Table 10-3 (1) Study on Optimum Development Scale (500MW)

Capacity of Reservoir	hr	4	6	8	10	12	14	
1) Cost Construction Cost of Pumped Storage *	MBaht	6,110	6,250	6,380	6,610	6,760	6,970	
Construction Cost per kW	Baht/kW	12.2	12.5	12.8	13.2	13.5	13.9	
Fixed Cost C1	MBaht	837	856	874	906	926	955	
Variable Cost C2	MBaht	233	233	233	233	233	233	
Total Cost C=C1+C2	MBaht	1,070	1,090	1,107	1,139	1,159	1,188	
Possible Daily Generationg Hour Td	hrs	4.00	5.68	6.08	6.48	6.88	7.28	
Effective Output of Pumped Storage	MW	333	473	500	500	500	500	
2) Benefit Construction Cost of Thermal	MBaht	5,198	7,381	7,797	7,797	7,797	7,797	
Fixed Benefit B1	MBaht	852	1,211	1,279	1,279	1,279	1,279	
Variable Benefit B2	MBaht	173	173	173	173	173	173	
Total Benefit B=B1+B2	MBaht	1,026	1,384	1,452	1,452	1,452	1,452	
3) Annual Surplus Benefit (B-C)	MBaht	-45	294	345	313	293	264	
4) Benefit Cost Ratio (B/C)		0.96	1.27	1.31	1.27	1.25	1.22	

(Note) * including transmission cost of 180MB

Table 10-3 (2) Study on Optimum Development Scale (600MW)

Capacity of Reservoir	hr	4	6	8	10	12	14	
1) Cost								
Construction Cost of Pumped Storage *	MBaht	7,700	7,840	8,050	8,270	8,490	8,750	
Construction Cost per kW	Baht/kW	12.8	13.1	13.4	13.8	14.2	14.6	
Fixed Cost C1	MBaht	1,055	1,074	1,103	1,133	1,163	1,199	
Variable Cost C2	MBaht	280	280	280	280	280	280	
Total Cost C=C1+C2	MBaht	1,335	1,354	1,383	1,413	1,443	1,479	
Possible Daily Generationg Hour Td	hrs	4.00	5.68	6.08	6.48	6.88	7.28	
Effective Output of Pumped Storage	MW	400	568	600	600	600	600	
2) Benefit								
Construction Cost of Thermal	MBaht	6,238	8,857	9,356	9,356	9,356	9,356	
Fixed Benefit B1	MBaht	1,023	1,453	1,534	1,534	1,534	1,534	
Variable Benefit B2	MBaht	208	208	208	208	208	208	
Total Benefit B=B1+B2	MBaht	1,231	1,661	1,742	1,742	1,742	1,742	
3) Annual Surplus Benefit (B-C)	MBaht	-104	307	360	329	299	264	
4) Benefit Cost Ratio (B/C)		0.92	1.23	1.26	1.23	1.21	1.18	

(Note) * including transmission cost of 700MB

Table 10-3 (3) Study on Optimum Development Scale (800MW)

Capacity of Reservoir	hr	4	6	8	10	12	14	
1) Cost								
Construction Cost of Pumped Storage *	MBaht	9,360	9,650	9,910	10,230	10,620	10,980	
Construction Cost per kW	Baht/kW	11.7	12.1	12.4	12.8	13.3	13.7	
Fixed Cost C1	MBaht	1,282	1,322	1,358	1,402	1,455	1,504	
Variable Cost C2	MBaht	373	373	373	373	373	373	
Total Cost C=C1+C2	MBaht	1,656	1,695	1,731	1,775	1,828	1,878	
Possible Daily Generationg Hour Td	hrs	4.00	5.68	6.08	6.48	6.88	7.28	
Effective Output of Pumped Storage	MW	533	757	800	800	800	800	
2) Benefit								
Construction Cost of Thermal	MBaht	8,317	11,810	12,475	12,475	12,475	12,475	
Fixed Benefit B1	MBaht	1,364	1,937	2,046	2,046	2,046	2,046	
Variable Benefit B2	MBaht	277	277	277	277	277	277	
Total Benefit B=B1+B2	MBaht	1,641	2,214	2,323	2,323	2,323	2,323	
3) Annual Surplus Benefit (B-C)	MBaht	-14	519	592	548	495	446	
4) Benefit Cost Ratio (B/C)		0.99	1.31	1.34	1.31	1.27	1.24	

(Note) * including transmission cost of 700MB

Table 10-3 (4)　Study on Optimum Development Scale (1,000MW)

Capacity of Reservoir	hr	4	6	8	10	12	14	
1) Cost Construction Cost of Pumped Storage *	MBaht	11,060	11,430	11,780	12,280	12,830	13,360	
Construction Cost per kW	Baht/kW	11.1	11.4	11.8	12.3	12.8	13.4	
Fixed Cost C1	MBaht	1,515	1,566	1,614	1,682	1,758	1,830	
Variable Cost C2	MBaht	467	467	467	467	467	467	
Total Cost C=C1+C2	MBaht	1,982	2,033	2,081	2,149	2,224	2,297	
Possible Daily Generationg Hour Td	hrs	4.00	5.68	6.08	6.48	6.88	7.28	
Effective Output of Pumped Storage	MW	667	947	1,000	1,000	1,000	1,000	
2) Benefit Construction Cost of Thermal	MBaht	10,396	14,762	15,594	15,594	15,594	15,594	
Fixed Benefit B1	MBaht	1,705	2,421	2,557	2,557	2,557	2,557	
Variable Benefit B2	MBaht	347	347	347	347	347	347	
Total Benefit B=B1+B2	MBaht	2,052	2,768	2,904	2,904	2,904	2,904	
3) Annual Surplus Benefit (B-C)	MBaht	70	735	824	755	680	607	
4) Benefit Cost Ratio (B/C)		1.04	1.36	1.40	1.35	1.31	1.26	

(Note) * including transmission cost of 700MB

Table 10-3 (5) Study on Optimum Development Scale (1,200MW)

Capacity of Reservoir	hr	4	6	8	10	12	14	
1) Cost Construction Cost of Pumped Storage *	MBaht	13,440	13,860	14,410	15,060	15,660	16,420	
Construction Cost per kW	Baht/kW	11.2	11.6	12.0	12.6	13.1	13.7	
Fixed Cost C1	MBaht	1,841	1,899	1,974	2,063	2,145	2,250	
Variable Cost C2	MBaht	560	560	560	560	560	560	
Total Cost C=C1+C2	MBaht	2,401	2,459	2,534	2,623	2,706	2,810	
Possible Daily Generationg Hour Td	hrs	4.00	5.68	6.08	6.48	6.88	7.28	
Effective Output of Pumped Storage	MW	800	1,136	1,200	1,200	1,200	1,200	
2) Benefit Construction Cost of Thermal	MBaht	12,475	17,715	18,713	18,713	18,713	18,713	
Fixed Benefit B1	MBaht	2,046	2,905	3,069	3,069	3,069	3,069	
Variable Benefit B2	MBaht	416	416	416	416	416	416	
Total Benefit B=B1+B2	MBaht	2,462	3,321	3,485	3,485	3,485	3,485	
3) Annual Surplus Benefit (B-C)	MBaht	61	862	951	862	779	675	
4) Benefit Cost Ratio (B/C)		1.03	1.35	1.38	1.33	1.29	1.24	

