6.2 Electrical Equipment

(1) Nam Mae Ngao Power Station

This power station is planned with the normal effective head of 82.5 m, maximum available discharge of 166.2 m^3/sec and power output of 116.9 MW.

To meet this scale of development, the number of units is to be two where each unit consists of 59.8 MW vertical-shaft Francis turbine, 65.1 MVA synchronous generator and 65.1 MVA main transformer.

The unit system where a generator is connected with a main transformer, is adopted for main circuit. The generators are connected by metal enclosed bus with the outdoor-type main transformers installed adjacent to the powerhouse, while the main transformers are connected by overhead line with 230 kV buses of switchyard.

The specifications of main equipments for Nam Mae Ngao power station are as listed below.

(i) Power plant output : 116.9 MW

(ii) Turbine

Type	:	Vertical-shaft Francis turbine
Number of units	:	2
Normal effective head	:	82.5 m
Max. Discharge	:	83.1 m^3/sec
Output	:	59.8 MW
Revolving speed	:	214 rpm

(iii) Generator

Type	:	Three-phase, AC, Synchronous generator
Number of units	:	2
Capacity	:	65.1 MVA (power factor: 0.9 lagging)
Frequency	:	50 Hz

(iv) Main transformer

Type	:	Three-phase, outdoor, oil-immersed
Number of units	:	2
Capacity	:	65.1 MVA
Voltage	:	230/13.8 kV

(v) Switchyard equipment

Type	:	Outdoor conventional type
Bus	:	Single-bus system
Number of circuits	:	2 (230 kV)

(2) Nam Mae Rit Power Station

This power station is planned with the normal effective head of 68.5 m, maximum available discharge of 41.2 m^3/sec and power output of 24 MW.

To meet this scale of development, the number of units is to be two where each unit consists of 12.3 MW vertical-shaft Francis turbine, 13.4 MVA synchronous generator and 13.4 MVA main transformer.

The unit system where a generator is connected with a main transformer is adopted for main circuit. The generators are connected by metal enclosed bus with the outdoor-type main transformers installed adjacent to the powerhouse, while the main transformers are connected by overhead line with 230 kV buses of switchyard.

The specifications of main equipments for Nam Mae Rit Power Station are as listed below.

(i) Power plant output : 24 MW

(ii) Turbine

Type	:	Vertical-shaft Francis turbine
Number of units	:	2
Normal effective head	:	68.5 m
Max. discharge	:	20.6 m^3/sec

Output	:	12.3 MW
Revolving speed	:	429 rpm

(iii) Generator

Type	:	Three-phase, AC, Synchronous generator
Number of units	:	2
Capacity	:	13.4 MVA (power factor: 0.9 lagging)
Frequency	:	50 Hz

(iv) Main transformer

Type	:	Three-phase, outdoor, oil-immersed
Number of units	:	2
Capacity	:	13.4 MVA
Voltage	:	230/13.8 kV

(v) Switchyard equipment

Type	:	Outdoor Conventional Type
Bus	:	Single-bus system
Number of circuit	:	2 (230 KV)

(3) Upper Mae Yuam 1 Power Station

This power station is planned with the normal effective head of 41.0 m, maximum available discharge of 53.0 m^3/sec and power output of 18.5 MW.

To meet this scale of development, the number of units is to be two where each unit consists of 9.5 MW vertical-shaft Francis turbine, 10.3 MVA synchronous generator and 10.3 MVA main transformer.

The unit system which a generator is connected with a main transformer, is adopted for main circuit. The generators are connected by metal enclosed bus with the outdoor-type main transformers installed adjacent to the powerhouse, while the main transformers are connected by overhead line with 230 kV buses of switchyard.

The specifications of main equipments for Upper Mae Yuam 1 power station are as listed below.

(i) Power plant output : 18.5 MW

(ii) Turbine

Type	:	Vertical-shaft Francis turbine
Number of units	:	2
Normal effective head	:	41.0 m
Max. Discharge	:	26.5 m^3/sec
Output	:	9.5 MW
Revolving speed	:	375 rpm

(iii) Generator

Type	:	Three-phase, AC, Synchronous generator
Number of units	:	2
Capacity	:	10.3 MVA (power factor: 0.9 lagging)
Frequency	:	50 Hz

(iv) Main transformer

Type	:	Three-phase, outdoor, oil-immersed
Number of units	:	2
Capacity	:	10.3 MVA
Voltage	:	230/13.8 kV

(v) Switchyard equipment

Type	:	Outdoor conventional type
Bus	:	Single-bus system
Number of circuits	:	2 (230 kV)

(4) Upper Mae Rit 2a Power Station

This power station is planned with the normal effective head of 126.9 m, maximum available discharge of 10.4 m^3/sec and power output of 11.2 MW.

