40
	Klong Ransit	2x40		+1x40	+1x40	3x40
	43564		new 2x20		+2x20	2x20
40	Lumpini	2x40				2x40
	Makasan	2x40				2x40
	Sapandam	4x40				4x40
	Pathumwan	2x40				2x40
	Silom	2x40				2x40
	Watlieb	2x40				2x40
	Yothee	2x40				2x40
	Bangkapi	2x40		+1x40	+1x40	3x40
	Bangna	2x40				2x40
	Bangsue	1x10	+1x40	+1x40 -1x10	-1x10 +2x40	2x40

Distribution Substation Expansion Program - Far Term (Case 9)

Unit : No. x MVA

Bloc No.	Substation	Capacity in 1991	Expansion			Capacity in 2001
			'92 ∿ '96	'97 ∿ 2001	TTL	
40	Donmuang	2x40				2x40
	Klong Jan	2x40		+1x40	+1x40	3x40
	Mahamek	2x40	+1x40		+1x40	3x40
	Mochit	2x40	+1x40		+1x40	3x40
	Nontaburi	2x20	+1x40 -1x20	+2x40 -1x20	+3x40 -2x20	3x40
	Plywood	1x20		+2x40 -1x20	+2x40 -1x20	2x40
	Prachacuen	2x40	+1x40		+1x40	3x40
	Prakanong	2x40				2x40
	Samsen	2x40				2x40
	Samrong	2x40				2x40
	Sansab	2x40				2x40
	Satupradit	2x40		+1x40	+1x40	3x40
	South BKK	1x20				1x20
	Tangkung	2x40				2x40
	Bangpood	2x20				2x20
	Sukhumvit	2x40				2x40
	Sipraya	2x40				2x40
	Chidlom	2x40				2x40
	Paholyotin	2x40				2x40
	Klongtoey	2x40				2x40
	Visutkasat			new 2x40	+2x40	2x40
	44341			new 2x40	+2x40	2x40
	41183		new 2x40	+1x40	+3x40	3x40
	39184	2x40		+1x40	+1x40	3x40
	43491	2x40				2x40
50	Paknam	2x40				2x40
	Bangpu	2x40				2x40
	Bangplee	1x40		+1x40	+1x40	2x40
	Onnuj	2x40				2x40
	Ramintra	2x40				2x40
	Ladplakao	1x40				1x40
	Minburi		new 2x20		+2x20	2x20

Distribution Substation Expansion Program - Far Term (Case 9)

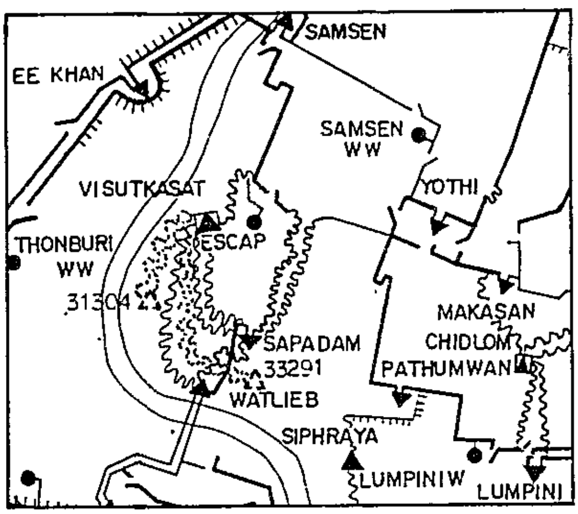
Unit : No. x MVA

Bloc No.	Substation	Capacity in 1991	Expansion			Capacity in 2001
			'92 ∿ '96	'97 ∿ 2001	TTL	
50	Bangbor	3x20				3x20
	44091	2x40	+1x40		+1x40	3x40
	46063			new 2x20	+2x20	2x20
	54264		new 2x20	+1x20	+3x20	3x20
	50141			new 2x20	+2x20	2x20
	57134			new 2x20	+2x20	2x20
	Number of Substation	57	+4	+7	+11	68
	Total Capacity (MVA)	3,990	'96 4,530	2001 5,460		5,460
	Total Load (MVA)	2,240	'96 2,853	2001 3,634		3,634
	Utilizing factor (%)	56.1	'96 63.0	2001 66.6		66.6

Table IV-21

Difference among Three Cases Selection of Distribution Substation

Bloc. No.	Substation	Case 2	Case 8	Case 9	Remark
20	Suksawad	0	0	-	
	28272	0	0	-	
	30224	0	0	-	
	16264	-	0	-	
40	Lardprao	0	0	-	
	Setsiri	-	0	-	
	33291	-	0	-	*
	31304	-	0	-	*
	40402	0	0	-	
	32243	0	0	-	
	44233	0	0	-	
	40263	-	0	-	
50	Bangping	-	0	-	
	54352	0	0	-	
	51221	-	0	-	
	67042	-	0	-	
TTL		8	16	0	



(Note)

* : Type of connection of subtransmission line is Feeder Transformer Type.

0 : selected by computer

- : not selected by computer

Table IV-22 Amount of Investment

Unit : Million baht

Year	Case 2	Case 8	Case 9
'82 ∿ '91	13,472	(+3,134) 16,606	(-1,696) 11,776
'92 ∿ 2001	48,367	(+6,157) 54,524	(-6,470) 41,897
TTL	61,840	(+9,289) 71,129	(-8,168) 53,672

Table IV-23 Present Value of Amount of Investment

Unit : Million baht

Year	Case 2	Case 8	Case 9
'82 ∿ '91	8,327	(+1,586) 9,913	(-952) 7,375
'92 ∿ 2001	13,180	(+1,465) 14,645	(-1,989) 11,191
TTL	21,507	(+3,051) 24,558	(-2,941) 18,566

Table IV-24 Amount of Expense

Unit : Million baht

Year	Case 2	Case 8	Case 9
'82 ∿ '91	11,129	(+1,178) 12,307	(-1,001) 10,128
'92 ∿ 2001	60,290	(+8,300) 68,590	(-9,007) 51,283
TTL	71,418	(+9,479) 80,897	(-10,007) 61,411

Table IV-25 Present Value of Amount of Expense

Unit : Million baht

Year	Case 2	Case 8	Case 9
'82 ∿ '91	6,325	(+594) 6,919	(-540) 5,785
'92 ∿ 2001	15,945	(+2,175) 18,120	(-2,401) 13,544
TTL	22,270	(+2,769) 25,039	(-2,941) 19,329

V. DEMAND FORECAST BY EACH MESH

V. DEMAND FORECAST BY EACH MESH

As a general rule, distribution substations located in a load center will result in the least energy loss. Therefore, it is essential to know where the center of load is in planning an optimum distribution system. For this purpose, MEA's supply territory was divided into meshes of 0.5 km x 0.5 km, 1 km x 1 km and 2 km x 2 km, and load forecasts for each mesh were made for the future years (1982 to 2001).

V-1 Method of Load Forecast for Each Mesh

Load forecast conducted by MEA is compiled in "MEA Load Forecast (1982 – 2001) dated August, 1980." The report estimates that the total demand on MEA's system in the year 2001 will be 30,099 GWH. (See Fig. V-1) The report also gives the planning area's projected demand in MWH. Based on the values projected by MEA, load forecasts for each mesh were made by us.

The projection flow for load forecast by each mesh is given in Fig. V-2, and a general description of the procedure taken is given below.

1. Projection of Large Power Demand

Load forecast of large power demand supplied at 69 kV or 115 kV (hereinafter called 69 kV customer demand) were made by using the actual value of 69 kV customer demand ratio (Rate 69*) in each of the Planning Area.

Note:* $\text{Rate 69} = \dfrac{\text{69 kV Customer (GWH)}}{\text{Medium and large business (GWH)}} \times 100\%$
(See Appendix 1 for details.)

2. Calculation of Distribution Demand

Deducting 69 kV customer demand from basic demand, the distribution demand supplied by MEA's distribution substations were calculated.

3. Conversion of kWH into kW

Distribution demand (kWH) in each Planning Area were converted* into kW (load), and growth rate of load (kW) was calculated for the period 1982 to 2001.

Note:* Conversion of kWH to kW by multiple regression method for details see Appendix 1.

4. Calculation of Future Loads

Actual loads (Report on Analysis of Existing Conditions – 1979) of each existing mesh were multiplied by kW increment factor of each Planning Area to arrive at the future load (1982 – 2001) of each mesh.

5. Addition of Special Loads

Projected loads of meshes with no load in 1979 and assumed future spot loads (industrial zone, housing district, etc.) were added to MEA's load projection data.

6. Calculation of kW of Large Power Demands

Loads (kW) were calculated by using actual annual load factors obtained from 69 kV customer demand (MWH).

The above calculations were performed by electronic computer, and a flow chart is given in Fig. V-3.

Fig V-1 MEA Load Forecast

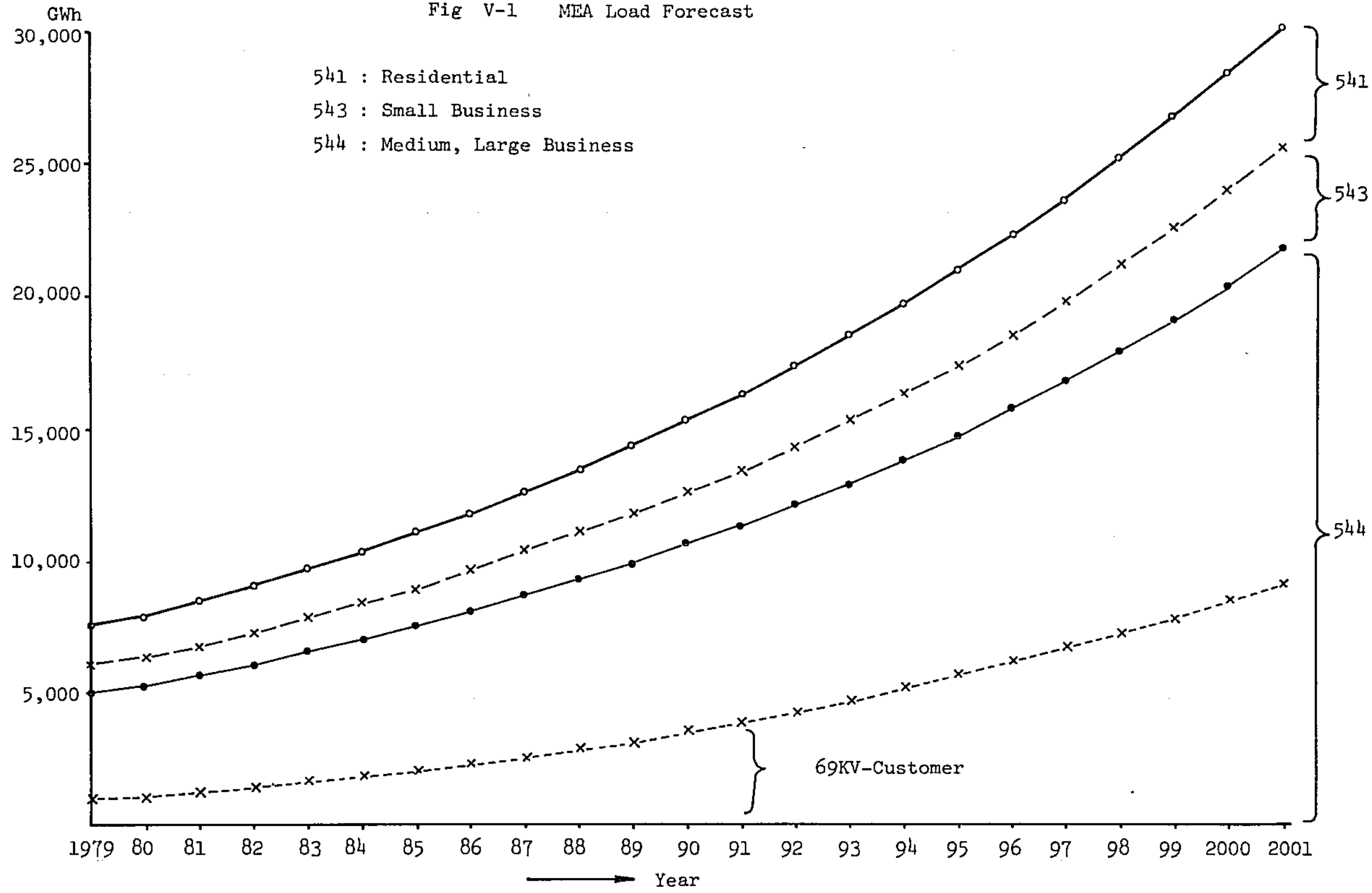
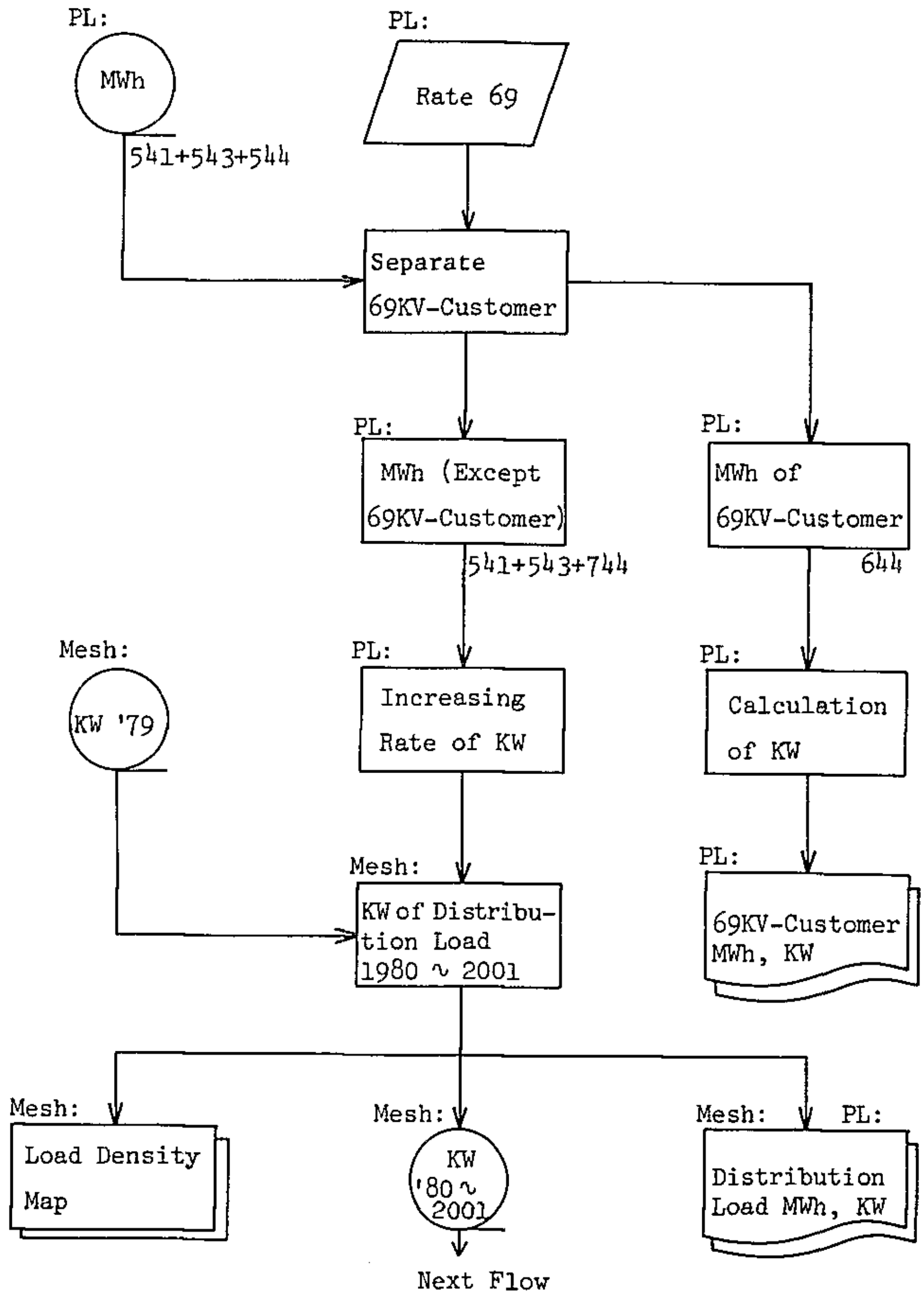


Fig.V-2 Projection Flow Chart



(Note)

PL : Each Planning Area

Mesh: Each Mesh

541 : Residential

543 : Small Business

544 : Medium and Large Business

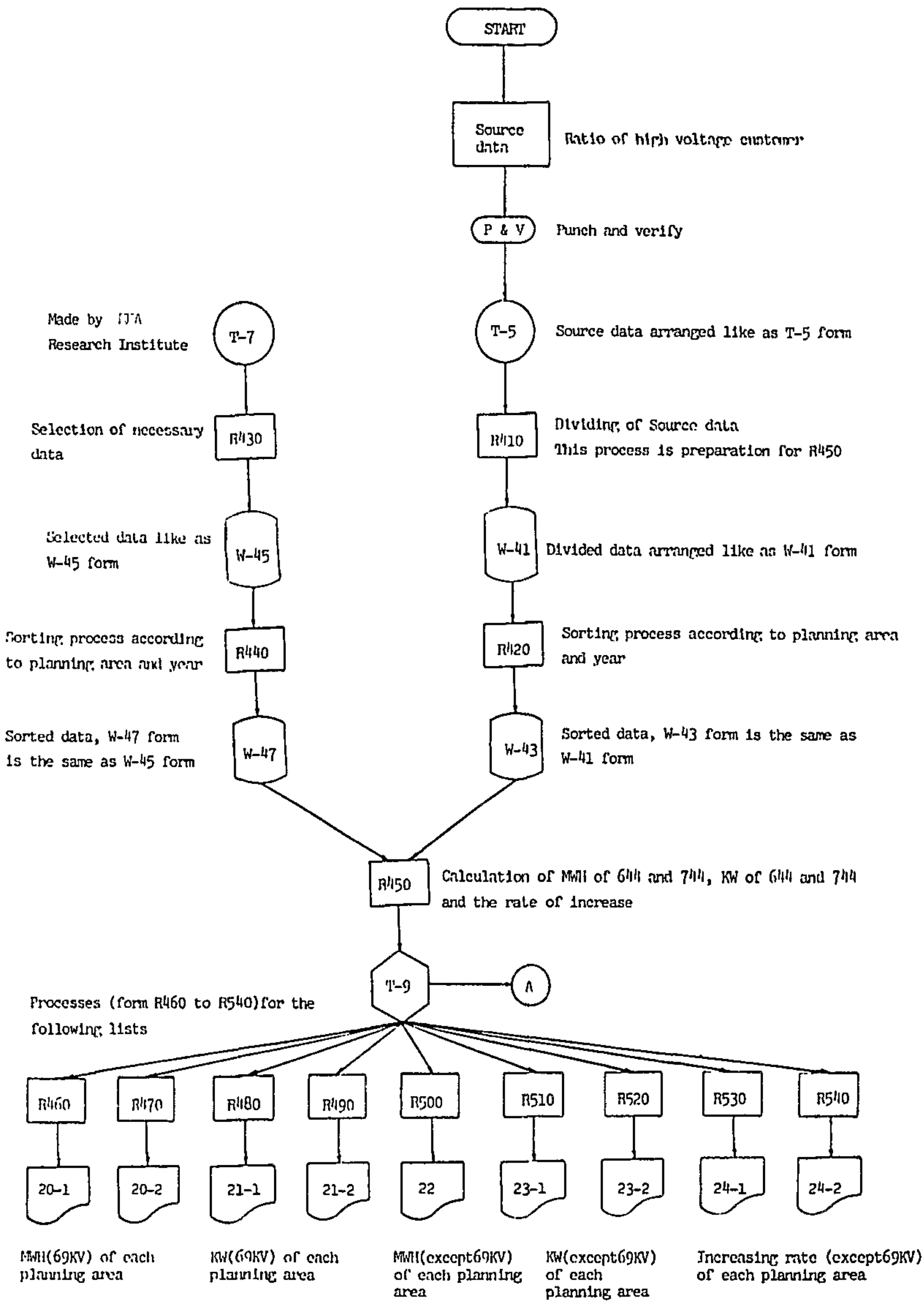
644 : 69KV-Customer

744 : Except 69KV-Customer

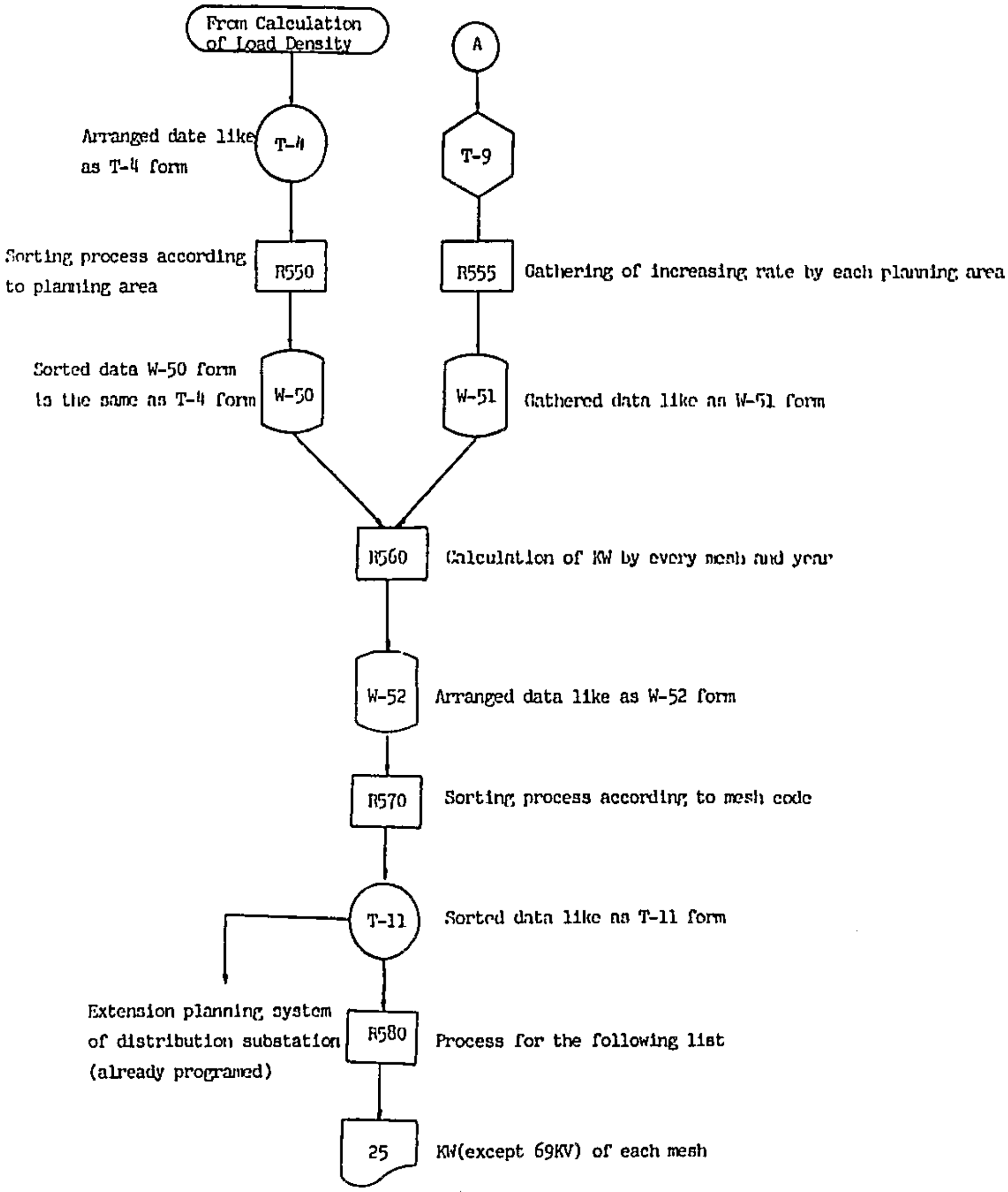
$$\text{Rate } 69 = \frac{644 \text{ MWh}}{544 \text{ MWh}} \times 100 \ \%$$

Fig. V-3 DEMAND DISTRIBUTION OF EACH MESH No.1

Prepared	Modified	Modified	Modified

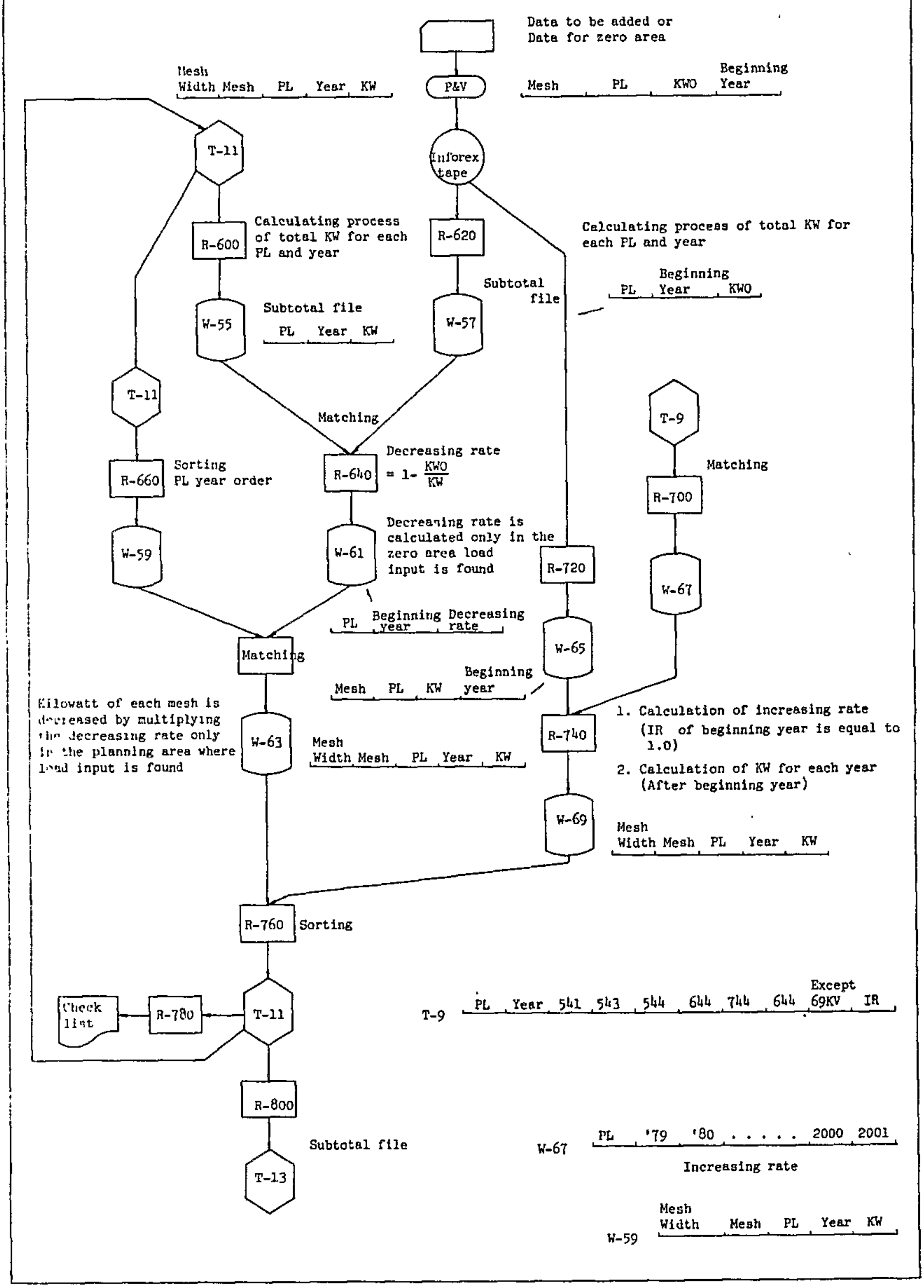


Prepared	Modified	Modified	Modified



Addition of Zero Area Load and Point Load

Prepared	Modified	Modified	Modified



V-2 Summary of Results of Load Projection

1. Total Load (kW)

Projected total load is summarized in Table V-1.