(Note) * including transmission cost of 1,200MB

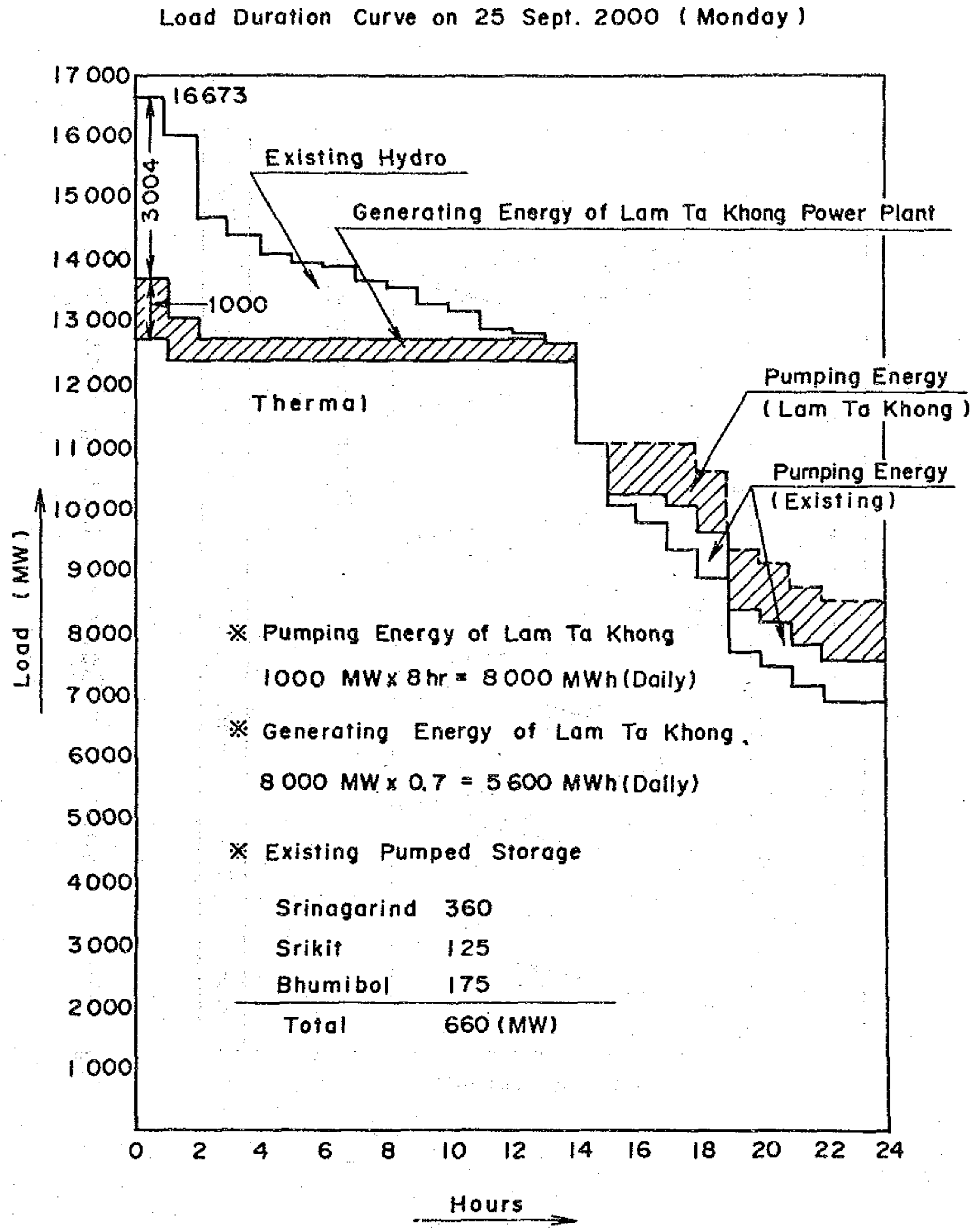


Fig. 10 – 3 Pumping Energy in Load Duration Curve

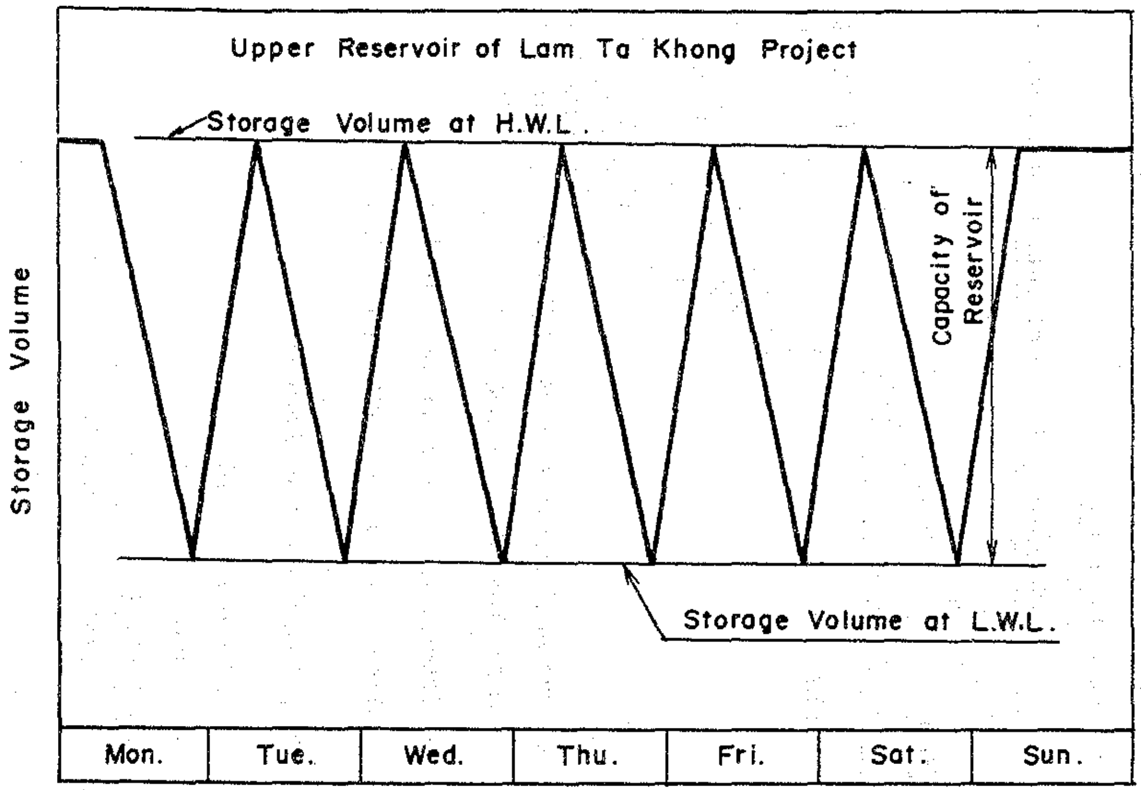


Fig. 10 — 4 Concept of Daily Regulating Reservoir

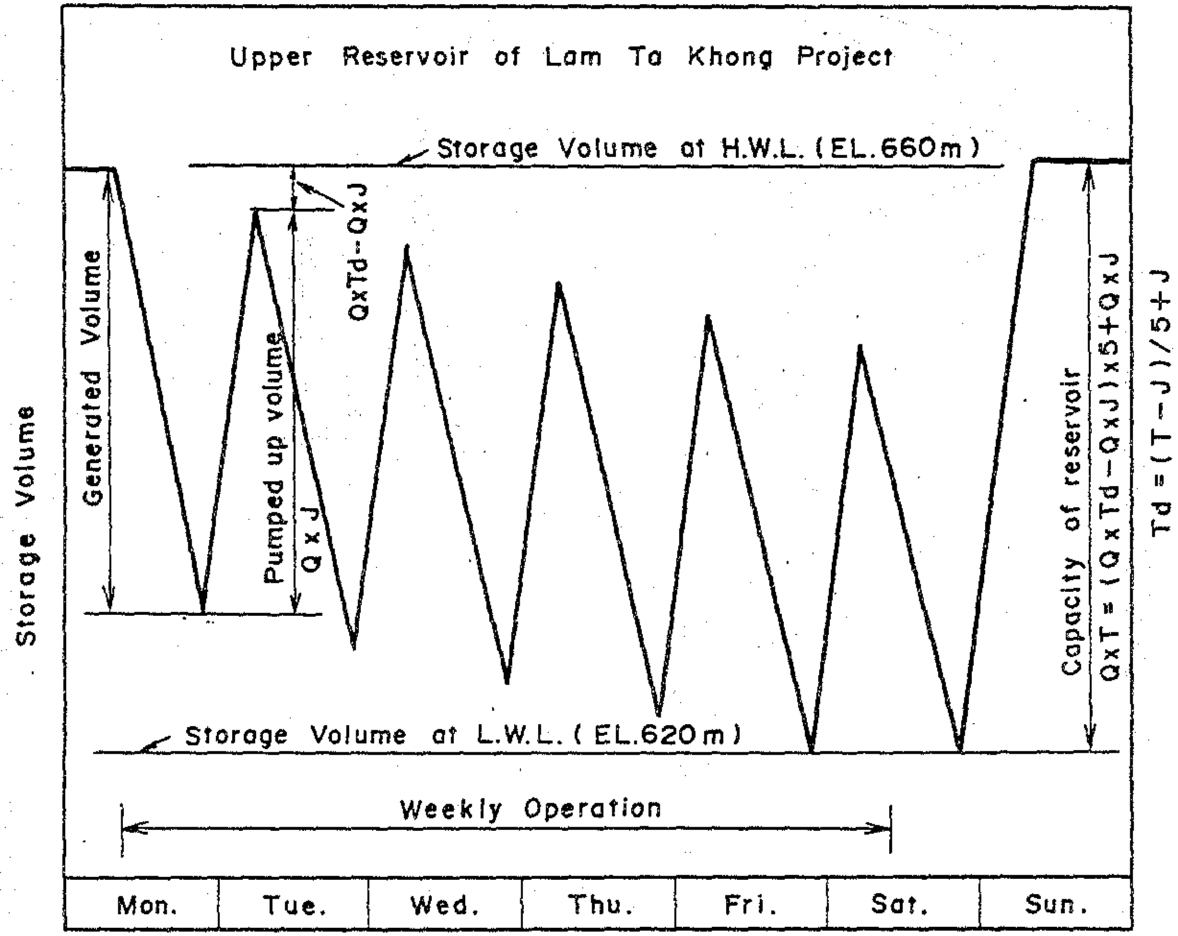


Fig. 10-5 Concept of Weekly Regulating Reservoir

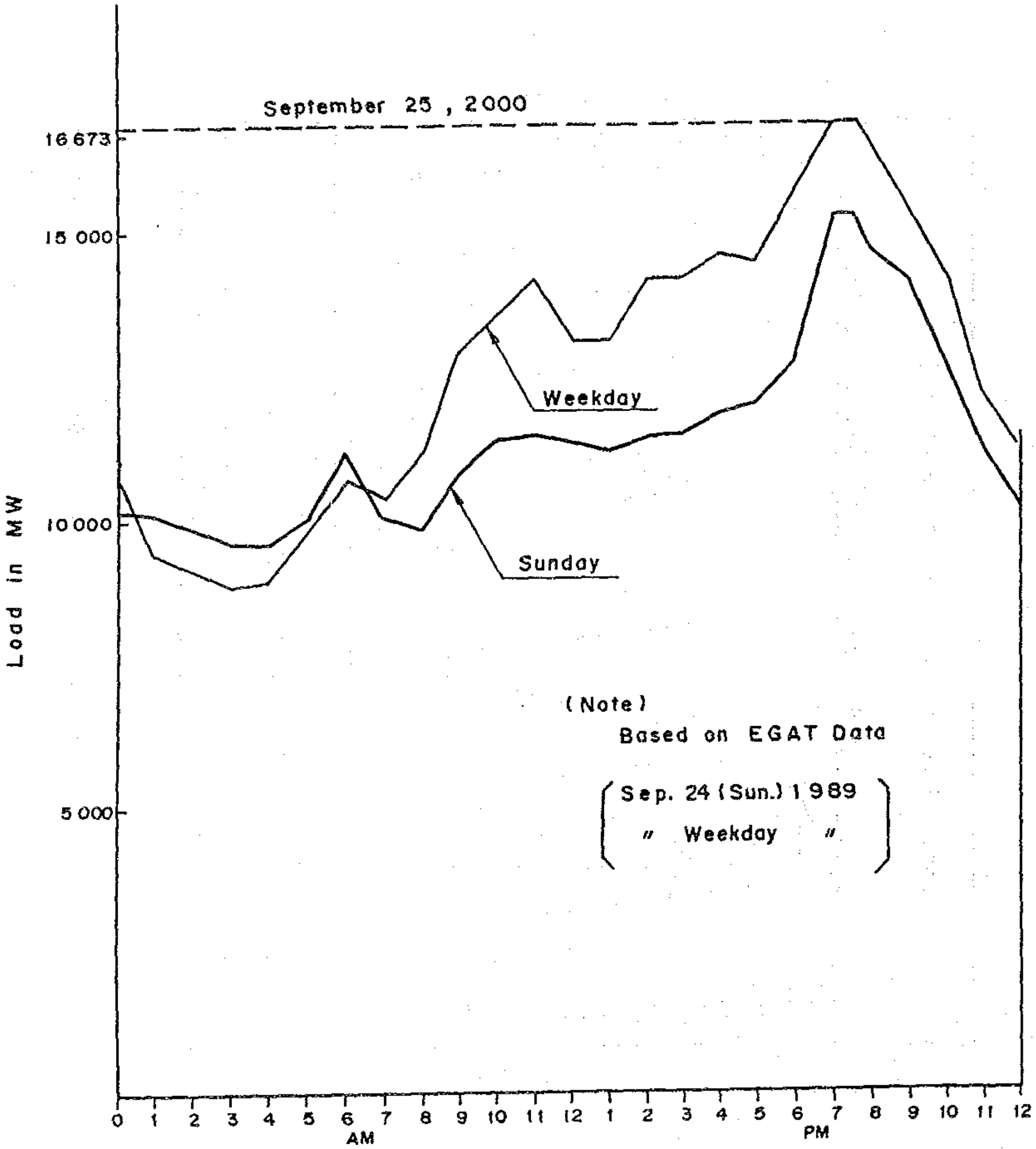


Fig.10-6 Typical Daily Load Curve

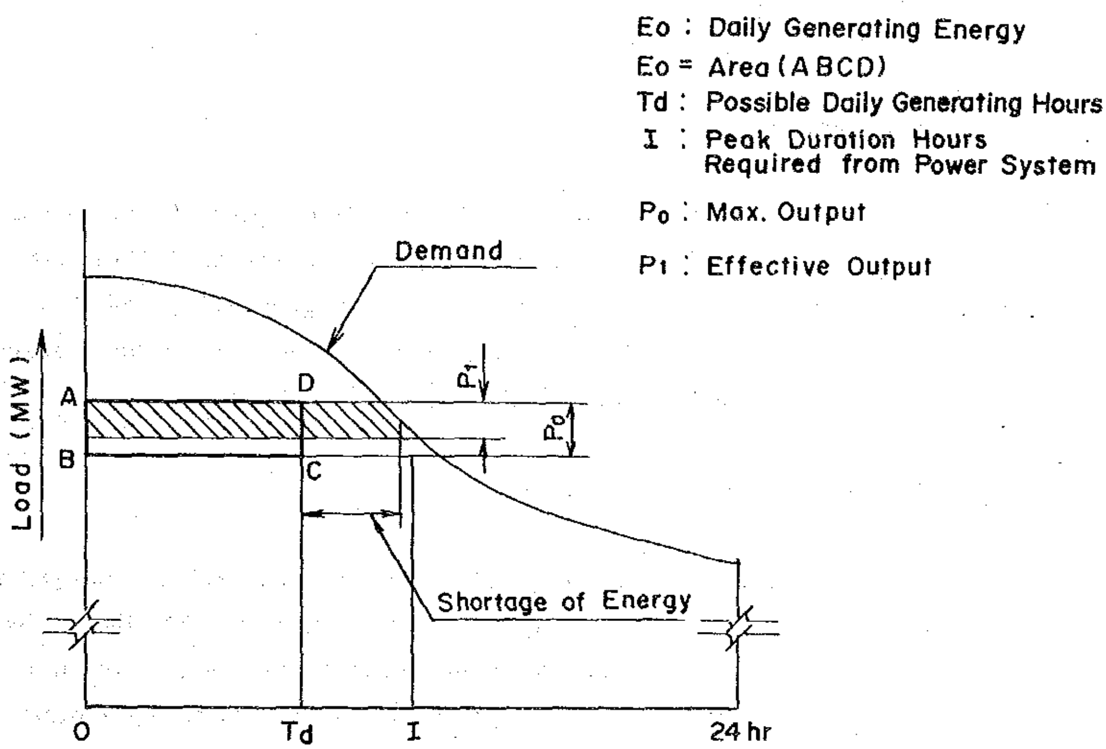


Fig. 10 - 7 Concept of Effective Output

10.5 Finalization of Development Plan (Feasibility Design Stage)

10.5.1 Comparison on Development Scheme considering Constraints of Development

Considering the most effective utilization of the pumped storage's resource at the site, the installed capacity of 1,000 MW and reservoir capacity of 8 hours were selected in Section 10.4.3 "Investigation Stage". Taking into account the development's constraints mentioned below, the development scheme is studied and finalized.

(1) Constraints

- Upper limit of pumping is 500 MW because of the power system stability on the basis of EGAT's transmission expansion plan up to year of 2006. However generating of 1,000 MW is possible without strengthening the main transmission line between Mae Moh and Bangkok.

(2) Conditions for Study

(a) JICA team foresees main transmission will be strengthened in the future and pumping of more than 500 MW is possible whether the Lam Ta Khong project will be carried out or not. However, considering the certainty of pumping and generating at present, the study is carried out on the condition that the pumping of 500 MW and generating of 1,000 MW are possible. The study period for economic analysis is 50 years.

(b) Commencement of Operation is assumed as follows.

- 1st Stage ; Year of 1997
- 2nd Stage (for 2 stages development) ; Year of 2007

(c) In case of 2 stages development, the following development is analized.

- Full Scale development (1,000 MW)
- 1st Stage development only (500 MW, reference)

(3) Alternative Cases of Development

Following four cases are studied for the conditions mentioned above. The concept of the four cases is shown in Fig. 10-8 and preliminary design is shown in DWG. 10-1 ~ 10-3.

Case 1 (DWG. 10-1)

Development Stage	:	Two Stages
1st Stage	:	Reservoir (500 MW x 8 hrs) and Generating Facilities with 250 MW x 2 units (Operation 1997)
2nd Stage	:	ditto (Operation 2007)

Case 2 (DWG. 10-2)

Development Stage	:	Two Stages
1st Stage	:	Reservoir (1000 MW x 8 hrs) and civil works for 250 MW x 2 units, Generating Facilities with 250 MW x 2 units (Operation 1997)
2nd Stage	:	Generating Facilities with 250 MW x 2 units (Operation 2007) including civil works

Case 3 (DWG. 10-3)

Development Stage	:	Two stages
1st Stage	:	Reservoir (1000 MW x 8 hours) and Generating Facilities with 250 MW x 2 units (Operation 1997) including civil works of the 2nd stage

2nd stage : Generating facilities with 250 MW x 2 units only (Operation 2007)

Case 4 (DWG. 10-3)

Development Stage : One stage
250 MW x 4 units (Operation 1997)

Reservoir Capacity : 1000 MW x 8 hrs

(Note) Concerning the turbine type for the 2nd stage development, two units of pump turbines are selected for the condition of 1000 MW generating and 500 MW pumping operation from a result of preliminary study.

(4) Methodology of Economic Comparison

(a) Concept of economic comparison is same as Chapter 14. However, in stead of annual cost (C) and annual benefit (B), net present value of benefit and cost are calculated by using Discounted Cash Flow method as mentioned in Chapter 14 "Economic Evaluation".

(b) Main numerical values for economic comparison is as follows which are used in Chapter 14 (Section 14.2).

Construction Cost of Alternative Thermal (฿)
= Effective Output of Hydro (MW) x 1.092 x 12,064 (฿/kW)

O&M Cost of Alternative Thermal
= Construction Cost of Alternative Thermal (฿)
x 0.03 + Annual Generating Energy (kWh)
x 0.8322 (฿/kWh)

O&M Cost of Pumped Storage

= Construction Cost of Pumped Storage x 0.0148

+ Annual Generating Energy (kWh)/0.7

x 0.4084 (฿/kWh)

(Note) The combined cycle power plant was selected for alternative thermal in "Investigation Stage", however a gas turbine power plant is selected in this section of "Feasibility Design Stage".

(c) Discount Rate 12%

(d) Effective output is determined in a daily load duration curve as of 2000 as shown in Fig. 10-10. In case of 1,000 MW of installed capacity, the effective output of 1,000 MW is adopted since the output of 1,000 MW can be used effectively in the power system. In the same way, effective output of 500 MW is adopted for 500 MW's installed capacity.

(e) Construction cost (economic cost) of the pumped storage project is estimated on the basis of preliminary design of DWG. 10-1 ~ 10-3.

(5) Results of the Study

The result of study is shown in Table 10-5 and the construction cost of each case is shown in Table 10-4.

Main points of the results are described below.

(a) Concerning the full scale development (1,000 MW development), Case-4 is feasible economically. It is the reason why the investment cost of full scale development is the lowest.

(b) In this case, daily possible generating hours are 4.1 hours (Saturday 3.2 hours). It is considered that degree of operating freedom of the power plant is not high, however this degree is on the range that can be allowed. Furthermore, in case more than 500 MW pumping is possible, daily opeating hours discribed below is possible.

750 MW pumping; 5.4 hours
1,000 MW pumping; 6.6 hours

(Note)

500 MW pumping 1,000 MW generating

$J = 6.3 \times 500/1,000 = 3.15$

$Td = (T - J)/D + J = (8 - 3.15)/5 + 3.15 = 4.1$

750 MW pumping 1,000 MW generating

$J = 6.3 \times 750/1,000 = 4.73$

$Td = (8 - 4.73)/5 + 4.73 = 5.4$

1,000 MW pumping 1,000 MW generating

$J = 6.3$

$Td = (8 - 6.3)/5 + 6.3 = 6.6$

10.5.2 Adopted Development Plan

As shown in Table 10-6 and DWG 10-3, full-scale development of installed capacity 1,000 MW and reservoir capacity of 8 hours is adopted in this report.

The operation is 500 MW pumping and 1,000 MW generating by the time that the main transmission system is strengthened.

- Position of the Lam Ta Khong Project in the daily load duration curve (year of 2000) and upper reservoirs' operation are shown in Fig. 10-9 and 10-10 respectively.

Table 10-4 Economic Cost

(million ฿)

Description	Case - 1			Case - 2			Case - 3			Case - 4
	1st Stage	2nd Stage	Total	1st Stage	2nd Stage	Total	1st Stage	2nd Stage	Total	Total
1. Preliminary Works	119.5	96.7	216.2	154.0	31.2	185.2	174.7	-	174.7	171.4
2. Environmental Mitigation	132.0	132.0	264.0	143.0	99.0	242.0	165.0	66.0	231.0	220.0
3. Civil Works	2,389.0	1,891.3	4,280.3	3,102.2	639.4	3,741.6	3,521.4	37.3	3,558.7	3,557.6
Upper Reservoir	1,200.4	997.0	2,197.4	1,851.1	-	1,851.1	1,851.1	-	1,851.1	1,851.1
Intake	29.4	29.4	58.8	53.9	-	53.9	53.9	-	53.9	53.9
Penstock	198.7	182.3	381.0	228.8	39.7	268.5	258.1	-	258.1	258.1
Powerhouse	437.8	396.0	833.8	458.2	361.5	819.7	618.6	37.3	655.9	654.9
Tailrace	516.0	280.1	796.1	503.6	238.3	741.9	733.0	-	733.0	733.0
Switchyard	6.6	6.6	13.2	6.6	-	6.6	6.6	-	6.6	6.6
4. Hydraulic Equipment	784.1	670.5	1,454.6	816.6	619.4	1,436.0	1,495.1	-	1,495.1	1,495.1
5. Electro-mechanical Equipment	2,474.9	2,352.4	4,827.3	2,434.6	2,271.8	4,706.4	2,432.5	2,012.8	4,445.3	4,423.2
6. Transmission Line	192.6	652.7	845.3	192.6	652.7	845.3	192.6	652.7	845.3	749.0
7. EGAT Administration	187.0	187.0	374.0	209.0	143.0	352.0	242.0	99.0	341.0	319.0
8. Engineering Service	187.0	187.0	374.0	209.0	143.0	352.0	242.0	99.0	341.0	319.0
Total Economic Cost	* 6,466.0	6,169.6	12,635.6	7,261.0	4,599.6	11,860.6	8,465.3	2,966.8	11,432.1	11,254.3

(Note) * Including the cost of a part of connecting conduit between two upper reservoirs and the cost of outlet for 2nd stage.

Table 10-5 Comparison on Development Scheme

	Case 1		Case 2		Case 3		Case 4
	1st Stage	1st & 2nd Stage	1st Stage	1st & 2nd Stage	1st Stage	1st & 2nd Stage	1st Stage
(500 MW Pumping)							
Installed Capacity (MW)	500	1,000	500	1,000	500	1,000	1,000
Year of 1st/2nd stages	1997	2007	1997	2007	1997	2007	1997
Possible Daily Generating Hours (hr)	6.6	4.1	6.6	4.1	6.6	4.1	4.1
Effective Output (MW)	500	1,000	500	1,000	500	1,000	1,000
Construction Cost (M฿)							
Pumped Storage	6,466*	12,636	7,261	11,861	8,465	11,432	11,254
Alternative Thermal	6,587	13,175	6,587	13,175	6,587	13,175	13,175
NPV (M฿) OF B-C	(310)	351	(-274)	140	(-1,111)	-310	1,504
B/C	(1.05)	1.05	(0.96)	1.02	(0.84)	0.96	1.16

(Note) Condition: 500 MW pumping, 1000 MW generating

(Note) 1st stage: year of 1997, 2nd stage: year of 2007

(Note) * including cost of a part of connecting conduit between two upper reservoirs and cost of the outlet for the 2nd stage

(Note) Calculation sheet of B-C and B/C: See Appendix B-6

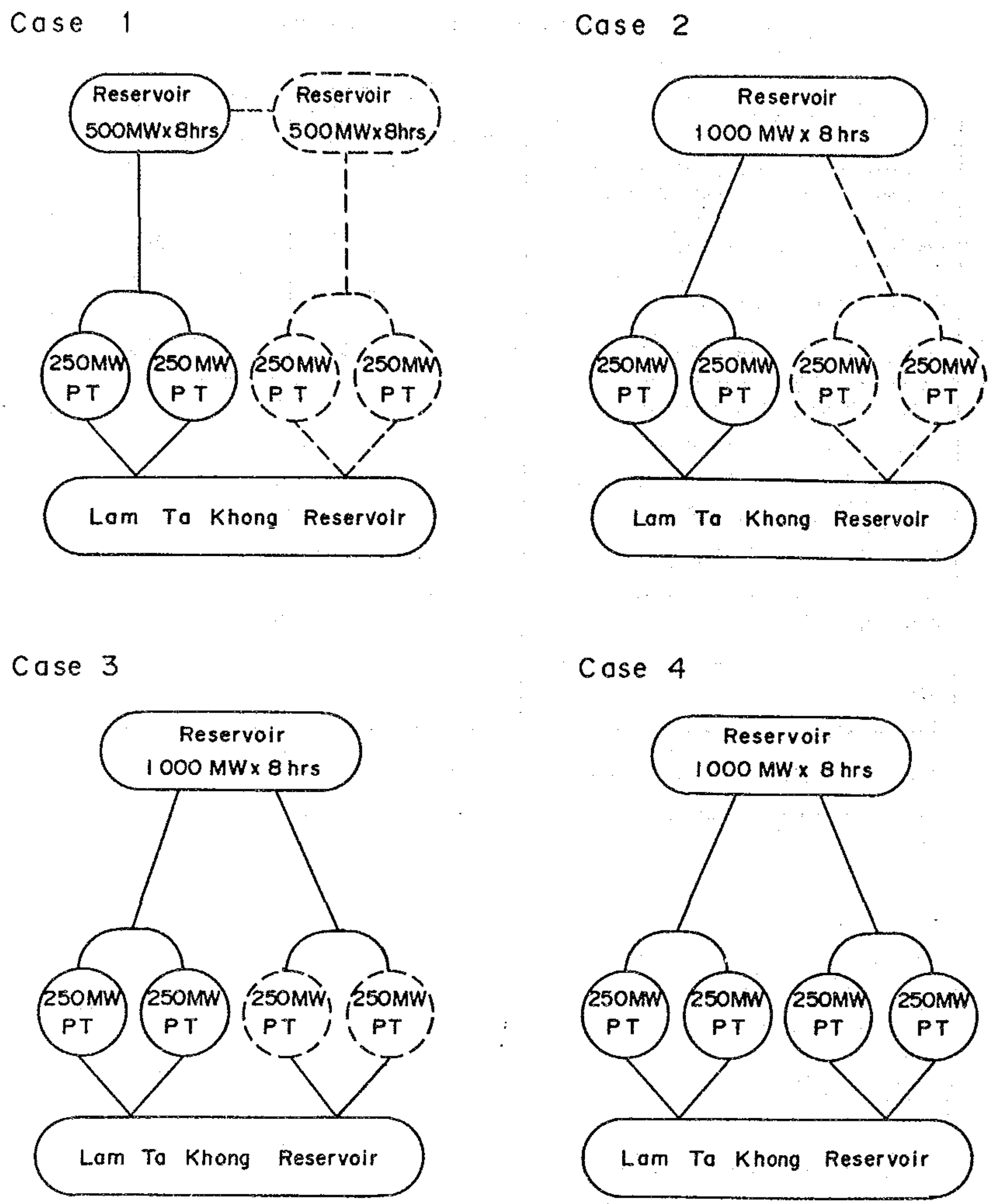
Table 10-6 Description of Adopted Development Plan

(1st Stage Only)

Item	Upper Reservoir	Lower Reservoir*
Normal High Water Level (WL.m)	660	277
Low Water Level (WL.m)	630	261
Available Drawdown (m)	30	16
Effective Storage Capacity (MCM)	5.0	290
Intake Water Level (m.MSL)	653	
Tail Water Level (m.MSL)	276	
Normal Effective Head (m)	357	
Maximum Discharge (m^3/s)	340	
Installed Capacity (MW)	1,000	
B-C (M/฿)	1,504	
B/C	1.16	

* : The Lam Ta Khong Reservoir (existing)

Note : Calculation sheet of B-C and B/C: See Appendix B-6



(Note) Solid line : 1st Stage
Dotted line : 2nd Stage
PT : Pump Turbine (Including Generator)