To meet this scale of development, the number of units is to be two where each unit consists of 5.8 MW vertical-shaft Francis turbine, 6.3 MVA synchronous generator and 6.3 MVA main transformer.

The unit system where a generator is connected with a main transformer is adopted for main circuit. The generators are connected by metal enclosed bus with the outdoor-type main transformers installed adjacent to the powerhouse, while the main transformers are connected by overhead line with 230 KV buses of switchyard.

The specifications of main equipments for Upper Mae Rit 2a Power Station are as listed below.

(i) Power Plant output : 11.2 MW

(ii) Turbine

Type	:	Vertical-shaft Francis turbine
Number of units	:	2
Normal effective head	:	126.9 m
Max. discharge	:	5.2 m^3/sec
Output	:	5.8 MW
Revolving speed	:	750 rpm

(iii) Generator

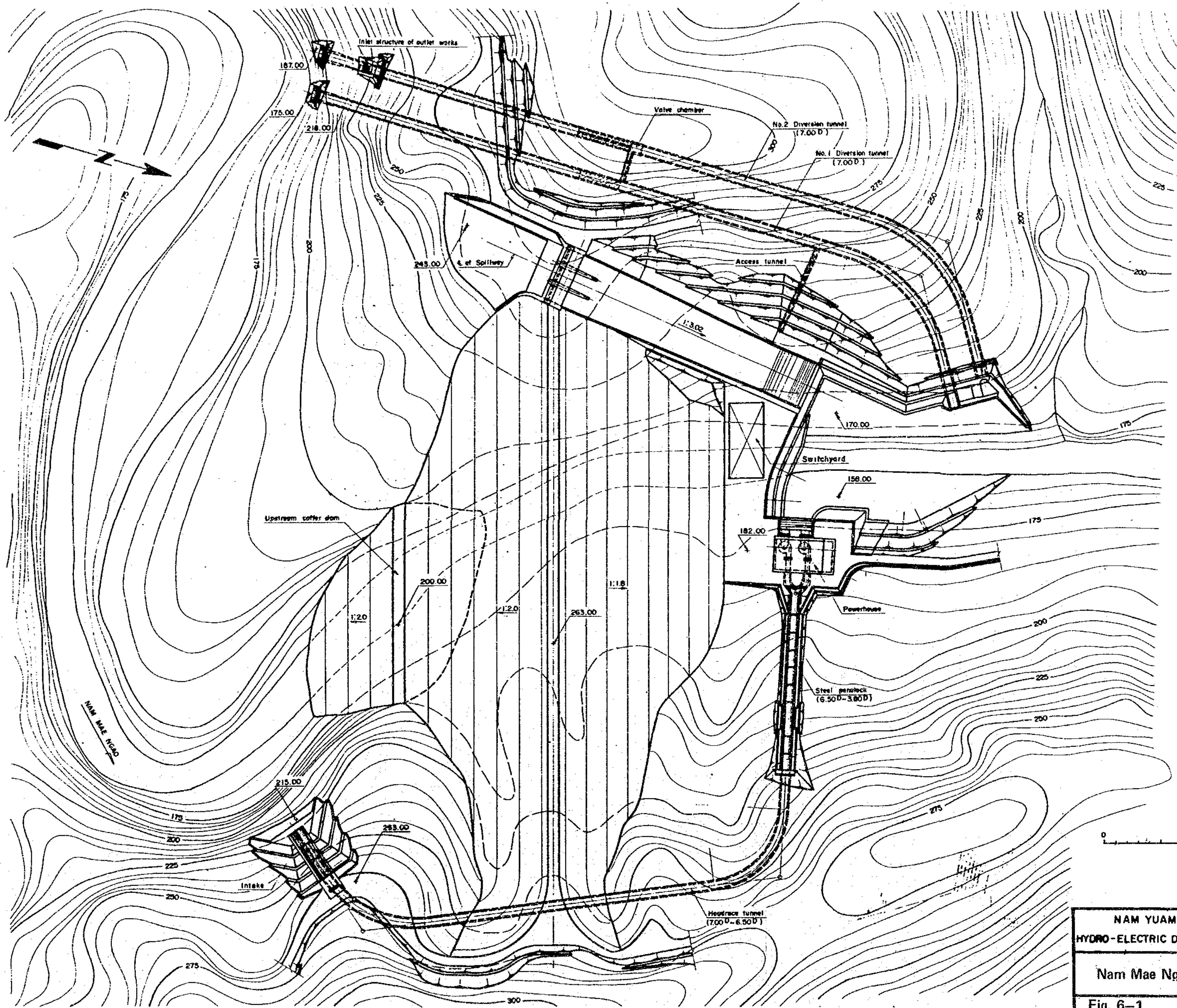
Type	:	Three-phase, AC, Synchronous generator
Number of units	:	2
Capacity	:	6.3 MVA (power factor: 0.9 lagging)
Frequency	:	50 Hz