Table V-1 MEA's Total Load

Year	Distribution Load (MW)	69 KV Customer Load (MW)	Total (MW)
1982	1,304	255	1,559
1986	1,651	407	2,058
1991	2,189	676	2,865
1996	2,889	1,060	3,949
2001	3,834	1,562	5,396
2001/1982	2.9	6.1	3.5

The estimated total load on MEA's system in the year 2001 is 5,396 MW which is 3.5 times the estimated demand in 1982.

Distribution demand in the total demand is 3,834 MW (2.9 times the estimated demand in 1982). This value is the basis in planning MEA's distribution substation expansion program.

Total load in each year is given in Table V-2, Estimation of MEA's Load.

2. Load (kW) by Planning Area

Projected distribution loads by Planning Area are given in Table V-3-kW (Except 69 kV) of Each Planning Area – No. 1 and No. 2

Projected 69 kV customer loads by Planning Area are given in Table V-4-kW (69 kV) of Each Planning Area – No. 1 and No. 2.

3. Distribution Load by Mesh

A summary of the projected distribution load (kW) by mesh is shown in Table V-5. In the 20 years future, there will exist differences in load density between districts.

Table V-5 Distribution Load by Mesh

Mesh	Average Load Density (kW/km^2) in 1979	in 2001
0.5 km^2	8,200	21,200
1.0 km^2	1,100	4,100
2.0 km^2	80	320

The projected values of distribution load (kW) by mesh are shown in the output print "Output 25 – kW of Each Mesh (Except 69 kV)". And the following load density maps are the output prints of electronic computer.

MEA Load Density Map	(1982)	ZE9Q	4013, 4014
〃 〃 〃 〃	(1986)	ZE9Q	4015, 4016
〃 〃 〃 〃	(1991)	ZE9Q	4017, 4018
〃 〃 〃 〃	(2001)	ZE9Q	4019, 4022

The load density maps are filed on "ATTACHMENT OF THE 20-YEAR MASTER PLAN".

Table V-2 ESTIMATION OF MEA's LOAD

September	Distribution Load (A)	69 KV-Customer		TTL (A+B)
		Annual Max.	Convert to Sep.(B)	
'82	1,304	282	255	1,559
'83	1,386	316	285	1,671
'84	1,472	357	322	1,794
'85	1,563	397	358	1,921
'86	1,651	451	407	2,058
'87	1,752	499	450	2,202
'88	1,858	550	496	2,354
'89	1,959	614	554	2,513
'90	2,070	681	615	2,685
'91	2,189	749	676	2,865
'92	2,315	821	741	3,056
'93	2,448	902	814	3,262
'94	2,589	984	888	3,477
'95	2,735	1,076	971	3,706
'96	2,889	1,175	1,060	3,949
'97	3,056	1,275	1,151	4,207
'98	3,233	1,380	1,245	4,478
'99	3,421	1,491	1,346	4,767
2000	3,622	1,608	1,451	5,073
2001	3,834	1,731	1,562	5,396

(MW)

(Note)

$$\text{Diversity Factor} = \frac{\Sigma \text{ Annual Max. MW of 69 KV-Customer}}{\Sigma \text{ MW of 69 KV-Customer at System Peak}} = 1.108$$

Table V -3

***** OUT PUT 23-1 (2) ***** KW (EXCEPT 69KV) OF EACH PL AREA (NO.1) PAGE 001

YEAR	BNO	BS0	B00	D10	D20	D30	P L L10	A R E A L20	L30	MM1	MM2	M10	M20	TOTAL
1979	27135.7	11109.2	43131.2	43989.6	41548.2	31928.4	13096.0	53631.2	61084.1	47400.5	10638.6	21516.1	65958.3	472167.1
1980	27821.3	11615.0	46849.3	46269.4	44813.4	32074.0	13041.1	54251.0	56772.8	49088.5	10741.7	22635.7	70485.7	486458.9
1981	30888.1	12508.9	49144.8	48926.3	48407.3	34507.1	13808.3	57259.5	58220.2	53676.7	11414.1	25103.6	75900.4	519765.3
1982	34154.6	13506.6	53353.1	51679.8	52038.9	37016.7	14640.2	55607.5	59698.6	58559.2	12140.3	27748.3	81573.2	551717.0
1983	37630.5	14607.5	57684.1	54536.2	55757.0	39615.3	15539.9	57795.9	61213.5	63754.1	12923.3	30575.5	87522.7	589155.5
1984	41327.6	14165.4	62182.2	57514.5	59596.7	42309.8	16510.3	60101.9	62770.9	69285.8	13766.4	33594.4	93762.4	626888.3
1985	45253.9	14731.8	66871.8	60610.4	63613.9	45114.0	17552.7	62531.5	64389.3	75163.7	14668.4	36812.8	100318.4	667632.6
1986	49427.0	15307.1	71806.4	63856.3	67860.4	43893.9	18672.3	65094.9	66063.1	81405.8	15634.4	40241.0	107198.0	706460.6
1987	53855.9	15898.2	77029.3	67256.8	72376.3	46000.8	19873.2	67787.3	67798.3	88037.5	16667.5	43889.6	114446.9	750917.6
1988	58560.7	16510.6	82578.9	70806.2	77217.2	48185.2	21158.2	70635.4	69606.1	95086.3	17769.5	47771.3	122071.9	797957.5
1989	58883.6	17151.2	88508.9	74540.2	82434.9	50452.4	22530.6	73638.7	71499.5	95000.7	18944.7	51899.9	130112.1	835597.4
1990	62086.5	17834.7	94871.2	78461.9	88078.2	52808.3	23995.7	76818.7	73478.9	99735.7	20199.3	53081.4	138594.1	880044.6
1991	65388.9	18570.3	101691.0	82570.6	94185.2	55267.0	25558.3	80192.1	75555.7	104599.5	21534.7	56183.7	147557.9	928854.9
1992	68809.7	19371.0	109014.5	86881.1	100803.9	57837.4	27225.3	83764.1	77730.9	109623.6	22955.8	59395.8	157029.4	980442.5
1993	72387.2	20254.1	116894.4	91437.9	107966.6	60525.5	28999.9	87571.9	80027.4	114846.4	22697.4	62732.6	167048.7	1033390.0
1994	76131.9	21230.8	125352.5	96211.1	115698.7	63341.3	30888.5	91615.6	82446.5	120297.7	23633.5	66223.4	177641.5	1090713.0
1995	80090.3	22310.6	134422.2	101231.0	124050.0	66297.6	32898.6	95943.2	84999.3	126033.5	24595.2	69893.8	188874.7	1151640.0
1996	84282.3	23512.7	144135.9	106514.9	133044.7	69401.1	35034.3	100561.0	87705.5	132086.8	25588.9	73769.2	200780.4	1216417.7
1997	88757.4	24846.8	154530.1	112057.0	142701.4	72670.4	37307.9	105495.4	90576.3	138523.6	26617.5	77876.1	213391.1	1285351.0
1998	93544.8	26321.1	165628.3	117893.1	153054.5	76115.9	39723.0	110777.8	93618.6	145396.8	27689.9	82255.0	226747.5	1358766.3
1999	98678.6	27945.1	177464.1	124029.5	164123.5	79751.9	42290.0	116436.1	96861.7	152753.6	28814.5	86941.3	240928.2	1437018.1
2000	104203.4	29727.2	190057.8	130492.0	175952.0	83593.8	45016.3	122491.3	100313.4	160650.3	29995.2	91961.3	255954.0	1520408.0
2001	110159.5	31674.5	203461.4	137283.9	188561.8	87658.0	47911.9	128985.5	103978.3	169168.1	31247.6	97344.6	271875.8	1609310.9
**	469459.4	440710.4	2416663.4	1905049.7	253884.7	1276365.8	603272.5	1878987.5	1746408.9	2350174.4	460878.4	1259446.4	435773.3	21497074.8

***** OUT PUT 23-2 (2) ***** K W (EXCEPT 69KV) O F E A C H P L A R E A (NO.2)

YEAR	P10	P20	Q00	R00	S10	S20	P L S30	A R E A T10	T20	W10	W20	W30	TOTAL	ALL TOTAL
1979	33019.0	39446.4	95718.9	204675.2	12494.8	37820.7	38538.7	59048.8	40770.5	35516.3	30844.2	28838.6	656732.1	1128899.2
1980	33537.7	34184.6	98005.4	207027.4	13104.3	36626.1	38866.3	72257.7	40932.4	35720.0	31098.4	29010.3	670370.6	1156829.5
1981	35859.4	35947.9	103558.6	223014.6	13854.1	37590.8	40150.3	75045.0	43732.4	37516.8	32425.0	30342.3	709037.2	1228802.5
1982	38276.3	37849.3	109674.5	239775.8	14656.0	38634.1	41514.7	79804.9	46678.0	39460.1	33816.9	31791.3	751931.9	1303648.9
1983	40785.7	39892.4	116356.9	257337.0	15514.2	39757.7	42967.3	84634.9	49775.4	41549.2	35271.6	33362.8	797205.1	1386360.6
1984	43394.0	42073.8	123601.9	275778.8	16433.1	40964.1	44508.7	89595.0	53036.2	43789.1	36789.3	35051.5	845015.5	1471903.8
1985	46111.7	44397.1	131392.8	295183.5	17414.8	42261.6	46150.8	94732.7	56448.4	46197.3	38374.5	36863.9	895529.1	1563161.7
1986	48961.1	46862.2	139740.3	315586.9	14265.0	43649.8	47888.4	100099.7	60023.0	48768.8	40025.1	38812.5	944682.8	1651143.4
1987	51962.5	49481.9	148641.5	337099.4	15006.2	45132.3	49730.8	105768.3	63776.3	51517.2	41739.5	40890.0	1000745.9	1751663.5
1988	55145.7	52247.3	158128.1	359780.4	15787.1	46712.6	51677.8	111792.3	67720.4	54456.0	43525.4	43111.9	1060085.0	1858042.5
1989	58550.1	55173.9	168197.8	383705.8	16610.4	48392.1	53734.9	118222.2	71876.5	57582.6	45383.1	45475.7	1122905.1	1958502.5
1990	62205.4	58262.8	178880.7	408940.2	17481.4	50180.9	55916.2	125118.9	76254.0	60918.5	47317.0	47995.2	1189471.2	2069515.8
1991	66140.9	61520.6	190185.2	435591.4	18398.2	52076.2	58213.1	132518.2	80881.9	64466.9	49327.4	50668.8	1259988.8	2188843.7
1992	70400.7	64960.3	202160.4	463731.5	19365.5	54084.3	60641.1	140489.5	85781.6	68243.5	51427.8	53509.6	1334795.8	2315238.3
1993	75020.4	68589.0	214851.3	493495.9	20384.0	56213.4	63203.7	149041.2	90982.2	72251.0	53624.1	56525.2	1414181.4	2447571.4
1994	80032.3	72407.8	228233.0	524915.3	21453.2	58463.5	65905.7	158223.2	96508.8	76517.1	55922.3	59722.7	1498304.9	2589017.9
1995	85467.3	76435.3	242429.0	558148.9	22580.4	60842.7	68757.9	168071.9	102391.5	76666.4	58327.7	63113.5	1583232.5	2734872.5
1996	91337.5	80684.1	257447.6	593273.2	23766.4	58928.6	71767.0	178613.0	108662.6	80075.9	60866.3	66704.8	1672127.0	2888544.7
1997	97697.1	85161.6	273346.4	630443.5	25015.4	60744.1	74934.7	189861.2	115346.4	83639.1	63539.8	70508.2	1770237.5	3055588.5
1998	104562.2	89882.8	290164.0	669740.6	26325.2	62646.7	78276.6	201859.7	122483.5	87368.2	66369.5	74537.7	1874216.7	3232983.0
1999	111941.8	94873.1	307978.0	711310.4	27705.6	64639.6	81802.5	214608.5	130099.7	91276.9	69364.1	78802.5	1984402.7	3421420.8
2000	119866.5	100126.5	326823.0	755295.9	29158.8	66731.6	85514.1	228178.6	138235.4	95376.8	72553.1	83315.1	2101175.4	3621583.4
2001	128368.6	105681.7	346790.6	801836.1	30685.7	68917.6	89433.5	242586.6	146917.6	99699.2	75952.0	88092.2	2224961.4	3834272.3
**	578643.9436142.4452305.9145687.7447459.8172011.1350094.8120172.0889314.7448572.9133884.1187046.3												29361335.6	50858410.4

Table V-4

*** OUT PUT 21-1 (1) ******* K W (69KV) O F E A C H P L A R E A (NO.1) PAGE 001

YEAR	BNO	D50	B00	D10	D20	D30	L10	L20	L30	MM1	MM2	M10	M20	TOTAL
						P L AREA								
1979				46916	253								10389	57558
1980				49679	5001				4998				9783	69461
1981			4999	52580	7698				5899				11327	82503
1982			7937	55486	10729			5000	6882				12980	99014
1983			11224	58428	14076			6303	7964				14742	112737
1984		4998	14831	61402	17725			7729	9140				16615	132440
1985		7275	18750	64453	21649			9286	10416				18605	150434
1986		9868	22946	67561	25827	5000		10970	11803				20717	174692
1987		12776	27402	70748	30249	6139		12796	13302				22946	196358
1988		15997	32100	74047	34891	7350		14763	14917				25302	219367
1989	4999	19528	37012	77438	39744	8641		16875	16649	4998			27785	253669
1990	7248	23348	42126	80942	44792	10010		19130	18503	7120		5000	30390	288609
1991	9739	27449	47437	84582	50040	11462		21529	20485	9482		7435	33122	322762
1992	12477	31813	52952	88367	55488	12997		24084	22597	12079		10157	35982	358993
1993	15445	36424	58645	92269	61141	14619		26775	24834	14911	4999	13164	38974	402200
1994	18651	41270	64553	96348	67024	16330		29626	27207	17979	6896	16447	42100	444431
1995	22076	46357	70688	100597	73143	18136		32613	29717	21271	9010	19992	45351	488951
1996	25723	51659	77070	105023	79528	20033		35752	32359	24791	11338	23799	48727	535802
1997	29571	57180	83728	109657	86213	22025		39037	35132	28514	13888	27851	52248	585044
1998	33623	62944	90700	114489	93230	24115		42468	38054	32447	16659	32132	55915	636776
1999	37869	68952	98018	119551	100619	26300		46043	41103	36578	19643	36624	59717	691017
2000	42301	75227	105743	124833	108406	28582		49772	44298	40905	22849	41329	63676	747921
2001	46914	81798	113888	130369	116648	30963		53643	47642	45412	26261	46245	67808	807591
**	306636	674863	1082749	1925765	1144114	262702		504194	483901	296487	131543	280175	765201	7858330

***** OUT PUT 21-2 (1) *****　　K W (69KV)　O F　E A C H　P L　A R E A　　(NO.2)

YEAR	P10	P20	Q00	R00	S10	S20	S30	T10	T20	W10	W20	W30	TOTAL	ALL TOTAL
1979	4700		72524	44168			12011		2017		1324		136744	194302
1980	4992	4999	74993	44636			11922		2340		1608		145490	214951
1981	6541	5353	82103	48191			12348	4998	3312		2037		164883	247386
1982	8382	5752	89231	51945			12818	8127	4454		2543		183252	282266
1983	10529	6202	96449	55915			13330	11653	5778		3132		202988	315725
1984	12989	6701	103814	60119			13887	15537	7290		3815		224152	356592
1985	15766	7254	111401	64577			14491	19759	8997		4594		246839	397273
1986	18852	7868	119265	69308	5000		15144	24284	10909		5483		276113	450805
1987	22246	8543	127473	74334	5451		15848	29084	13030		6491		302500	498858
1988	25941	9285	136056	79675	5941		16607	34127	15364		7620		330616	549983
1989	29923	10097	145079	85355	6473		17424	39405	17908		8882		360546	614215
1990	34184	10985	154591	91397	7047		18293	44886	20669		10285		392337	680946
1991	38727	11953	164647	97826	7670		19231	50580	23642		11833		426109	748871
1992	43536	13007	175279	104670	8343		20228	56462	26827		13533		461885	820878
1993	48614	14148	186519	111957	9070		21293	62570	30218		15391		499780	901980
1994	53963	15390	198477	119717	9857		22433	68908	33822		17413		539980	984411
1995	59589	16733	211122	127982	10706		23645	75485	37626	5001	19608		587497	1076448
1996	65526	18178	224537	136786	11621	5000	24932	82352	41643	6597	21969		639141	1174943
1997	71769	19739	238768	146165	12607	5947	26302	89545	45868	8359	24508		689577	1274621
1998	78350	21413	253867	156158	13673	6963	27763	97092	50305	10285	27228		743097	1379873
1999	85316	23207	269888	166806	14817	8047	29306	105070	54957	12382	30127		799923	1490940
2000	92692	25133	286889	178153	16045	9205	30949	113471	59829	14659	33208		860233	1608154
2001	100505	27189	304930	190244	17367	10442	32686	122372	64941	17105	36469		924250	1731841
**	933632	289129	3827902	2306084	161688	45604	452891	1155767	581746	74388	309101		10137932	17996262

VI. PLANNING CRITERIA AND CONDITIONS

VI. PLANNING CRITERIA AND CONDITIONS

VI-1 Planning Criteria

Planning criteria which form the basis of planning distribution system expansion program were studied from a technical standpoint and the criteria developed are given in Table VI-1. Described hereunder are the main points of the said criteria.

1. The service area of MEA was divided into 3 areas, identified as "A", "B" and "C", and criteria for facilities and service most suited to the load density were established.

2. Criteria for Facilities

(1) Studies were made for the following 3 cases of distribution transformer capacity.

Case A	3 x 40 MVA & 3 x 20 MVA
Case B	2 x 40 MVA & 2 x 20 MVA
Case C	3 x 30 MVA & 3 x 20 MVA

(2) Subtransmission line

Normally open π loop (2 incoming lines) type
Feeder transformer type
2 circuits T branch type

Note: See Report on Existing Condition Appendix 13.

(3) Distribution line

Multi-interlinked type and radial type

3. Operation Criteria

(1) Supply voltage

230 kV, 69 kV (115 kV), 12 kV (24 kV)*

Note:* See Report on Existing Condition Appendix 14.

(2) Voltage drop of distribution line

Voltage drop limits under normal operation were determined as follows in order that voltage at the customer could be maintained within a certain range when interchange of power is performed among distribution lines at time of fault.

12 kV normal condition – "A" area 300 V
"B" area 600 V
"C" area 900 V

Note: See Appendix 2. Service voltage for each area.

(3) Utilization factor of transformer in distribution substation

In order to maintain supply reliability during outage of 1 bank of distribution transformer, the maximum utilization factor of each bank was determined as follow:

"A" area	85%
"B" area	80%
"C" area	65%

(4) Operation during fault

a. Fault in one circuit of subtransmission line

Distribution substation will receive power by switching to another circuit.

b. Fault in 1 bank of transformers in distribution substation

Load of the bank in fault will be supplied by the following mean.

- Supply power from another bank in the same substation
- Supply power from another substation by switching operation of distribution line
- Supply power from a mobile transformer

c. During fault of distribution line

In a distribution line of multi-interlinked type, the fault section is isolated by switching operation of distribution line to supply power to customers. In a distribution line of radial type, the power source side of the fault section is supplied power by switching operation of distribution line.

Table VI-1

PLANNING CRITERIA

Item \ Class	A area	B area	C area
1. Classification of Service Area	1. Main part of Bangkok urban area 2. Load density is more than 5000 KW/KM^2 in 1979. 3. Geographical coverage is 34 km^2. 4. Many important loads are located in this area.	1. Area surrounding Bangkok urban area. 2. Load density is between 500 KW/KM^2 and 5000 KW/KM^2. in 1979. 3. Geographical coverage is 608 km^2. 4. This area is under rapid development and power demand is growing quickly.	1. Remote area far from Bangkok urban area. Mostly, agricultural field, farmer village and fisherman village 2. Load density is less than 500 KW/KM^2 in 1979. 3. Geographical coverage is 2464 km^2.
2. Facility Criteria (1) Unit capacity of Distribution substation			
Case A	40 MVA x 3 units	40 MVA x 3 units	20 MVA x 3 units
Case B	40 MVA x 2 units	40 MVA x 2 units	20 MVA x 2 units
Case C	30 MVA x 3 units	30 MVA x 3 units	20 MVA x 3 units
(2) Type of distribution substation	Underground or indoor	Indoor or outdoor	Outdoor

Item \ Class	A area	B area	C area
(3) Type of connection of subtransmission lines	Normally open π - loop (two incoming lines) and Feeder transformer	Normally open π - loop (two incoming lines)	Normally open π - loop (two incoming lines) and Double circuit T-branch
(4) Type of subtransmission line	Underground or overhead.	Underground or overhead	Overhead
(5) Type of distribution lines	Multi-interlinked Underground or overhead	Multi-interlinked Underground or overhead	Radial overhead
(6) Control of distribution switches	Automatic or remote control	Time share control (loop)	Time share control (radial)
3. Operation criteria			
(1) Frequency	50 Hz	50 Hz	50 Hz
(2) System voltage			
Transmission line	230 KV	230 KV	230 KV
Subtransmission line	69 KV	69 KV	69 KV or 115 KV
Distribution line	12 KV	12 KV or 24 KV	24 KV or 12 KV
(3) Allowable load current of distribution feeder			
Overhead Normal	(336.4 MCM) 400 A	(336.4 MCM) 400 A	(336.4 MCM) 400 A
Emergency	(") 530 A	(") 530 A	(") 530 A
Underground Normal	(650 MCM)500A(in case of single cct. in duct), (500 MCM) 400 A	(650 MCM)500A(in case of single cct. in duct), (500 MCM) 400 A	-
Emergency	(650 MCM) 600 A (in case of single cct. in duct), (500 MCM) 500 A	(650 MCM) 600 A (in case of single cct. in duct), (500 MCM) 500 A	-

Item \ Class	A area	B area	C area
(4) Allowable voltage drop on primary distribution feeder			
12 KV Normal	300 V	600 V	900 V
Emergency	600 V	1100 V	1200 V
24 KV Normal	-	1200 V	1800 V
Emergency	-	2100 V	2400 V
(5) Utilization factor of transformer in distribution substation	Through the planning period	Through the planning period	Through the planning period
Normal	85 % (Max. for each substation)	80 % (Max. for each substation)	65 % (Max. for each substation)
Emergency	120 % (Within 4 - 5 hours)	120 % (Within 4 - 5 hours)	120 % (Within 4 - 5 hours)
(6) Power factor at substation	90 %	90 %	90 %
(7) Emergency operation (Distribution substation)			
- One bank of transformer goes into fault at peak time.	In case that the substation is equipped with 3 banks, customer service will be interrupped only during switching operation	In case that the substation is equipped with 3 banks, customer service will be interrupped only during switching operation	In case that the substations equipped with 3 banks, customer service will be interrupped only during switching operation

Item / Class	A area	B area	C area
	In case that the substation is still equipped with 1 or 2 banks, customer service will interrupted also only during switching operation.	In case that the substation is still equipped with 1 or 2 banks, customer will be interrupted during switching operation and despatching of portable transformer.	In case that the substation is still equipped with 1 or 2 banks, customer service will be interrupted during switching operation and despatching of portable transformer.
(Subtransmission line) - One circuit of subtransmission line goes into fault at peak time.	Customer service will be interrupted during switching operation at the substation.	Customer service will be interrupted during switching operation at the substation.	Customer service will be interrupted during switching operation at the substation.
(Distribution Line) - When one circuit of distribution line goes out of operation by reason of fault or maintenance work :	All customers are served by another substation and its own bank, except the faulted section or maintenance work section	Great part of all customers are served by another substation and its own bank except the faulted section or maintenance work section.	Only the sections on power source side of faulted section or maintenance work section are served by its own bank.

VI-2 Planning Conditions

1. Technical Conditions

(1) Determination of blocs for calculation

In the study of load allocation to distribution substations there are the following limiting conditions.

a. topographic restrictions (large river) do not allow interconnection of distribution lines
b. interchange of distribution load not possible because of different distribution voltages
c. difficult to interchange distribution load via several distribution substations

MEA's service territory is divided into 2 zones by a large river and there are 2 distribution voltages, viz., 12 kV and 24 kV. Taking into account these existing conditions, in the calculation of distribution system, blocs were established as shown in Fig. VI-1 and restrictions were designed on the interchange of power between blocs.

(2) Sites for distribution substations

In planning a substation, river, lake on topographic conditions will not permit the construction of the substation. Also, in actual construction of substation, existing building, park or other structures make it impossible to build a substation. Therefore, in selecting a site for a substation, this should be done by finding the most suitable site from among several candidate sites. 91 sites for distribution stations were selected in consultation with MEA. These sites are shown in Appendix 3.

(3) Fixation of short term program

New substations and addition of transformers to existing substations that are being implemented by MEA were fixed as shown in Table VI-2 and calculations were made.

(4) Transformer capacity of new substation

Studies of 2 cases of transformer capacity were made. These are 2 banks from the offset and 1 bank initially.

(5) Limitation of number of feeders

40 MVA – 6 feeders (12 kV), 3 feeders (24 kV)
30 MVA – 5 feeders (12 kV), 3 feeders (24 kV)
20 MVA – 3 feeders (12 kV), 2 feeders (24 kV)

(6) Adoption of thermal resistants aluminum conductor (TAAC)

For the reasons described below TAAC was adopted for subtransmission lines and calculations were made.

a. MEA's subtransmission lines are overhaed lines supported on concrete poles constructed adjacent to buildings and house, therefore, it is not possible to modify the lines to multiple circuits.

b. From limitation of strength of concrete poles, it is not possible to replace conductors to sizes above 2 x 795 MCM.

c. Weight and strength of TAAC are almost the same as AAC now in use, but the power transmitting capacity of TAAC is 1.6 times of AAC.

2. Economic Conditions

The following economic conditions were applied in the investment calculations.