Fig. 10-8 Development Cases of 1000 MW

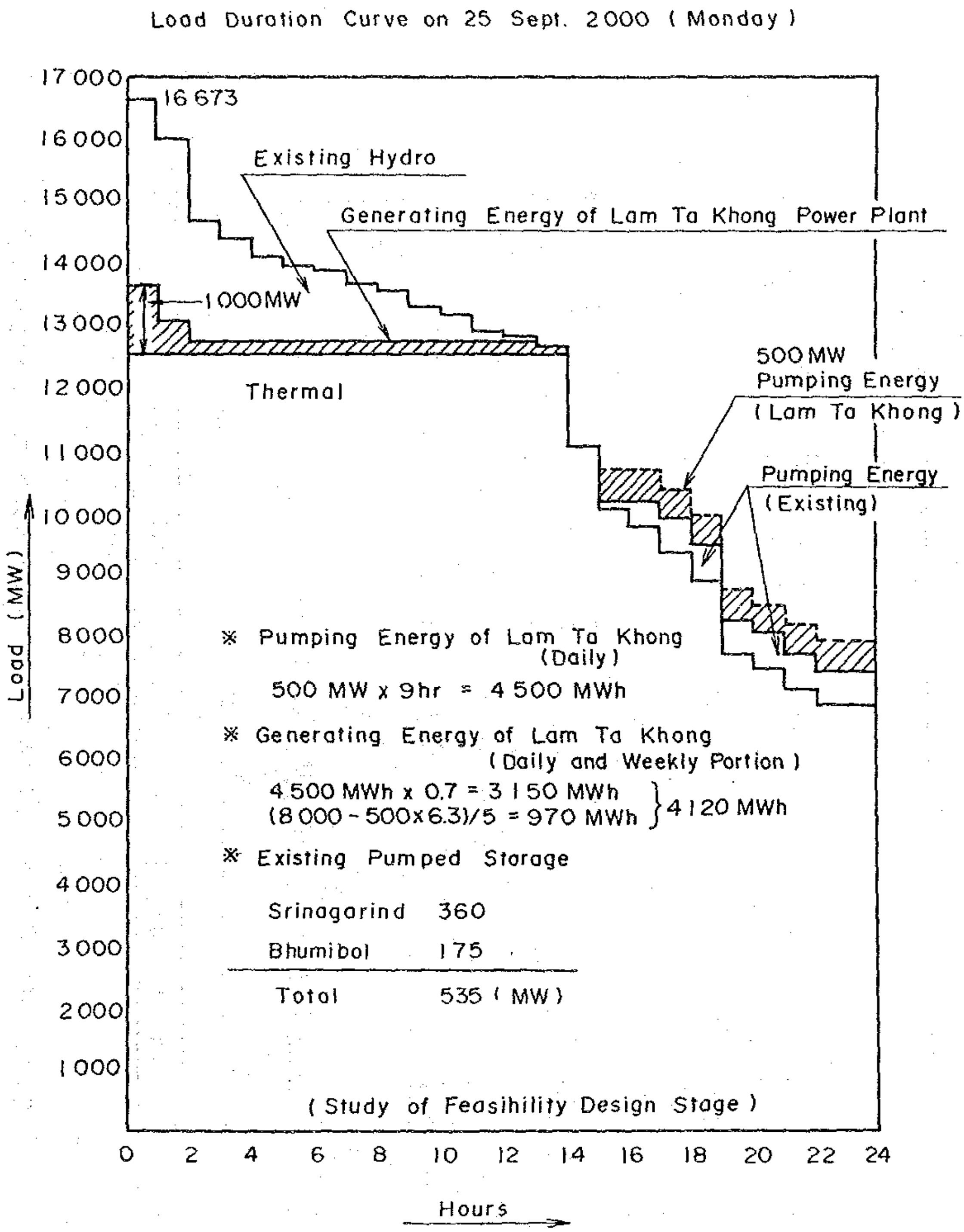


Fig. 10 - 9 Position of Lam Ta Khong Power Plant in Load Duration Curve

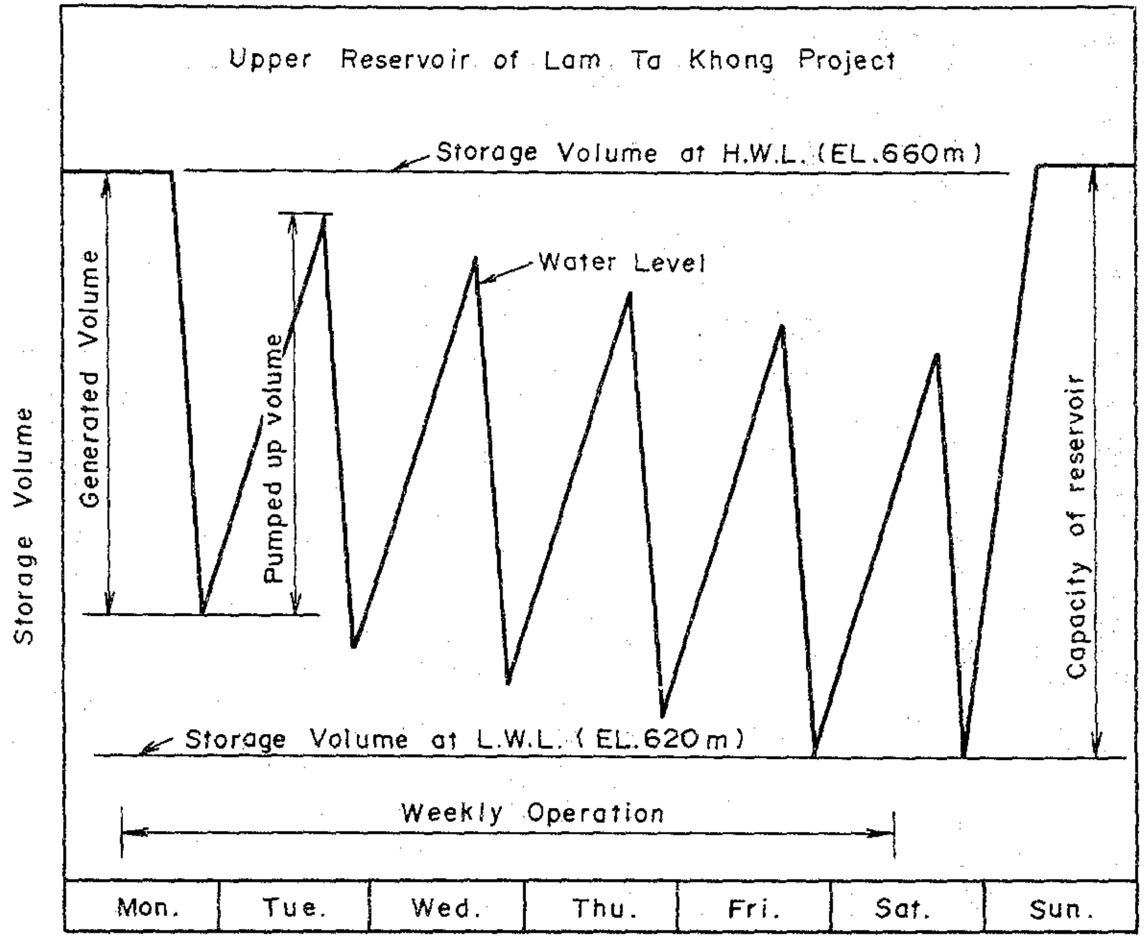
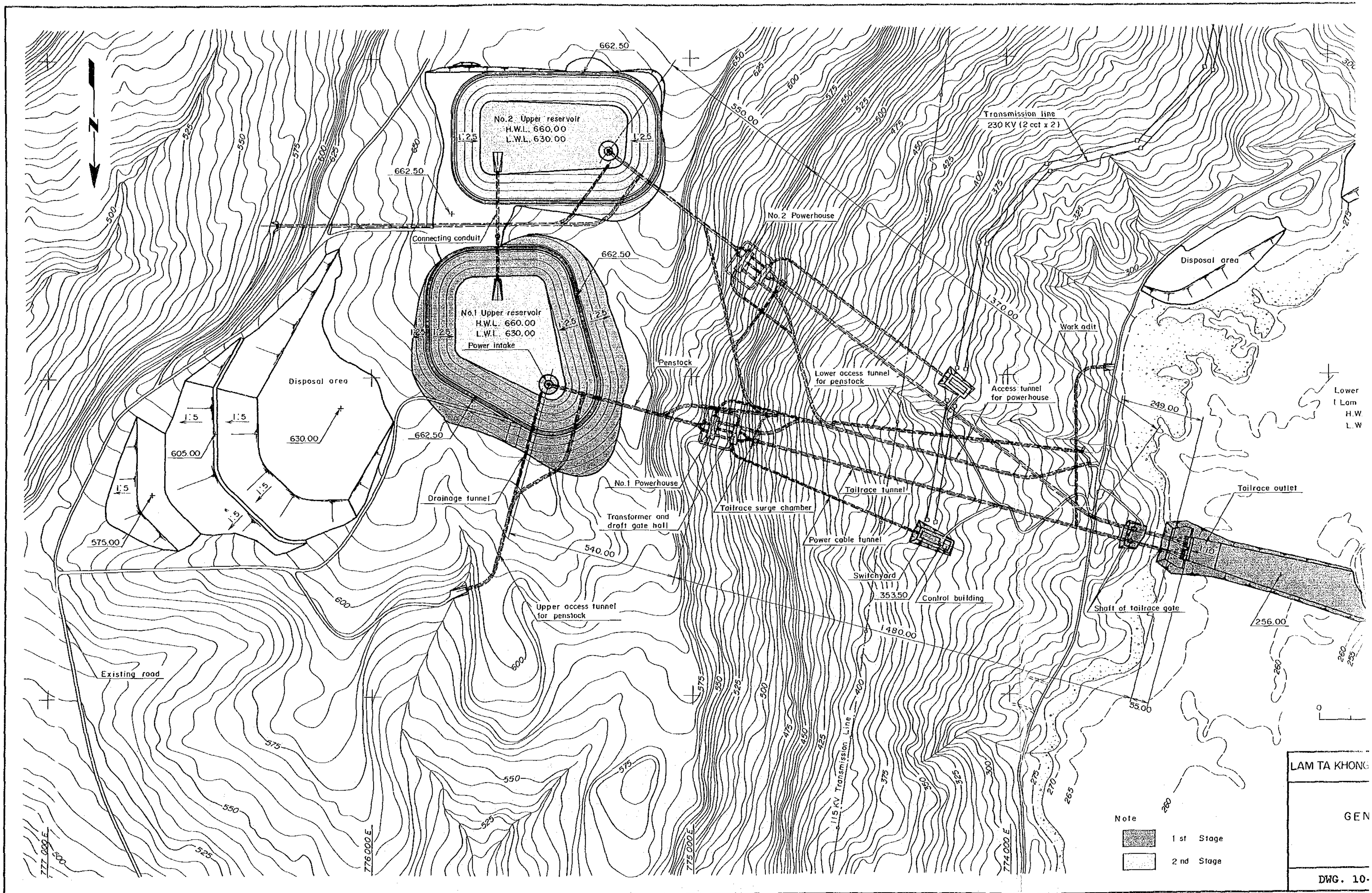
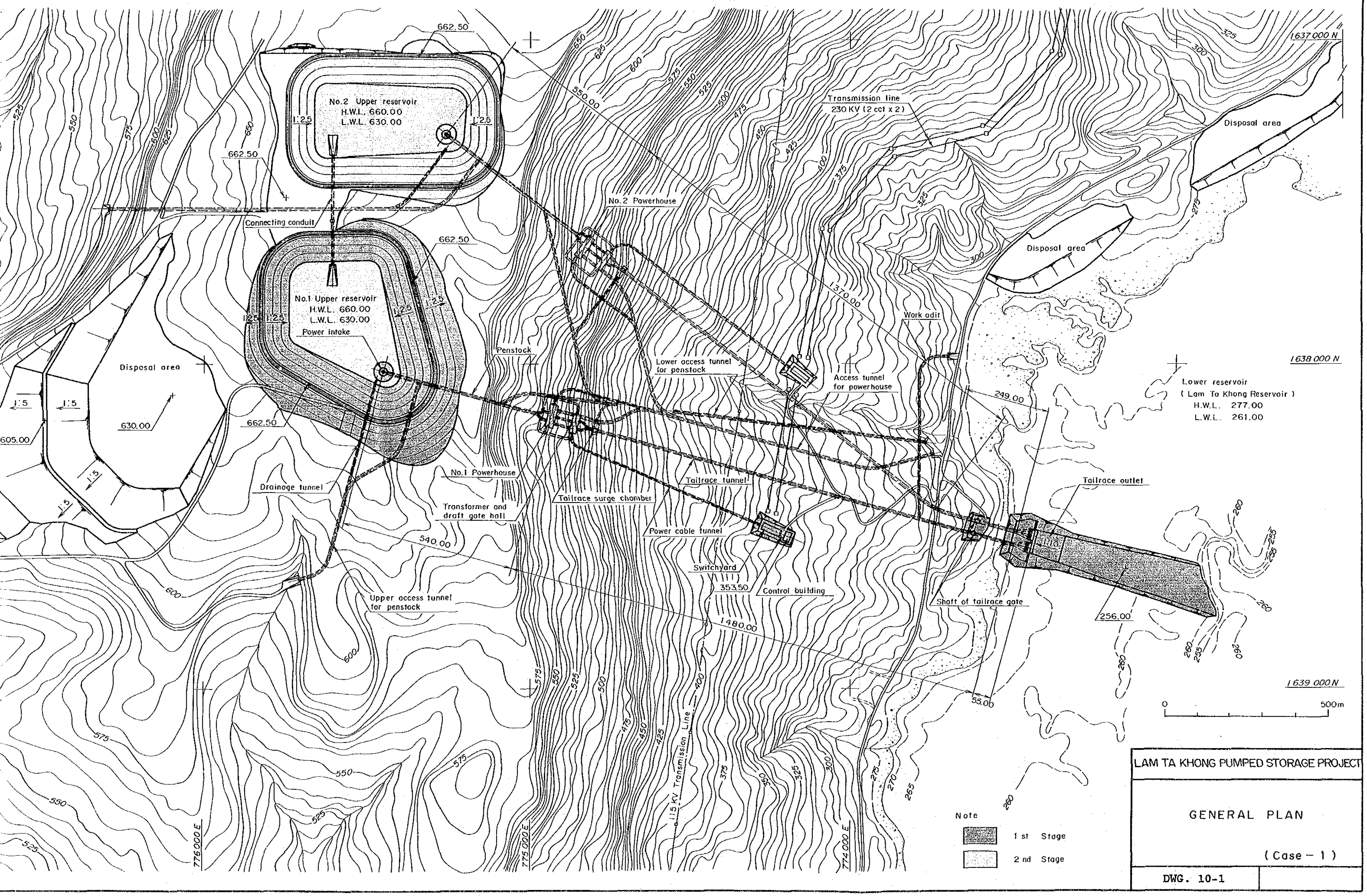


Fig. 10-10 Concept of Reservoir Operation for Adopted Plan


N
No.2 Upper reservoir
H.W.L. 660.00
L.W.L. 630.00
No.1 Upper reservoir
H.W.L. 660.00
L.W.L. 630.00
Power intake
662.50
1:2.5
Connecting conduit
Disposal area
630.00
605.00
575.00
1:5
Drainage tunnel
Penstock
No.2 Powerhouse
No.1 Powerhouse
Transformer and
draft gate hall
Tailrace surge chamber
Tailrace tunnel
Power cable tunnel
Switchyard
353.50
Control building
Lower access tunnel
for penstock
Access tunnel
for powerhouse
Upper access tunnel
for penstock
Work adit
Transmission line
230 KV (2 cct x 2)
115 KV Transmission Line
Disposal area
Tailrace outlet
Shaft of tailrace gate
256.00
550.00
1370.00
249.00
540.00
1480.00
55.00
Existing road
777 000 E
776 000 E
775 000 E
774 000 E
Lower
Lam
H.W
L.W
Note
1 st Stage
2 nd Stage
LAM TA KHONG
GEN
DWG. 10-

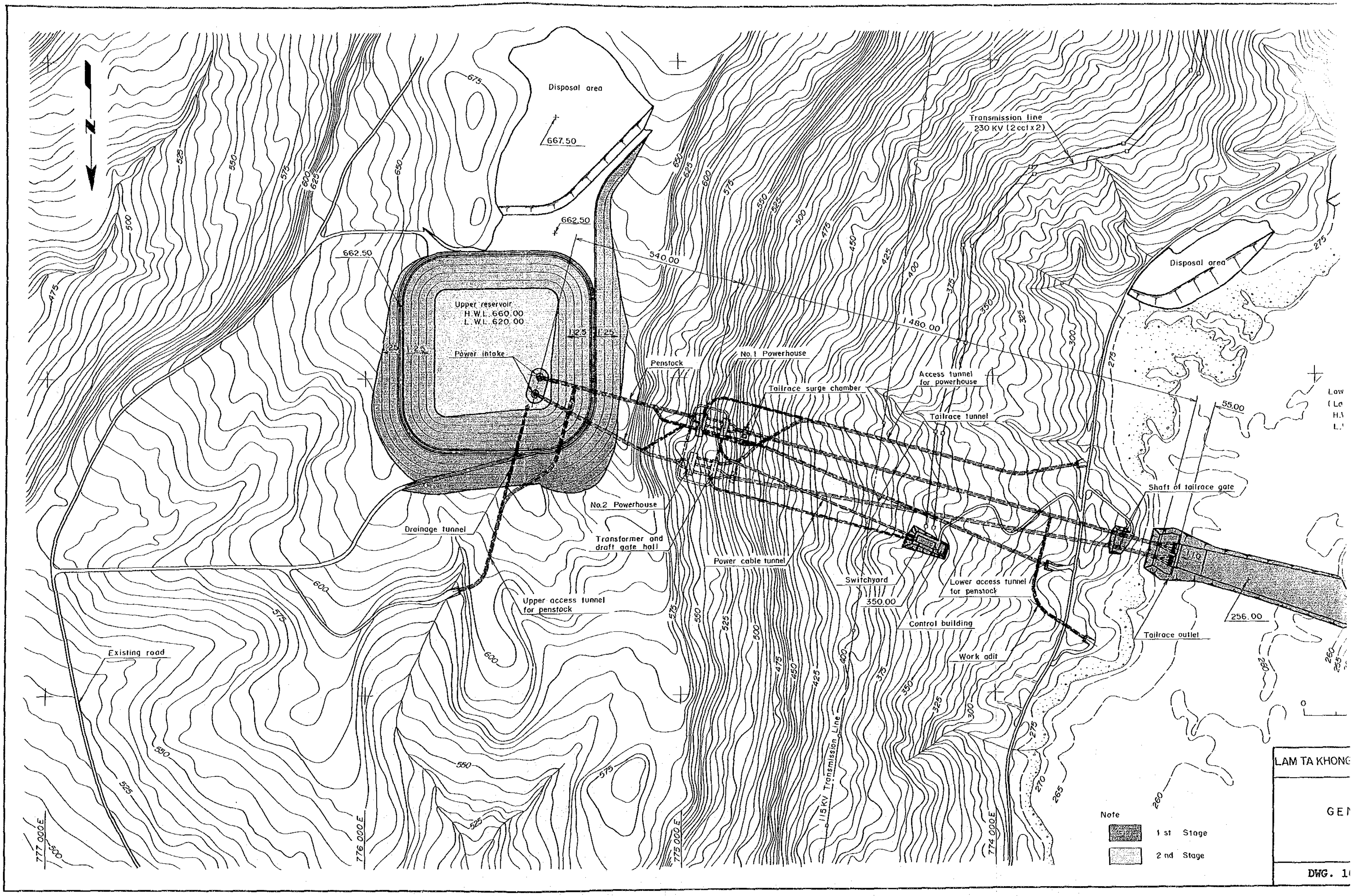


LAM TA KHONG PUMPED STORAGE PROJECT

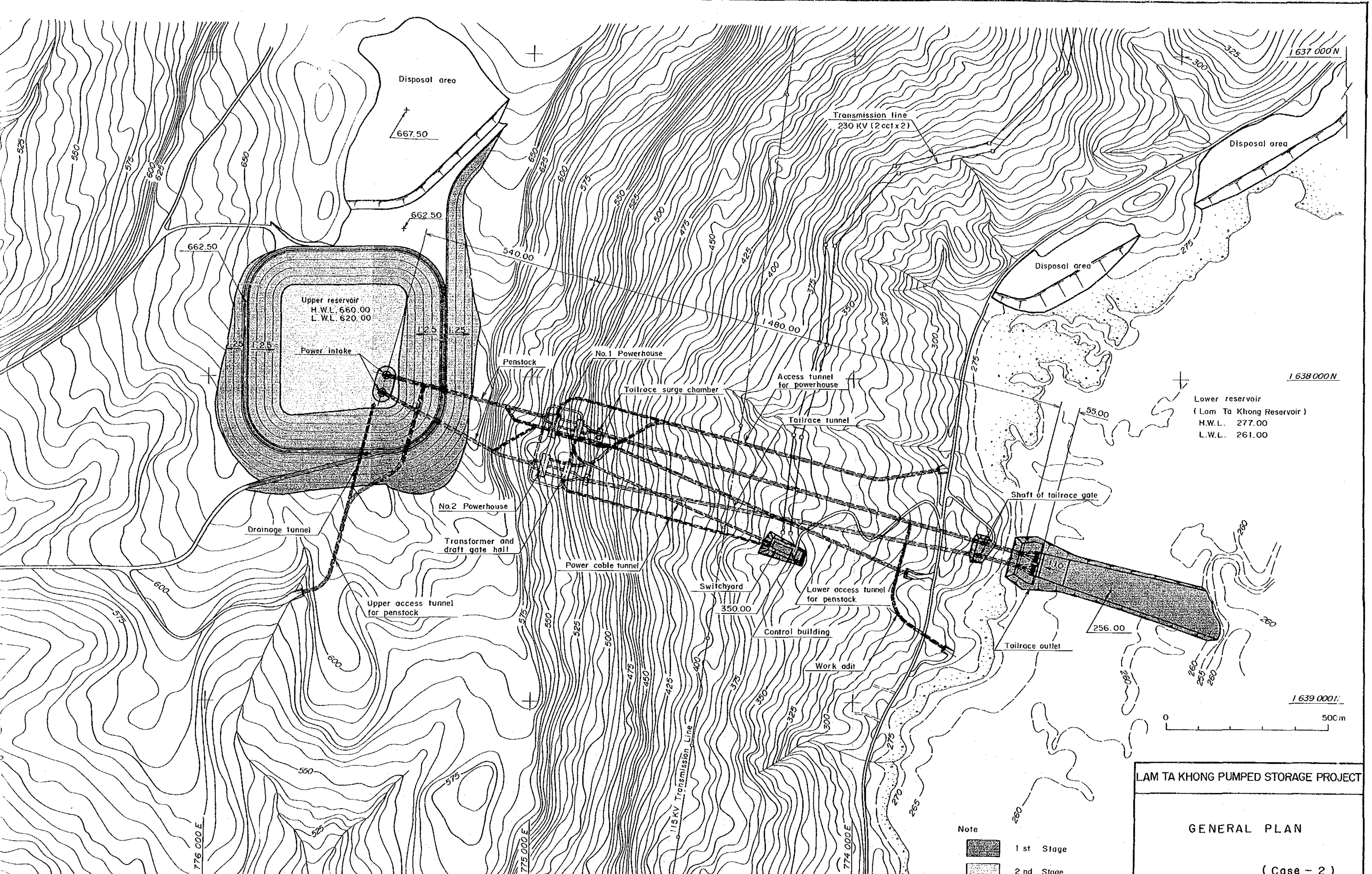
GENERAL PLAN

(Case – 1)