(iv) Main transformer

Type	:	Three-phase, outdoor, oil-immersed
Number of units	:	2
Capacity	:	6.3 MVA
Voltage	:	230/6.6 kV

(v) Switchyard equipment

Type	:	Outdoor Conventional type
Bus	:	Single-bus system
Number of circuits	:	2 (230 kV)

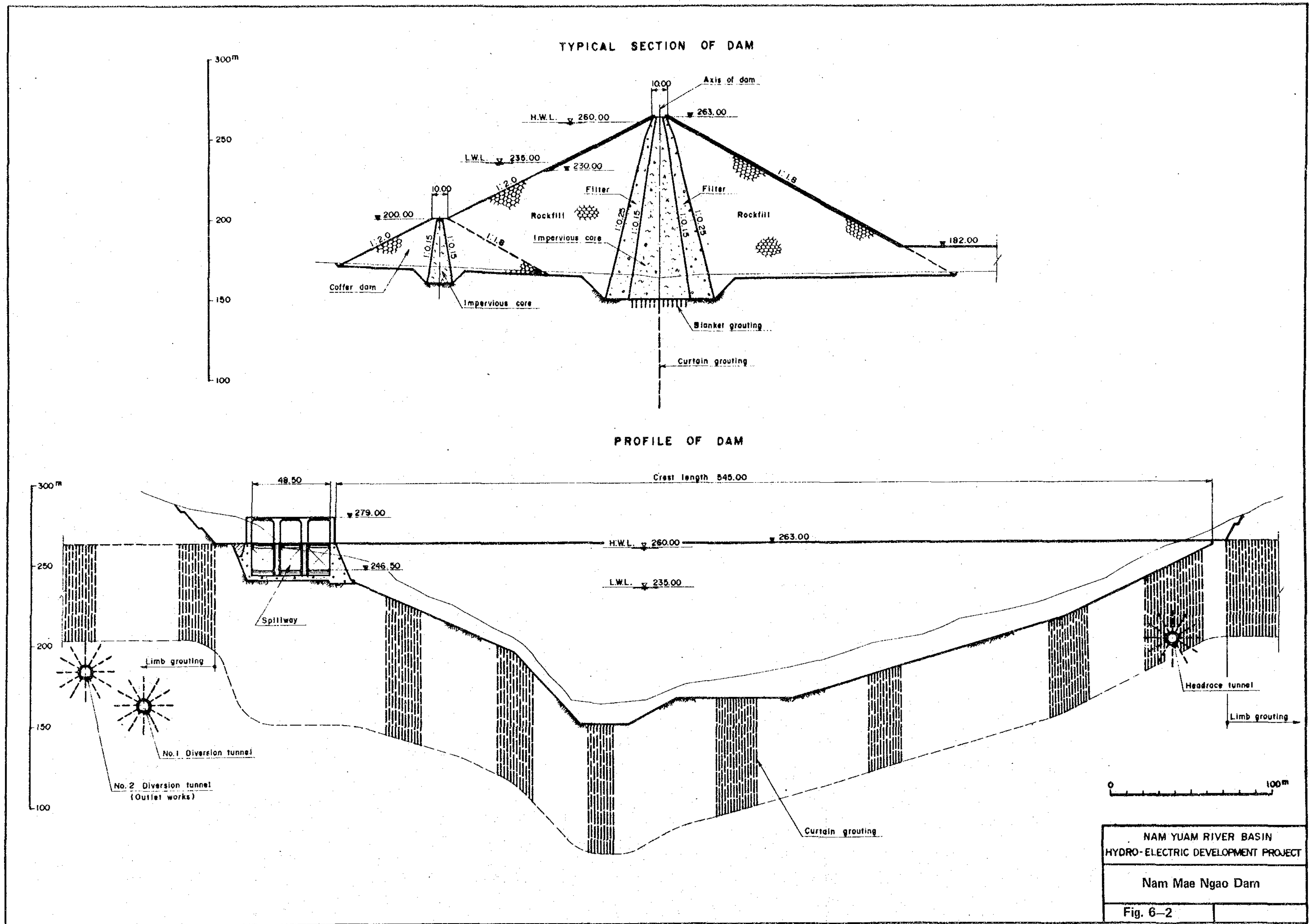