(1) Unit cost

a. use MEA's 1979 unit cost
b. use Japanese unit cost, then taxes and duties are:
   – equipment, 69 kV and over – 18%
   – equipment, under 69 kV – 42%

(2) Overhead charges

a. Engineering Depart. charge – 2% for local materials
   5% for imported materials
   (no tax)
b. Purchase & Store Depart. charge – same as above
c. Construction Depart. charge – 50% of construction cost

(3) Physical contingency – 3%

(4) Evaluated cost of energy loss – 0.6020 B/kWH
(Price of energy purchased from EGAT, 1979)

(5) Price escalation – 8% annually

(6) Rate of interest – 8.5% annually

(7) Annual expense of investment

a. Transmission lines .... 12.99% of accumulated total of annual investment

(detail)
(a) Average useful life – 29 years
(b) Depreciation factor – 3.45%
(c) Interest rate – 8.5%
(d) Operation & maintenance expense factor – 1.04%

b. Substations .... 15.12% of accumulated total of annual investment

(detail)
(a) Average useful life – 24 years
(b) Depreciation factor – 4.17%
(c) Interest rate – 8.5%
(d) Operation & maintenance expense factor – 2.45%

c. Distribution lines .... 15.65% of accumulated total of annual investment

(detail)
(a) Average useful life – 21 years
(b) Depreciation factor – 4.76%
(c) Interest factor – 8.5%
(d) Operation & maintenance expense factor – 2.39%

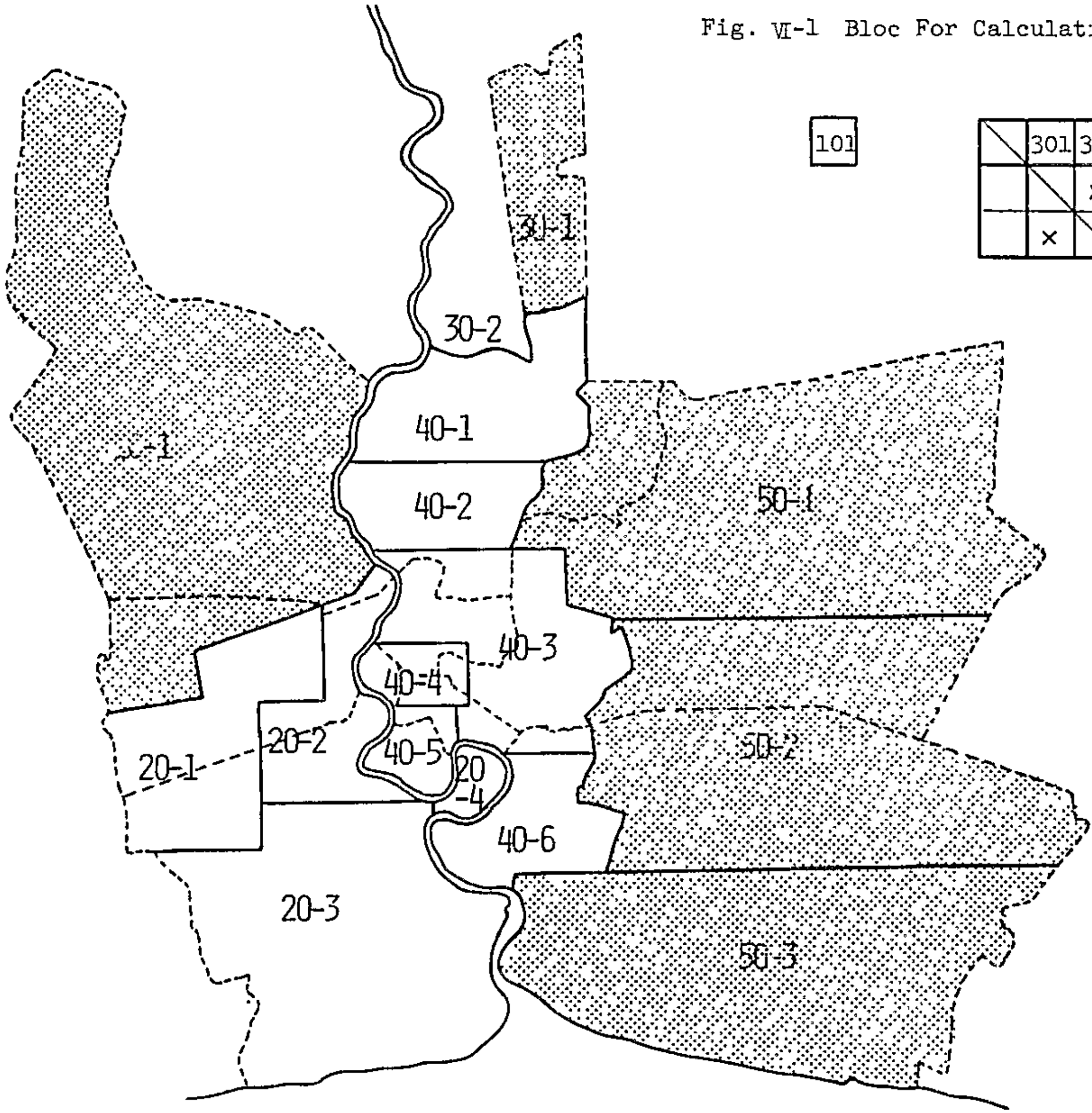
d. Vehicle & equipment ..... 22.14% of accumulated total of annual investment

(detail)
(a) Average useful life – 8 years (scrap value 10%)
(b) Depreciation factor – 11.25%
(c) Interest factor – 8.5%
(d) Operation & maintenance expense factor – 2.39%

Note: (1) Expense factor is capital expense factor (depreciation factor & interest factor) plus operation & maintenance expense factor (excluding salary and wages)

(2) Data from Accounting and Finance Dept. MEA.

Fig. VI-1 Bloc For Calculation



o : Can Interlink

x : Cann't Interlink

101

	301	302
		x
	x	

	201	202	203	204
201		o	x	x
202	o		o	x
203	x	o		o
204	x	x	o	

	401	402	403	404	405	406
401		o	x	x	x	x
402	o		o	x	x	x
403	x	o		o	o	o
404	x	x	o		o	x
405	x	x	o	o		x
406	x	x	o	x	x	

	501	502	503
501		o	x
502	o		o
503	x	o	

Table Ⅵ -2

PLANNING CONDITION

Fixation of construction

(1) New Substation

1981	1982	1983	1984
LADPLAKAO 1x40 MVA	SIPRAYA 1x40 MVA	KLONG TOEY 2x40 MVA	
	PAHOLYOTHIN 1x40 MVA	PRAN NOK 1x40 MVA	
		BANGBON 1x40 MVA	
		POO-JAO	
		VISUTKASAT	
		CHIDLOM 12KV 2x40 MVA	

(2) Addition of Transformer

1981	1982	1983	1984
KLONG JAN 2x20 → 2x40	KLONG SANPASA-MIT	BANGKOK NOI	PLYWOOD
PECHKASEM 2x20 → 3x20	NONTABURI	SIPRAYA 1x40 → 2x40	PECHKASEM 3x20 → 2x20 1x40
YOTHEE 1x40 → 2x40	SATUPRADIT 1x40 → 2x40	PAHOLYOTHIN 1x40 → 2x40	BANGBON 1x40 → 2x40
SANSAB 1x40 → 2x40			
TAKSIN 1x40 → 2x40			
BANGNA 1x40 → 2x40			

(Note) ☐ is fixed

VII. CASE STUDY WITH COMPUTER FOR EXPANSION OF DISTRIBUTION SYSTEM

VII. CASE STUDY WITH COMPUTER FOR EXPANSION OF DISTRIBUTION SYSTEM

VII-1 Calculation Method for Expansion of Distribution System

Calculation of expansion of distribution system was performed with large capacity electronic computer by using the already established distribution substation planning program developed in Japan. A general description of the calculation method is given below.

1. Input Data

(1) Load (kW) over a 20 years period for each mesh

(2) Planning criteria and planning condition (covering all matters described in the preceding chapter)

(3) Data of existing sustations (location[1] capacity, number of banks, voltage, number of distribution feeders, possibility of increasing number of banks and other factors)

(4) Data of proposed new substations (location[1], capacity, ultimate number of banks, voltage, ultimate number of distribution feeder and other factors)

Note:[1] Input data of location are all mesh coordinates.

(5) Data of subtransmission lines (length, conductor size and other data of subtransmission lines constructed in relation to construction of new substations and addition to existing substations)

(6) Data of distribution lines (permissible load current, allowable voltage drop and other data of underground cables and overhead lines)

(7) Data for calculation of reliability (bank outage rate, duration of outage and other data)

2. Description of the Calculation

(1) Planning of distribution substation

Fig. VII-1 gives the calculation procedure in planning of substation

a. Calculate to find whether or not the total capacity of transformers is adequate for the total load of a bloc. (coincident factor of each transformer in the bloc is taken as 0.9)

b. In the case of shortage of capacity of a substation, establish an ideal supply area for each new candidate substation, and calculate whether or not the load in that area is over 80% of a unit capacity (ex. 40 MVA x U.F.)

c. If the shortage of supply capacity is over 80% of a unit capacity, then construct a new substation. If there are more than 1 candidate substations where the shortage of capacity is over 80% of a unit capacity, calculate the $\Sigma W.\ell$ of each candidate substation and select the substation with the smallest $\Sigma W.\ell$.

d. If the shortage of capacity is less than 80% of a unit capacity, cope with the situation by adding another transformer in an existing substation. The determination of which substation should be expanded is made by calculating the $\Sigma W.\ell$ of each existing substation and selecting the one with the smallest $\Sigma W.\ell$.

e. After making the selection of a substation to be newly constructed or expanded, recalculate to ascertain the total load of a bloc is within the total capacity of transformers (including new substation) in that bloc. If there is shortage of capacity, reperform the calculations mentioned above until there is sufficient capacity.

f. At the point when the total load of a bloc is within the total capacity of transformers in that bloc, then calculate the optimum service area of substation in the bloc.

g. The calculation procedures for selection of new or expansion of substations and optimization of service area of each substation are as follows:

  a) find the load (W) of a mesh and the sitance (ℓ) between a mesh and substation
  b) find the service area giving the smallest value of $\Sigma W.\ell$.

  Note: i) The above calculations are made from the standpoint of optimum load sharing of substations in a bloc (least distribution expense). The least expense including subtransmission lines and substations, should be finally evaluated by comparing, all cases after calculating construction costs and annual expense.

  ii) For details of calculation of $\Sigma W.\ell$, see Appendix 4, Load Sharing Calculation.

(2) Planning of subtransmission line

When the location and capacity of a distribution substation are determined, find the length and conductor size of subtransmission line by the following method. These are input data obtained by manual calculation.

a. Comparative studies are made of type of connection, and the most economical type for each area is selected. The expansion program is based on this standard type. (See Report on Existing Condition Appendix 13)

b. When the location of substation is determined, connection is made to the closest existing subtransmission line.

c. The conductors of existing subtransmission lines are replaced from aluminum conductors to thermal resistance aluminum conductors in order to increase the transmitting capacity thereby avoiding the construction of new lines and as a result improving the overall economy.

Note: A substation is a point whereas a subtransmission line is a line. Therefore, it is difficult to theoretically select an optimum scheme because in the selection of route, it is influenced by existing lines and topography. As a practical solution, the planning was done by the above method.

(3) Planning of high voltage distribution line

Calculation procedure in planning high voltage distribution line is shown in Fig. VII-2.

a. Find the optimum number of feeders according to the maximum load carrying capacity of distribution line (for 4 directions).

b. Calculate average voltage drop for minimum number of feeders (for 4 directions).

c. If the voltage drop exceeds a limit, judge if an additional feeder can be installed. (there is a limit to the number of feeder.)

d. If the voltage drop exceeds a limit and an additional feeder cannot be installed, as an improvement work, modify the overhead line to double conductors, or install SVR (Stepup Voltage Regulator)

e. Calculate amount of interchange power from another bank in the same substation or from another substation by switching of distribution line, and then calculate interchange factor.

Note:[1] $$\text{Interchange factor} = \frac{\text{Interchange power (kW)}}{\text{Normal Max. Load on Outage Bank (kW)}}$$

(4) Calcualtion of construction cost

The procedure of calculation of construction cost for financial analysis is as follows:

a. Multiply quantities of work of subtransmission line, substation and distribution by unit prices to calculate construction cost taking into account price escalation, and then calculate the annual investment.

b. Discount the annual investment in (a) above by a given interest rate to calculate present value.

c. Accumulate the annual investment of (a) above, and multiply by an annual expense factor to calculate annual expense. The annual expense should include evaluated value of distribution loss (kWH).

d. Calculate the present value of each year's annual expense

Note: Present value (ℓi) of annual expense

$$\ell i = (P1 + P2 + \cdots\cdots + Pi) \times \frac{\alpha}{(1+\gamma)^i} + \frac{\ell \cdot Wi}{(1+\gamma)^i}$$

ℓi : Present value of expense in i year
Pi : Investment in i year
Wi : Distribution loss (kWH) in i year
γ : Interest rate
α : Annual expense factor
ℓ : Evaluated value of distribution loss in kWH

(5) Reliability calculation

Reliability calculation is performed as follows on the assumption of outage of 1 bank of transformer in a substation.

a. Based on data of outage rate and continuous outage hours of 1 bank, the annual outage hours for each substation are calculated.

b. From the load at the time of outage of 1 bank, deduct interchange power between banks and interchange power from another distribution line, and calculate the load (power) shedded.

c. Calculate the average annual outage time.

3. Output

Output of a distribution substation planning system is as follows:

(1) New and expansion plan of substation – demand and supply balance by bloc

(2) New and expansion plan of substation – unit capacity of substation

(3) New and expansion plan of substation – distribution of load among substations

(4) Map of supply district

(5) Expansion plan of high voltage distribution line

(6) Construction cost by substation

(7) Amount of investment

(8) Conversion to present value of amount of investment

(9) Amount of expense

(10) Conversion of amount of expense to present value

(11) Calculation of reliability

Fig VII-1 Outline of Distribution Substation Planning

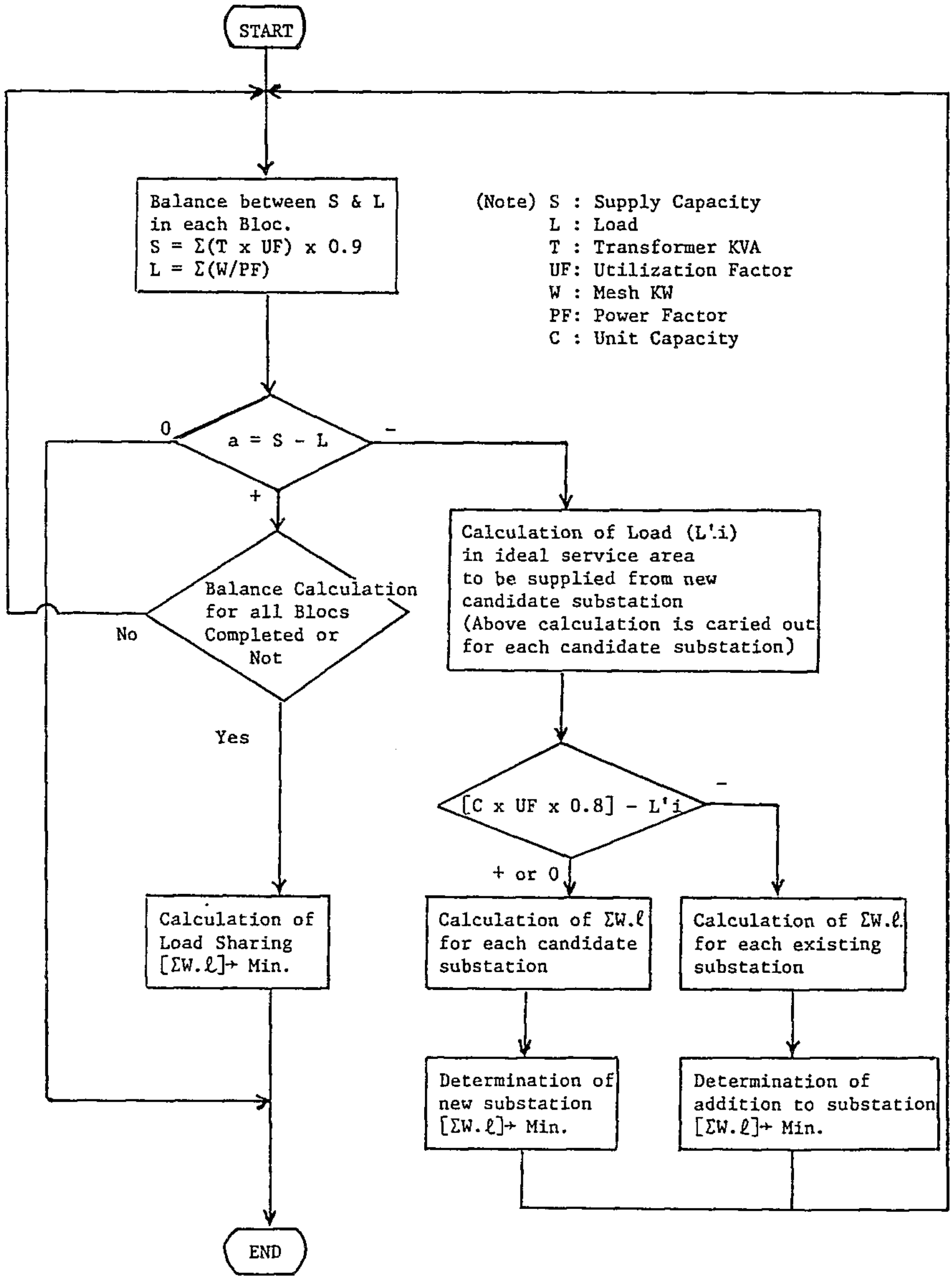
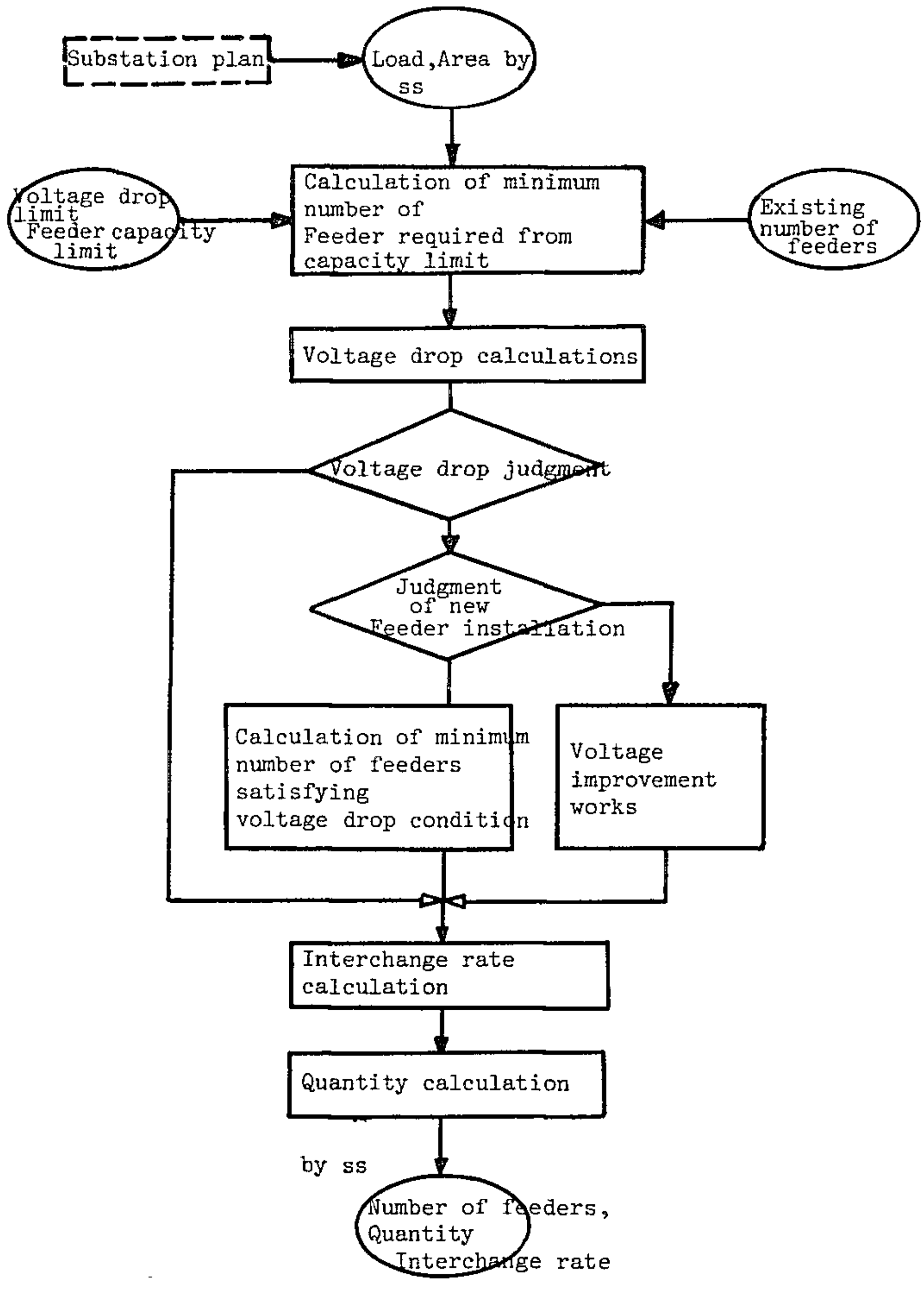


Fig. VII-2 Outline of Thigh Tension Distribution Line Planning



VII-2 Results of Calculations

1. Case Study

Comparative calculations were made for 7 cases under the conditions described below.

(1) Case 1 – trial case

(2) Cases 2 to 7

a. Maximum utilization factor of transformers is applied from the initial year of service.

b. Capacity of distribution substations and number of transformer banks at the start of service are arranged for differing combinations as shown in Table VII-1.

2. Result of Comparative Calculations

(1) Total capacity and utilization factor of distribution substations

For each case (Cases 2 – 7) studied, the total capacity of substations and utilization factors are given in Table VII-2.

a. Total capacity

An optimum load distribution among substations was performed for each case in relation to the projected load, and the total capacity of substations thus obtained is as follow.

1991	3,970 ~ 4,020 MVA
2001	6,290 ~ 6,600 MVA

Fig. VII-3 to VII-8 give the yearly changing pattern of total capacity of substations corresponding to load. These figures indicate the following important features.

- In the period 1982 to 1984, since substations to be constructed are already determined, there will be an increase in total capacity of substations, but in the period 1984 to 1991, the growth in the total capacity is small.

- In the far term (1992 to 2001), total capacity of substations will increase corresponding to the growth of demand.

- Annual increase in total capacity of substations will be in large steps for substations with initial installation of 2 banks and in small steps for substations with initial installation of 1 bank.

b. Utilization factor

Utilization factor$\left(\frac{\text{total load}}{\text{total capacity}} \times 100\%\right)$ of substations at system peak are as follow indicating that the values for each case are quite similar.

1991 – 60.5 to 61.3
2001 – 64.6 to 67.7

Fig. VII-9 gives the yearly charging pattern of utilization factor of each case. In each case, there is a gradual climb in the curves until in and around 1996 and then flattens. These indicate that –

– determining a higher value of upper limit of utilization factor of 1 bank of transformer in the planning criteria will not result in a rapid rise of utilization factor. Since, the utilization factor at present is low, the utilization factor will gradually increase corresponding to growth of load.
– the maximum utilization factor of MEA's system would be 65 to 68% considering the loads of each area.

(2) Number of substations

A comparison of computed number of substations for each case is given in Table VII-3.

In the year 1991, the number of substations for each case is between 57 and 63 indicating a small difference between cases, but in the year 2001, the number is between 76 and 109 indicating a bigger difference between cases.

The number of substations to be built from 1982 to 2001 differs widely between cases. That is, in case 2, the number is 30 while in case 7, the number is 63. The cause of this difference is evident by examining the number of substations in the year 2001 shown in Table VII-3. The cause can be summarized as follows:

a. In the cases (Cases 3, 5 and 7) of substations of initial installation of 1 bank of transformer, the number of substations with 1 bank will increase corresponding to growth of load.

b. In the cases (Case 4 – 80 MVA, 40 MVA) where the capacity of a substation is small, the number of substations will increase.

c. In the cases (Case 2 – 120 MVA, 80 MVA) where the capacity of a substation is large, the number of substations will be little.

Fig. VII-10 gives the annual trend in the growth of number of substations. From this Fig., it will be noted that –

a. in the near term, the growth in the number of substations is small, and this trend is almost the same for all cases.
b. in the far term, the difference between cases becomes big.

(3) Number of distribution feeders

The number of distribution feeders for each case is shown in Table VII-4. It will be noted in the table, that there is no great difference in the number of feeder between the cases. The cause of this phenomena is that the total load of each case is identical and in the process of calculations with an electronic computer, the least required number of feeders were obtained.

(4) Comparison of amount of investment

In comparison, amount of investment in each year included price escalation (8%) is calculated, and in order to evaluate the difference in the amount of investment annually, the annual investments were converted to present value of a basic year (1979) using a discount rate of 8.5%.

The amount of investment converted to present value (1979) is shown in Table VII-5 and Fig. VII-11.

The results of comparison are summarized as follows:

a. Amount of investment over the 20 years period converted to present value is 21,510 to 22,750 million Bahts, indicating that investment of Case 2 is the least.

b. Amount of investment in the near term is approximately 1/3 of the amount of investment in the 20 years period, and there is very little difference in the amount of investment between Case 2 and Case 4. In the far term, the amount of investment is the least for Case 2.

c. Investment by facilities indicates that when the investments for subtransmission line and distribution substation are small, the investments for distribution line are large, and when the investments for subtransmission line and distribution substation are large, the investments for distribution lines are small.

(5) Comparison of amount of expense

In order to evaluate the difference in the amount of investment for each facility, amount of expense was calculated.

Amount of expense consists of depreciation, interest charge, and operation and maintenance costs (excluding salary and wages) arising from the investment in facilities.

Amount of expenses is computed by multiplying fixed rates to accumulated total of amount of investments in a certain year. In the comparison of amount of expenses calculated energy losses for each case were multiplied by an evaluated unit price and the results were included.

Calculation of amount of expenses and evaluation of energy loss were made for each year, and then converted to present value of a base year (1979).

The amount of expenses converted to present value (1979) are given in Table VII-6 and Fig. VII-12. The results of the comparison are summarized as follows.

a. Amount of expenses over a 20 years period converted to present value is 22,270 to 23,090 million Bahts, indicating that Case 2 gives the smallest amount of expense.

b. Amount of expenses in the near term is approximately 1/3 of total amount of expenses of 20 years period, and there is very little difference in these expenses in Cases 2, 4 and 5. Case 2 gives the least amount of expenses in the far term.

(6) Conclusion

The results of the comparison are summarized below.

a. MEA's distribution system has a margin in the capacity at present, and there is no need to build many new substations in the near term.

b. In the far term, since the load will grow at a rapid pace annually, the matter which will require careful consideration is when and where new distribution substations and additional transformers at distribution substations should be constructed or installed.

c. In comparison of the cases of 1 bank initial start and 2 banks initial start, it is found that 1 bank initial start is not advantageous because of the greater number of substations that are required (Cases 3, 5 and 7).

d. In comparison of Case 4 (40 MVA x 2 = 80 MVA) and Case 6 (30 MVA x 3 = 90 MVA), there is little difference in the capacity of 1 substation, and therefore there is little difference between the 2 cases in the number of new substations that will be required.

e. In Case 2, annual investment and expense are little difference with Case 4 in the near term, but in the far term when the load density grows, the advantage of Case 2 is evident.

From the results of the above analysis and for the reasons described below, Case 2 is recommended as the most optimum program.

- over the 20 years period, the amount of investments and amount of expenses is the least, and particularly in the far term, the amount of investments and expenses are small.

- the number of new substation that are required is the least and would result in lesser problems in acquisition of land for substations in the future.

- since the number of required substations is little, acquisition of right-of-way of subtransmission line will be easy.

- as predescribed before, there are no problems in respect of power flow, short circuit current and supply reliability of MEA's power system.

As the next optimum program, Case 4 is recommended.