DWG. 10-1



N
Disposal area
667.50
662.50
662.50
540.00
1 480.00
Upper reservoir
H.W.L. 660.00
L.W.L. 620.00
1:2.5
Power intake
Penstock
No.1 Powerhouse
Tailrace surge chamber
Access tunnel for powerhouse
Tailrace tunnel
Transmission line
230 KV (2 cct x 2)
Disposal area
55.00
Shaft of tailrace gate
No.2 Powerhouse
Transformer and draft gate hall
Drainage tunnel
Power cable tunnel
Switchyard
350.00
Lower access tunnel for penstock
Upper access tunnel for penstock
Control building
Work adit
Tailrace outlet
256.00
Existing road
115 KV Transmission Line
777 000 E
776 000 E
775 000 E
774 000 E
Note
1 st Stage
2 nd Stage
LAM TA KHONG
GEN
DWG. 1

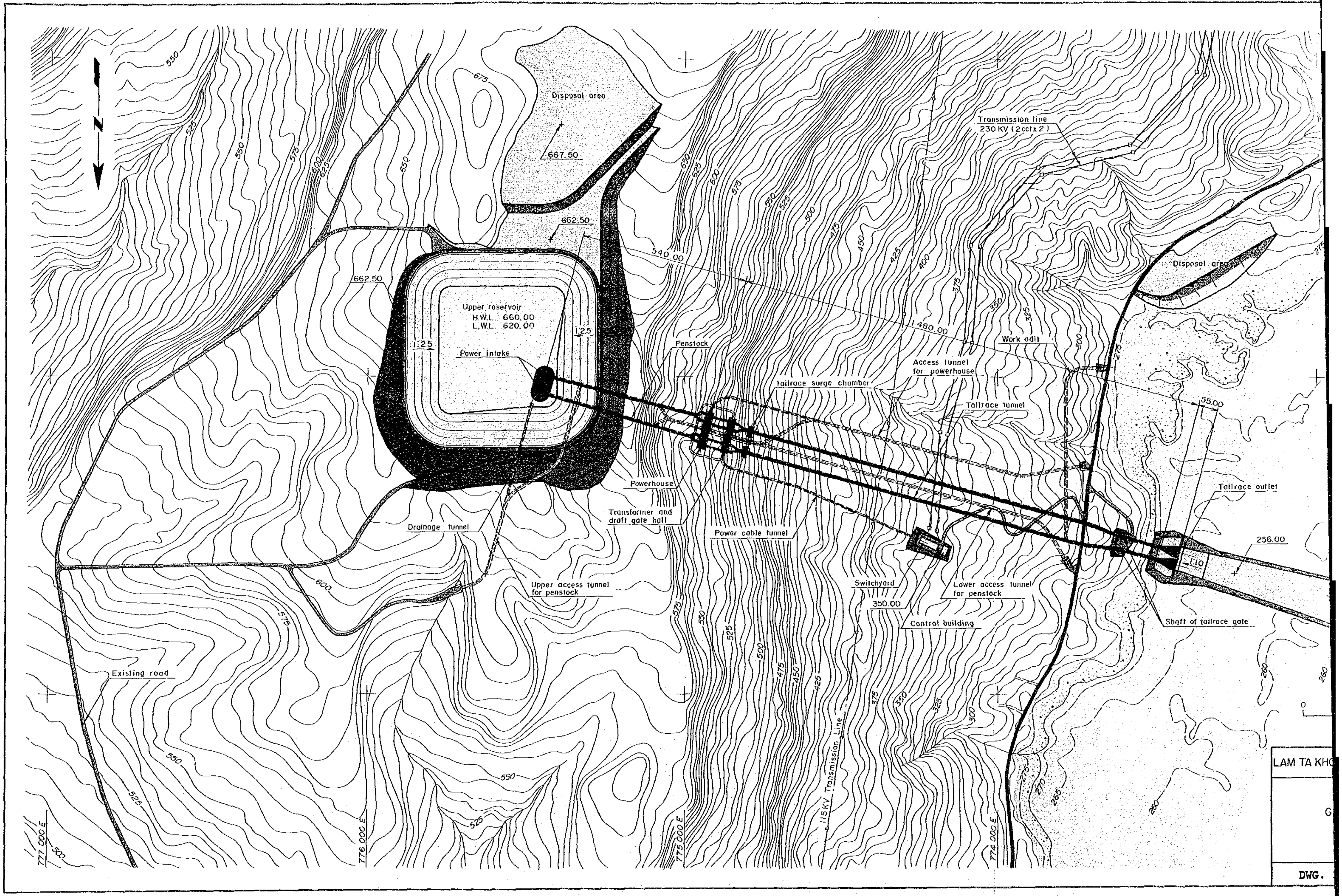


LAM TA KHONG PUMPED STORAGE PROJECT

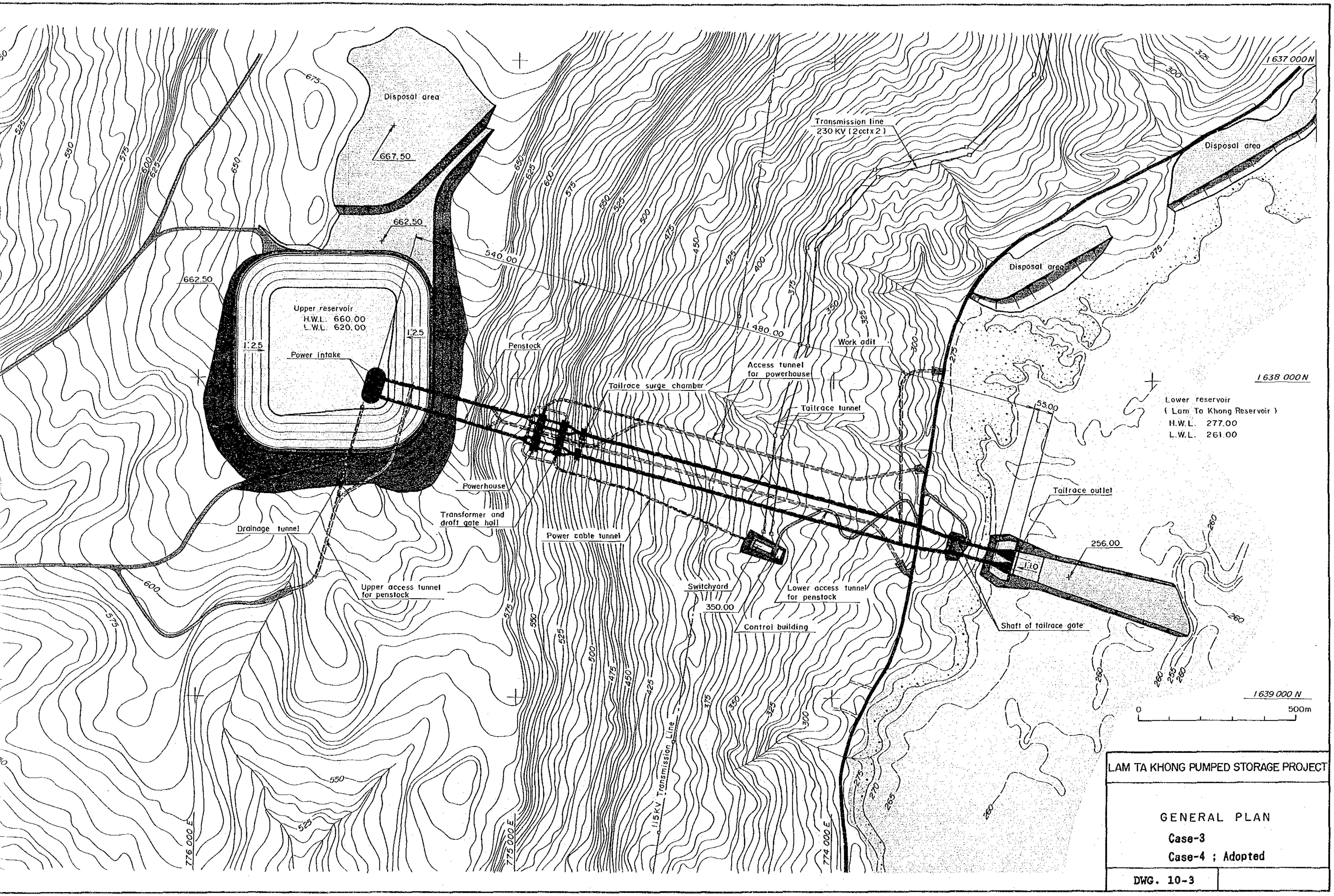
GENERAL PLAN

(Case - 2)

DWG. 10-2



N
Disposal area
667.50
662.50
662.50
540.00
Upper reservoir
H.W.L. 660.00
L.W.L. 620.00
1:2.5
1:2.5
Power intake
Penstock
Tailrace surge chamber
Access tunnel for powerhouse
Tailrace tunnel
Work adit
480.00
55.00
Transmission line 230 KV (2cct x 2)
Disposal area
Powerhouse
Transformer and draft gate hall
Power cable tunnel
Drainage tunnel
Upper access tunnel for penstock
Switchyard
350.00
Control building
Lower access tunnel for penstock
Shaft of tailrace gate
Tailrace outlet
256.00
1:10
Existing road
115 KV Transmission Line
777.000 E
776.000 E
775.000 E
774.000 E
LAM TA KHO
DWG.



LAM TA KHONG PUMPED STORAGE PROJECT

GENERAL PLAN

Case-3

Case-4 ; Adopted

DWG. 10-3

CHAPTER 11

POWER TRANSMISSION LINE & POWER SYSTEM ANALYSIS

CHAPTER 11 POWER TRANSMISSION PLAN AND POWER SYSTEM ANALYSIS

CONTENTS

List of Tables

List of Figures

Fig. 11-15 Generation Angle Swing Curves with Lam Ta Khong 4*250 MW When Three-phase Fault Occurs on the Saraburi 2 - Lam Ta Khong line at Peak Hours in 1997

CHAPTER 11 POWER TRANSMISSION PLAN AND POWER SYSTEM ANALYSIS

11.1 Power System in Thailand

The outline of power system in Thailand is as shown in Fig. 11-1. The voltages of transmission lines forming the power system are; 500 kV, 230 kV, 115 kV and 69 kV. The frequency is 50 Hz.

The power system of Thailand is divided into the following 4 regions, each region being connected by transmission lines of 500 kV, 230 kV or 115 kV.

Region 1: Metropolitan area and its surrounding area
Region 2: North-East area
Region 3: South area
Region 4: North and middle area

As of September 1990, the total capacity of power generating facilities in Thailand is 7,970.3 MW (Diesel power plant 28.6 MW is not included) which consists of 2,249.2 MW by hydro power (28.2%), 4,306.5 MW by oil/gas and lignite fired thermal (54.0%), 1,176.6 MW by combined cycle (14.8%) and 238.0 MW by gas turbine (3.0%).

The regional distribution of electric power source and power supply to each area as of September 1990 are as follows;

(1) In Region 1, there are thermal power stations of large capacity such as South Bangkok power station (1,330 MW). Bang Pakong power station (2,276.6 MW), etc. and also reservoir type power stations of large capacity such as Srinagarind power station (540 MW), Khao Laem power station (300 MW), etc.
A total capacity of these facilities is 4,752.3 MW (59.6% of the total installed capacity of power sources in this country).

(2) In Region 2, there are hydro power stations of medium scale such as Chulabhorn power station (40 MW), Sirindhorn power station (36 MW), and some gas turbine power stations and a total capacity of these facilities is 136.3 MW (1.7% of the total installed capacity in the

country). These power supply sources, capable of load-frequency control, operate in the peak time. The base power supply is transmitted mainly from Region 4 through the 230 kV transmission lines and also from Region 1 through the 115 kV transmission lines. Some of the power required in this area is supplied by purchasing surplus energy (power) of Nam Ngum power station (150 MW) in Laos, a neighboring country.

(3) In Region 3, there are thermal power stations such as Khanom power station (150 MW), Krabi power station (34 MW), Suratani power station (30 MW), etc. and also hydro power stations such as Rajjaprabha power station (240 MW), Bang Lang power station (72 MW), etc. A total capacity of these facilities including the gas turbine at Hat Yai is 611.3 MW (7.7% of the total installed capacity in the country). Regarding the power supply for base load, the power is supplied from Khanom and Krabi thermal power stations and Region 1 through the Second Central-Southern Tie Line (230 kV) which has been completed recently. The electric power is mutually exchanged between Thailand and Malaysia by means of the 115/132 kV Power System Interconnection.

(4) Installed in Region 4 are Mae Moh thermal power station with output of 1,425 MW (as of September 1990), and hydro power stations of large capacity such as Bhumibol power station (535 MW), Sirikit power station (375 MW), etc. A total output of these facilities is 2,470 MW, which is 31.0% of the total power generating facilities of this country.

EGAT has been making their efforts to develop power generation facilities, in order to meet the rapidly increasing demand for electric power in recent years. EGAT is now concentrating their efforts to develop Mae Moh area in the northern district and the eastern seaside zone of Region 1.

The trunk power lines connecting among these regions have also been reinforced. Recently, the 500 kV line connecting Mae Moh thermal power station with Greater Bangkok Area has been started operation at 500 kV in the entire line length. The 230 kV second Central-Southern Tie Line has also been newly completed to connect Region 1 with Region 3. Furthermore, the following power lines are being constructed at present;

Voltage (kV)	From-To	Length (km)	No. of circuit	Conductor (MCM)	Commissioning Year
500	Mae Moh - Tha Tako	333	2	4 x 795 ACSR	1992
230	Tha Tako - Khon Kaen 3	300	2	1 x 1272 ACSR	1992

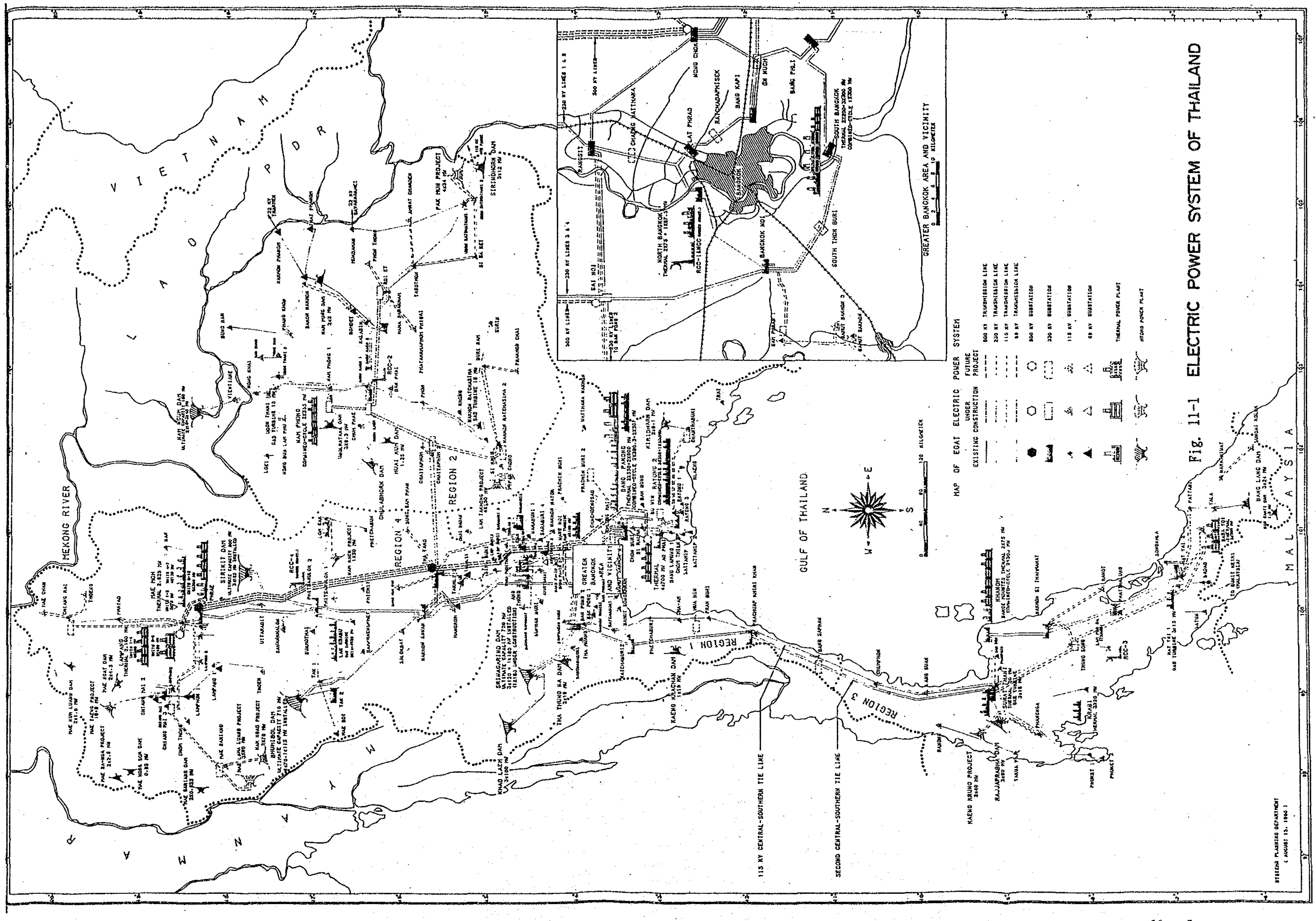


Fig. 11-1 ELECTRIC POWER SYSTEM OF THAILAND

11.2 Transmission of Power from a Pumped Storage Power Plant

Generally a transmission line for a power source is planned according to the following procedure:

(1) A substation to which the power plant will send power is selected from the substations existing at present and those expected to be completed by the time when the power plant is commissioned.

(2) The transmission voltage is selected from the voltages used as standard.

(3) Number of circuits and conductors for the transmission line are decided by taking into consideration of the required transmission capacity, reliability, difficulty/easiness to secure the route of line, economic aspect, future power development plans, future expansion plans of network, etc.

(4) Whether the established transmission plan is appropriate for the system operation or not is checked by power system analyses.

The transmission line must have sufficient power transmission capacity and reliability so that the plant can be properly operated. It must not cause any deterioration in the power system stability.

If the transmission line is a short distance line, its capacity is decided by the current capacity of the conductors. However, if it is a long distance line, the transmission capacity is decided mainly by the power system stability.

In case when the power system includes a pumped storage power plant, pumping operation at off-peak hours offers severer condition than generating operation at peak hours from a viewpoint of power system stability.

When pumping, the phase angle difference between the phase angle of the voltage of generator supplying power for pumping and the phase angle of the voltage of motor in pumping operation is great, which causes the stability of power system to become considerably deteriorated.

If the system is not strong enough, even a very small disturbance such as rapid change of load will cause vibration to the generators and the motors, and put some of the machines out of step. In such a state, the power system must be reinforced, sometimes extensively.

The scale of pumping project is decided from the economic aspect of the projected site and degree of necessity for system operation. In this regard, the transmission facilities required for the stable operation of power system become very important, because they greately influence the economic aspect of the project and sometimes have decisive effect on developing it.

The transmission lines which exist at present and those which are to be installed in the near future should be firstly examined if they can send power to and from the newly born project (e.g. Lam Ta Khong project).

If they are possible to be used, the new project will become feasible and economically developed.

If they can not be utilized because of their capacity shortage or because of power stability problem, a new transmission line exclusively for the project and/or an expansion of transmission system will be needed.

If the development of the project requires an excessively great amount of investment in the power transmission system, the project will not be feasible and the development of it will become meaningless.

A power system grows continuously and expands year and year, because power supply sources and necessary transmission system must be constructed to cope with increasing power demand.

The expansion of the network is closely connected with the load forecasts of areas and development plan of energy sources, and it also concerned with the policy of the government and/or power companies.

If the development of the project needs new lines and an expansion of transmission system in the main part of the power system, another examination by EGAT will be necessary, because these new facilities will give effect to the future power system expansion and EGAT's policy as well.

Therefore the expansion plan of transmission lines formulated by EGAT as PDP 90-03 was treated as a basis and not changeable in principle, to make a plan of necessary transmission facilities which enables Lam Ta Khong project to be developed economically.

11.3 Capacity of Lam Ta Khong Project Recommended from Power System Analysis

11.3.1 Preliminary Study of the Scale Developed in the First Stage

We have agreed to study the following capacities for this project.

(1) 600 MW (150 MW x 4)
(2) 800 MW (200 MW x 4)
(3) 1,000 MW (250 MW x 4)

The result of our study is stated in Chapter 10 with our suggestion of the most appropriate scale.