NAM YUAM RIVER BASIN

HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Ngao General Plan

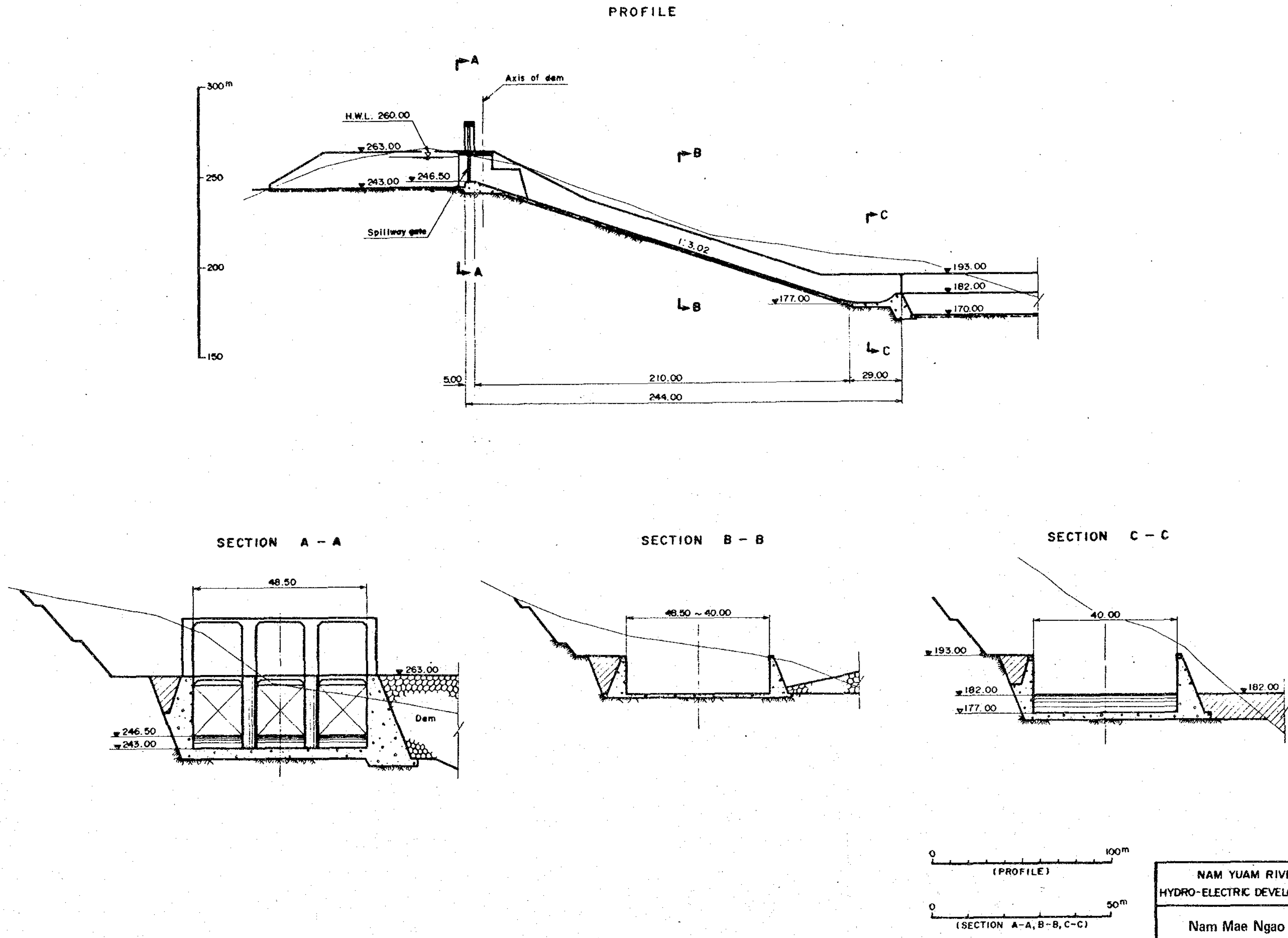
Fig. 6–1



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Ngao Dam

Fig. 6–2

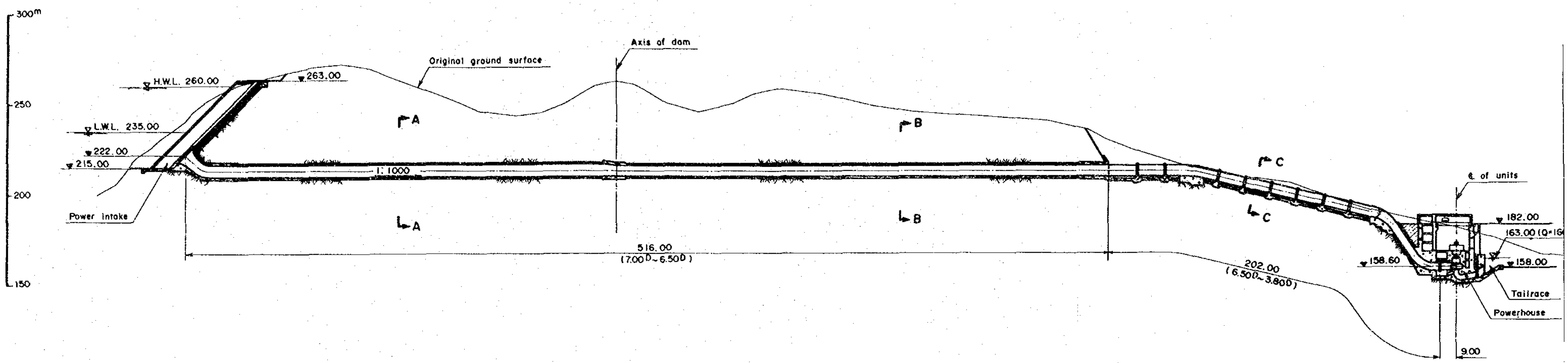


NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

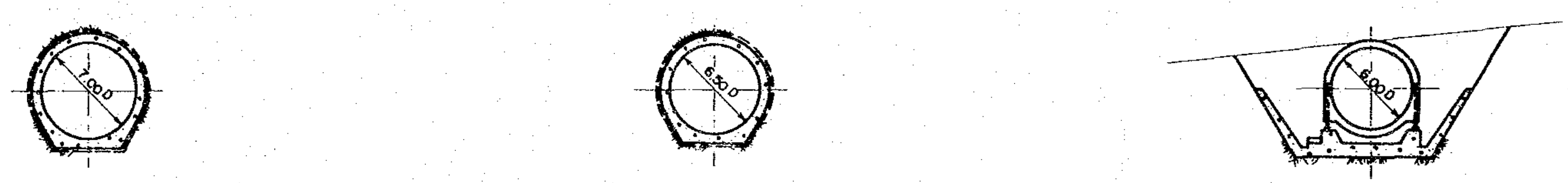
Nam Mae Ngao Spillway

Fig. 6–3

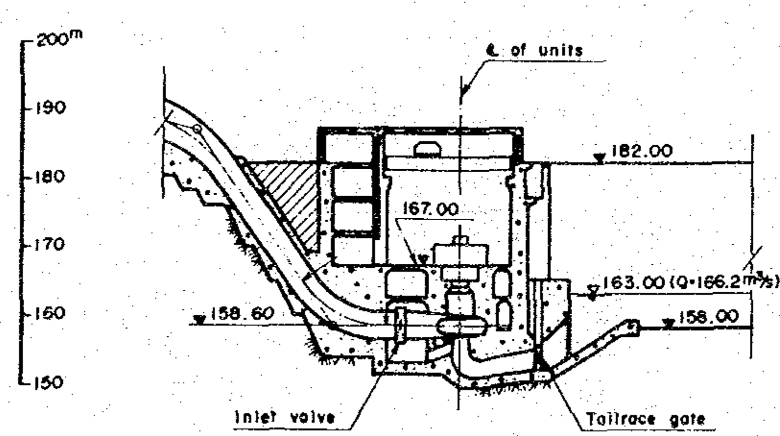
PROFILE OF WATERWAY



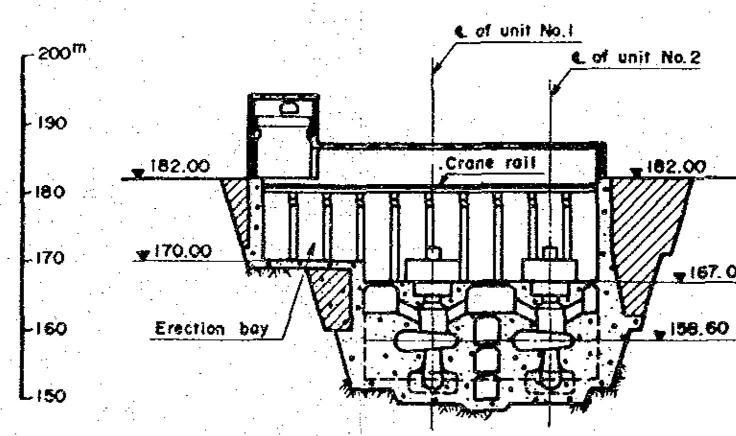
SECTION A – A SECTION B – B SECTION C – C