Table VII -1 Calculating conditions for each cases

Utilization factor	Final capacity	Installation procedure	Case No.
A Area : 0.85	A area 40 x 3 B area 40 x 3 C area 20 x3	2-Bank start	2
		1 "	3
B Area : 0.80	A area 40 x 2 B area 40 x 2 C area 40 x 2	2-Bank start	4
		1 "	5
C Area : 0.65	A area 30 x 3 B area 30 x 3 C area 20 x 3	2-Bank start	6
		1 "	7

Table VII-2 Comparison of Total Capacity and Total Utilizing Factor

	Case 2 (40-3B,2S)	Case 3 (40-3B,1S)	Case 4 (40-2B,2S)	Case 5 (40-2B,1S)	Case 6 (30-3B,2S)	Case 7 (30-3B,1S)
1982						
Capacity (MVA)	3,150		(Same)			
Load (MVA)	1,448		(Same)			
Utl. Factor (%)	46.0		(Same)			
1991						
Capacity (MVA)	3,990	3,970	3,970	3,970	4,020	3,970
Load (MVA)	2,432	2,432	2,432	2,432	2,432	2,432
Utl. Factor (%)	60.9	61.3	61.3	61.3	60.5	61.3
2001						
Capacity (MVA)	6,540	6,290	6,600	6,290	6,380	6,300
Load (MVA)	4,261	4,261	4,261	4,261	4,261	4,261
Utl. Factor (%)	65.1	67.7	64.6	67.7	66.8	67.6

(Note) 40-3B, 2S : 40 MVA, 3 Bank, 2 Bank start

Fig. VII-3 Capacity of Distribution Substation (Case 2)

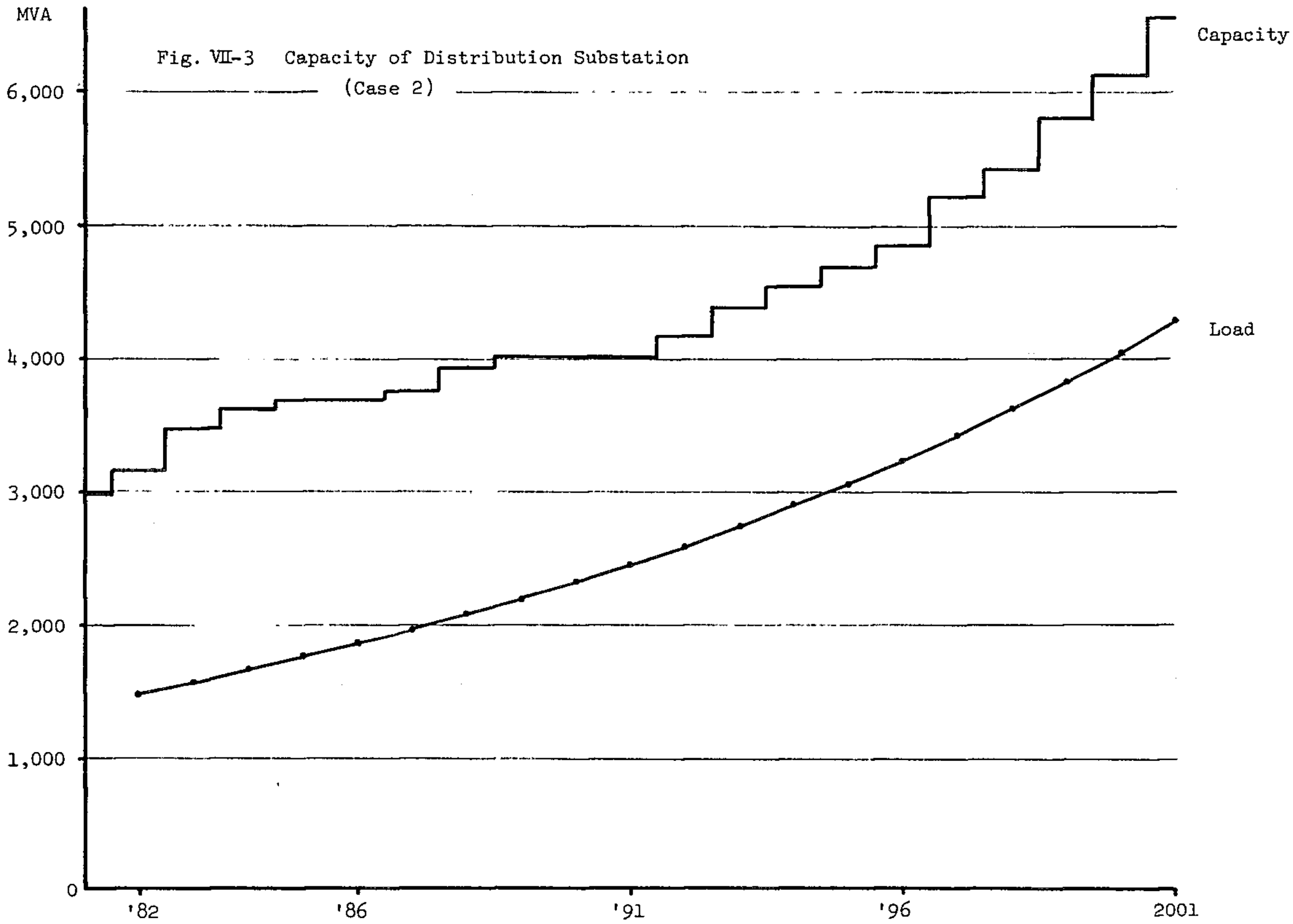


Fig. VII-4 Capacity of Distribution Station (Case 3)

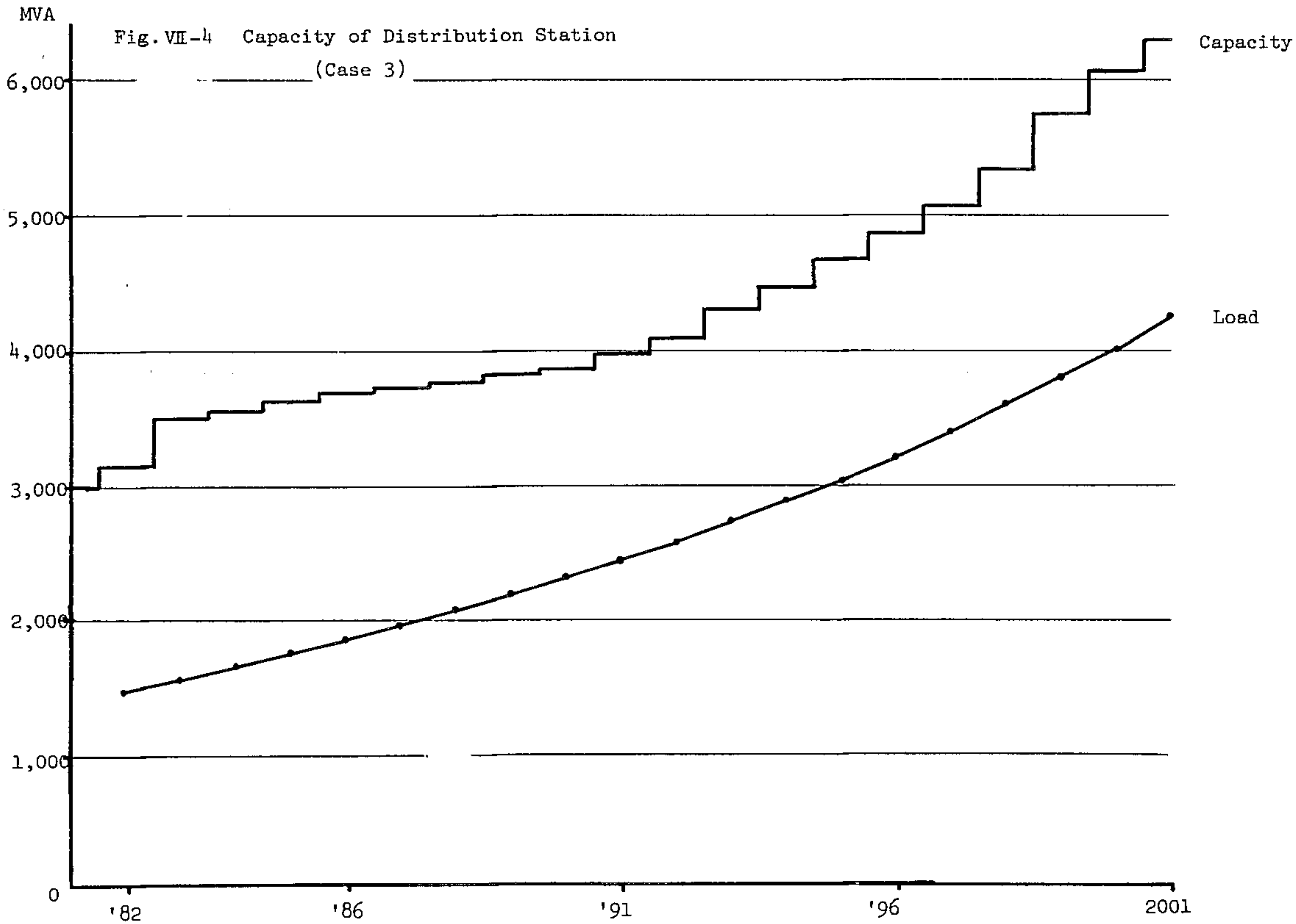
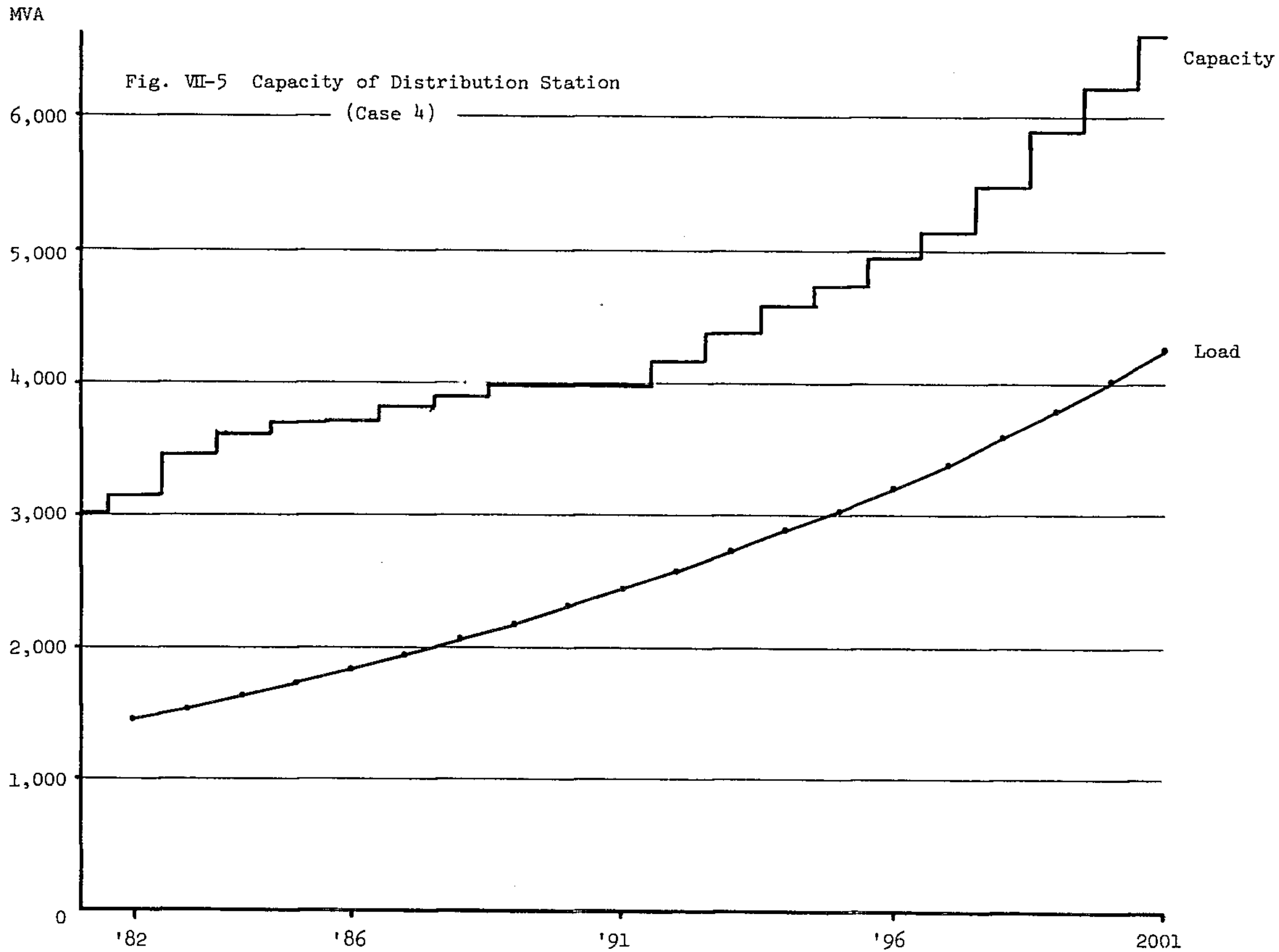


Fig. VII-5 Capacity of Distribution Station (Case 4)



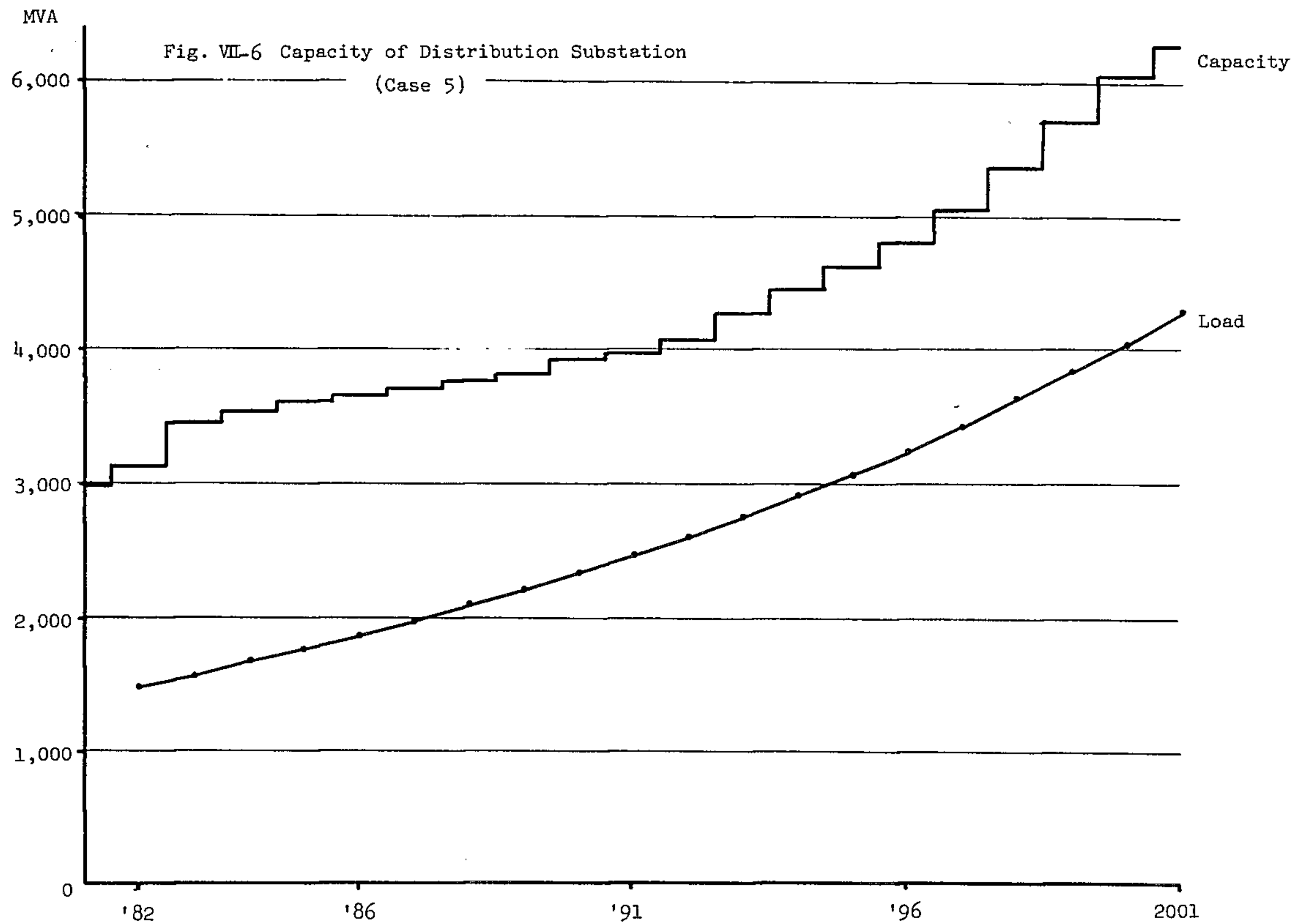
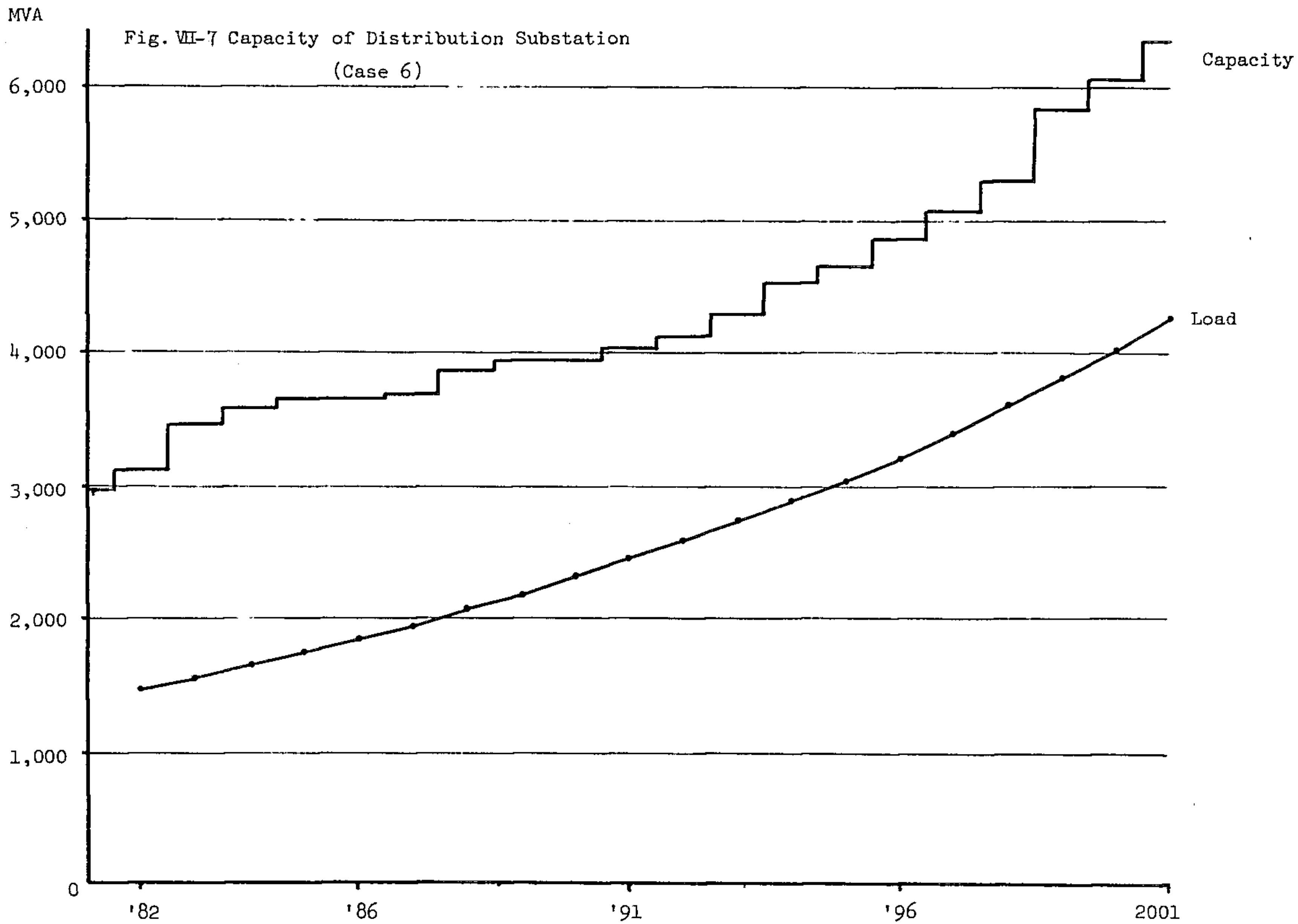


Fig. VII-6 Capacity of Distribution Substation (Case 5)

Fig. VII-7 Capacity of Distribution Substation
(Case 6)



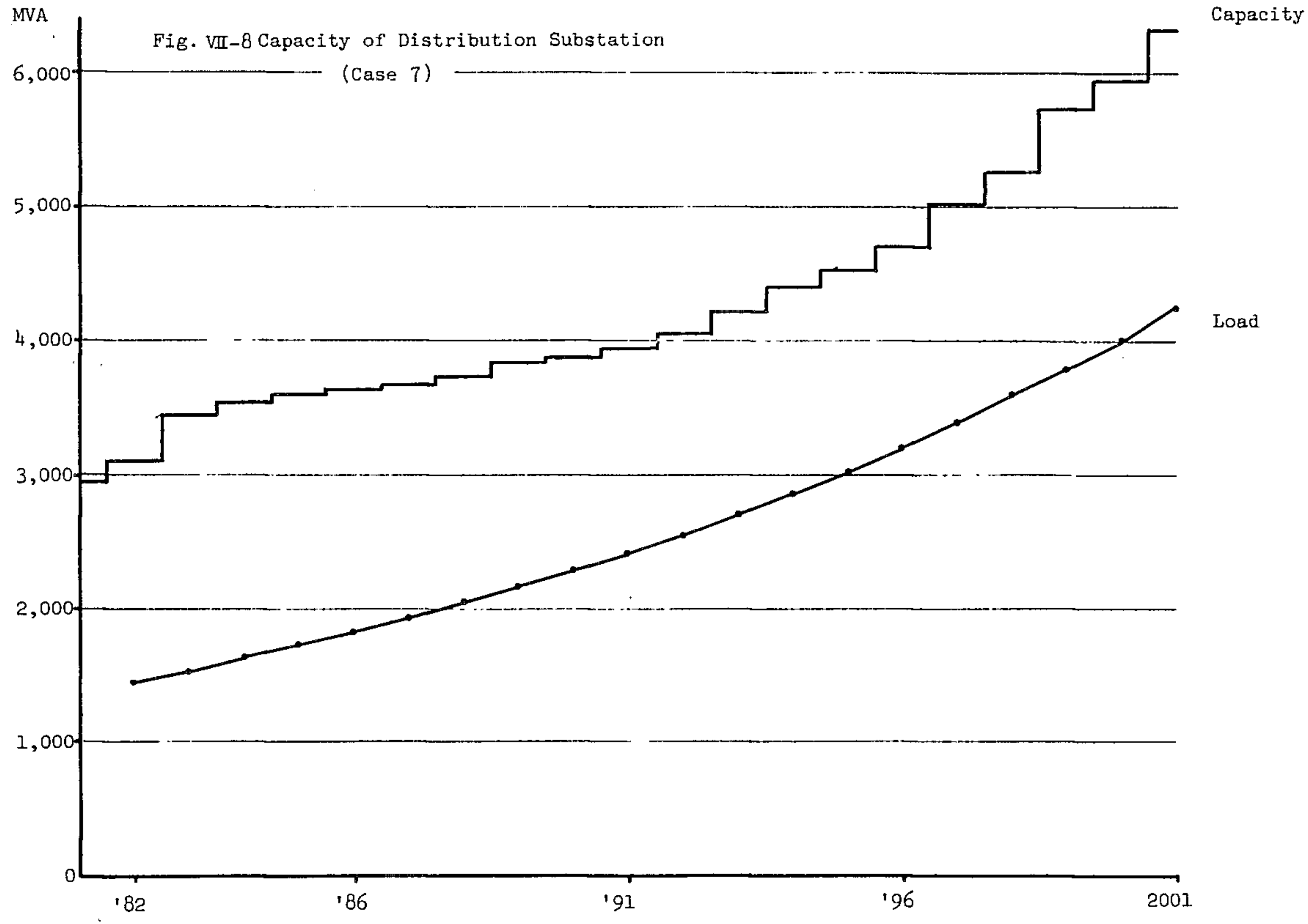


Fig. VII-8 Capacity of Distribution Substation

(Case 7)

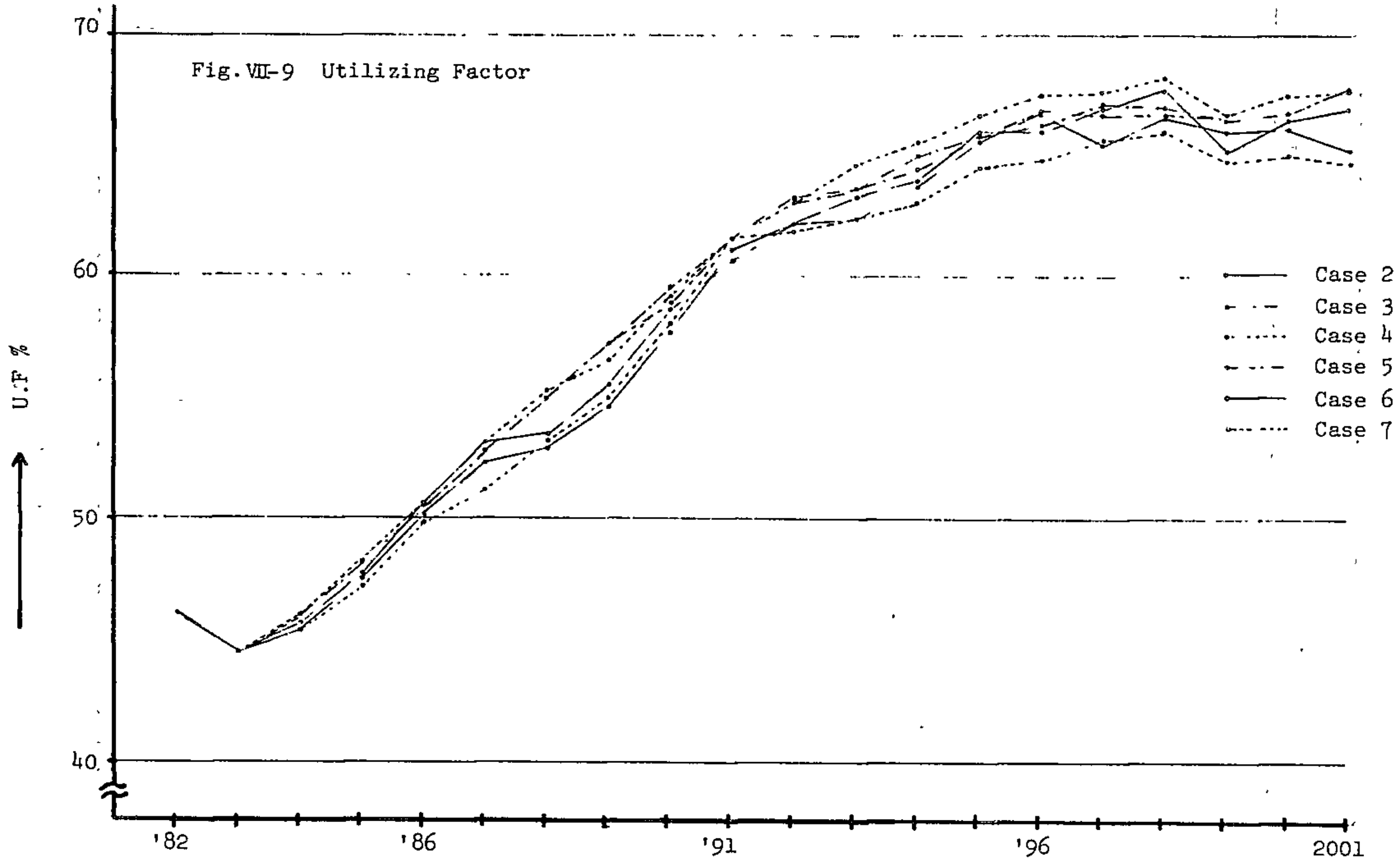


Fig.VII-9 Utilizing Factor

Table VII-3 Comparison of Number of Distribution Substation

	Case 2 (40-3B,2S)	Case 3 (40-3B,1S)	Case 4 (40-2B,2S)	Case 5 (40-2B,1S)	Case 6 (30-3B,2S)	Case 7 (30-3B,1S)
Existing (81')	46	46	46	46	46	46
('82 ∿ '91)	(+11)	(+15)	(+12)	(+15)	(+13)	(+17)
1991	57	61	58	61	59	63
('92 ∿ 2001)	(+19)	(+42)	(+34)	(+45)	(+27)	(+46)
2001	76	103	92	106	86	109
('82 ∿ 2001)	(+30)	(+57)	(+46)	(+60)	(+40)	(+63)
Details on 2001						
1x20 MVA	1	10	1	12	1	13
1x30 "						19
1x40 "	3	28	2	26	2	3
2x10 "	1	1	1	1	1	1
2x20 "	5	6	17	11	6	5
2x30 "					18	18
2x40 "	32	45	68	51	25	34
2x Combine				2	2	1
3x20 MVA	7	5			9	6
3x30 "					8	4
3x40 "	24	4	*1 1	*1 1	1	1
3xCombine	2	2	*2 1	*2 1	12	3
4x40 MVA	1	1	1	1	1	1

(Note) Combine : Combination of different capacity
*1 : Klong Ransit (for PEA)
*2 : Pechkasem (fixed Distribution Substation)