However, there is a possibility that the scale of this plant may be limited by the stability, i.e., the strength of power system, at a time when the plant is commissioned, because pumping operation causes a very severe state of stability of power system as described before.

We have mentioned in the intermittent report that pumping of 450 MW-600 MW would be possible from the result of preliminary analysis on the power system in fiscal 1997 when the project is expected to be developed.

In the study, Lam Ta Khong pumped storage power plant has been assumed to be connected with Saraburi 2 substation and Thalan 3 substation, which is to be constructed by 1993, by 230 kV transmission lines. The capacity at pumping operation has been examined by a dynamic simulation of a five-cycle three-phase fault on the 230 kV transmission line connected with Lam Ta Khong pumped storage, at off-peak hours in 1997-2000.

As a result, it was shown that pumping capacity at the first step of development could be 450 MW-600 MW, though it depends on patterns of transmission of power from the plant.

However, it is necessary to study stability of power system taking a three-phase fault on a 500 kV line into account, for the purpose of choosing appropriate capacity in the first step of development of Lam Ta Khong project.

The 500 kV transmission system is the core of the power system in Thailand and a fault on the 500 kV line may produce such a severe disturbance on the whole of power system that the plant can not continue to operate.

Possible pumping capacity of Lam Ta Khong pumped storage power plant depends on the developed capacity of Lampang thermal power plant, measures for stability of the region 3 power system, and the expansion plan of 500 kV transmission system, besides patterns of transmission of power from the project.

This report presents the result of study on capacity of Lam Ta Khong project centering the possibility of developing 500 MW as the first step capacity. The study includes dynamic stability analysis which simulates a line fault on 500 kV transmission lines as well. The power system built in the revised EGAT power development plan (PDP 90-03) is basic in the study.

11.3.2 Power Flow Calculation

Before conducting the dynamic stability analysis, we calculated the distribution of voltage and power flow at peak time and night time in the year of 1997 when Lam Ta Khong project is incorporated in the power system.

EPDC's computer program for power system analysis, CASTLE, was used for the power flow calculation.

Typical power flow diagrams are shown as the result of calculation in Fig. 11-2 and Fig. 11-3.

In the power flow diagram, generators and transformers of a power plant and transformers of a substation are shown by one unit respectively. As for 230 kV transmission lines, a plural number of circuits are shown by only one line, but for 500 kV transmission lines, one circuit is shown by one line each.

A shunt reactor which is connected with each circuit at the end of 500 kV lines is shown collectively on the 500 kV buses of the substations.

The existing 230 kV line, one circuit, installed between Tha Tako and Saraburi 2 is assumed to be taken into projected Thalan 3 substation for the reason below.

1) It is necessary to secure enough transmission capacity between Saraburi 2 and Thalan 3.

2) If the line is not taken into Thalan 3, a transmission facility between Thalan 3 and Saraburi 2 will be only one circuit and a fault on the line will cause the machines of Lam Ta Khong power plant to put out of step.

The 230 kV transmission line installed between Saraburi 2 and Nakhon Ratchasima 2 is to be taken into the project to formulate the transmission system for Lam Ta Khong project.

In case that the Lam Ta Khong power plant has a capacity of 1,000 MW, the plant is connected with the above 230 kV transmission line by 1 π connection and with Thalan 3 substation by a 230 kV double-circuit transmission line respectively.

It was found that the power system stability in 1997 limits pumping power of the plant to 500 MW, although it gives no problem for generation of 1,000 MW power.

Therefore, it is conceivable to install four units with a capacity of 250 MW each from the beginning of service to cope with the power demand growing at a high rate, which enables the plant to generate power of 1,000 MW by four units, although pumping at night time must be done by two units at most.

The power flow diagrams indicate the results of power flow calculation according as the above power plant operation.

Load factor at each substation is assumed to be 0.95 on a 230 kV bus. For power demand at night time, is used 50% of the peak demand estimated for the year. Table 11-1 shows constants of facilities such as transmission lines and transformers used for power flow calculation.

In the power system operation, bus voltage of each substation is normally held within tolerance of +/-5% of nominal in consequence of supply of reactive power from generators, tap changing of transformers, and supply and/or absorption of reactive power by shunt capacitors and/or shunt reactors.

Table 11-2 shows reactive power facilities supposed from the result of the power flow calculation to maintain the voltages at the above level.

The results of power flow calculation show that there are no problems such as overloading on Mae Moh - Tha Tako - Thalan 3 - Saraburi 2 transmission system which has close connection to power transmission for Lam Ta Khong pumped storage, but the Thalan 3 - Ang Thong 2 transmission line may be overloaded when the plant generates 1,000 MW. Some measures should be taken to avoid this problem.

Reactive power facilities are required at many substations to hold voltages in the power system within the allowed range.

It is important to maintain the voltage at Saraburi 2 and Nakhon Ratchasima 2 especially at night pumping hours.

11.3.3 Power System Stability Analysis

11.3.3.1 Conditions for Power System Stability Analysis

Stability of power system has been analysed under various conditions of power demand, capacity of Lam Ta Khong plant, method of power transmission and fault location of transmission line.

Technical conditions for analyses are as follows;

(1) Fiscal year analysed 1997-2000

(2) Power demand peak time and night time

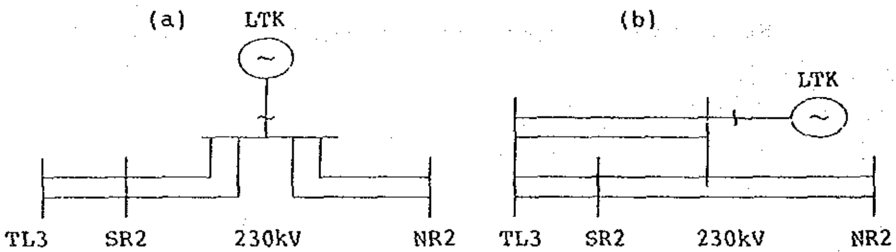
(3) Capacity of Lam Ta Khong 500 MW, 600 MW and 1,000 MW

(4) Main facilities of the power system

Table 11-3 indicates a state of main facilities especially related to stability of Lam Ta Khong.

(5) Pattern of transmission of power from Lam Ta Khong

The figure (a) which shows the use of the 230 kV line between Saraburi 2 and Nakhon Ratchasima 2 has been studied mainly, but figure (b) which shows reinforcement of the lines between Lam Ta Khong and Thalan 3 has been studied as well for the alternative in which the capacity of the plant was assumed 600 MW.



(6) Provisions for power system stabilization

All the generators to be newly installed at remote places and the generators for pumping use were assumed to be equipped with a high-initial response excitation system and power system stabilizer (PSS).

A static var compensator (SVC) was assumed to be installed at Ban Saphan substation which is to be placed under the 230 kV Second Central-Southern Tie Line in addition to existing Tha Tako substation.

SVC at Tha Tako	230 kV	SC	80 MVar x 2
		TCR	150 MVar x 2
SVC at Ban Sapahn	230 kV	SC	300 MVar
		TCR	50 MVar

(7) Fault conditions

Conditions of a line fault for the stability analysis is indicated in Table 11-4.

11.3.3.2 Results of Power Stability Analysis

The results of the power system analysis are shown in Table 11-5.

(1) In case when Lam Ta Khong plant, 500 MW, is connected with the existing 230 kV line between Saraburi 2 and Nakhon Ratchasima 2 as indicated in the figure (a), the power system will be stable in 1997, even with any of line faults of Case 1, 2 and 3 in Table 11-4.

(2) As for the impact of a line fault on the stability, Case 1 has the severest impact, while Case 3 the most lenient one.

(3) In case when Lam Ta Khong plant has a capacity of 600 MW, its

pumping machines will be put out of step, if such a line fault on a 500 kV line as above mentioned Case 1 or Case 2 happens during pumping operation.

With a line fault of a 230 kV line such as Case 3, the power system will be able to keep stable.

(4) Even though the transmission system between Lam Ta Khong and Thalan 3 is reinforced with a 230 kV double-circuit line such as the pattern of figure (b), Lam Ta Khong (600 MW) will be put out of step, if a line fault occurs on a 500 kV line during pumping operation.

(5) Accordingly the capacity for pumping operation of Lam Ta Khong pumped storage power plant should be 500 MW or below in case when it is incorporated in 1997 into the power system projected in PDP 90-03.

If 600 MW is required for pumping, it is necessary to reinforce the main power system of Mae Moh - Tha Tako - Thalan 3 and to construct a transmission line between Thalan 3 and Lam Ta Khong.

(6) The power system will become a very severe state from a viewpoint of power system stability after July 1999 in which Unit 2 (300 MW) of Lampang thermal power plant is commissioned, because the phase angle difference between the phase angle of the generator voltage of Mae Moh power plant and the phase angle of the motor voltage of Lam Ta Khong will be increased in proportion to the increase of power from the north to the south.

(7) For the power system in 1999, the stability limit with Lam Ta Khong (500 MW) is presented in its pumping operation in the case when the system load is approximately 70% of the year's peak load.

(8) For the power system in 2000, Lampang Unit 3 and Unit 4 will be

(8) For the power system in 2000, Lampang Unit 3 and Unit 4 will be commissioned in January and July in 2000 respectively, and power flow toward the south will be increased.

Due to the additional 500 kV transmission line (single circuit) constructed between Lampang and Tha Tako, there is no stability problem in pumping operation in the case when the system load is approximately 50% of the year's peak load.

However, the power system is in a very severe condition from a viewpoint of stability, because phase angle difference between the phase angle of the generator voltage of the remote power plants and the phase angle of the motor voltage of Lam Ta Khong is very large.

Therefore, it is required to study the main power system after the year 2000 with regard to improvement of the stability.

(9) As for generation of 1,000 MW by Lam Ta Khong power plant, there is no problem of power system stability as shown in the swing curves on Fig. 11-15.

11.3.4 Short Circuit Current

Three phase short circuit current at peak time in 1997 was computed corresponding to the power flow diagram (Fig. 11-2). Flows of short current at the substations in the vicinity of Lam Ta Khong power plant are shown in Fig. 11-14.

Direct-axis subtransient reactance Xd" was used for the machines in the calculation.

Table 11-1 Line and transformer constants (% value on 100MVA base) of the power system in 1997

* BRANCH DATA (POSITIVE-SEQUENCE) *

CODE	FROM	TO	R	X	Y/2
B01	TTK-500	MM3-500	0.2700	3.3600	181.3000
B01A	TTK-500	MM3-500	0.2700	3.3600	181.3000
B051	MM3-500L	MM3-500	0.0010	0.0100	0.0000
B05	TTK-500L	MM3-500L	0.2600	3.4800	167.4000
B052	TTK-500	TTK-500L	0.0010	0.0100	0.0000
B061	TTK-500M	TTK-500	0.0010	0.0100	0.0000
B06	NCO-500M	TTK-500M	0.1800	2.2000	116.4000
B062	NCO-500	NCO-500M	0.0010	0.0100	0.0000
B07	NCO-500	TTK-500	0.1800	2.2000	116.4000
B0911	SN-500	AP2-500	0.2000	2.3700	124.0400
B08	AP2-500	NCO-500	0.1200	1.4400	75.5400
B10	SN-500	NCO-500	0.0800	0.9300	48.5000
B12	PL2	MM3-230	0.8100	5.8300	25.7700
B13	PL2	SK	1.8300	4.3800	17.8000
B14	KK3	NPO2	0.0900	0.8800	7.3800
B15	LS	PL2	0.6200	4.4600	19.6200
B16	KK3	LS	0.8700	6.3200	27.9700
B17	NS	PL2	1.0900	5.2100	21.2100
B18	NS	BB	1.0800	7.8200	34.9300
B19	TA2	BB	0.5400	4.1700	4.0600
B20	NS	TA2	1.6200	12.4500	12.1800
B22	CYP2	KK3	0.5550	4.0300	17.7200
B23	TTK-230	NS	0.2400	1.7400	7.6300
B24	CYP2	TTK-230	0.9300	6.7300	29.8100
B25	AT2	NS	0.6300	4.5200	20.1400
B26	TL3	TTK-230	1.7900	13.0000	14.5900
B27	AT1	TTK-230	1.4600	10.5600	11.7300
B281	TL3	TTK-230	0.6400	6.8200	13.9500
B282	TL3	TTK-230	0.6400	6.8200	13.9500
B29	TL3	AT2	0.5500	3.9600	4.3500
B30	SR2	TL3	0.1500	1.0800	4.7400
B31	LTK	SR2	0.7500	5.4000	5.9300
B331	LTK	TL3	0.9500	6.8400	7.5100
B332	LTK	TL3	0.9500	6.8400	7.5100
B3234	NR2	SR2	1.1900	8.6200	9.5000
B33	NR2	LTK	0.7000	5.0400	5.5300
B35	NR2	CYP2	0.4500	3.2400	14.2400
B36	AT1	AT2	0.1700	1.2600	1.3900
B37	SNO-230	AT2	0.3600	2.5400	11.2800
B381	BPI2	AT1	0.2500	1.8000	7.9300
B382	RS	BPI2	0.1500	1.0800	4.7400

* BRANCH DATA (POSITIVE-SEQUENCE) *

CODE	FROM	TO	R	X	Y/2
B39	SNR	KHL	0.4200	3.0100	13.0200
B40	BP2	SNR	0.2700	1.9600	34.4300
B41	SNO-230	BP2	0.1300	0.9700	16.9600
B42	RS	SNO-230	0.0600	0.6400	5.2600
B43	BN	SNO-230	0.1500	1.0600	4.7100
B44	NB	RS	0.1900	1.3900	1.5400
B45	LPR	RS	0.1800	1.2700	1.4000
B46	LPR	NB	0.0700	0.5000	0.6900
B47	NCO-230	RS	0.1000	1.0500	8.5700
B48	RCHD	LPR	0.0100	0.1200	0.9800
B49	BK	RCHD	0.0200	0.1700	1.4200
B50	ON	BK	0.0200	0.1500	3.7300
B52	BN	NB	0.1800	1.4400	1.3300
B53	ON	NCO-230	0.0400	0.4400	3.6000
B54	KLM	NCO-230	0.0900	0.9000	7.3500
B55	BPK2	NCO-230	0.1100	1.1100	9.0900
B56	BPK2	ON	0.1200	1.2600	10.2800
B57	BPK	KLM	0.0200	0.2100	1.7100
B58	AP	BPK	0.2600	1.8900	8.3200
B59	AP	BPK2	0.2600	1.8900	8.3200
B60	BPK	BPL	0.1100	1.1600	9.4500
B61	BPL	ON	0.0500	0.3800	1.6700
B62	SB	BPL	0.0800	0.5700	2.5200
B64	STB	SB	0.0400	0.3100	4.1700
B65	BN	STB	0.0200	0.1700	2.2500
B67	AP	AP2-230	0.0100	0.1600	0.3200
B68	BW	AP	0.1100	0.7900	3.4900
B69	RY2	BW	0.2300	1.6500	7.2900
B70	RTB2	BP2	0.2100	1.5000	6.5900
B71	PKK	RTB2	0.9700	7.0400	31.2200
B721	BSP	PKK	0.1000	0.7800	3.5100
B722	ST	BSP	1.5700	11.5900	52.2600
B73	RJP	ST	0.2600	1.8500	8.1200
B74	KHN	ST	0.3800	2.7600	12.0700
B75	TS	ST	0.6100	4.4000	19.2200
B76	NST	KHN	0.4900	3.5300	15.3700
B77	NST	TS	0.2700	1.9500	8.5000
B78	PTL	NST	0.4500	3.2400	14.1100
B79	HY2	PTL	0.4100	2.9200	12.8500

* BRANCH DATA (POSITIVE-SEQUENCE) *

CODE	FROM	TO	R	X	Y/2
TG01	MM1-G	MM3-115	0.0000	3.8300	0.0000
TG02	MM2-G	MM3-230	0.0000	1.7800	0.0000
TG03	MM3-G	MM3-500	0.0000	0.7200	0.0000
TG06	BB-G	BB	0.0000	6.3800	0.0000
TG07	NPO2-G	NPO2	0.0000	2.1400	0.0000
TG09	SNR-G	SNR	0.0000	2.9100	0.0000
TG10	NB-G	NB	0.0000	3.7500	0.0000
TG11	SB-G	SB	0.0000	0.4400	0.0000
TG12	BPK-G	BPK	0.0000	0.8100	0.0000
TG13	BPK2-G	BPK2	0.0000	0.6100	0.0000
TG14	AP2-G	AP2-500	0.0000	0.8250	0.0000
TG15	RY2-G	RY2	0.0000	0.8300	0.0000
TG17	KHN-G	KHN	0.0000	1.2900	0.0000
TG22	LTK-G	LTK	0.0000	2.3000	0.0000
T01	MM3-500	MM3-230	0.0000	0.7200	0.0000
T02	MM3-230	MM3-115	0.0000	3.9400	0.0000
T03	TTK-500	TTK-230	0.0000	0.7200	0.0000
T03B	TTK-230	TTK-115	0.0000	6.2000	0.0000
T03B-SV	TTK230SV	TTK-230	0.0000	0.1000	0.0000
T04	SN-500	SNO-230	0.0000	1.0900	0.0000
T05	NCO-500	NCO-230	0.0000	1.0900	0.0000
T06	AP2-500	AP2-230	0.0000	1.0900	0.0000

Table 11-2 Reactive Power Facilities Considered in Power Flow Calculation

Facility	Substation	Voltage(kV)	Capacity(MVar)
Shunt Capacitor	South Thon Buri	230	120(60)
	Rangsit	230	120(60)
	Nong Chok	230	180(180)
	On Nuch	230	120(120)
	Ang Thong 1	230	120(60)
	Ang Thong 2	230	240(60)
	Saraburi 2	230	120(120)
	Bang Pa-In 2	230	60(60)
	Phatthalung	230	60(60)
	Hat Yai 2	230	120(60)
	Nakhon Ratchasima 2	230	60
	Lat Phrao	230	120
	Ratchaburi 2	230	240
	Bang Phli	230	120
	Ao Phai	230	60
	Bang Kapi	230	120
	Ratchadaphisek	230	240
	Bangkok Noi	230	120
	Ban Pong 2	230	120
	Sai Noi	230	120
	Nakhon Sawan	230	60
	Khon Kaen 3	230	120
Shunt Reactor	Mae Moh 3	500	290(290)
	Tha Tako	500	440(440)
	Nong Chok	500	245(245)
	Ao Phai	500	150(150)
	Prachuap Khiri Khan	230	50
	Surat Thani	230	50

Note; ( ) indicates capacity planned to be installed by EGAT

Table 11-3 Transition of Main Facilities from Fiscal 1997 to 2000

Facility		1997	1999	2000
Transmission Line	500kV line			
	Mae Moh - Tha Tako	1 circuit ACSR795MCM*4 326km	1 circuit ACSR795MCM*4 326km	1 circuit ACSR795MCM*4 326km
		2 circuits ACSR795MCM*4 333km	1 circuit ACSR795MCM*4 333km	1 circuit ACSR795MCM*4 333km
	Tha Tako - Nong Chok	2 circuits ACSR795MCM*4 215km	2 circuits ACSR795MCM*4 215km	2 circuits ACSR795MCM*4 215km
	Mae Moh - Lampang	-	1 circuit ACSR795MCM*4 18km	1 circuit ACSR795MCM*4 18km
	Lampang - Tha Tako	-	1 circuit ACSR795MCM*4 351km	2 circuits ACSR795MCM*4 351km
	Nong Chok - Ao Phai	1 circuit ACSR795MCM*4 140km	1 circuit ACSR795MCM*4 140km	1 circuit ACSR795MCM*4 140km
	Ao Phai - Sai Noi	1 circuit ACSR795MCM*4 230km	1 circuit ACSR795MCM*4 230km	1 circuit ACSR795MCM*4 230km
	Nong Chok - Sai Noi	1 circuit ACSR795MCM*4 90km	1 circuit ACSR795MCM*4 90km	1 circuit ACSR795MCM*4 90km
	230kV line			
	Tha Tako - Thalan 3	2 circuits ACSR1272MCM*2 130km	2 circuits ACSR1272MCM*2 130km	2 circuits ACSR1272MCM*2 130km
		1 circuit ACSR1272MCM 183km	1 circuit ACSR1272MCM 183km	1 circuit ACSR1272MCM 183km
	Thalan 3 - Saraburi 2	2 circuits ACSR1272MCM 30km	2 circuits ACSR1272MCM 30km	2 circuits ACSR1272MCM 30km
	Saraburi 2 - Lam Ta Khon	2 circuits ACSR1272MCM 75km	2 circuits ACSR1272MCM 75km	2 circuits ACSR1272MCM 75km
	Lam Ta Khon - Nakhon Ratchasima 2	2 circuits ACSR1272MCM 70km	2 circuits ACSR1272MCM 70km	2 circuits ACSR1272MCM 70km
	Saba Yoi -Thung Song	-	-	2 circuits ACSR1272MCM*2 260km
	Saba Yoi - Hat Yai 2	-	-	2 circuits ACSR1272MCM*2 80km
Substation	Tha Tako	500kV/230kV 600MVA * 3	500kV/230kV 600MVA * 3	500kV/230kV 600MVA * 4
	Nong Chok	500kV/230kV 600MVA * 2	500kV/230kV 600MVA * 2	500kV/230kV 600MVA * 2
	Sai Noi	500kV/230kV 600MVA * 2	500kV/230kV 600MVA * 2	500kV/230kV 600MVA * 2
Thermal Power	Mae Moh 3	1u - 3u 75MW * 3	1u - 3u 75MW * 3	1u - 3u 75MW * 3
		4u - 7u 150MW * 4	4u - 7u 150MW * 4	4u - 7u 150MW * 4
		8u - 13u 300MW * 6	8u - 13u 300MW * 6	8u - 13u 300MW * 6
	Ao Phai	1u, 2u 700MW * 2	1u - 3u 700MW * 3	1u - 3u 700MW * 3
	Lampang	-	1u, 2u 300MW * 2	1u - 4u 300MW * 4
	Saba Yoi	-	-	1u 300MW
Pumped Storage	Srinagarind	4u, 5u 180MW * 2	4u, 5u 180MW * 2	4u, 5u 180MW * 2
	Bhumibol	8u 175MW	8u 175MW	8u 175MW
	Lam Ta Khong	1u, 2u 250MW * 2	1u, 2u 250MW * 2	1u, 2u 250MW * 2