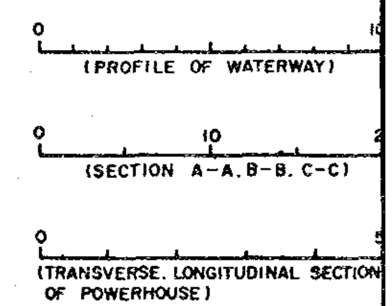


TRANSVERSE SECTION OF POWERHOUSE



LONGITUDINAL SECTION OF POWERHOUSE

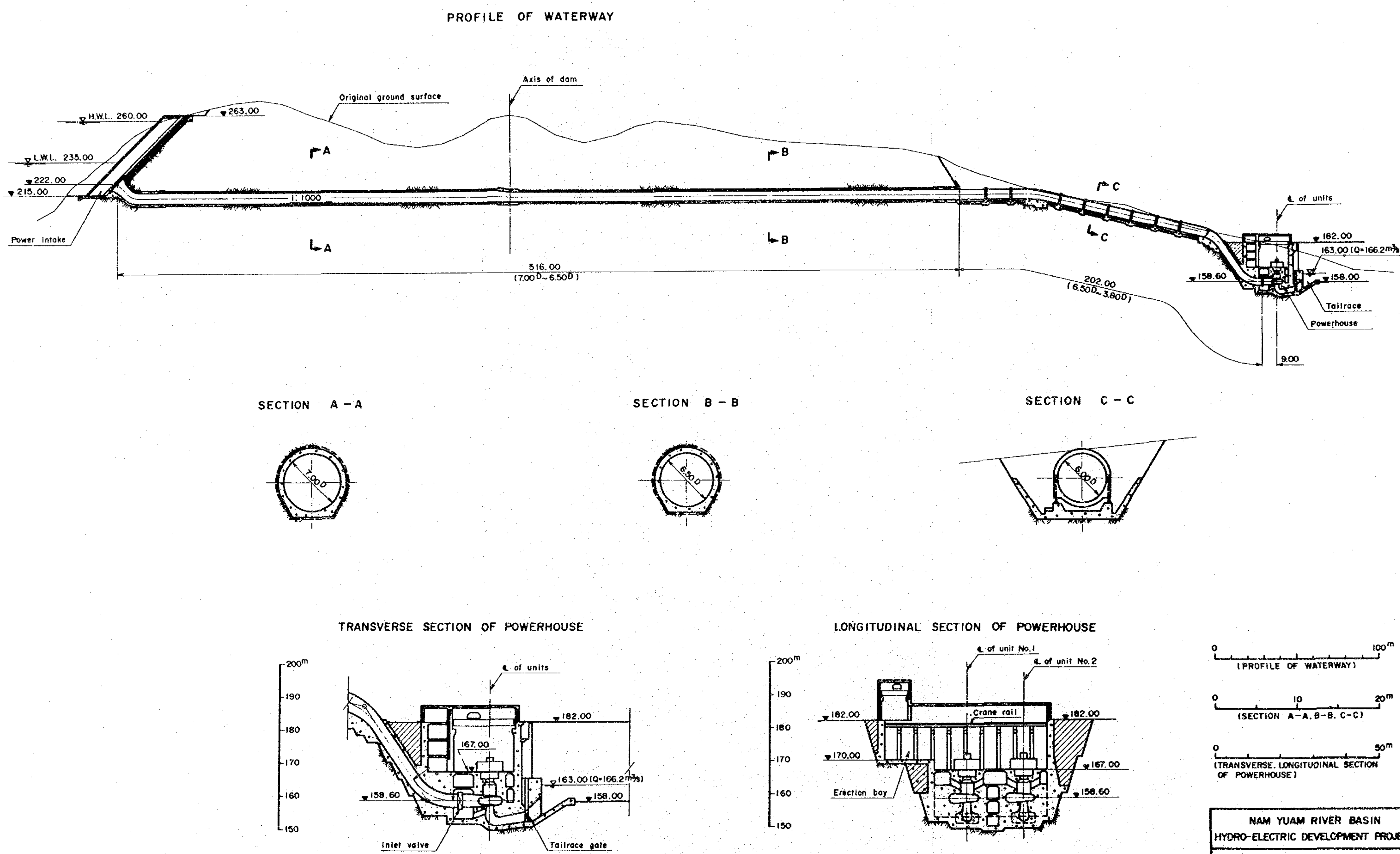




NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT

Nam Mae Ngao Waterwa

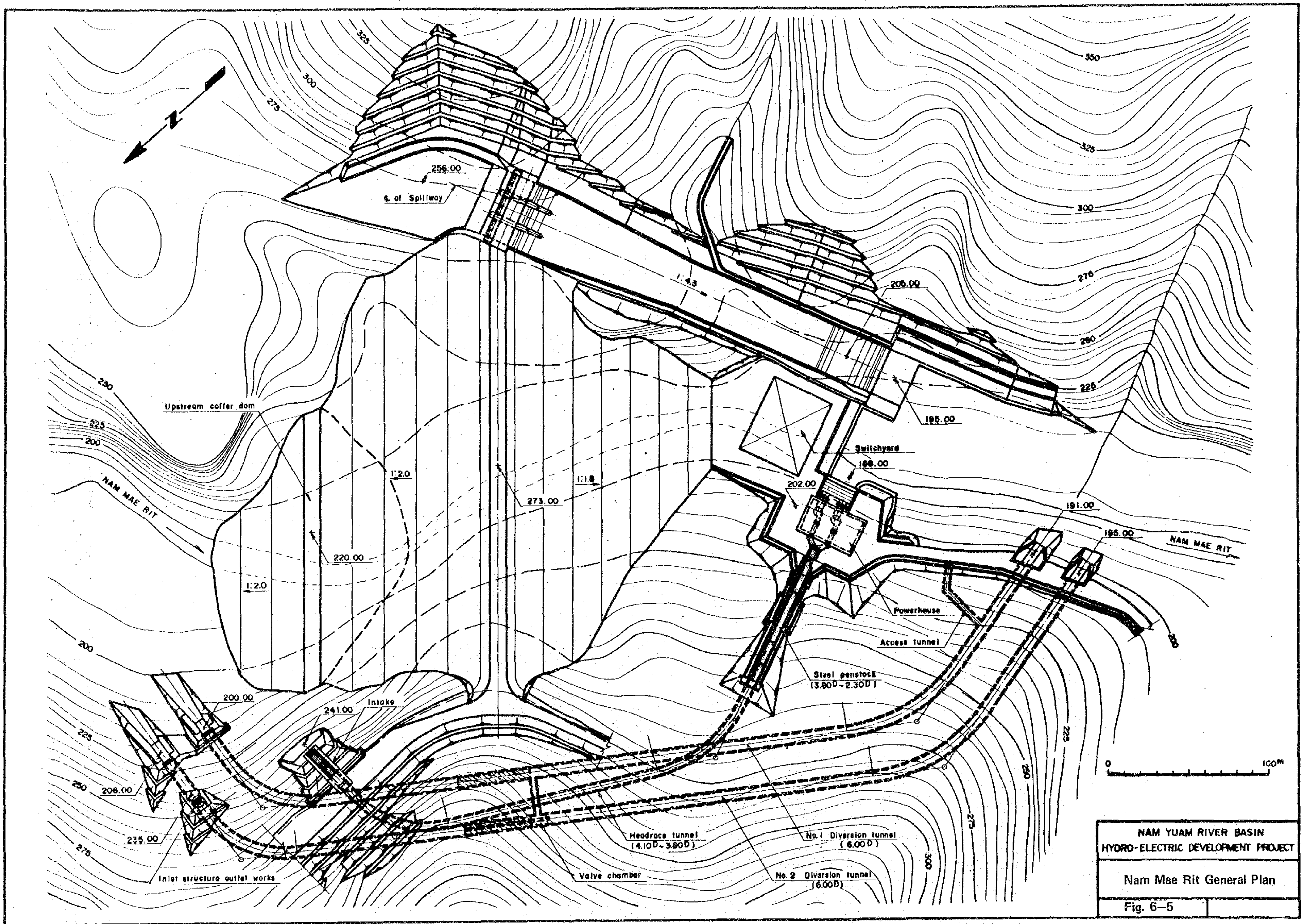
Fig. 6–4



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