Fig. VII-10 Number of Distribution Substation

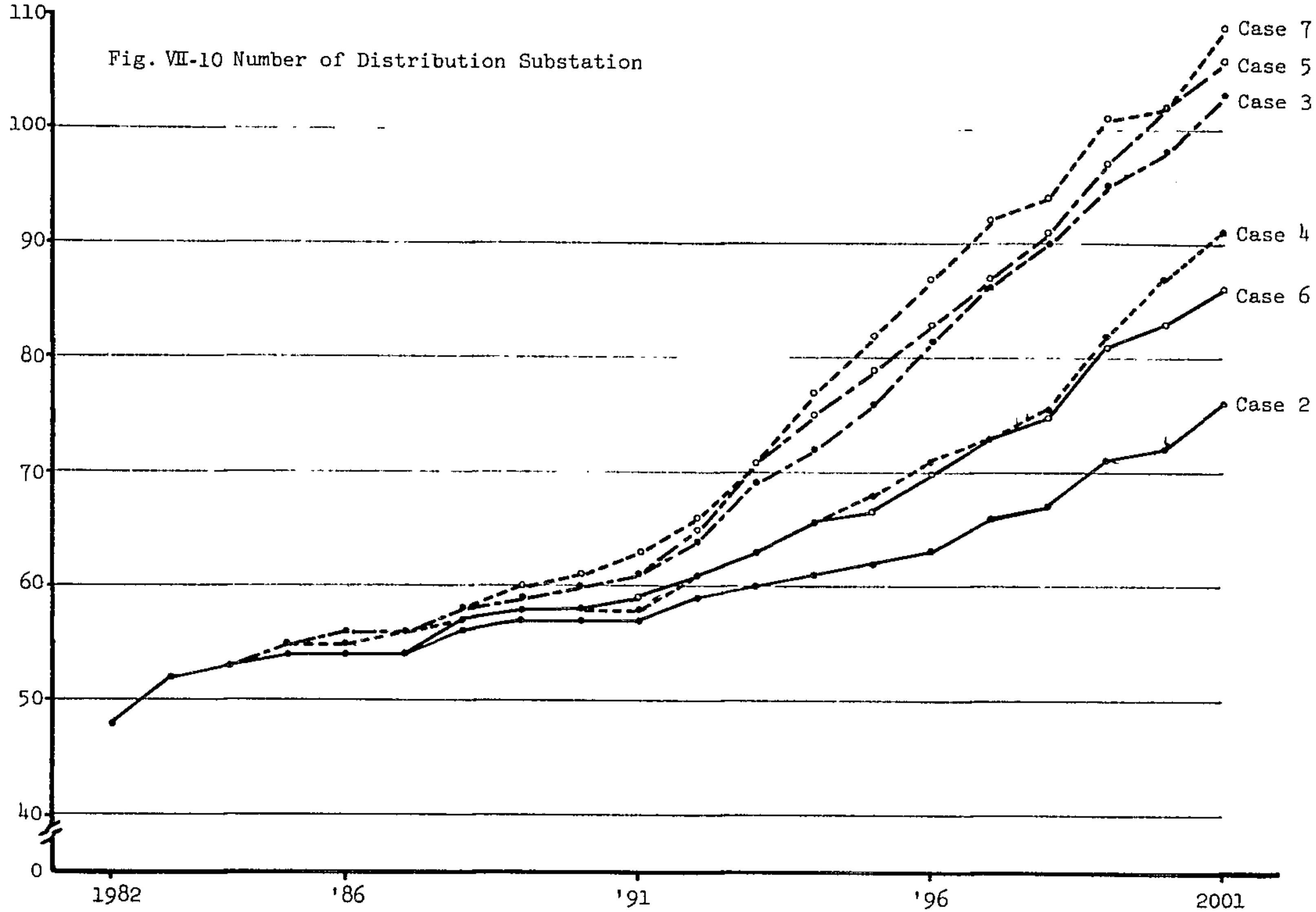


Table VII-4 Comparison of Number of Feeder

	Case 2 (40-3B,2S)	Case 3 (40-3B,1S)	Case 4 (40-2B,2S)	Case 5 (40-2B,1S)	Case 6 (30-3B,2S)	Case 7 (30-3B,1S)
Existing	345	345	345	345	345	345
1991	487	491	489	490	492	495
2001	770	773	801	780	769	774

Table VII-5 Comparison of Present Value of Amount of Investments ('79)

Unit : 10^6 Baht

	Case 2 (40-3B,2S)	Case 3 (40-3B,1S)	Case 4 (40-2B,2S)	Case 5 (40-2B,1S)	Case 6 (30-3B,2S)	Case 7 (30-3B,1S)
1982 - 1991						
S.T.	750	820	810	810	850	820
D.S.	1,480	1,640	1,540	1,600	1,620	1,710
D.L.	5,560	5,550	5,470	5,480	5,570	5,530
V.E.	540	540	540	540	540	540
TTL	8,330	8,550	8,360	8,430	8,580	8,600
1992 - 2901						
S.T.	1,900	2,150	2,050	2,230	1,990	2,260
D.S.	2,600	3,240	2,980	3,270	2,810	3,400
D.L.	7,990	7,800	7,900	7,700	7,910	7,800
V.E.	690	690	690	690	690	690
TTL	13,180	13,880	13,620	13,890	13,400	14,150
1982 - 2001						
S.T.	2,650	2,970	2,860	3,040	2,840	3,080
D.S.	4,080	4,880	4,520	4,870	4,430	5,110
D.L.	13,550	13,350	13,370	13,180	13,480	13,330
V.E.	1,230	1,230	1,230	1,230	1,230	1,230
TTL	21,510	22,430	21,980	22,320	21,980	22,750

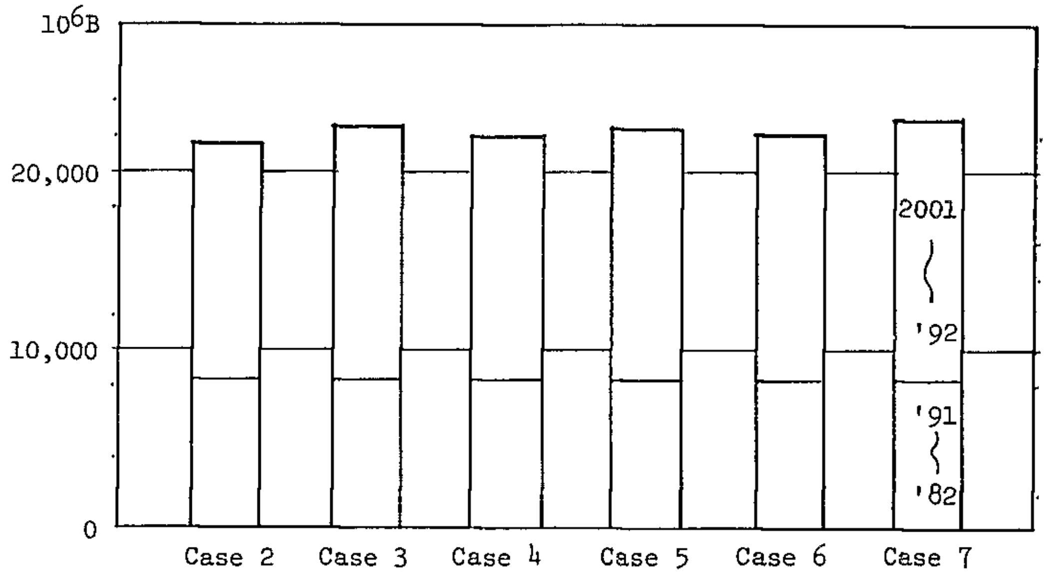
S.T. : Sub-transmission Line

D.S. : Distribution Substation

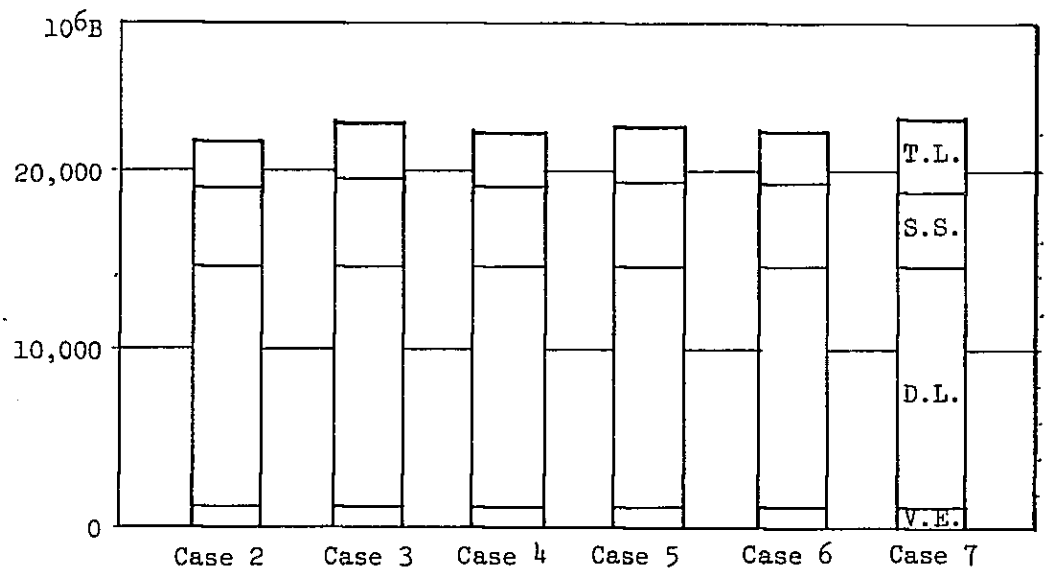
D.L. : Distribution Line

V.E. : Vehicle & Equipment

Fig. VII-11 Present Value of Amount of Investments ('79)



(Note) 2001 - '92 : Total value , '91 - '82 : Total value



(Note) T.L. : Transmission line S.S. : Substation
D.L. : Distribution line V.E. : Vehicle & equipment

Table VII-6 Comparison of Present Value of Amount of Expenses ('79)

	Case 2 (40-3B,2S)	Case 3 (40-3B,1S)	Case 4 (40-2B,2S)	Case 5 (40-2B,1S)	Case 6 (30-3B,2S)	Case 7 (30-3B,1S)
1982-1991						
S.T.	350	400	390	390	380	390
D.S.	1,020	1,080	1,060	1,060	1,070	1,090
D.L.	3,830	3,790	3,770	3,750	3,810	3,780
V.E.	510	510	510	510	510	510
Loss	620	610	620	610	610	620
TTL	6,330	6,390	6,350	6,320	6,380	6,390
1992-2001						
S.T.	1,770	1,950	1,850	2,000	1,850	2,030
D.S.	2,720	3,320	2,980	3,320	2,980	3,480
D.L.	9,220	9,130	9,100	9,010	9,200	9,070
V.E.	1,210	1,210	1,210	1,210	1,210	1,210
Loss	1,020	910	960	920	970	910
TTL	15,940	16,520	16,100	16,460	16,210	16,700
1982-2001						
S.T.	2,120	2,350	2,240	2,390	2,230	2,420
D.S.	3,740	4,400	4,040	4,380	4,050	4,570
D.L.	13,050	12,920	12,870	12,760	13,010	12,850
V.E.	1,720	1,720	1,720	1,720	1,720	1,720
Loss	1,640	1,520	1,580	1,530	1,580	1,530
TTL	22,270	22,910	22,450	22,780	22,590	23,090

S.T. : Sub-transmission Line

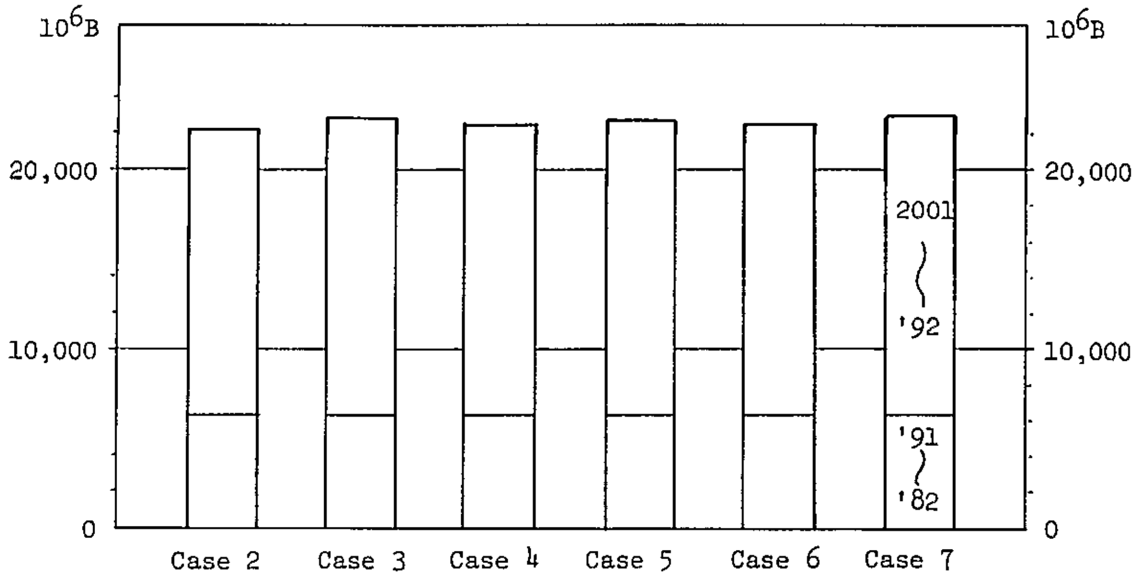
D.S. : Distribution Substation

D.L. : Distribution Line

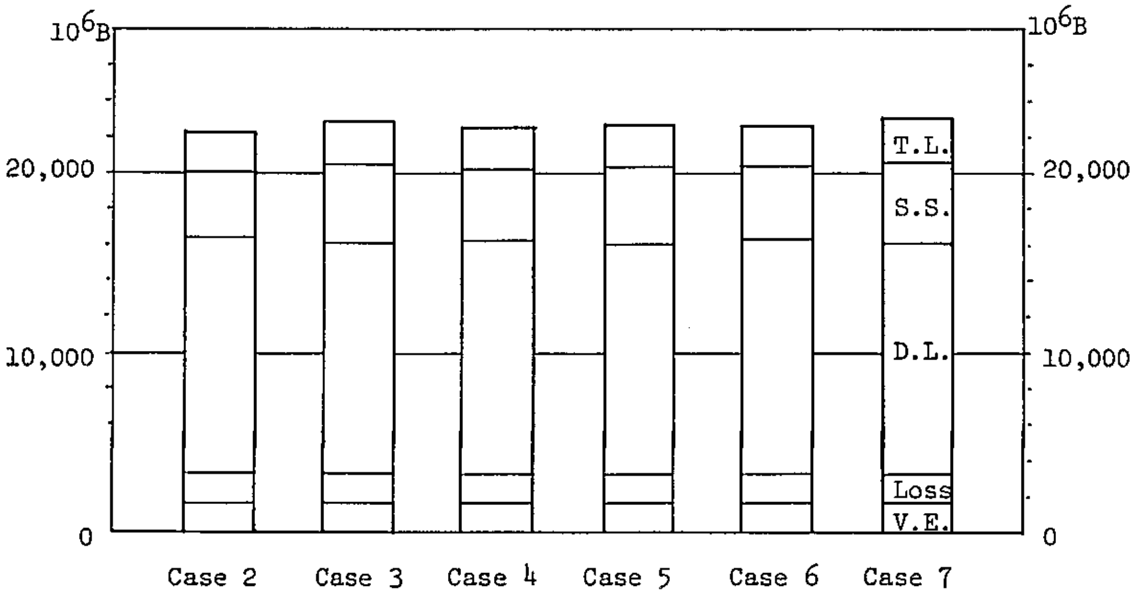
V.E. : Vehicle & Equipment

Loss : Loss of Distribution Line

Fig. VII-12 Present Value of Amount of Expenses ('79)



(Note) 2001 - '92 : Total value, '91 - '82 : Total value



(Note) T.L. : Transmission line S.S. : Substation
D.L. : Distribution line Loss : Distribution loss
V.E. : Vehicle & equipment

VIII. APPENDICES

VIII. APPENDICES

Appendix 1 Conversion of The MEA's Basic Demand for Mesh Load

1. Preface

MEA's whole basic demand (GWh) and demand of each PL Area were estimated based on the MEA LOAD FORECAST (1982 – 2001) August, 1980.

Concerning to the planning of distribution facilities, it is necessary to convert the basic demand (GWh) to the load (KW) shown below.

(1) Customers' load supplied by 69 KV and 115 KV (hereafter called 69 KV-Customer)

(2) Customers' load supplied from the MEA's distribution substation (hereafter called distribution load)

Furthermore, distribution load must be distributed by each mesh.

2. Estimation of 69 KV-Customer's Load

(1) Estimation of 69 KV-Customer's GWh

The following rate is applied for the load estimation of 69 KV-Customer.

$$\text{Rate 69} = \frac{\text{69 KV-Customer (GWh)}}{\text{Medium \& Large Business (GWh)}} \times 100\%$$

a. Actual record of Rate 69

The values of Rate 69 from 1975 to 1979 are shown in Fig. 1.

b. Model curve of Rate 69

It is assumed that a 69 KV-Customer (5,000 KW) is appeared in a certain PL Area for the every 50 GWh load increase, the values of Rate 69 can be shown like as Fig. 2.

c. Standard increasing curve of Rate 69

Standard increasing curve of Rate 69, which is based on the actual record of Rate 69 except PL Area S30 and R00, is shown in Fig. 3.

Increasing curve : $y = 52.0 - 65.566 \times 0.99396^{x}$

x ; Medium and Large Business of PL Area (GWh) 544

y ; Rate 69 (%)

d. Application of Rate 69

GWh of each PL Area except the particular area (R00) is increased, the value of Rate 69 will be increased depending on the standard increasing curve. (Fig. 4)

e. Estimation results

Estimation results of 69 KV-Customer (GWh) are like as OUTPUT 20 and these are tabulated below.

Table 1.

Unit: GWh

		1979	1991	2001
	541	1,478	2,885	4,638
	543	1,043	2,107	3,791
544	744	4,097	7,382	12,567
544	(TTL)	(6,618)	(12,374)	(20,996)
544	644	1,021	3,936	9,103
	GTTL	7,639	16,310	30,099

(2) Estimation of 69 KV-Customer's kilowatt (KW)

Kilowatt (KW) of 69 KV-Customer was calculated by applying the 60% load factor (MEA's actual record), and calculation results are like as OUTPUT 21.

(3) Estimation of number of 69 KV customers

The average maximum demand (KW) of a 69 KV customer is growing each year. A trend line of average maximum demand of 69 KV customers was obtained from actual data recorded by MEA, and from this trend line, the number of 69 KV customers was calculated.

Trend line $Y = 5.05 + 0.29X$ (KW)
Y : average maximum demand (KW) of a 69 KV customer
X : 1979 is 1

3. Estimation of Distribution Load

(1) Multiple regression between KW and MWh

Multiple regression analysis between KW and MWh was conducted for each planning area.

Regressive equation can be written as follows.

$$Y = a + bX_1 + cX_2 + dX_3$$

here,

Y ; KW

X_1 ; MWh of residential [541]

X_2 ; MWh of small business [543]

X_3 ; MWh of medium and large business [744]
(except 69 KV-Customer)

Above data are found in each planning area.

a, b, c, d ; Coefficient have to be obtained.

Analysed results

Regressive equation is :

$$Y = -2{,}415.4 + 0.068324X_1 + 0.40594X_2 + 0.16135X_3$$

Multiple correlation coefficient . 0.9796

(2) Calculation of KW increasing rate of each PL area

Kilowatt (KW) increasing rate ($IR_{n.p}$) of each PL Area was obtained by the following equation.

$$IR_{n.p} = \frac{Y_{n.p}}{Y_{79.p}} \qquad n \text{ ; } 1980 - 2001 \quad p \text{ ; PL Area}$$

Kilowatt (KW) increasing rate of each PL Area is like as OUTPUT 24.

(3) Estimation of KW of each mesh

Kilowatt (KW) of each mesh from year 1980 – 2001 was obtained according to the following procedure, that is,

Multiply KW (1979) of each mesh, which is already calculated, by KW increasing rate $IR_{n.p}$ of each PL Area.

Estimation results of distribution load (KW) of each mesh are like as OUTPUT 25, and KW in 1991 and 2001 is shown on the Load Density Map.

Furthermore, distribution load of each mesh is tabulated in Table V-5 for 0.5 Km^2, 1 Km^2 and 2 Km^2 area.

4. Conclusion

MEA's basic demand was converted to 69 KV-Customer load and distribution load, and results are tabulated in Table 3 and Table 4.

Table 2. Calculation Result of Load (KW) by Mesh

		500 m mesh	1.0 km mesh	2.0 km mesh	Total
Number of mesh		137	608	451	1,196
Area	km^2	34.25	608	1,804	2,446.25
KW	1979 (A)	282,151.7	695,913.3	150,834.2	1,128,899.2
	2001 (B)	726,792.4	2,521,934.9	585,540.3	3,834,267.6
	Ratio:B/A	2.576	3.624	3.882	3.396
Load density	1979 KW/km^2	8,238.0	1,144.6	83.6	461.5
	2001 "	21,220.2	4,147.9	324.6	1,567.4

Table 3.

Unit: MW

Year	Distribution Load	69 KV Customer Load	Total
1982	1,304	255	1,559
1986	1,651	407	2,058
1991	2,189	676	2,865
1996	2,889	1,060	3,949
2001	3,834	1,562	5,396

Distribution facilities planning will be studied by applying the above results as basic load.

Fig. 1 Rate 69 (1975 ∿ 1979)