Table 11-4 Fault Conditions Applied for Power System Stability Analyses

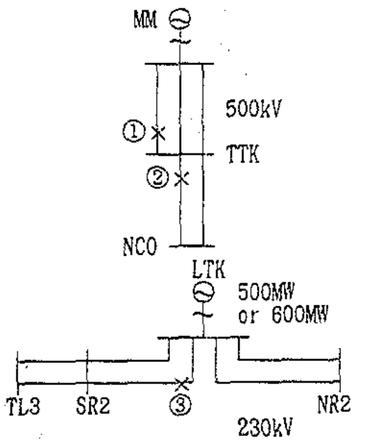
Case	Faulted Line	Fault Location	Fault Type
1	Mae Moh - Tha Tako 500kV Line	Adjacent to the 500kV bus at Tha Tako	4cycle, 3-phase fault
2	Tha Tako - Nong Chok 500kV Line	Ditto	Ditto
3	Saraburi 2 - Lam Ta Khong 230kV Line	Adjacent to the 230kV bus at Lam Ta Khong	5cycle, 3-phase fault
4	Thalan 3 - Lam Ta Khong 230kV Line	Ditto	Ditto

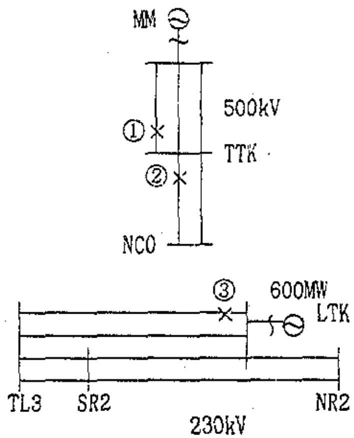
Table 11-5 The Result of Power System Stability Analysis of Lam Ta Khong Pumped Storage Power Plant

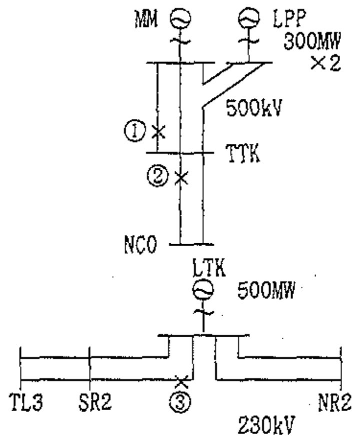
○ Stable
△ Marginal
× Unstable

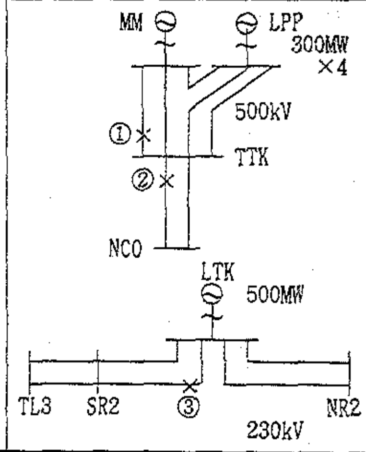
Fiscal Year		1997				1999	2000
Lam Ta Khong Scale (MW)		500		600	600	500	500
Peak(P)/Nihgt(N)		P	N	N	N	N	N
Fault Point	①	○ (Fig 11-4)	○ (Fig 11-6) *○ (Fig 11-7)	× (Fig 11-10)	*× (Fig 11-11)	○ (Fig 11-12)	○ (Fig 11-13)
	②	○	○ (Fig 11-8)	×	△	○	○
	③	○ (Fig 11-5)	○ (Fig 11-9)	○	○	○	○

Power System and Fault Point









Note 1. The substation loads at night were assumed 50% of the peak demand of the fiscal year, except two cases, marked with *, where 75% were adopted.
2. In the fiscal 1999, pumping operation in the 70% demand of the peak damand of the year, will be stable but almost marginal.

Fig. 11-2 POWER FLOW DIAGRAM

1997 PEAK

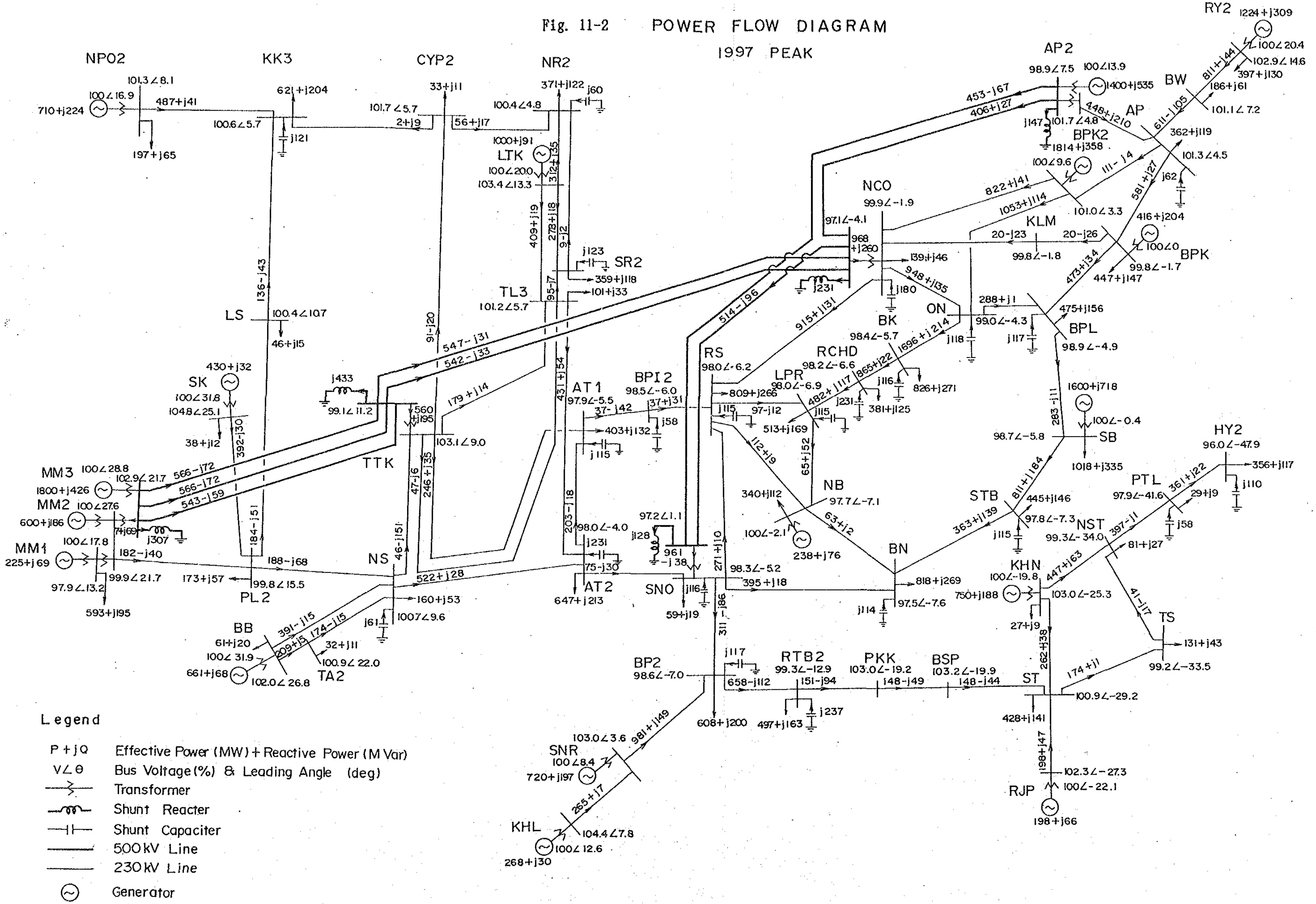


Fig. 11-3 POWER FLOW DIAGRAM

1997 NIGHT

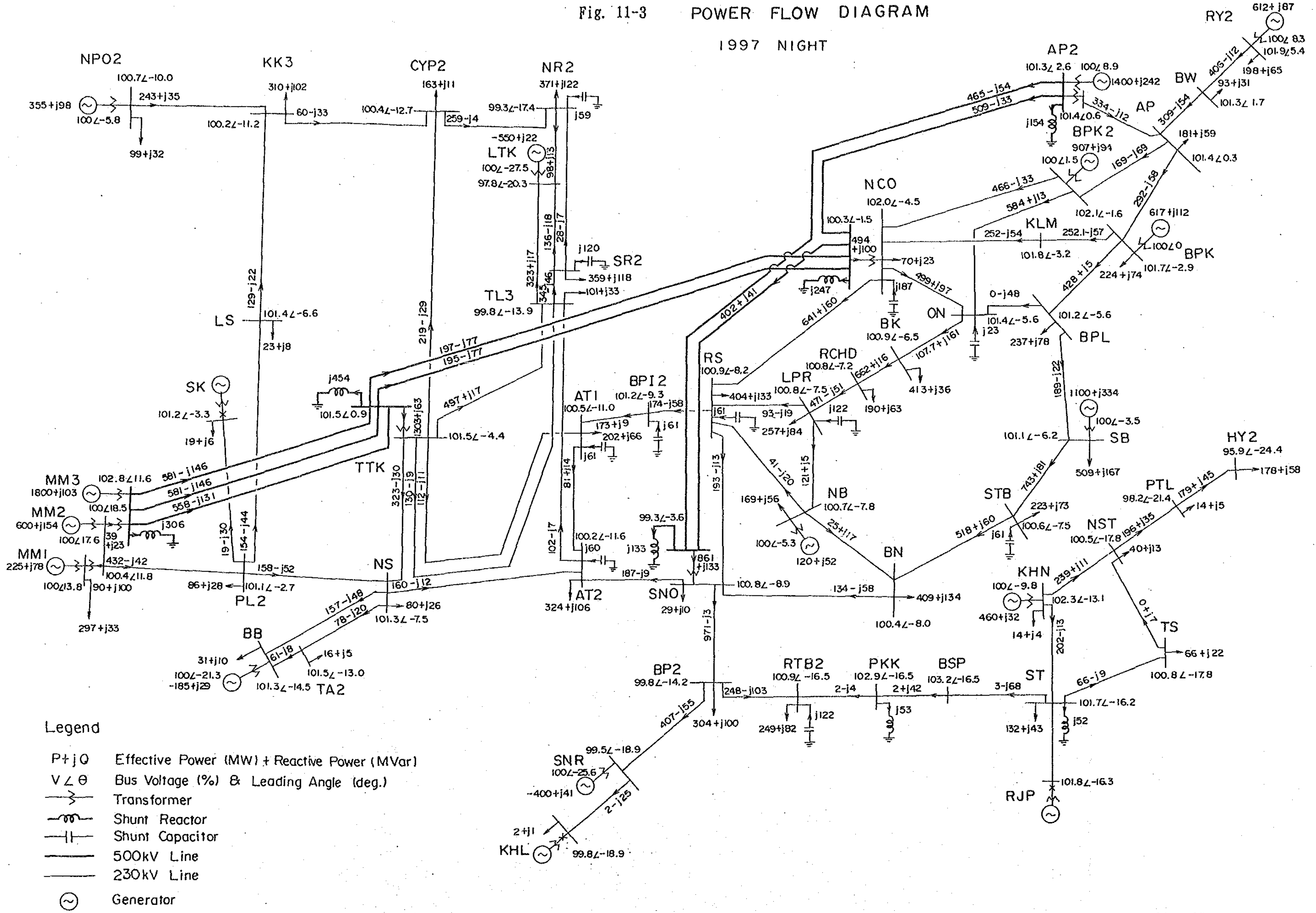
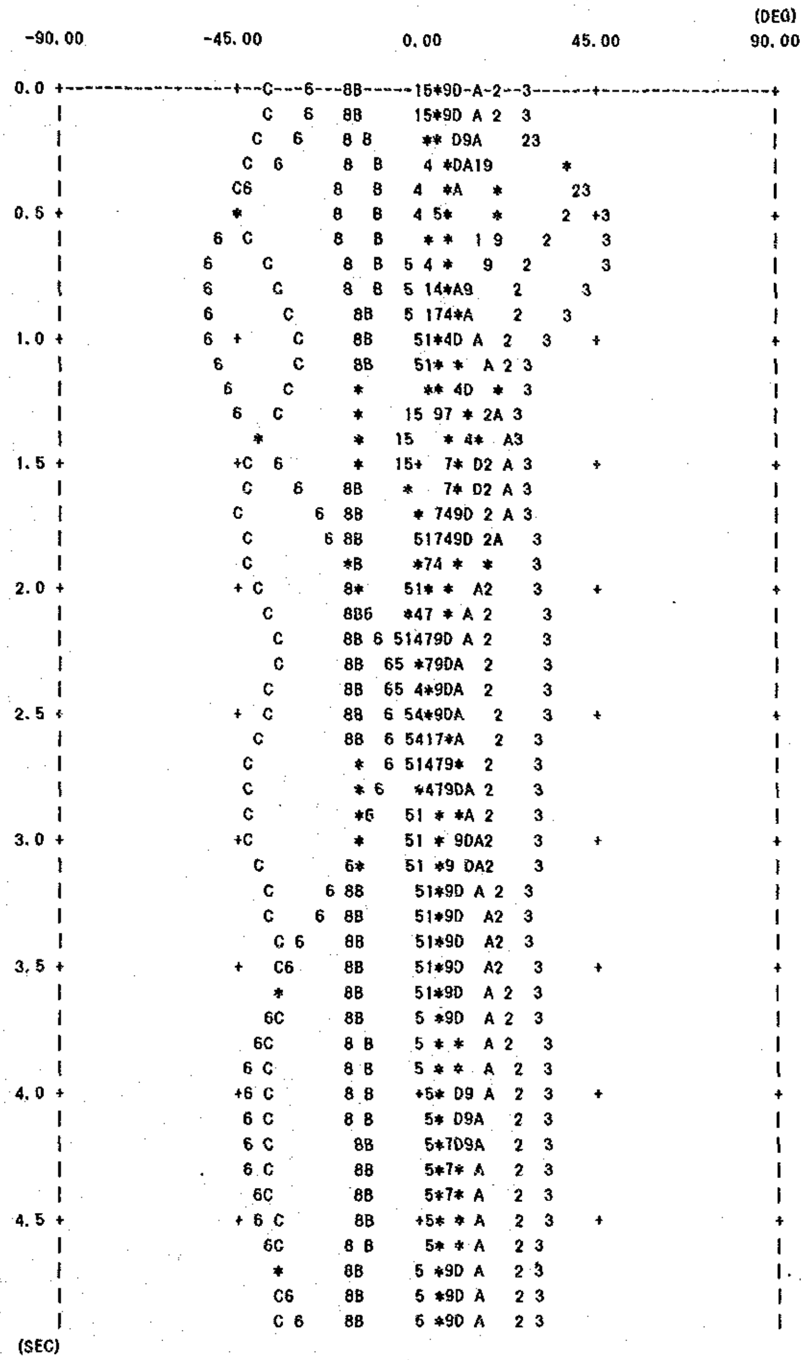


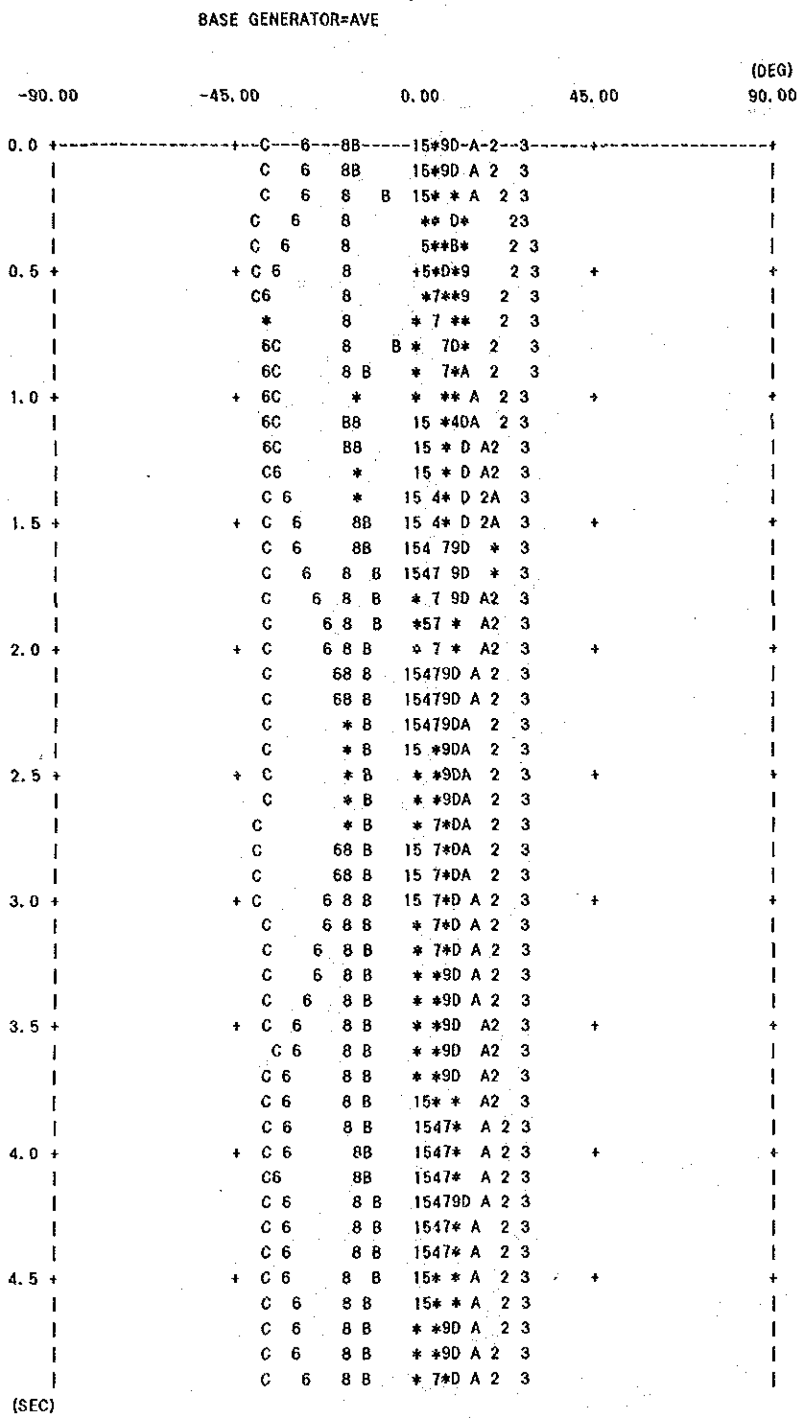
Fig. 11-4 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at peak hours in 1997.

BASE GENERATOR=AVE



SYMBOL GNO	SYMBOL GNO	SYMBOL GNO
1=MM1-G	2=MM2-G	3=MM3-G
4=NPO2-G	5=SB-G	6=KHN-G
7=AP2-G	8=SNR-G	9=BB-G
A=RY2-G	B=LTK-G	C=BPK-G
D=BPK2-G		

Fig. 11-5 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Saraburi 2-Lam Ta Khong line at peak hours in 1997.



SYMBOL GNO	SYMBOL GNO	SYMBOL GNO
1=MM1-G	2=MM2-G	3=MM3-G
4=NPO2-G	5=SB-G	6=KHN-G
7=AP2-G	8=SNR-G	9=BB-G
A=RY2-G	B=LTK-G	C=BPK-G
D=BPK2-G		

Fig. 11-6 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at off-peak hours in 1997.

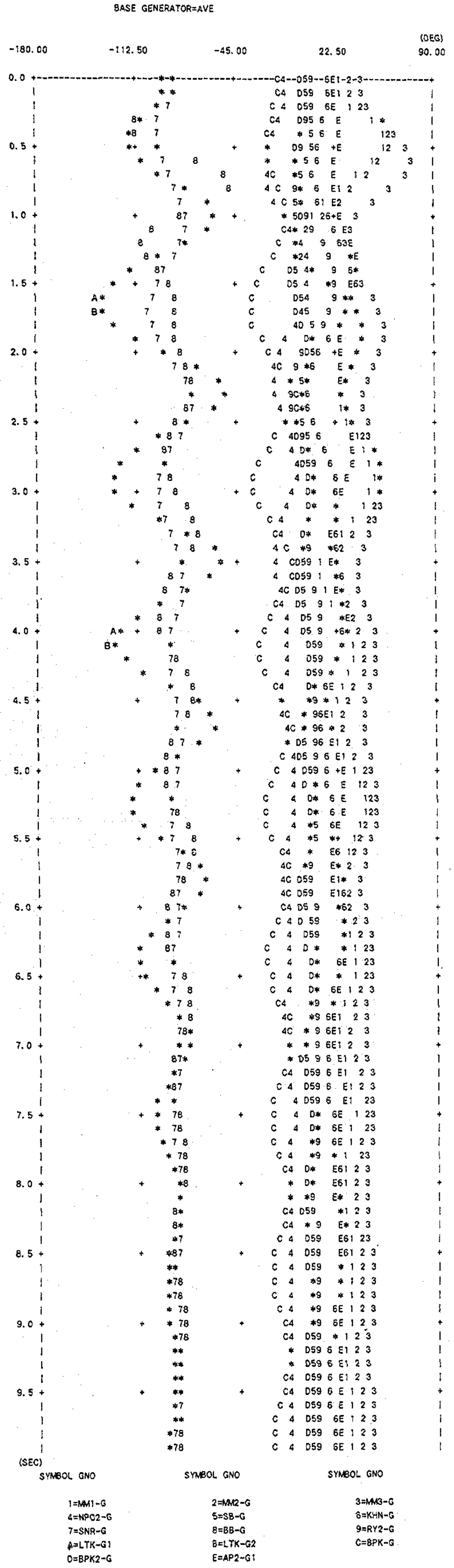


Fig. 11-7 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at off-peak hours in 1997.

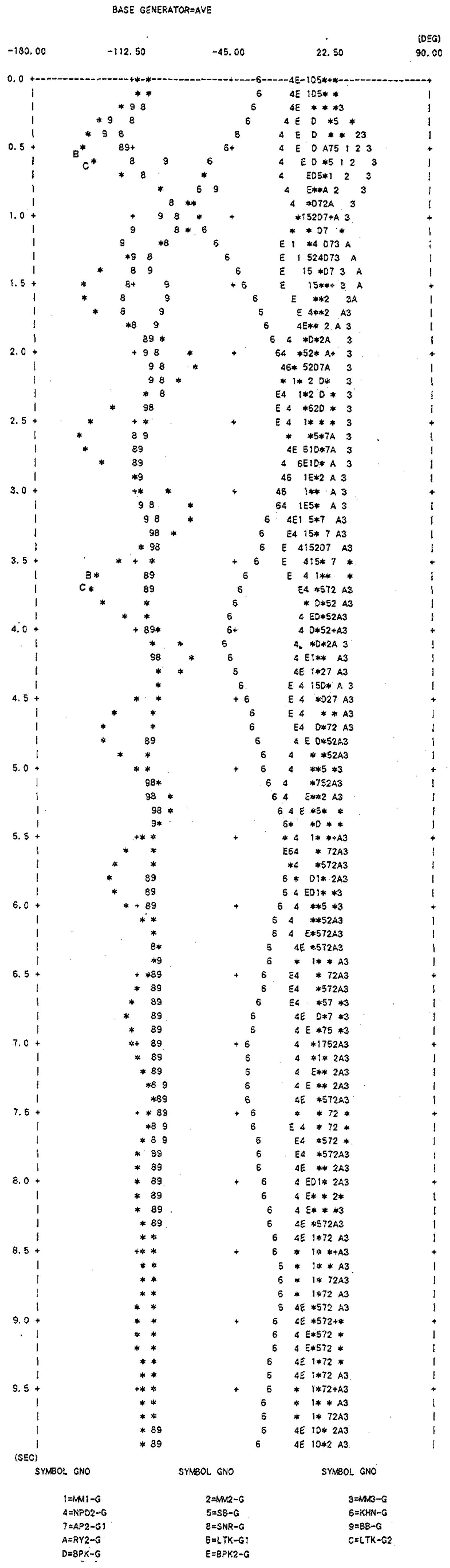


Fig. 11-8 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Tha Tako-Nong Chok line at off-peak hours in 1997.

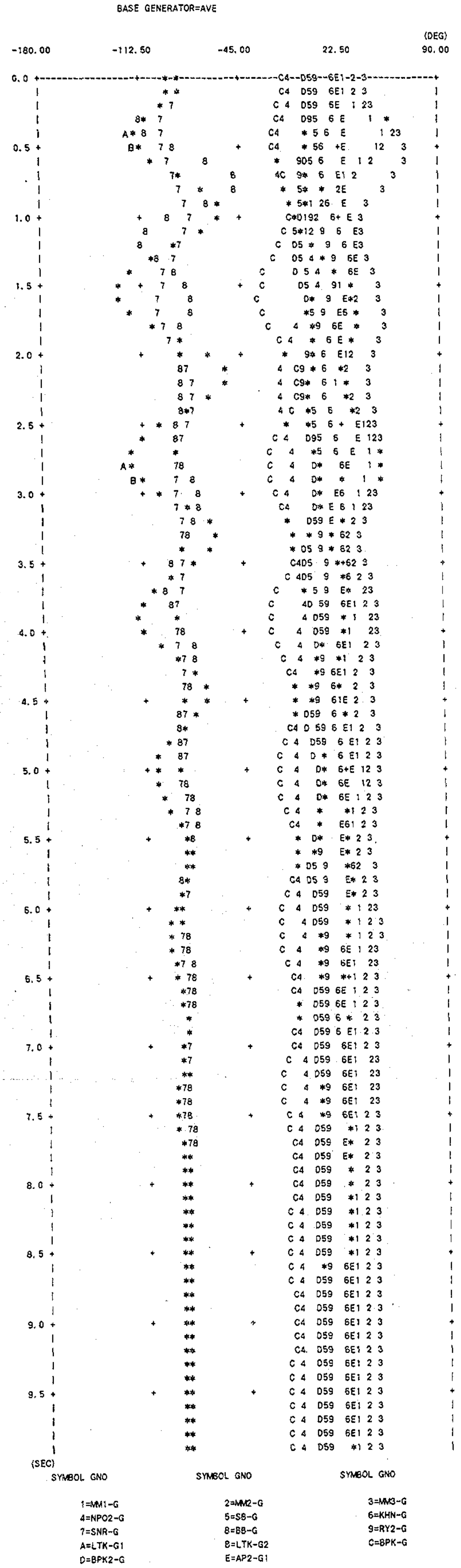


Fig. 11-9 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Saraburi 2-Lam Ta Khong line at off-peak hours in 1997.

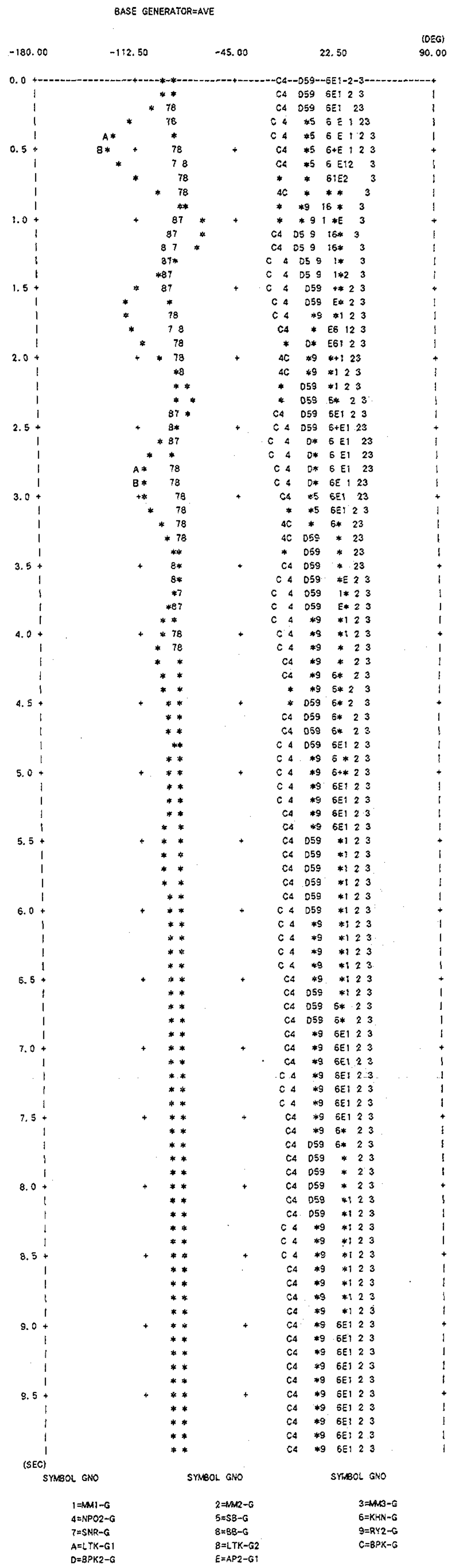


Fig. 11-10 Generation angle swing curves with Lam Ta Khong 3*200MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at off-peak hours in 1997.

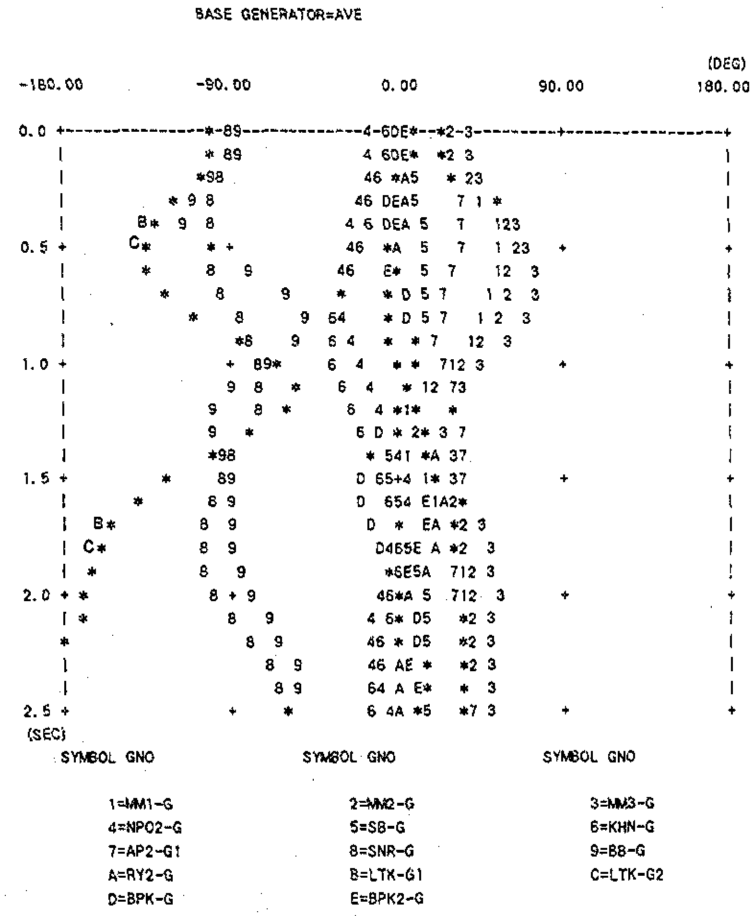


Fig. 11-11 Generation angle swing curves with Lam Ta Khong 3*200MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at off-peak hours in 1997.

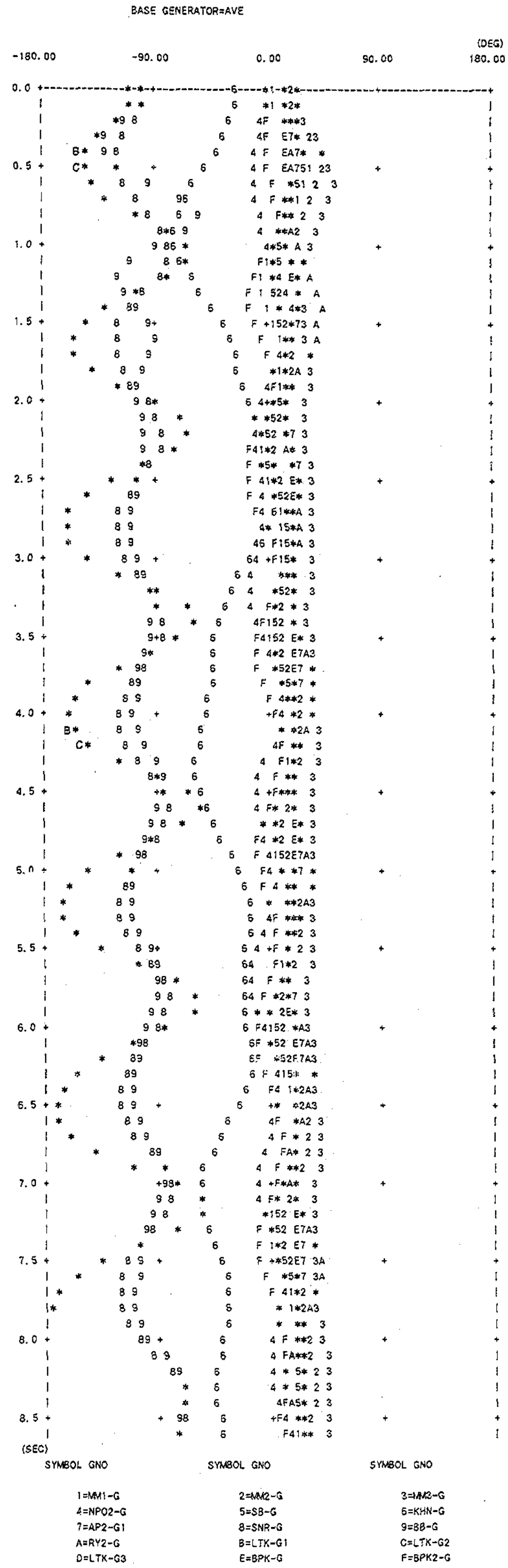


Fig. 11-12 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at off-peak hours in 1999.

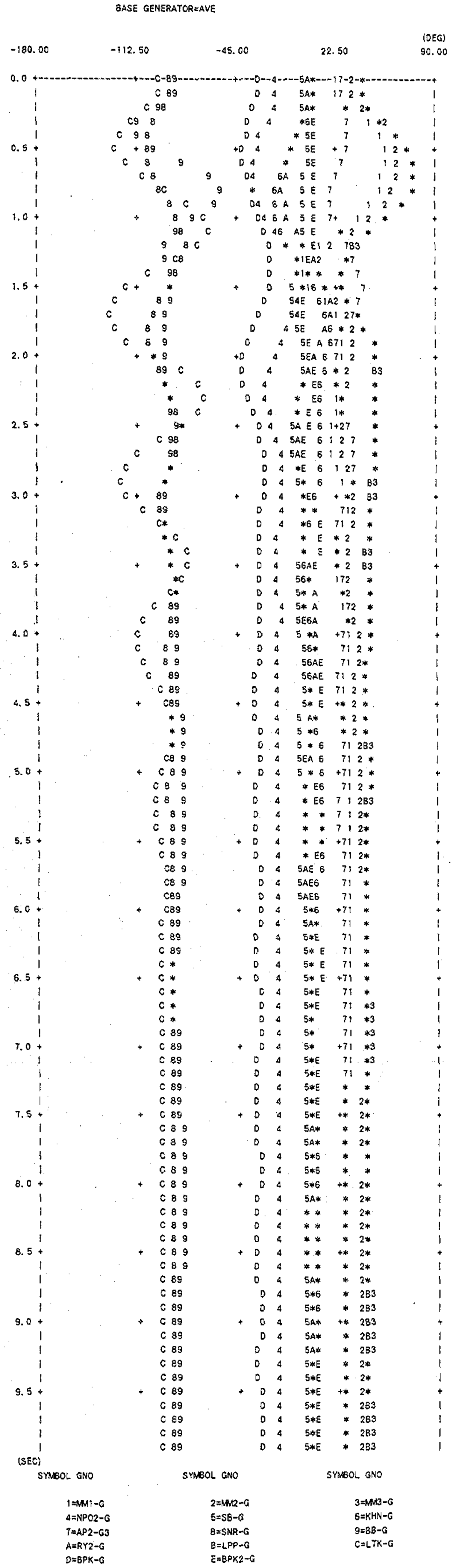


Fig. 11-13 Generation angle swing curves with Lam Ta Khong 2*250MW when a three-phase fault occurs on the Mae Moh-Tha Tako line at off-peak hours in 2000.

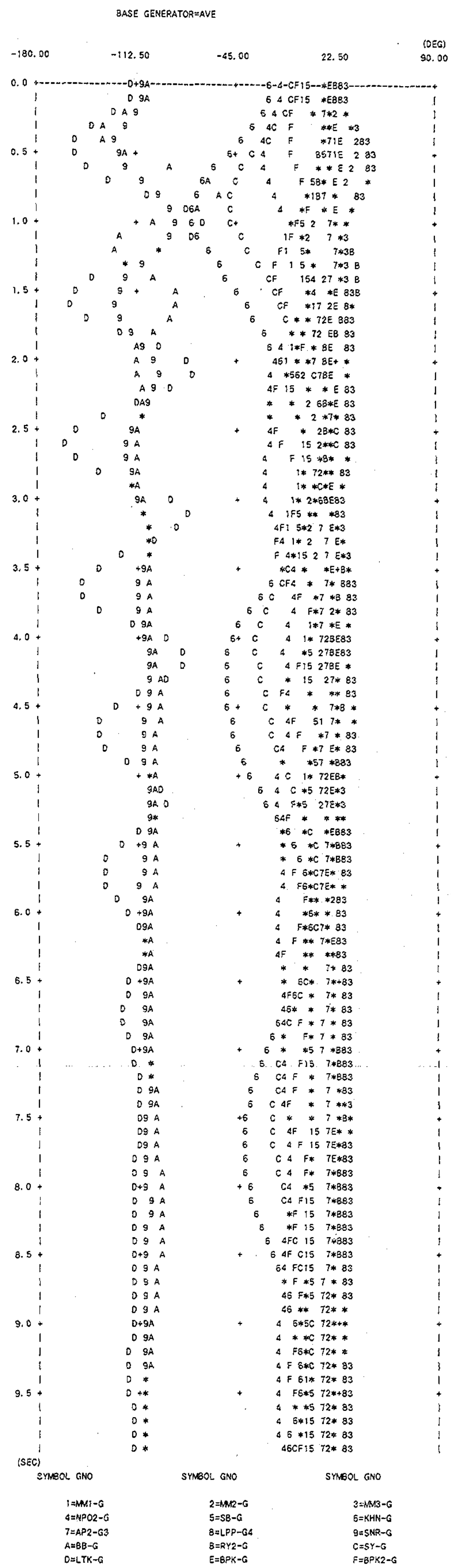


Fig. 11-14 Three-phase short circuit currents and capacities on the buses around the Lam Ta Khong project in 1997 (x_d'' is used)