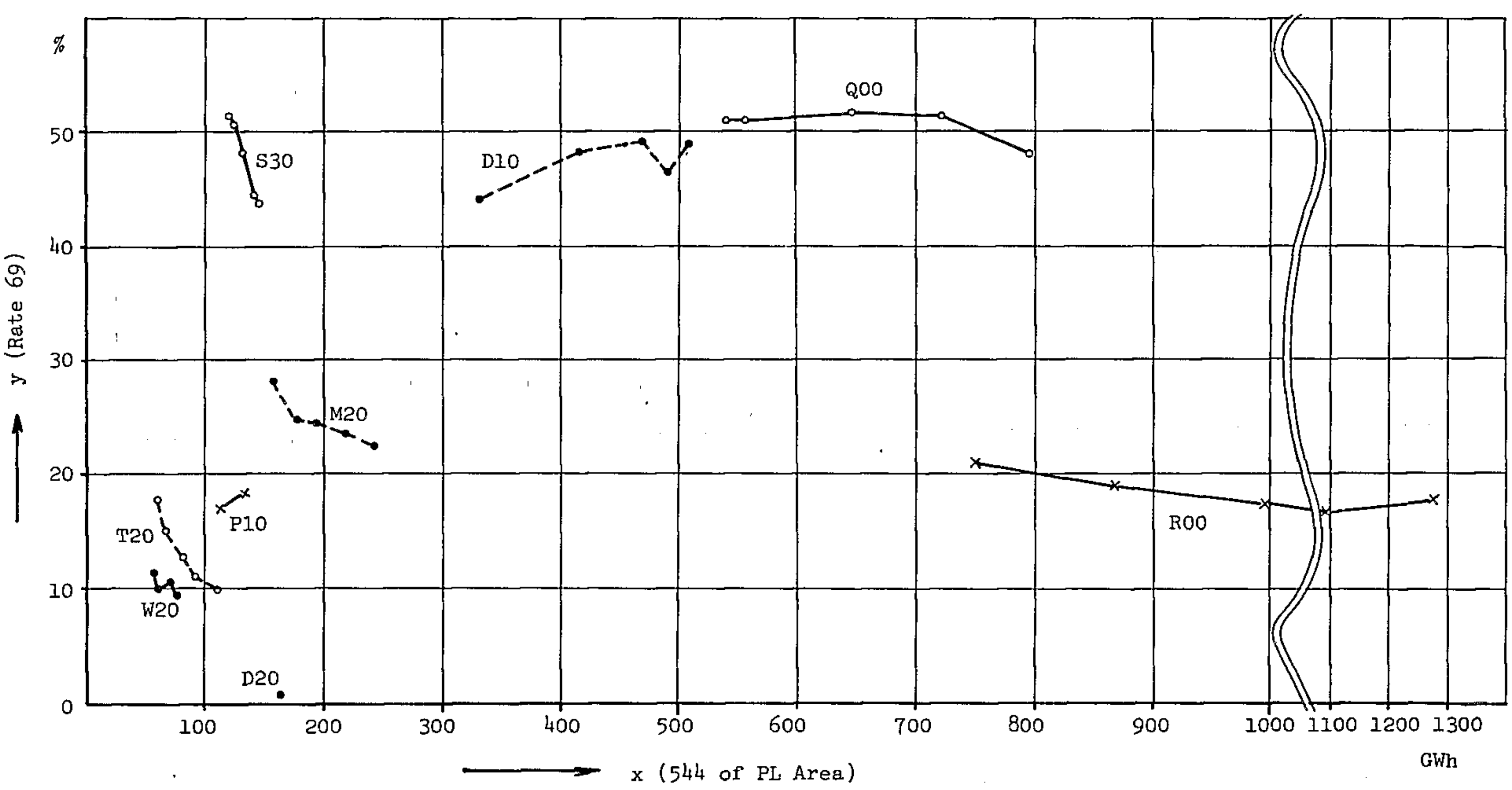


Fig. 2 Model Curve of Rate 69

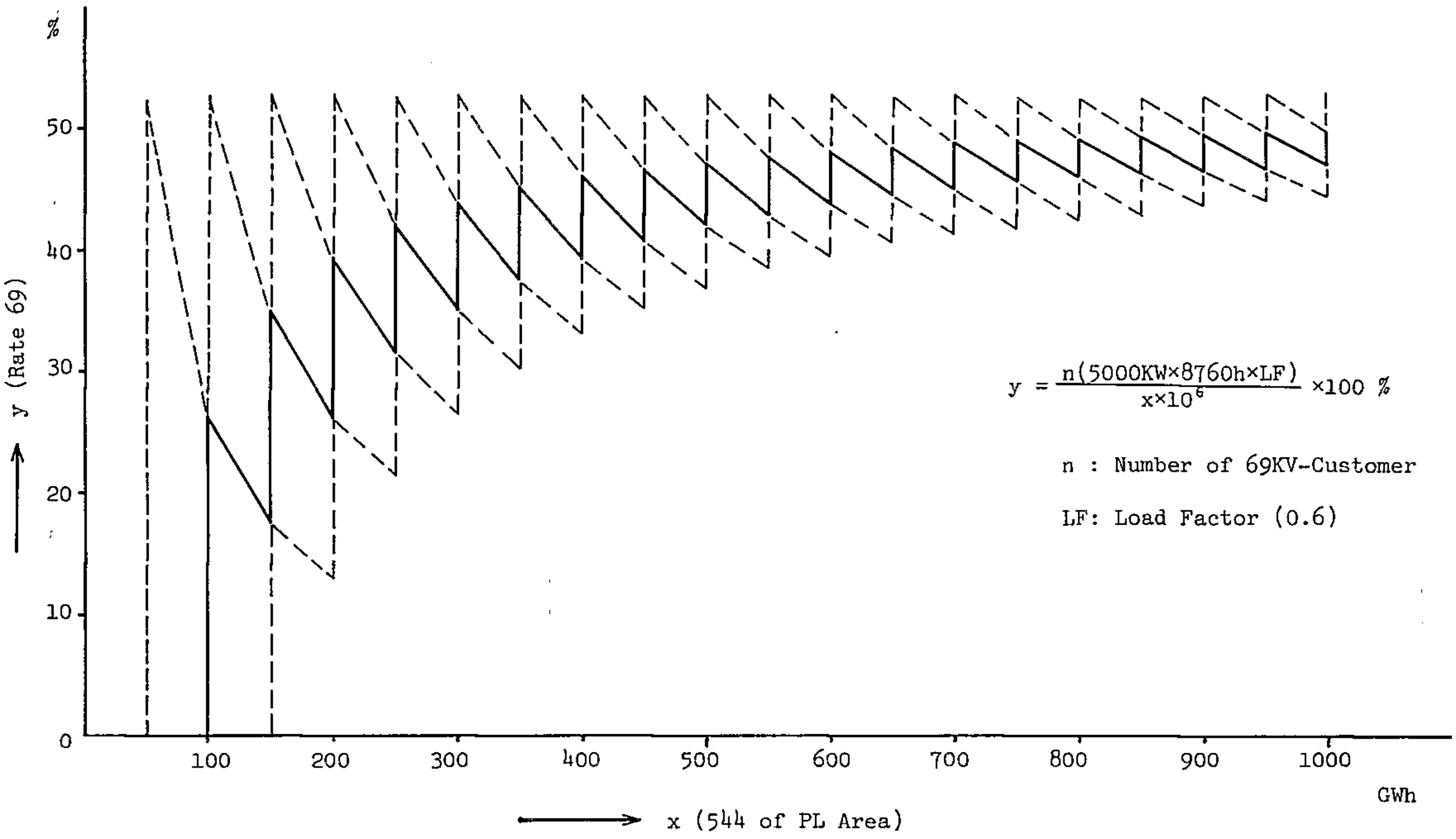


Fig. 3. Standard Increasing Curve of Rate 69

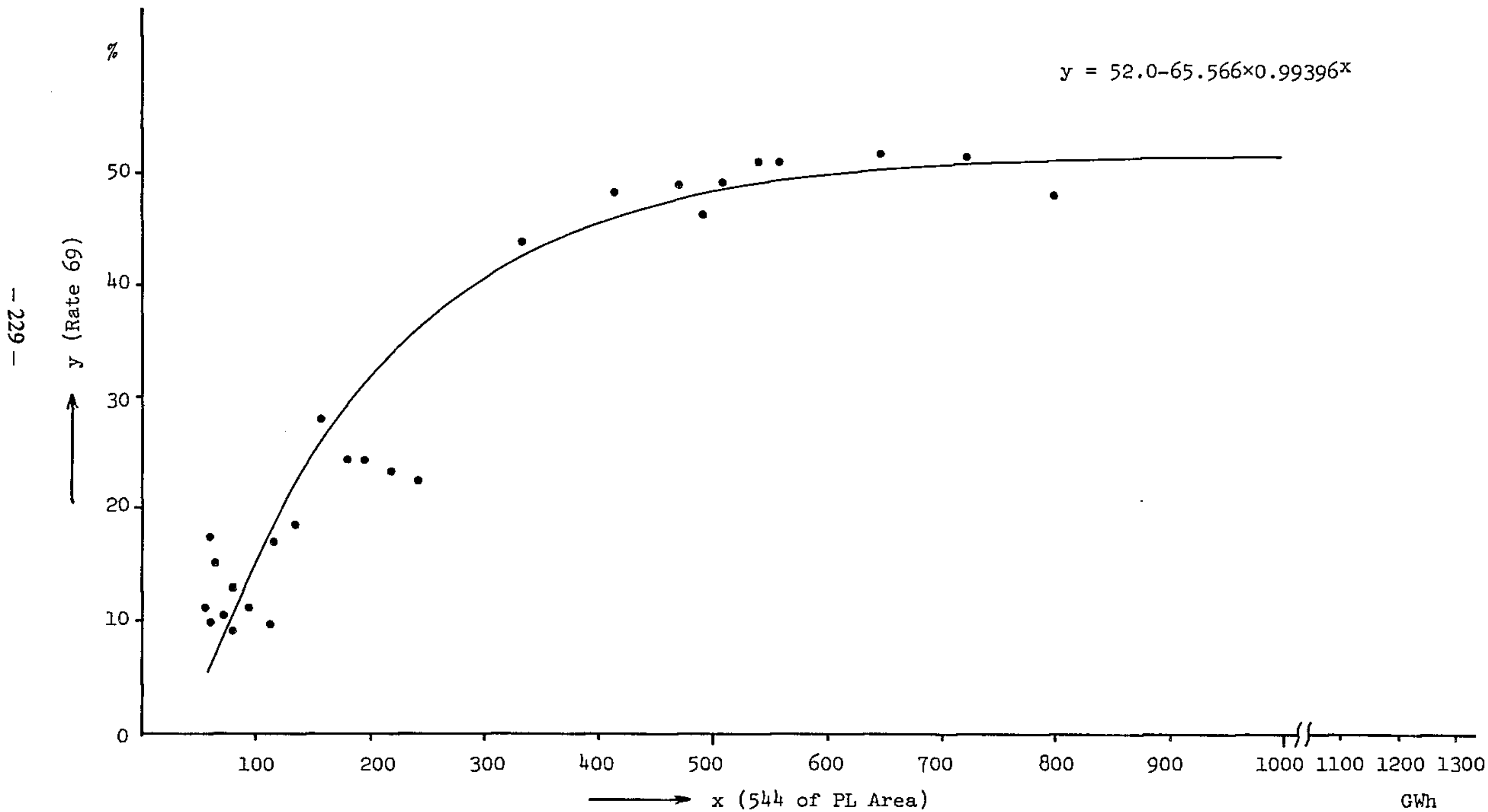
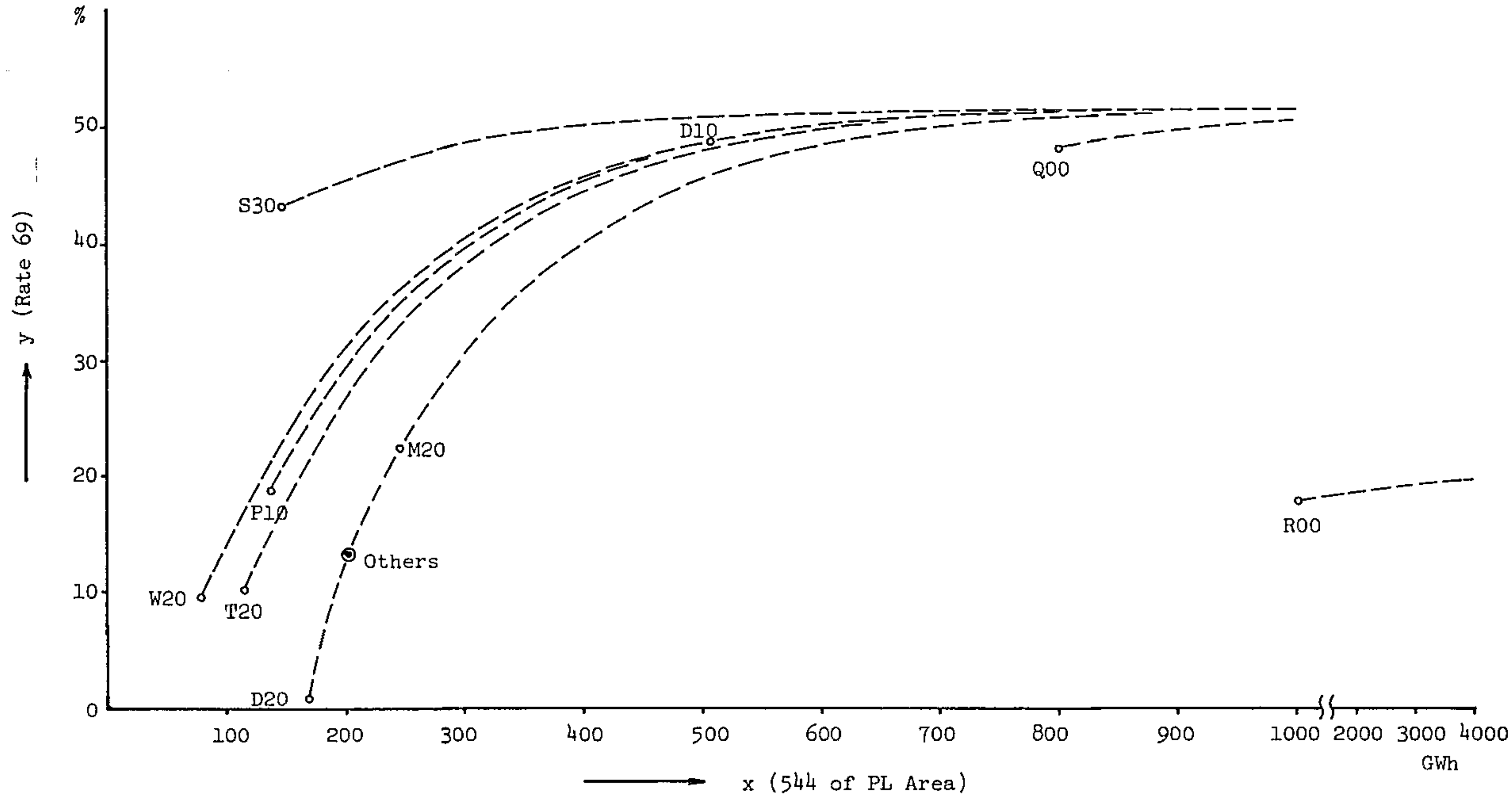


Fig. 4. Estimation of Rate 69



Appendix 2

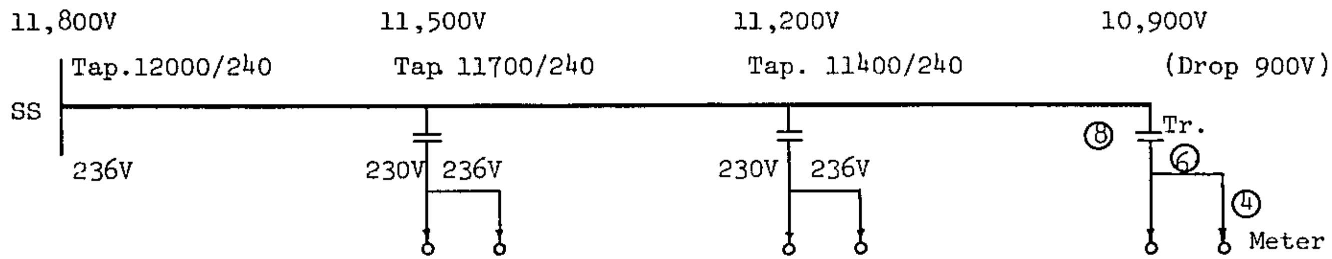
SERVICE VOLTAGE FOR EACH AREA

Unit : Volt

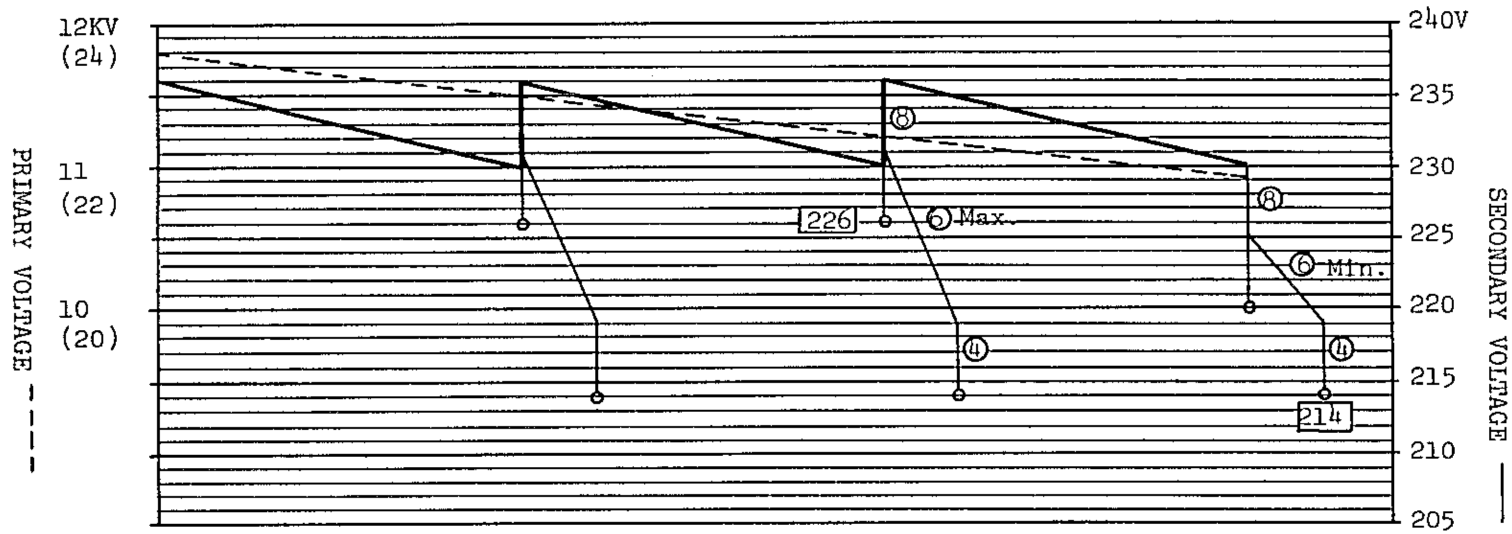
		Light Load	Heavy Load
A Area	Normal Voltage		
	Min	218	214
	Max	222	226
	Emergency Voltage		
	Min	214	213
	Max	220	230
B Area	Normal Voltage		
	Min	218	214
	Max	226	226
	Emergency Voltage		
	Min	215	208
	Max	223	230
C Area	Normal Voltage		
	Min	218	214
	Max	230	226
	Emergency Voltage		
	Min	215	203
	Max	226	230

Study of Distribution Line Voltage Drop.

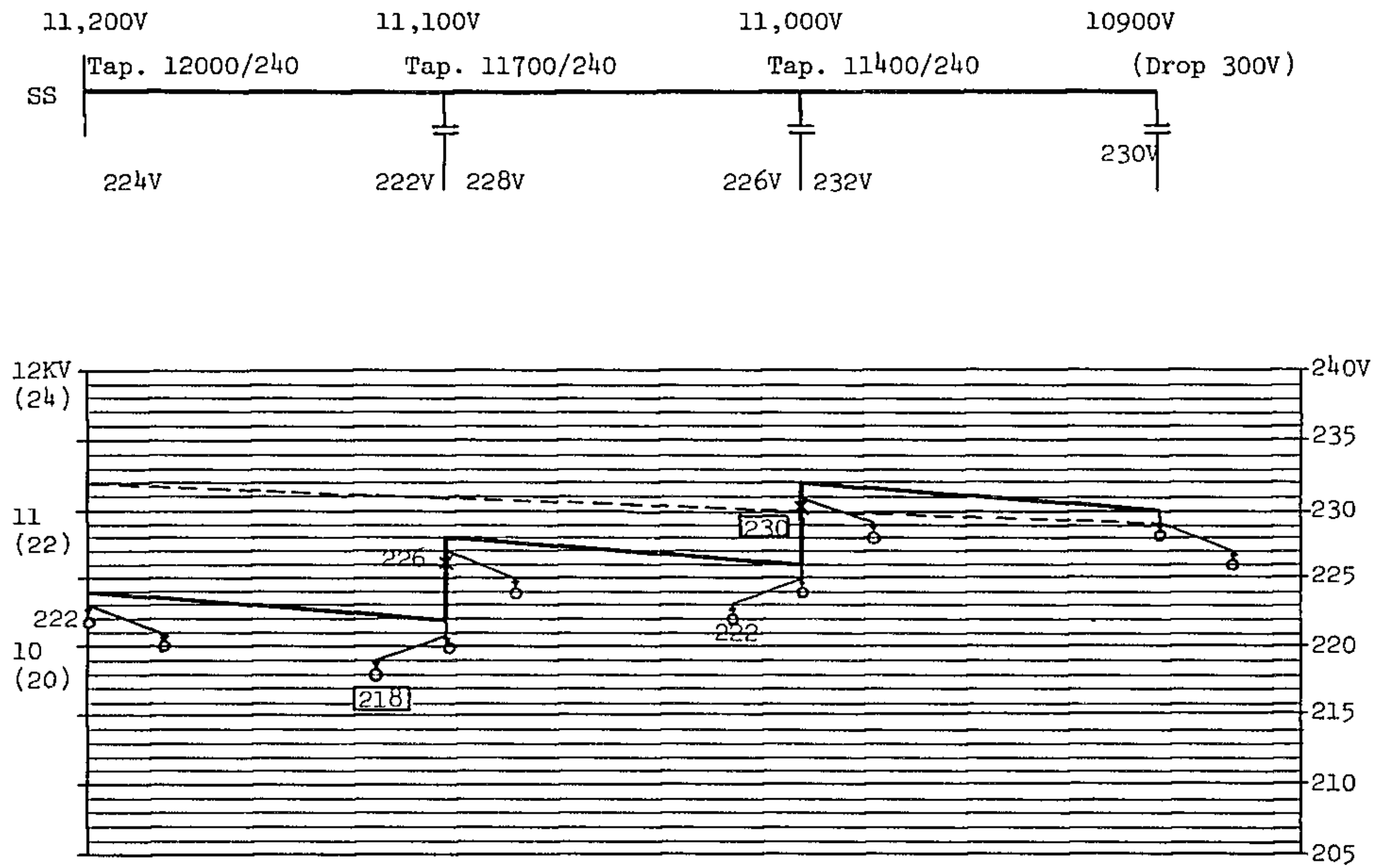
Normal Voltage -- Heavy Load



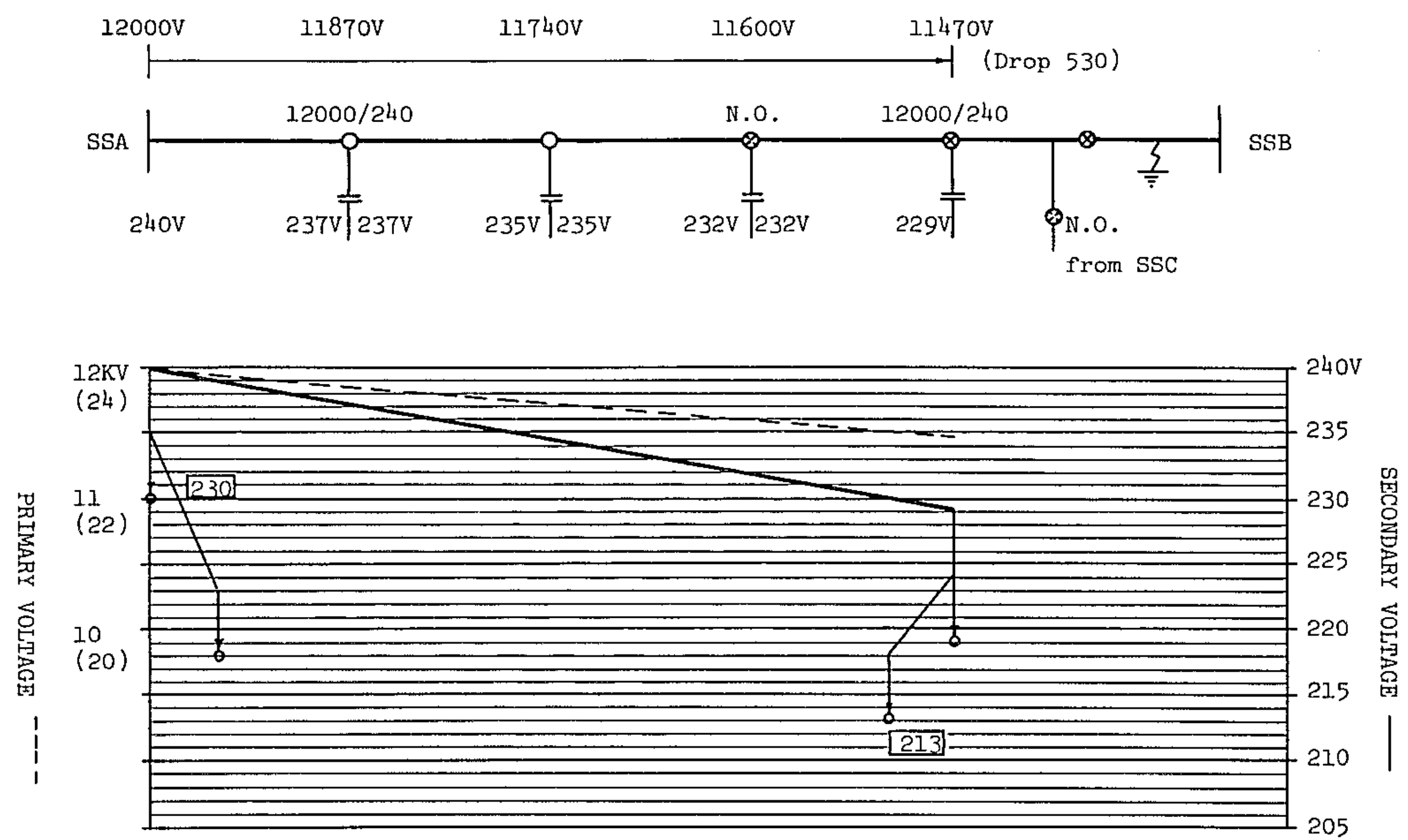
⑧ Voltage drop through Tr.
⑥ " in secondary line
④ " in service wire