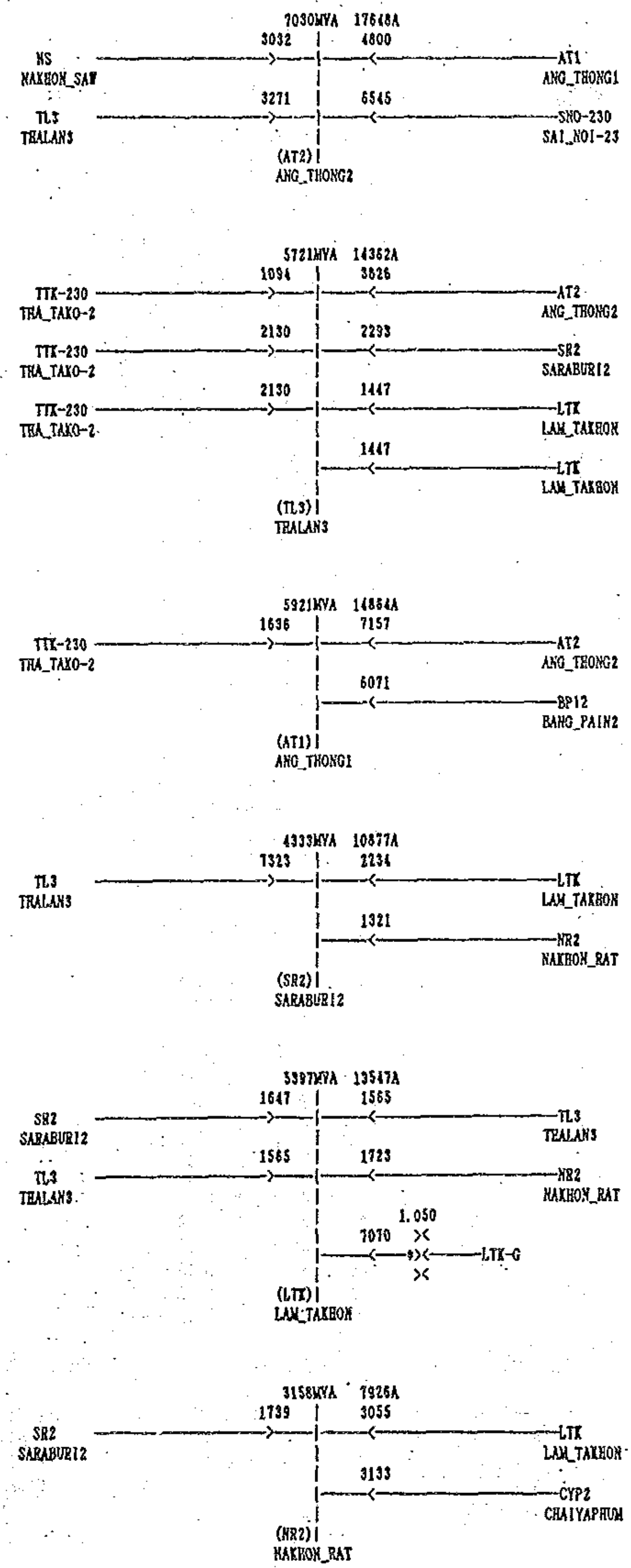
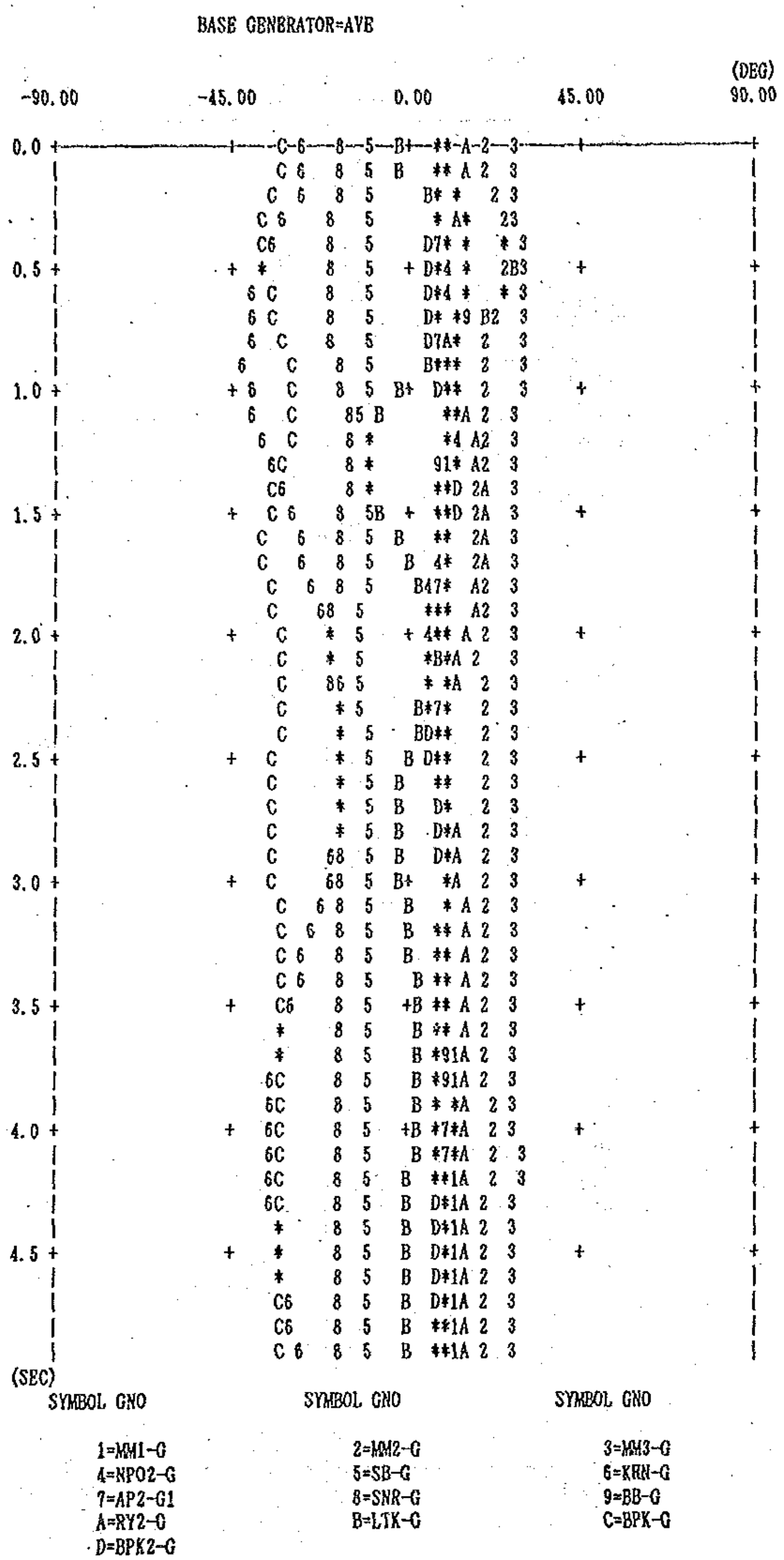


Fig. 11-15 Generation angle swing curves with Lam Ta Khong 4*250MW when a three-phase fault occurs on the Saraburi 2-Lam Ta Khong line at peak hours in 1997.



11.4 Power Transmission Plan

Since the area of Lam Ta Khong project is under restrictions of the environment control, the installation of 500 kV equipment may not be possible. In the case of 230 kV transmission line, the installations of 4 circuits are believed to be the maximum.

The way to send power generated by Lam Ta Khong project depends on the developing scale of the project, but we have made up a plan of power transmission to meet a capacity of 1,000 MW.

In the vicinity of this pumping project, there are two circuits of 230 kV transmission line which connects Saraburi 2 substation and Nakhon Ratchasima 2 substation (115 kV is currently used).

Since this line has a capacity of 429 MVA per circuit (conductor 1 x 1272 MCM ACSR), it can be used to send a part of power for Lam Ta Khong project, by taking its one circuit into the project site as shown by figure (b) in the section 11.3.3.

In addition, a 230 kV double-circuit transmission line should be constructed between the pant and the newly constructed Thalan 3 substation.

Therefore, two 230 kV double-circuit transmission lines must be constructed to connect the Lam Ta Khong power plant to the power system.

This pattern of power transmission enables the plant to pump up water by two units of 250 MW and to generate power by four units of 250 MW.

CHAPTER 12

PRELIMINARY DESIGN

CHAPTER 12 PRELIMINARY DESIGN

CONTENTS

Page

List of Figures

List of Drawing

CHAPTER 12 PRELIMINARY DESIGN

12.1 Upper Reservoir

12.1.1 General

The upper reservoir is a pool type regulating pondage with 340 x 10^3 m^2 of reservoir area and 10,300 x 10^3 m^3 of reservoir capacity made by digging and partially embanking a gentle sloped plateau at about 640 m above the sea level on the right side shore about 6.5 km up stream from Lam Ta Khong Dam. The maximum output is 1,000 MW and the power can be generated for 8 hours.

The inner surfaces of pool are covered with the asphalt concrete. The embankment is made by using some of the muck. The upper reservoir is large scale pool type reservoir with an allover asphalt facing fill-type dam.

The asphalt facing is 25 - 30 cm in thickness and about 360 x 10^3 m^2 in area.

The excavated amount of dam is about 7,000 x 10^3 m^3 and the embankment volume is 6,200 x $10^3 m^3$. Some of the excavated muck is used for the dam embankment.

12.1.2 Location of Upper Reservoir

For the location of upper reservoir, the most advantageous area was selected by taking into consideration the topography, geology, extension of waterway, dam construction cost, etc. The watershed classification area 1A designated by the National Environmental Board was avoided, thus preserving proper environmental condition (see DWG. 12-5).

If the upper reservoir is made on the northern side, the hight of dam must be increased, thus requiring to increase the amount of dam embankment. On the other hand, when the upper reservoir is located on the southern side, dam excavation increases, thus making it uneconomical. If the reservoir is located on the east side, the waterway should be extended, thus resulting in uneconomical. The west side is the watershed classification area 1A with cliffs. The most advantageous position is selected by taking all these conditions into consideration.

12.1.3 Geologic Condition

The geologic condition of upper reservoir is such that the surface stratum contains 3 - 4 m of weathered residual soil and under this surface stratum, about 5 - 15 m thick claystone and 10 - 35 m thick coarse-grained sandstone layer are alternately distributed. Therefore, the foundation of dam is the claystone and coarse-grained sandstone layer.

12.1.4 Structure of Upper Reservoir

The upper reservoir is a square with a side of about 620 m with a large curve at each corner, thus avoiding concentration of stress on the asphalt facing and making it easy to construct the asphalt facing.

The slope grade of inner surface of reservoir and outer surface grade of bank are all 1:2.5, in order to ensure safety of asphalt facing and to ensure proper scenery.

The following table shows the specification for upper reservoir.

Specification for Upper Reservoir

Item	Specification
Form of dam	Asphalt facing fill-type dam
Height of dam	60 m
Width of dam crest	10 m
Length of dam crest	2,210 m
Altitude of dam crest	E.L 662.50 m
Grade of dam alignment surface	(Both back and inner side) 1:2.5
Total excavated amount	6,960 x 10^3 m^3
Total embankment amount	6,190 x 10^3 m^3
Asphalt facing area	(Sloped surface) 220 x 10^3 m^2 (Bottom surface) 140 x 10^3 m^2

The upper reservoir is made by excavating the northern side of gently sloped hill; 10 - 15% slope. The excavated depth is about 45 m (max.) and the deepest part of reservoir is 50.5 m from dam crest.

The bank in the vicinity of intake is highest, maximum being about 60 m.

The material used for embankment is the excavated claystone. Comparatively hard claystone and coarse sandstone are used for the transition layer which is used as the foundation of asphalt facing.

The width of dam crest is 10 m, because the width of paving machine used for the asphalt facing is taken into consideration. The altitude of dam crest is E.L 662.50 m including 2.50 m of freeboard from the highest water level, because the wind, earthquake, structure of dam etc, are taken into consideration.

The available drawdown is 40 m, because the effective capacity, reservoir area, dam construction cost, etc. are taken into consideration. The bottom of upper reservoir is designed in such a way that it is constructed on the hard coarse sandstone.

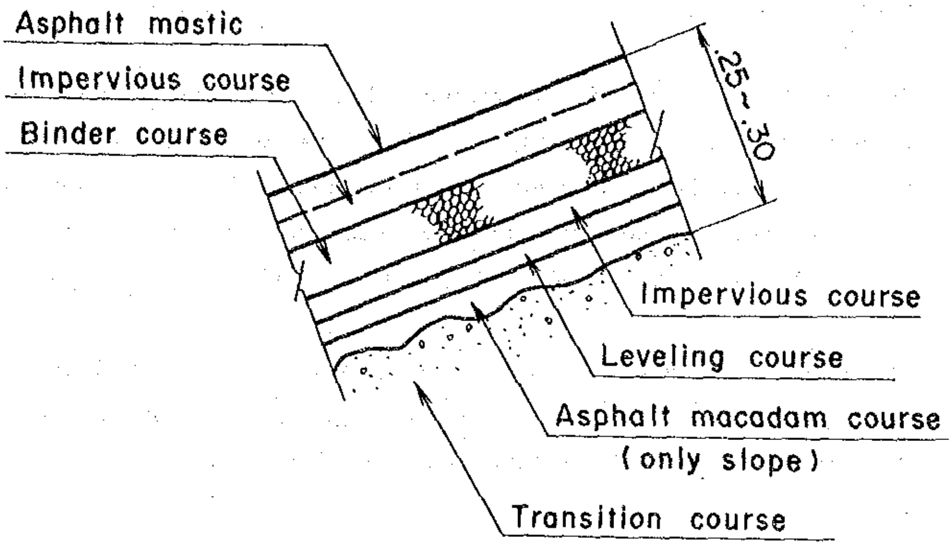
12.1.5 Asphalt Facing

The entire inner surfaces of upper reservoir is covered with the asphalt facing, in order to prevent water from leaking through the excavated foundation and embankment surface.

The inclined side and bottom of asphalt facing are provided with binder coarse of asphalt facing concrete and a high dense non-water permenting type highly dense asphalt concrete is used for both upper and lower layers of the middle drain layer. Therefore, if water should leak through the upper layer, the water quickly flows into the inspection gallery through the binder coarse of asphalt facing concrete.

The thickness of asphalt facing is 30 cm for the inclined layer and 25 cm for the bottom. The area of sloped surface is about 220 x 10^3 m^2 and that of bottom surface is about 140 x 10^3 m^2.

Constructed under the asphalt facing is the transition layer with 60 cm of thickness for the sloped area and 50 cm of thickness for the bottom area. The transition layer plays very important roles such as reinforcing the resistance against the deformation of asphalt facing, cause by water pressure, draining the water springing out of surrounding bedrock and preventing the back pressure. The following figure shows the composition of asphalt facing.



Composition of Asphalt Facing

12.1.6 Drainage System

The water leaked through asphalt facing and the spring water sprung from the bedrock are allowed to flow into the inspection gallery on the bottom of upper reservoir through the binder course and transition layer of asphalt facing.

Several inspection galleries are installed around the entire periphery of the bottom of upper reservoir, periphery of power intake and across the bottom of reservoir. The leaked water and sprung water flowed into the inspection galleries are collected in one location, led into the vertical drainage shaft and drainage tunnel and spontaneously drained to the dale on the northern side of upper reservoir.

The vertical drainage shaft and drainage tunnel are indispensable, because they are used as the drainage while the construction work is in progress.

12.1.7 Disposal Area

The disposal area is provided along the south side of upper reservoir, thus shortening the distance to transport the muck of upper reservoir and reducing unit cost of the upper reservoir excavation . Excavated muck form the upper reservoir and the upper horizontal tunnel of the penstock is dumped in this disposal area.

Surfaces of this disposal area is gently inclined and covered with grasses, and also the surroundings are planted taking the environmental condition into consideration.

12.2 Waterway

12.2.1 General

The route of waterway is designed in such a way that the length of waterway on the gradual mountain ridge is kept shortest. Since the penstock is installed across watershed classification area 1A, it is installed underground to meet the environmental control. Since the tailrace is very long, 1,470 m, a surge chamber is installed to ensure full safety against the fluctuation in power generation and also to enable the powerstation to operate AFC (Automatic Frequency Control). To ensure proper inspection and maintenance, the tailrace is provided with draft gates and tailrace gate.

The following table shows specifications for waterway.

Specification for Waterway

Item		Specification
Power intake	Type Inner dia. x Height x No. of ways	Morning-glory shape reinforced concrete D(18.00-5.80)m x 51m x 2 ways
Penstock	Type Inner dia. x Length x No. of way	Underground laid type D(5.80-2.60)m x 690m x (2~4) ways
Tailrace tunnel	Type Inner dia. x Length x No. of way	Circular pressure tunnel D(4.90-6.60)m x 1,470m x (4~2) ways
Surge chamber	Type (Shaft) Inner dia. x Height x No. of way (Upper water chamber) Width x Height x Length x No. of way	Simple, upper water chamber type D8.90 x 107.00 x 2 ways 10.00m x 10.00m x 35.00m x 2 ways
Tailrace outlet	Type Width x Height x Length x No. of way	Reinforced concrete 4 series box culvert type (6.60-30.00)m x (6.60-10)m x 55.00m x 2 ways

12.2.2 Geologic Condition

The foundation for the power intake is set on the hard and coarse-grained sandstone.

The bedrock of penstock and tailrace consists of mainly siltstone and fine-grained sandstone with coarse-grained sandstone being partially distributed. Since these strata are kept nearly horizontal, there may be some troubles such as the fall of rocks near the top when excavating the horizontal tunnel, specially the tailrace tunnel. It is known that the siltstone is slaked when it is immersed in water.

However, such a trouble may be eliminated by the drainage work during excavation and by adopting NATM method.

12.2.3 Power Intake

Since the upper reservoir is pool type regulating pondage, it is made in the morning-glory shape, because the power intake has to be installed on the bottom of reservoir. This intake functions as the outlet when pumping, and therefore the pier is set vertical and the top slab, flow regulating beam, etc. are installed to meet the hydraulic characteristics, thus preventing vortex and drift.

The intake is connected to the penstock through vertical shaft with the curved section. The vertical shaft of power intake is provided with the steel lining pipe.

12.2.4 Penstock

The penstock is underground laid type steel pipe with total length of about 690 m x 2 - 4 ways, which connects with the upper, middle and lower horizontal sections and the upper and lower inclined tunnel (51°). The inner diameter of the penstock varies from 5.80 to 2.60 m. 2 way is provided form the horizontal part of upper to the inclined tunnel of lower. For the sections lower than the horizontal tunnel of lower, 4 ways are provided.

The static head, for the steel penstock is 90 m for the upper part and 461 m for the lowest part and the maximum design head including the water-hammer pressure is about 600 m. The steel pipe is made of SM58 and HT80, which withstand the total hydraulic pressure. Total weight of steel pipe is about 7,580 t. Provided in the upper horizontal tunnel is an upper access tunnel for penstock through which the muck is hauled out and steel pipe is carried in.

The middle horizontal tunnel is provided with the lower access tunnel for penstock. This lower access tunnel for penstock is sloped down toward the tunnel entrance, thus draining water when the construction work around the penstock is in progress and when the construction work is completed while at the same time serving as the working tunnel for tailrace surge chamber and being used for checking and maintenance.

The upper and lower inclined tunnels have a gradient of 51° so that the muck falls easily, several tunnels around the powerhouse are illustrated in DWG.12-6.

12.2.5 Tailrace

The tailrace is circular pressure tunnel with a total length of 1,470 m x 4 - 2 ways.

Sine the tailrace tunnel is considerably long, the surge chamber is required against load built-up and load rejection. The surge chamber is a simple upper water chamber type with the inner diameter of 8.90 m and height of 107.0 m. The upper water chamber (width 10 m x height 10 m x length 35 m) is connected to the lower access tunnel for penstock, thus playing a role of work adit while construction work is in progress and also supplying/exhausting air while surging.

Topographic features in the vicinity of outlet is gently sloped (1:20 - 50) down toward the lower reservoir. According to the result of boring (DHT-3), the surface deposit is comparatively thin and the siltstone is easily exposed. The end of tunnel is designed to pass in the fine-grained sandstone under the siltstone.

The outlet is designed in such a way that it is continuously widened from the circular pressure tunnel and changes to the 4-series box culvert, thus ensuring that the water flow velocity is smoothly reduced and water is smoothly diffused while generating power and that the water flow is stabilized without containing air while pumping.

The bottom of the reservoir located in front of the outlet is excavated in such a way that it becomes in a trapezoid section and is gradually widened to ensure stable discharge/intake of water. The finished height is arranged so that it gradually changes from E.L 248.50 m at outlet to E.L 256.00 m.

Installed at the tailrace tunnel are 4 draft gates (Bonnet type; ϕ4.90 m) and 2 tailrace gates (Roller gate; width 5.20 m x height 6.60 m) which are used for the maintenance and inspection of turbines and tunnels. A screen is also installed at the outlet.

The L.W.L. of the Lam Ta Khong reservoir (lower reservoir) is EL. 261.00m. The Nakhon Ratchasima Water Supply Expansion Project designed the L.L.W.L. of the lower reservoir to be EL. 259.00m, thus the outlet is designed to be able to intake/discharge at the L.L.W.L. of 259.00m.