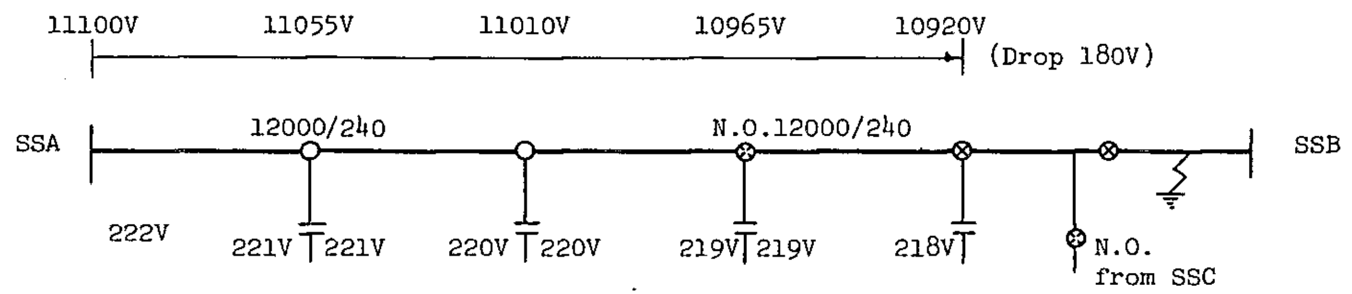
Normal Voltage - Light Load

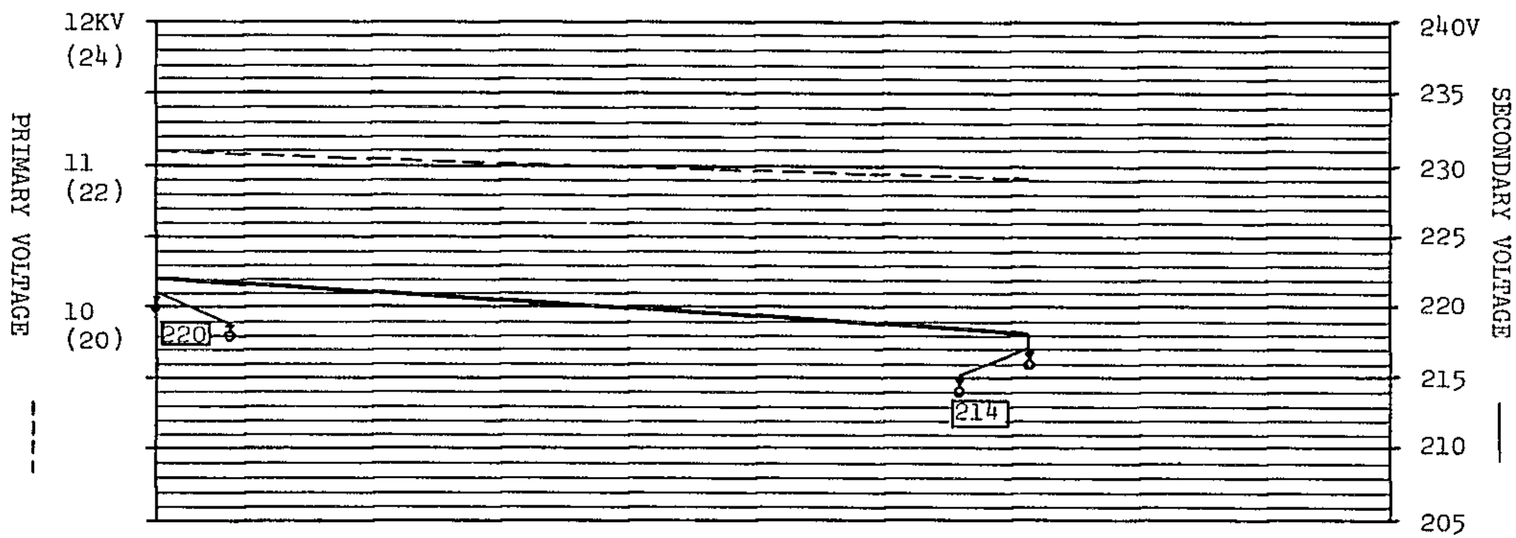


Emergency Voltage - Heavy Load - A area

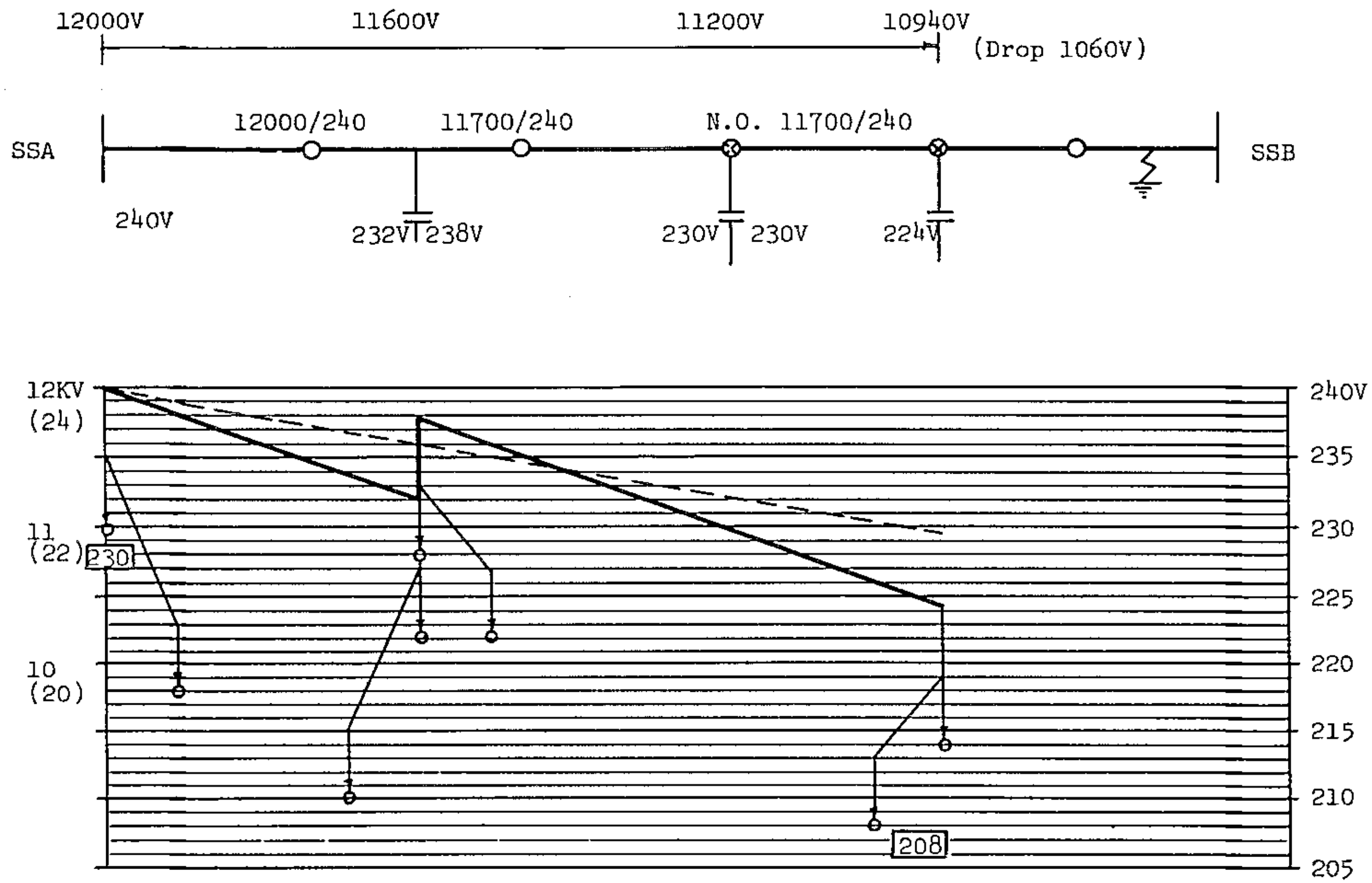


Emergency Voltage - Light Load - A area

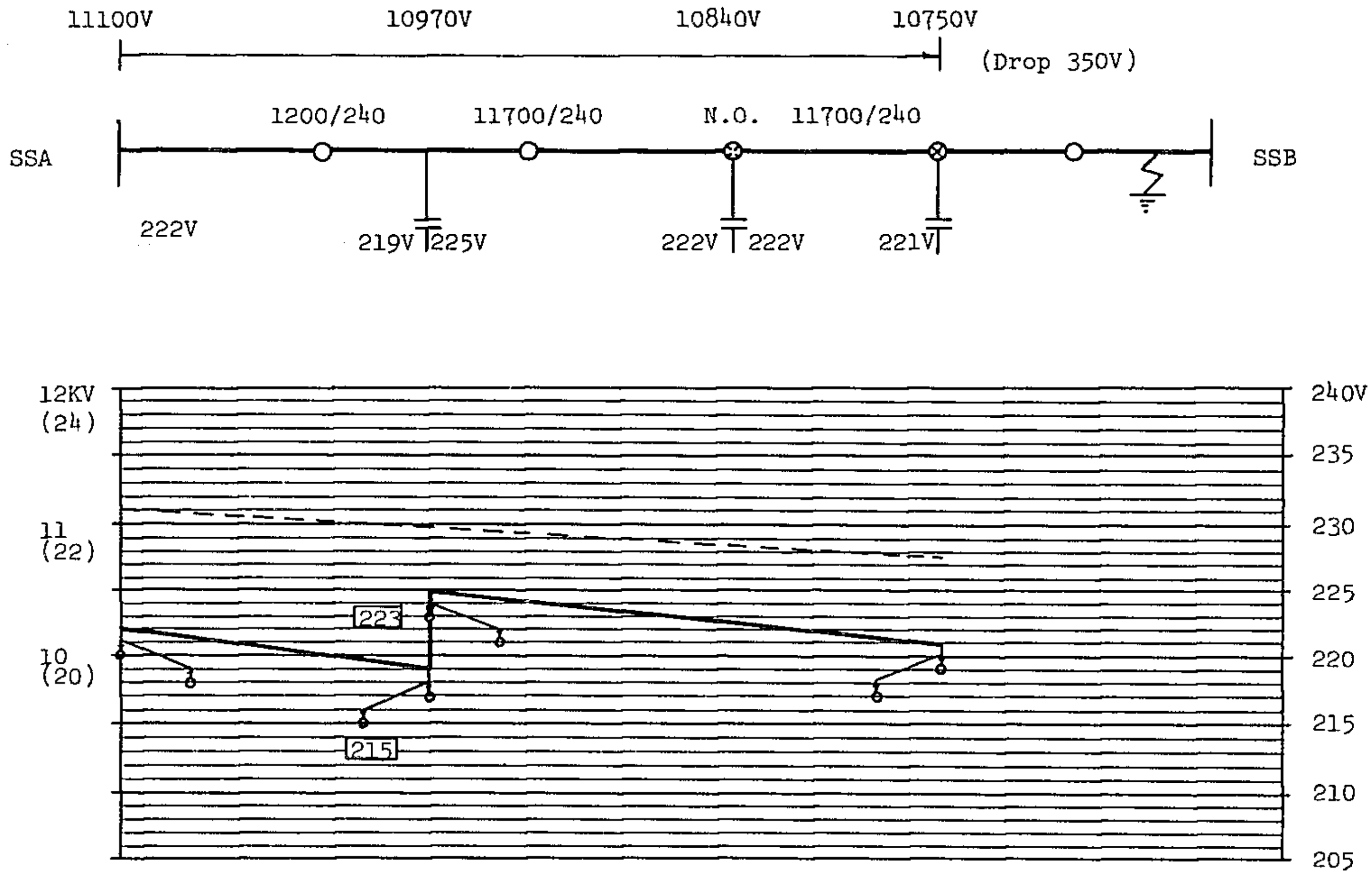




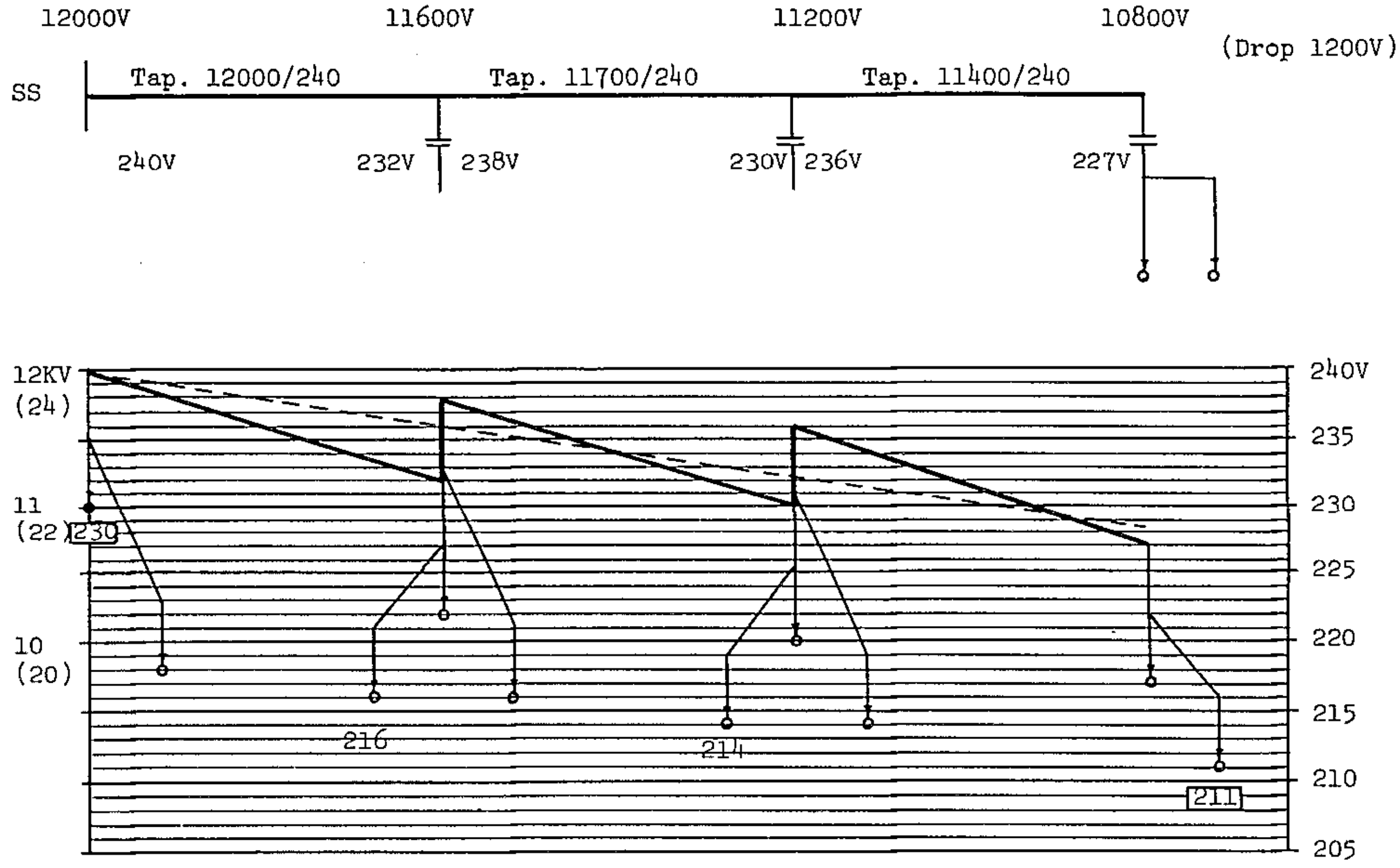
Emergency Voltage - Heavy Load - B area



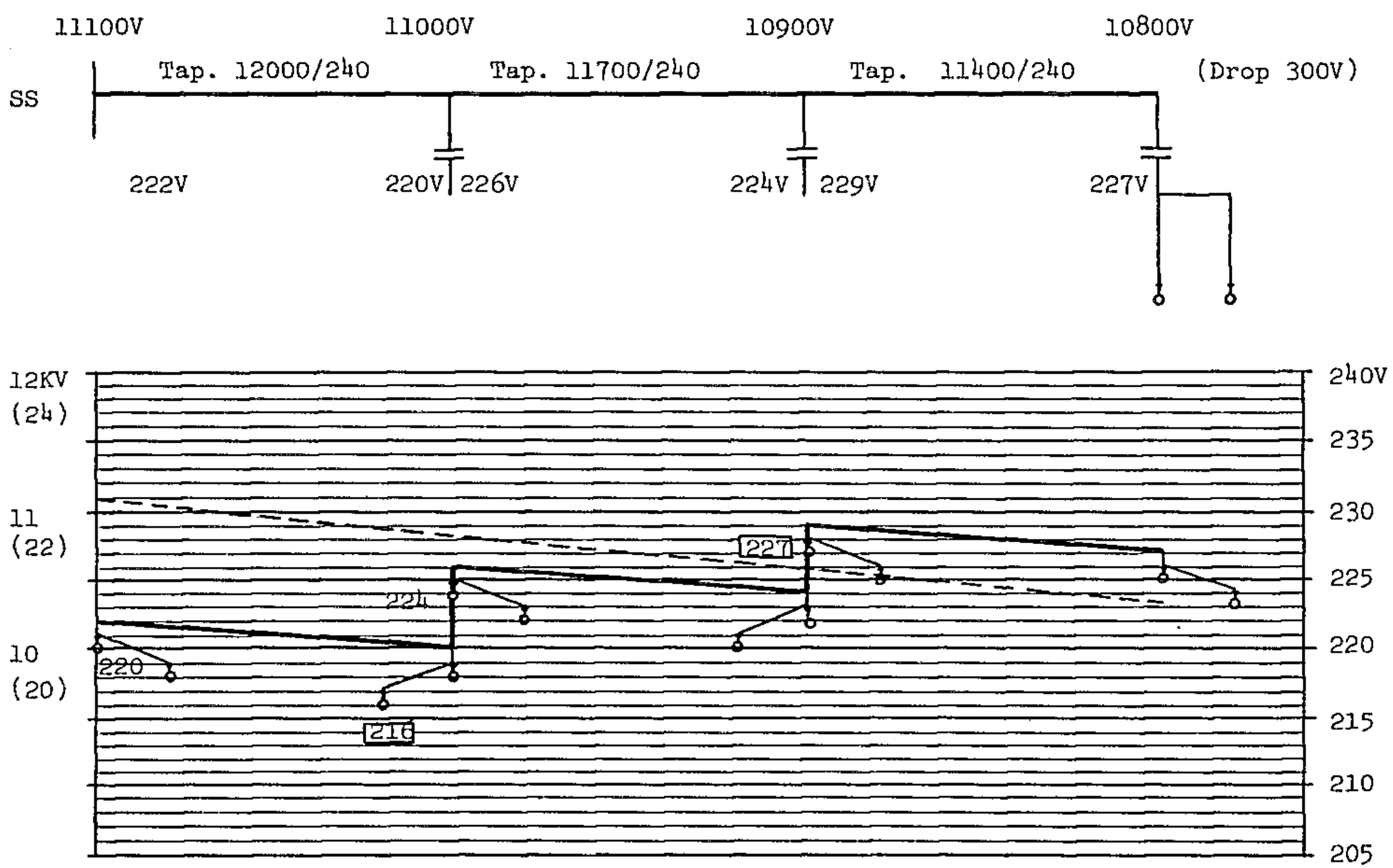
Emergency Voltage - Light Load - B area



Emergency Voltage - Heavy Load - C area



Emergency Voltage - Light Load - C area



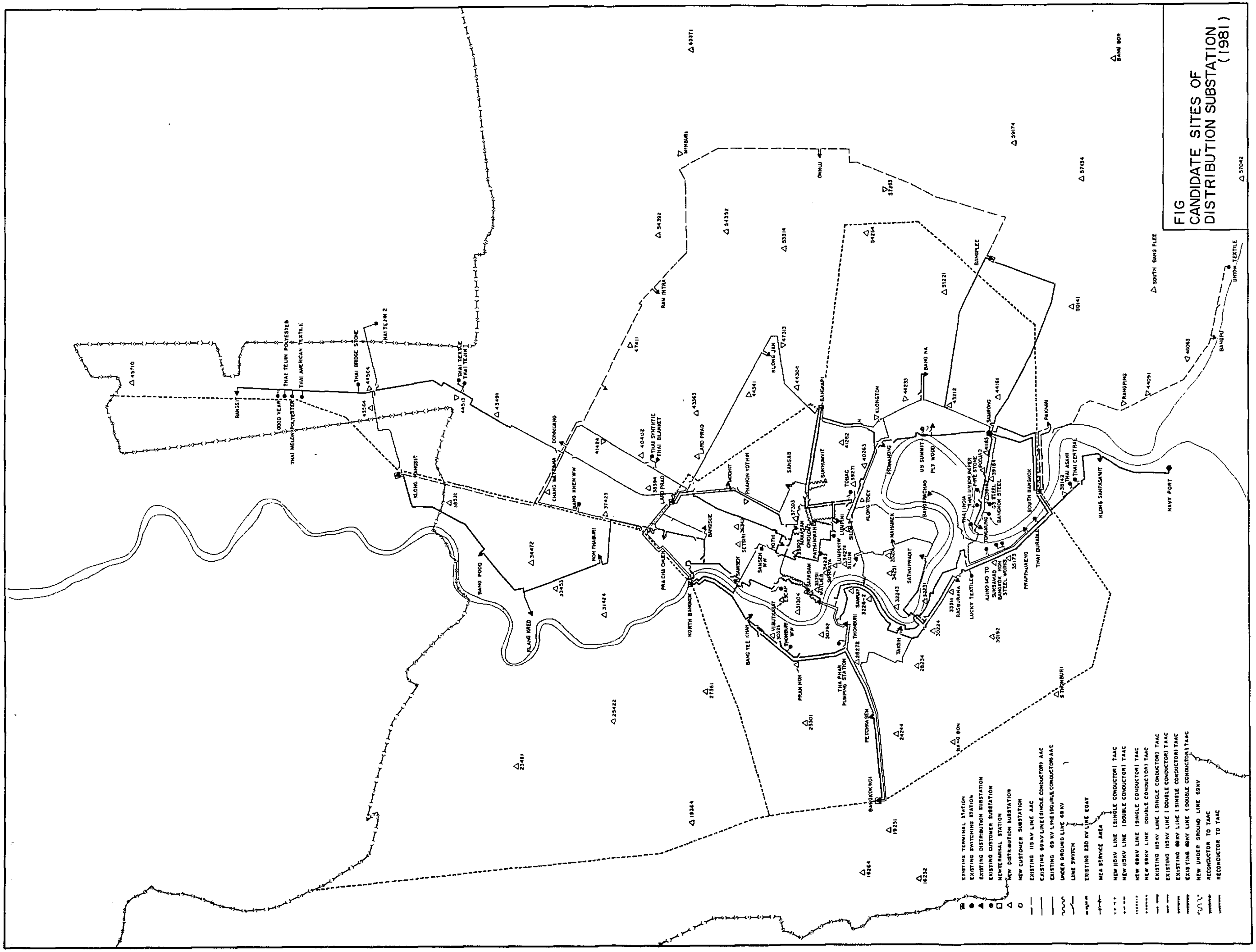


FIG
CANDIDATE SITES OF
DISTRIBUTION SUBSTATION
(1981)

Appendix 4 Load Sharing Calculation (Transportation problem method)

Process of load share calculation is as follows:

1. Ideal service area will be fixed for each SS. (Only geographical restriction condition should be applied. Each mesh is served by the nearest SS.)

2. If the load in ideal service area is bigger than the capacity of the SS (such as C SS in sample diagram), calculation is done as follows;

(1) Find out an adjacent SS which has its surplus capacity (such as B SS) and following calculation is done on each mesh served by C SS.

$$L_{di} = | L_{ij} - L_{ic} |$$

where L_{ij} .... distance between mesh i and adjacent SS_j (B SS or D SS)

L_{ic} .... distance between mesh i and C SS

(2) Next, find out a mesh which has minimum value of L_{di}, and the load of that mesh is transferred to be under the service of j SS.

(3) Above process are refrained until the adjacent SS becomes on full loading.

(4) If two or more substations appears in shortage of capacity after fixing of ideal service area, above-described calculation process should be followed on all of each mesh served by those SSs.

3. In such a case that any adjacent SS has not enough surplus capacity, calculation process is as follows;

(1) Find a nearest SS (A SS in example) which has still surplus capacity.

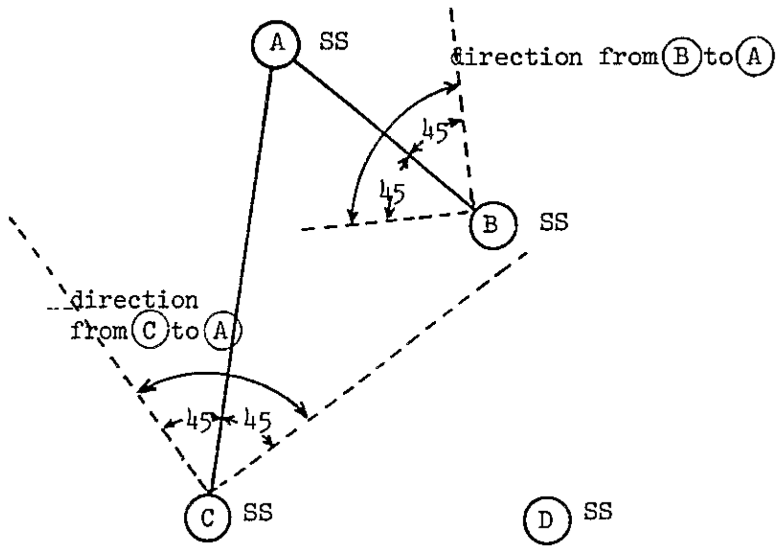
(2) Have a look in the direction toward A SS from C SS, (*) and find another SS (B SS in example) which is located most nearly of C SS. (B SS has not surplus capacity.)

(3) Load P_m under service of C SS is transferred to be served by B SS in same manner of above term 2. Where P_m is equivalent to the smaller one of surplus capacity of A SS and shorted capacity of C SS.

(4) Next, have a look in the direction towards A SS from B SS, and find a nearest SS (A SS in this case). Load P served by B SS is transferred to A SS, while P is quantity of P_m.

(5) Such process would be refrained until capacity-shorted substation can be found no more.

* Definition of "direction"



A
SS
direction from B to A
45
45
B
SS
direction
from C to A
45
45
C
SS
D
SS

Appendix 5 Distribution Substation Expansion Program of Each Cases

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 2)

Unit . No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangkok Noi	2x20				+1x20			+1x40 -1x20														1x40 2x20
	16232															new 2x20							2x20
	Bangyekhan	2x40																					2x40
	Pechkasem	3x20			+1x40 -1x20																		1x40 2x20
	North BKK	2x20																					2x20
	Rasburana	2x40												+1x40									3x40
	Thonburi	2x40											+1x40										3x40
	Taksin	2x40															+1x40						3x40
	Pran Nok			new 1x40											+1x40								2x40
	Samray																	new 2x40			+1x40		3x40
	28272																					new 2x40	2x40
	32231									new 2x40						+1x40							3x40
	30224																			new 2x40			2x40
	Klong Sanpsamit	2x20																					2x20
	Prapradaen	2x40																					2x40
	Bangbon			new 1x40	+1x40																		2x40
	Suksawad																			new 2x40			2x40
	Bangkrejao	2x10																					2x10
30	Rangsit	2x40																				+1x40	3x40
	43564													new 2x20						+1x20			3x20
	Klong Rangsit	1x40						+1x40											+1x40				3x40
40	Bangpood	2x20																				+1x20	3x20
	43491				new 2x40																		2x40
	Donmuang	2x40																					2x40
	Nontaburi	2x20												+1x40 -1x20				+1x40 -1x20	+1x40				3x40
	Prachacuen	2x40													+1x40								3x40
	40402																				new 2x40		2x40
	Bangkapi	2x40																	+1x40				3x40
	Bangsue	1x10												+1x40	+1x40 -1x10					+1x40			3x40
	Klong Jan	2x40															+1x40						3x40
	Mochit	2x40														+1x40							3x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 2)

Unit · No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Sansab	2x40																			+1x40		3x40
	Sukhumvit	1x40	+1x40																				2x40
	Paholyotion		new 1x40	+1x40																			2x40
	Lardprao																					new 2x40	2x40
	44341																	new 2x40			+1x40		3x40
	Lumpini	2x40																			+1x40		3x40
	Makasan	2x40																					2x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																				+1x40	3x40
	Silom	2x40																					2x40
	Watlieb	2x40																		+1x40			3x40
	Yothee	2x40																					2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat																	new 2x40					2x40
	Mahamek	2x40												+1x40									3x40
	Satupradit	1x40	+1x40															+1x40					3x40
	32243																					new 2x40	2x40
	Bangna	2x40																					2x40
	Plywood	1x20														+1x40 -1x20		+1x40					2x40
	Samrong	2x40																					2x40
	South BKK	1x20																			+1x40 -1x20		1x40
	Tangkung	2x40																			+1x40		3x40
	44233																					new 2x40	2x40
	41183												new 2x40				+1x40						3x40
	39184								new 2x40										+1x40				3x40
50	Ramintra	2x40																					2x40
	Ladplakao	1x40																					1x40
	Minburi														new 2x20								2x20
	54352																			new 2x20			2x20
	Bangplee	1x40																		+1x40			2x40
	Onnuj	2x40																					2x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 2)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
50	54264												new 2x20					+1x20					3x20
	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangbor					new 2x20		+1x20															3x20
	44091								new 2x40					+1x40									3x40
	46063																			new 2x20		+1x20	3x20
	50141																		new 2x20			+1x20	3x20
	57134																new 2x20	+1x20					3x20
	Number of substation	46	+2 48	+4 52	+1 53	+1 54	54	54	+2 56	+1 57	57	57	+2 59	+1 60	+1 61	+1 62	+1 63	+3 66	+1 67	+4 71	+1 72	+4 76	+30 76
	Total capacity (MVA)	2,990	3,150	3,470	3,610	3,670	3,670	3,730	3,910	3,990	3,990	3,990	4,150	4,370	4,520	4,660	4,820	5,200	5,400	5,780	6,100	6,540	
	Total load (MVA)		1,448	1,541	1,636	1,737	1,835	1,946	2,064	2,176	2,299	2,432	2,573	2,720	2,877	3,039	3,210	3,395	3,592	3,802	4,024	4,261	
	Utilizing factor (%)		46.0	44.4	45.3	47.3	50.0	52.2	52.8	54.5	57.6	60.9	62.0	62.2	63.6	65.2	66.6	65.3	66.5	65.8	66.0	65.1	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 3)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangkok Noi	2x20																					2x20
	19251															new 1x20							1x20
	16264								new 1x20											+1x20			2x20
	16232					new 1x20																	1x20
	Bangyerhan	2x40																					2x40
	Pechkasem	3x20			+1x40 -1x20																		1x40 2x20
	North BKK	2x20																					2x20
	Rasburana	2x40																+1x40					3x40
	Thonburi	2x40																					2x40
	Taksin	2x40																					2x40
	Pran Nok			new 1x40																			1x40
	Samray											new 1x40								+1x40			2x40
	30321																				new 1x40		1x40
	28272													new 1x40								+1x40	2x40
	32231									new 1x40									+1x40				2x40
	30224												new 1x40								+1x40		2x40
	28234																new 1x40						1x40
	30292															new 1x40							1x40
	24244														new 1x40								1x40
	Klong Sanpasamit	2x20																					2x20
	Prapradaen	2x40																					2x40
	Bangbon			new 1x40	+1x40																		2x40
	Suksawad																			new 1x40			1x40
	Bangkrajao	2x10																					2x10
30	Rangsit	2x40																					2x40
	44564																			new 1x40			1x40
	43564													new 1x20									1x20
	45710																new 1x20						1x20
	Klongransit	1x40						+1x40											+1x40				3x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 3)

Unit . No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Bangpood	2x20										+1x20											3x20
	43491				new 1x40											1x40							2x40
	Donmuang	2x40																					2x40
	Nontaburi	2x20															+1x40						1x40 2x20
	Prachacuen	2x40																					2x40
	40402													new 1x40									1x40
	31424																		new 1x40				1x40
	38394																				new 1x40		1x40
	Bangkapi	2x40																					2x40
	Bangsue	1x10																	+1x40				1x40 1x10
	Klong Jan	2x40																					2x40
	Mochit	2x40																					2x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Sansab	2x40																					2x40
	Sukhumvit	1x40	+1x40																				2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Lardprao														new 1x40								1x40
	Klongton																		new 1x40				1x40
	Setsiri																new 1x40					+1x40	2x40
	47313																	new 1x40					1x40
	44341													new 1x40							+1x40		2x40
	40263															new 1x40						+1x40	2x40
	41282																			new 1x40			1x40
	Lumpini	2x40																					2x40
	Makasan	2x40																					2x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																					2x40
	Silom	2x40																					2x40
	Watlieb	2x40																					2x40
	Yothee	2x40																					2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat																	new 1x40					1x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 1)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Silom 2																				new 1x40		1x40
	34274																					new 1x40	1x40
	33291																		new 1x40				1x40
	31304																			new 1x40			1x40
	Mahamek	2x40																					2x40
	Satupradit	1x40	+1x40																				2x40
	32243													new 1x40									1x40
	35251																					new 1x40	1x40
	34251																	1x40					1x40
	Bangna	2x40																					2x40
	Plywood	1x20																				-1x20 +1x40	1x40
	Samrong	2x40																					2x40
	South BKK	1x20																					1x20
	Tangkung	2x40																					2x40
	44233												new 1x40								+1x40		2x40
	38192																new 1x40		+1x40				2x40
	41183										new 1x40				+1x40					+1x40			3x40
	39184								new 1x40														1x40
	44181															new 1x40							1x40
50	Ramintra	2x40																					2x40
	Ladplakao	1x40																					1x40
	Minburi														new 1x20								1x20
	47411																					new 1x20	1x20
	54352																	1x20					1x20
	65371																			new 1x20			1x20
	Bangplee	1x40																		+1x40			2x40
	Onnuj	2x40																					2x40
	54264												new 1x20			+1x20		+1x20					3x20
	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangping																					new 1x40	1x40
	Bangbor					new 1x20			+1x20		+1x20												3x20
	44091						new 1x40					+1x40		+1x40									3x40
	46063																	new 1x20		+1x20	+1x20		3x20

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 3)

Unit No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
50	50141																new 1x20						1x20
	57134																new 1x20		+1x20	+1x20			3x20
	67942																					new 1x20	1x20
	Number of substation	46	+2 48	+4 52	+1 53	+2 55	+1 56	56	+2 58	+1 59	+1 60	+1 61	+3 64	+5 69	+3 72	+4 76	+6 82	+5 87	+3 90	+5 95	+3 98	+5 103	+57 103
	Total capacity (MVA)	2,990	3,150	3,470	3,570	3,610	3,650	3,690	3,770	3,810	3,870	3,970	4,070	4,290	4,430	4,630	4,850	5,070	5,370	5,730	6,030	6,290	
	Total load (MVA)		1,448	1,541	1,636	1,737	1,835	1,946	2,064	2,176	2.299	2,432	2,573	2,720	2,877	3,039	3,210	3,396	3,592	3,802	4,024	4,261	
	Utilizing factor (%)		46.0	44.4	45.8	48.1	50.3	52.7	54.8	57.1	59.4	61.3	63.2	63.4	64.9	65.6	66.2	67.0	66.9	66.4	66.7	67.7	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 4)

Unit No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangyekhan	2x40																					2x40
	Klong Sanpasamit	2x20																					2x20
	Pechkasem	3x20			+1x40 -1x20																		1x40 2x20
	North BKK	2x20												+1x40 -1x20						+1x40 -1x20			2x40
	Prapradaen	2x40																					2x40
	Rasburana	2x40																					2x40
	Thonburi	2x40																					2x40
	Taksin	2x40																					2x40
	Bangkok Noi	2x20																					2x20
	Bangkrajao	2x10																					2x10
	Dangbon			new 1x40	+1x40																		2x40
	Pran Nok			new 1x40									+1x40										2x40
	Suksawad																			new 2x40			2x40
	Samray														new 2x40								2x40
	28272																		new 2x40				2x40
	32231									new 2x40													2x40
	30224																new 2x40						2x40
	28234																					new 2x40	2x40
	16264															new 2x40							2x40
	16232					new 2x20																	2x20
	24244																				new 2x40		2x40
30	Rangsit	2x40																					2x40
	Klong Ransit	1x40						+1x40											+1x40				3x40
	43564													new 2x20									2x20
	45710																			new 2x20			2x20
40	Lumpini	2x40																					2x40
	Makasan	2x40																					2x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																					2x40
	Silom	2x40																					2x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 4)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Watlieb	2x40																					2x40
	Yothee	2x40																					2x40
	Bangkapi	2x40																					2x40
	Bangna	2x40																					2x40
	Bangsue	1x10												+1x40	+1x40 -1x10								2x40
	Donmuang	2x40																					2x40
	Klong Jan	2x40																					2x40
	Mahamek	2x40																					2x40
	Mochit	2x40																					2x40
	Nontaburi	2x20												+1x40 -1x20	+1x40 -1x20								2x40
	Plywood	1x20														+1x40	+1x40 -1x20						2x40
	Prachacuen	2x40																					2x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Samrong	2x40																					2x40
	Sansab	2x40																					2x40
	Satupradit	1x40	+1x40																				2x40
	South BKK	1x20																+1x40	+1x40 -1x20				2x40
	Tangkung	2x40																					2x40
	Bangpood	2x20																					2x20
	Sukhumvit	1x40	+1x40																				2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat																	new 2x40					2x40
	Lardprao																	new 2x40					2x40
	Setsiri																				new 2x40		2x40
	38462																				new 2x20		2x20
	33291																			new 2x40			2x40
	31304																					new 2x40	2x40
	40402																new 2x40						2x40
	47313																					new 2x40	2x40
	32243													new 2x40									2x40
	31424																				new 2x40		2x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 4)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	44233																			new 2x40			2x40
	44341															new 2x40							2x40
	40263																		new 2x40				2x40
	41183												new 2x40										2x40
	39184								new 2x40														2x40
	44181																					new 2x40	2x40
	43491				new 2x40																		2x40
	34251																					new 2x40	2x40
50	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangplee	1x40																+1x40					2x40
	Onnuj	2x40																					2x40
	Ramintra	2x40																					2x40
	Ladplakao	1x40																					1x40
	Bangping																			new 2x40			2x40
	Minburi														new 2x20								2x20
	Bangbor					new 2x20																	2x20
	44091							new 2x40															2x40
	46063																new 2x20						2x20
	54264												new 2x20										2x20
	54352																			new 2x20			2x20
	51221																				new 2x20		2x20
	50141														new 2x20								2x20
	57134												new 2x20										2x20
	67042																		new 2x20				2x20
	Number of substation	46	+2 48	+4 52	+1 53	+2 55	55	+1 56	+1 57	+1 58	58	58	+3 61	+2 63	+3 66	+2 68	+3 71	+2 73	+3 76	+6 82	+5 87	+5 92	+46 92
	Total capacity (MVA)	2,990	3,150	3,470	3,610	3,690	3,690	3,810	3,890	3,970	3,970	3,970	4,170	4,370	4,580	4,720	4,960	5,180	5,460	5,880	6,200	6,600	
	Total load (MVA)	1,366	1,448	1,541	1,636	1,737	1,835	1,946	2,064	2,176	2,299	2,432	2,573	2,720	2,877	3,039	3,210	3,395	3,592	3,802	4,024	4,261	
	Utilizing factor (%)	45.7	46.0	44.4	45.3	47.1	49.7	51.1	53.1	54.8	57.9	61.3	61.7	62.2	62.8	64.4	64.7	65.5	65.8	64.7	64.9	64.6	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 5)

Unit . No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangyekhan	2x40																					2x40
	Klong Sanpasamit	2x20																					2x20
	Pechkasem	3x20			+1x40 -1x20																		1x40 2x20
	North BKK	2x20																					2x20
	Prapradaen	2x40																					2x40
	Rasuburana	2x40																					2x40
	Thonburi	2x40																					2x40
	Taksin	2x40																					2x40
	Bangkok Noi	2x20																					2x20
	Bangkrajao	2x10																					2x10
	Bangbon			new 1x40	+1x40																		2x40
	Pran Nok			new 1x40																			1x40
	Suksavad																			new 1x40			1x40
	Samray											new 1x40								+1x40			2x40
	30321																				new 1x40		1x40
	28272													new 1x40							+1x40		2x40
	32231									new 1x40								+1x40					2x40
	30224												new 1x40						+1x40				2x40
	28234																new 1x40						1x40
	30292															new 1x40						+1x40	2x40
	19251															new 1x20							1x20
	16264								new 1x20											+1x20			2x20
	16232					new 1x20																	1x20
	24244														new 1x40								1x40
30	Rangsit	2x40																					2x40
	Klong Rangsit	1x40						+1x40											+1x40				3x40
	44564																			new 1x40			1x40
	43564													new 1x20									1x20
	45710																new 1x20						1x20

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 5)

Unit . No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Lumpini	2x40																					2x40
	Makasan	2x40																					2x40
	Sapandam	4x40																					4x40
	Pathumuwan	2x40																					2x40
	Silom	2x40																					2x40
	Watlieb	2x40																					2x40
	Yothee	2x40																					2x40
	Bangkapi	2x40																					2x40
	Bangna	2x40																					2x40
	Bangsue	1x10																	+1x40				1x40 1x10
	Donmuang	2x40																					2x40
	Klong Jan	2x40																					2x40
	Mahamek	2x40																					2x40
	Mochit	2x40																					2x40
	Nontaburi	2x20															+1x40 -1x20						1x40 1x20
	Plywood	1x20																				+1x40 -1x20	1x40
	Prachacuen	2x40																					2x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Samrong	2x40																					2x40
	Sansab	2x40																					2x40
	Satupradit	1x40	+1x40																				2x40
	South BKK	1x20																					1x20
	Tangkung	2x40																					2x40
	Bangpood	2x20																					2x20
	Sukhumvit	1x40	+1x40																				2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat																	new 1x40					1x40
	Silom 2																				new 1x40		1x40
	Ladprao														new 1x40						+1x40		2x40
	Klongton																		new 1x40				1x40
	Setsiri																new 1x40				+1x40		2x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 5)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Jangwatna																				new 1x20		1x20
	34274																					new 1x40	1x40
	33291																		new 1x40				1x40
	31304																			new 1x40			1x40
	40402													new 1x40				+1x40					2x40
	47313																	new 1x40					1x40
	32243													new 1x40									1x40
	31424																			new 1x40			1x40
	44233												new 1x40							+1x40			2x40
	38394																					new 1x40	1x40
	38192																new 1x40		+1x40				2x40
	44341													new 1x40								+1x40	2x40
	35251																					new 1x40	1x40
	40263															new 1x40							1x40
	41183										new 1x40				+1x40								2x40
	39184								new 1x40												+1x40		2x40
	44181															new 1x40							1x40
	43491				new 1x40							+1x40											2x40
	41282																			new 1x40			1x40
	34251																	new 1x40					1x40
50	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangplee	1x40																+1x40					2x40
	Onnuj	2x40																					2x40
	Ramintra	2x40																					2x40
	South Bangplee																				new 1x40		1x40
	Ladplakao	1x40																					1x40
	Bangping																		new 1x40				1x40
	Minburi														new 1x20								1x20
	Bangbor					new 1x20			+1x20														2x20
	44091						new 1x40				+1x40												2x40
	46063														new 1x20		+1x20						2x20
	54264												new 1x20			+1x20							2x20
	47411																					new 1x20	1x20

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 5)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
50	54352																	new 1x20					1x20
	65371																			new 1x20			1x20
	51221																				new 1x20		1x20
	50141													new 1x20				+1x20					2x20
	57134												new 1x20			+1x20							2x20
	67042																		new 1x20			+1x20	2x20
	Number of substation	46	+2 48	+4 52	+1 53	+2 55	+1 56	56	+2 58	+1 59	+1 60	+1 61	+4 65	+6 71	+4 75	+4 79	+4 83	+4 87	+4 91	+6 97	+5 102	+4 106	+60 106
	Total capacity (MVA)	2,990	3,150	3,470	3,570	3,610	3,650	3,690	3,770	3,810	3,890	3,970	4,090	4,290	4,450	4,630	4,810	5,090	5,390	5,710	6,030	6,290	
	Total load (MVA)		1,448	1,541	1,636	1,737	1,835	1,946	2,064	2,176	2,299	2,432	2,573	2,720	2,877	3,039	3,210	3,395	3,592	3,802	4,024	4,261	
	Utilizing factor (%)		46.0	44.4	45.8	48.1	50.3	52.7	54.8	57.1	59.1	61.3	62.9	63.4	64.6	65.6	66.7	66.7	66.6	66.6	66.7	67.7	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 6)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangyekhan	2x40																					2x40
	Klong Sanpasamit	2x20																					2x20
	Pechkasem	3x20			+1x40 -1x20																		1x40 2x20
	North BKK	2x20																					2x20
	Prapradaen	2x40																					2x40
	Rasburana	2x40																+1x30					1x30 2x40
	Thonburi	2x40										+1x30											1x30 2x40
	Taksin	2x40																					2x40
	Bangkok Noi	2x20				+1x20																	3x20
	Bangkrajao	2x10																					2x10
	Bangbon			new 1x40	+1x40																		2x40
	Pran Nok			new 1x40															+1x30				1x30 1x40
	Suksawad																			new 2x30			2x30
	Samray												new 2x30										2x30
	28272																new 2x30						2x30
	32231									new 2x30													2x30
	30224														new 2x30				+1x30				3x30
	28234																				new 2x30		2x30
	30292																					new 2x30	2x30
	16232								new 2x20											+1x20			3x20
	24244																			new 2x30			2x30
30	Rangsit	2x40																				+1x30	1x30 2x40
	Klong Ransit	1x40						+1x40											+1x40				3x40
	43564													new 2x20						+1x20			3x20
40	Lumpini	2x40																			+1x30		1x30 2x40
	Makasan	2x40																				+1x30	1x30 2x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																				+1x30	1x30 2x40
	Silom	2x40																					2x40
	Watlieb	2x40																					2x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 4)

Unit . No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Yothee	2x40																					2x40
	Bangkapi	2x40																					2x40
	Bangna	2x40																					2x40
	Bangsue	1x10													+1x30	-1x10 -1x30							2x30
	Donmuang	2x40																					2x40
	Klong Jan	2x40																					2x40
	Mahamek	2x40												+1x30									1x30 2x40
	Mochit	2x40																					2x40
	Nontaburi	2x20												+1x30							-1x20 +1x30		1x20 2x30
	Plywood	1x20													+1x30						-1x20 +1x30		2x30
	Prachacuen	2x40																		+1x30			1x30 2x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Samrong	2x40																					2x40
	Sansab	2x40																					2x40
	Satupradit	1x40	+1x40														+1x30						1x30 2x40
	South BKK	1x20																		-1x20 +1x30		+1x30	2x30
	Tangkung	2x40																			+1x30		1x30 2x40
	Bangpood	2x20															+1x20						3x20
	Sukhumvit	1x40	+1x40																				2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat																	new 2x30					2x30
	Lardprao																new 2x30						2x30
	Klongton																				new 2x30		2x30
	Setsiri																		new 2x30				2x30
	33291																			new 2x30			2x30
	40402															new 2x30						+1x30	3x30
	47313																			new 2x30			2x30
	32243																			new 2x30			2x30
	44233																new 2x30			+1x30			3x30
	44341													new 2x30									2x30
	40263																	new 2x30				+1x30	3x30

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 6)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	41183											new 2x30				+1x30							3x30
	39184								new 2x30										+1x30				3x30
	43491				new 2x30															+1x30			3x30
50	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangplee	1x40																		+1x30			1x30 1x40
	Onnuj	2x40																					2x40
	Ramintra	2x40																					2x40
	Ladplakao	1x40																					1x40
	Minburi														new 2x20								2x20
	Bangbor					new 2x20		+1x20															3x20
	44091								new 2x30				+1x30										3x30
	46063																		new 2x20	+1x20			3x20
	54264												new 2x20					+1x20					3x20
	54352																			new 2x20			2x20
	51221																					new 2x20	2x20
	50141																	new 2x20			+1x20		3x20
	57134														new 2x20		+1x20						3x20
	67042																					new 2x20	2x20
	Number of substation	46	+2 48	+4 52	+1 53	+1 54	54	54	+3 57	+1 58	58	+1 59	+2 61	+2 63	+3 66	+1 67	+3 70	+3 73	+2 75	+6 81	+2 83	+3 86	+40 86
	Total capacity (MVA)	2,990	3,150	3,470	3,590	3,650	3,650	3,670	3,870	3,930	3,930	4,020	4,150	4,310	4,510	4,620	4,870	5,080	5,310	5,840	6,060	6,380	
	Total load (MVA)		1,449	1,541	1,636	1,737	1,835	1,946	2,064	2,176	2,299	2,432	2,573	2,720	2,877	3,039	3,210	3,395	3,592	3,802	4,024	4,261	
	Utilizing factor (%)		46.0	44.4	45.6	47.6	50.3	53.0	53.3	55.4	58.5	60.5	62.0	63.1	63.8	65.8	65.9	66.8	67.6	65.1	66.4	66.8	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 7)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangyekhan	2x40																					2x40
	Klong Sanpasarit	2x20																					2x20
	Pechkasem	3x20			-1x20 +1x40																		1x40 2x20
	North BKK	2x20																					2x20
	Prapradaen	2x40																					2x40
	Rasburana	2x40																	+1x30				1x30 2x40
	Thonburi	2x40																					2x40
	Taksin	2x40																					2x40
	Bangkok Noi	2x20																					2x20
	Bangkrajao	2x10																					2x10
	Bangbon			new 1x40	+1x40																		2x40
	Pran Nok			new 1x40																			1x40
	Suksawad																			new 1x30			1x30
	Samray										new 1x30							+1x30					2x30
	30321																new 1x30						1x30
	28272											new 1x30								+1x30			2x30
	32231									new 1x30							+1x30					+1x30	3x30
	30224												new 1x30						-1x30				2x30
	28234															new 1x30					+1x30		2x30
	30292														new 1x30						+1x30		2x30
	19251															new 1x20							1x20
	16264								new 1x20											+1x20			2x20
	16232					new 1x20																	1x20
	24244													new 1x30								+1x30	2x30
30	Rangsit	2x40																					2x40
	Klong Ransit	1x40						+1x40											+1x40				3x40
	44564																			new 1x30			1x30
	43564													new 1x20									1x20
	45710																new 1x20						1x20

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 7)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Lumpini	2x40																					2x40
	Makasan	2x40																					2x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																					2x40
	Silom	2x40																					2x40
	Watlieb	2x40																					2x40
	Yothee	2x40																					2x40
	Bangkapi	2x40																					2x40
	Bangna	2x40																					2x40
	Bangsue	1x10																	+1x30			+1x30	1x10 2x30
	Donmuang	2x40																					2x40
	Klong Jan	2x40																					2x40
	Mahamek	2x40																					2x40
	Mochit	2x40																					2x40
	Nontaburi	2x20																					2x20
	Plywood	1x20																					1x20
	Prachacuen	2x40																					2x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Samrong	2x40																					2x40
	Sansab	2x40																					2x40
	Satupradit	1x40	+1x40																				2x40
	South BKK	1x20																					1x20
	Tangkung	2x40																					2x40
	Bangpood	2x20															+1x20						3x20
	Sukhumvit	1x40	+1x40																				2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Klongtoey			new 2x40																			2x40
	Poojao																			new 1x30		+1x30	2x30
	Visutkasat																	new 1x30					1x30
	Silom 2																			new 1x30			1x30
	Lardprao														new 1x30						+1x30		2x30
	Klongton																	new 1x30					1x30

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 7)

Unit . No.x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Setsiri															new 1x30			+1x30				2x30
	34274																				new 1x30		1x30
	33291																		new 1x30				1x30
	31304																			new 1x30			1x30
	34283																					new 1x30	1x30
	43212																		new 1x30				1x30
	40402													new 1x30						+1x30			2x30
	47313																new 1x30				+1x30		2x30
	32243													new 1x30								+1x30	2x30
	31424															new 1x30							1x30
	44233											new 1x30									+1x30		2x30
	38394																	new 1x30			+1x30		2x30
	38192														new 1x30		+1x30						2x30
	44304																					new 1x30	1x30
	44341													new 1x30						+1x30			2x30
	35251																			new 1x30			1x30
	40263														new 1x30					1x30			2x30
	41183									new 1x30						+1x30		+1x30					3x30
	39184								new 1x30														1x30
	44181												new 1x30									+1x30	2x30
	43491				new 1x30					+1x30										+1x30			3x30
	41282																	new 1x30					1x30
	35303																					new 1x30	1x30
	34251																new 1x30						1x30
50	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangplee	1x40																		+1x30			1x30 1x40
	Onnuj	2x40																					2x40
	Ramintra	2x40																					2x40
	Ludplakao	1x40																					1x40
	Bangping																					new 1x30	1x30
	Minburi														new 1x20								1x20
	Bangbor					new 1x20			+1x20			+1x20											3x20
	44091						new 1x30			+1x30			+1x30										3x30

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 7)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
50	46063																new 1x20	+1x20		+1x20			3x20
	54264												new 1x20			+1x20		+1x20					3x20
	47411																					new 1x20	1x20
	54352																	new 1x20					1x20
	65371																			new 1x20			1x20
	51221																					new 1x20	1x20
	50141															new 1x20				+1x20	+1x20		3x20
	57134														new 1x20			+1x20	+1x20				3x20
	67042																					new 1x20	1x20
	Number of substation	46	+2 48	+4 52	+1 53	+2 55	+1 56	56	+2 58	+2 60	+1 61	+2 63	+3 66	+5 71	+6 77	+5 82	+5 87	+5 92	+2 94	+7 101	+1 102	+7 109	+63 109
	Total capacity (MVA)	2,990	3,150	3,470	3,560	3,600	3,630	3,670	3,740	3,860	3,890	3,970	4,080	4,220	4,400	4,560	4,770	5,030	5,270	5,710	5,970	6,300	
	Total load (MVA)		1,448	1,541	1,636	1,737	1,835	1,946	2,064	2,176	2,299	2,432	2,573	2,720	2,877	3,039	3,210	3,395	3,592	3,802	4,024	4,261	
	Utilizing factor (%)		46.0	44.4	45.9	48.2	50.5	53.0	55.2	56.4	59.1	61.3	63.1	64.5	65.4	66.6	67.3	67.5	68.2	66.6	67.4	67.6	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 8)

Unit .No.x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangyekhan	2x40																					2x40
	Klong Sanpasamit	2x20																					2x20
	Pechkasem	3x20			-1x20 +1x40																		1x40 2x20
	North BKK	2x20																					2x20
	Prapradaen	2x40																					2x40
	Rasburana	2x40											+1x40										3x40
	Thonburi	2x40										+1x40											3x40
	Taksin	2x40														+1x40							3x40
	Bangkok Noi	2x20				+1x20			+1x40 -1x20														1x40 2x20
	Bangkrajao	2x10																					2x10
	Bangbon			new 1x40	+1x40																		2x40
	Pran Nok			new 1x40										+1x40		+1x40							3x40
	Suksawad																	new 2x40					2x40
	Samray																new 2x40					+1x40	3x40
	28272																			new 2x40		+1x40	3x40
	32231									new 2x40					+1x40								3x40
	30224																		new 2x40		+1x40		3x40
	16264																				new 2x20		2x20
	16232													new 2x20									2x20
30	Rangsit	2x40																		+1x40			3x40
	Klong Rangsit	1x40						+1x40									+1x40						3x40
	43564											new 2x20						+1x20					3x20
40	Lumpini	2x40																+1x40					3x40
	Makasan	2x40																		+1x40			3x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																	+1x40				3x40
	Silom	2x40																					2x40
	Watlieb	2x40																+1x40					3x40
	Yothee	2x40																					2x40
	Bangkapi	2x40															+1x40						3x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 8)

Unit : No.x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Bangna	2x40																					2x40
	Bangsue	1x10											+1x40	+1x40 -1x10				+1x40					3x40
	Donmuang	2x40																					2x40
	Klong Jan	2x40													+1x40								3x40
	Mahamek	2x40										+1x40											3x40
	Mochit	2x40												+1x40									3x40
	Nontaburi	2x20										+1x40 -1x20				+1x40 -1x20	+1x40						3x40
	Plywood	1x20													+1x40			+1x40 -1x20					2x40
	Prachacuen	2x40												+1x40									3x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Samrong	2x40																					2x40
	Sansab	2x40																	+1x40				3x40
	Satupradit	1x40	+1x40													+1x40							3x40
	South BKK	1x20																	+1x40 -1x20			+1x40	2x40
	Tangkung	2x40																	+1x40				3x40
	Bangpood	2x20																	+1x20				3x20
	Sukhumvit	1x40	+1x40																				2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat															new 2x40							2x40
	Lardprao																			new 2x40			2x40
	Setsiri																					new 2x40	2x40
	33291																				new 2x40		2x40
	31304																					new 2x40	2x40
	40402																		new 2x40				2x40
	32243																		new 2x40				2x40
	44233																			new 2x40			2x40
	44341															new 2x40			+1x40				3x40
	40263																				new 2x40		2x40
	41183											new 2x40				+1x40							3x40
	39184							new 2x40									+1x40						3x40
	43491				new 2x40																+1x40		3x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case B)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
50	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangplee	1x40																+1x40					2x40
	Onnuj	2x40																					2x40
	Ramintra	2x40																					2x40
	Ladplakao	1x40																					1x40
	Bangping																					new 2x40	2x40
	Minburi													new 2x20							+1x20		3x20
	Bangbor				new 2x20			+1x20															3x20
	44091								new 2x40				+1x40										3x40
	46063																	new 2x20			+1x20		3x20
	54264											new 2x20				+1x20							3x20
	54352																	new 2x20					2x20
	51221																				new 2x20		2x20
	50141																new 2x20			+1x20			3x20
	57134														new 2x20	+1x20							3x20
	67042																				new 2x20		2x20
	Number of substation	46	48	52	54	54	54	55	56	57	57	60	60	62	63	65	67	70	73	76	81	84	84
	Total capacity (MVA)	2,990	3,150	3,470	3,650	3,670	3,670	3,810	3,910	3,990	3,990	4,250	4,370	4,600	4,760	5,140	5,420	5,780	6,220	6,580	6,960	7,320	
	Total load (MVA)		1,463.5	1,560.1	1,664.3	1,778.0	1,894.7	2,026.5	2,159.3	2,302.0	2,456.4	2,621.3	2,796.0	2,983.8	3,185.9	3,399.3	3,624.9	3,865.9	4,126.4	4,364.2	4,655.8	4,967.7	
	Utilizing factor (%)		0.465	0.450	0.456	0.484	0.516	0.532	0.552	0.577	0.616	0.617	0.640	0.649	0.669	0.661	0.669	0.669	0.663	0.663	0.669	0.679	

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 9)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
10	North BKK	1x40																					1x40
	Klongkred	1x20																					1x20
20	Bangyekhan	2x40																					2x40
	Klong Sanpasamit	2x20																					2x20
	Pechkasem	3x20			+1x40 -1x20																		1x40 2x20
	North BKK	2x20																					2x20
	Prapradaen	2x40																					2x40
	Rasburana	2x40														+1x40							3x40
	Thonburi	2x40													+1x40								3x40
	Taksin	2x40																		+1x40			3x40
	Bangkok Noi	2x20				+1x20			+1x40 -1x20														1x40 2x20
	Bangkrajao	2x10																					2x10
	Bangbon			new 1x40	+1x40																		2x40
	Pran Nok			new 1x40													+1x40						2x40
	Samray																				new 2x40		2x40
	32231											new 2x40						+1x40					3x40
	16232																	new 2x20					2x20
30	Rangsit	2x40																					2x40
	Klong Ransit	1x40							+1x40												+1x40		3x40
	43564														new 2x20								2x20
40	Lumpini	2x40																					2x40
	Makasan	2x40																					2x40
	Sapandam	4x40																					4x40
	Pathumwan	2x40																					2x40
	Silom	2x40																					2x40
	Watlieb	2x40																					2x40
	Yothee	2x40																					2x40
	Bangkapi	2x40																				+1x40	3x40
	Bangna	2x40																					2x40
	Bangsue	1x10														+1x40		+1x40 -1x10					2x40
	Donmuang	2x40																					2x40
	Klong Jan	2x40																	+1x40				3x40

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 9)

Unit : No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
40	Mahamek	2x40														+1x40							3x40
	Mochit	2x40															+1x40						3x40
	Nontaburi	2x20													+1x40 -1x20					+1x40 -1x20		+1x40	3x40
	Plywood	1x20																+1x40 -1x20			+1x40		2x40
	Prachacuen	2x40															+1x40						3x40
	Prakanong	2x40																					2x40
	Samsen	2x40																					2x40
	Samrong	2x40																					2x40
	Sansab	2x40																					2x40
	Satupradit	1x40	+1x40																		+1x40		3x40
	South BKK	1x20																					1x20
	Tangkung	2x40																					2x40
	Bangpood	2x20																					2x20
	Sukhumvit	1x40	+1x40																				2x40
	Sipraya		new 1x40	+1x40																			2x40
	Chidlom			new 2x40																			2x40
	Paholyotin		new 1x40	+1x40																			2x40
	Klongtoey			new 2x40																			2x40
	Visutkasat																					new 2x40	2x40
	44341																			new 2x40			2x40
	41183													new 2x40					+1x40				3x40
	39184									new 2x40												+1x40	3x40
	43491				new 2x40																		2x40
50	Paknam	2x40																					2x40
	Bangpu	2x40																					2x40
	Bangplee	1x40																				+1x40	2x40
	Onnuj	2x40																					2x40
	Ramintra	2x40																					2x40
	Ladplakao	1x40																					1x40
	Minburi																new 2x20						2x20
	Bangbor					new 2x20			+1x20														3x20
	44091									new 2x40						+1x40							3x40
	46063																					new 2x20	2x20

DISTRIBUTION SUBSTATION EXPANSION PROGRAM (Case 9)

Unit . No. x MVA

Bloc No.	Substation	Exist.	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	2001	TTL
50	54264														new 2x20					+1x20			3x20
	50141																				new 2x20		2x20
	57134																		new 2x20				2x20
	Number of substation	46	48	52	53	54	54	54	54	56	56	57	57	58	60	60	61	62	63	64	66	68	68
	Total capacity (MVA)	2,990	3,150	3,470	3,610	3,670	3,670	3,670	3,750	3,910	3,910	3,990	3,990	4,070	4,210	4,370	4,530	4,660	4,780	4,940	5,180	5,460	
	Total load (MVA)		1448.3	1521.8	1596.4	1674.1	1759.5	1845.2	1936.5	2032.2	2133.8	2240.0	2351.3	2466.7	2588.9	2716.7	2853.3	2994.7	3143.3	3299.7	3460.6	3633.9	
	Utilizing factor (%)		0.460	0.439	0.442	0.456	0.479	0.503	0.516	0.520	0.546	0.561	0.589	0.606	0.615	0.622	0.630	0.643	0.658	0.668	0.668	0.666	