Ngao Waterway

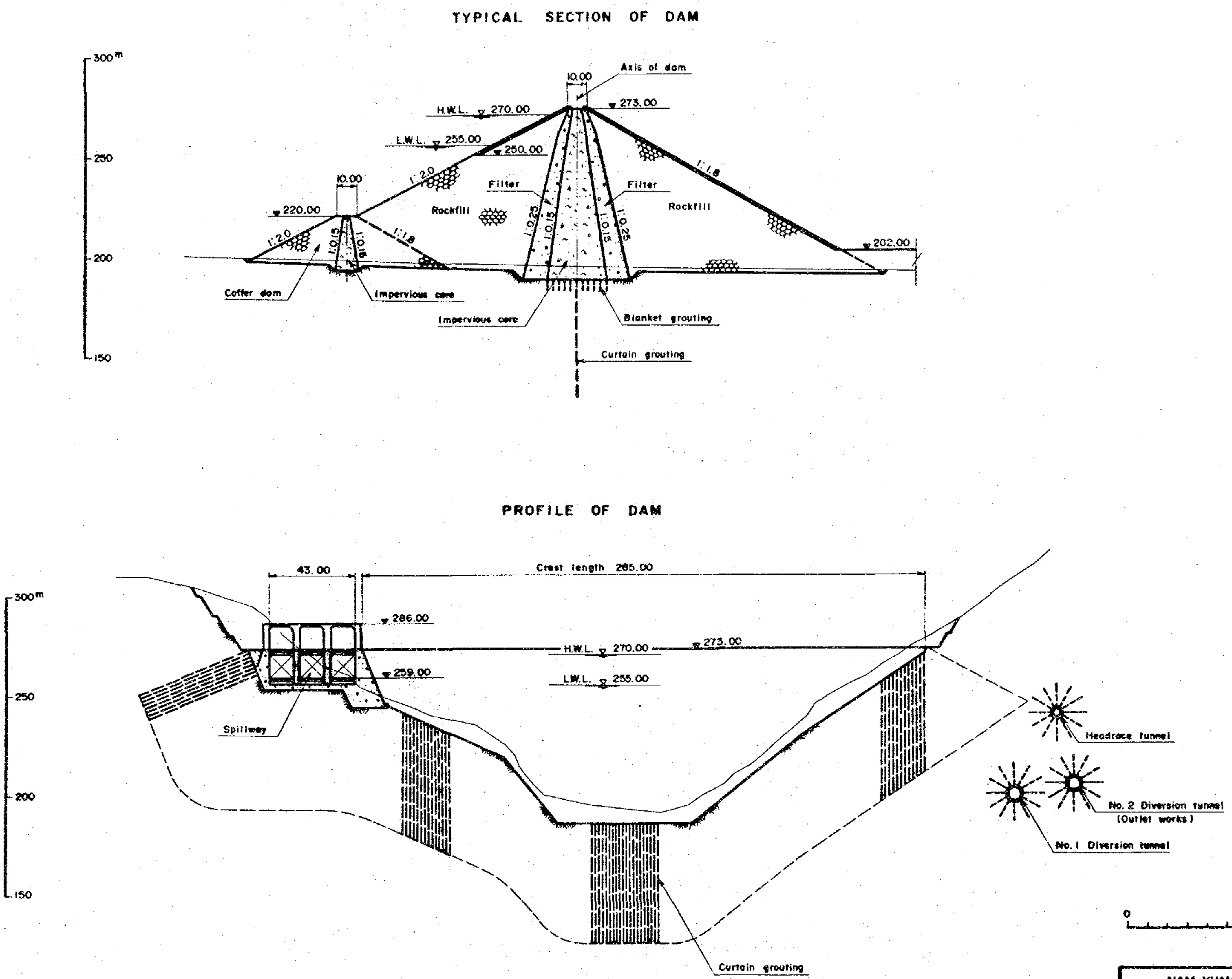
Fig. 6-4



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Rit General Plan

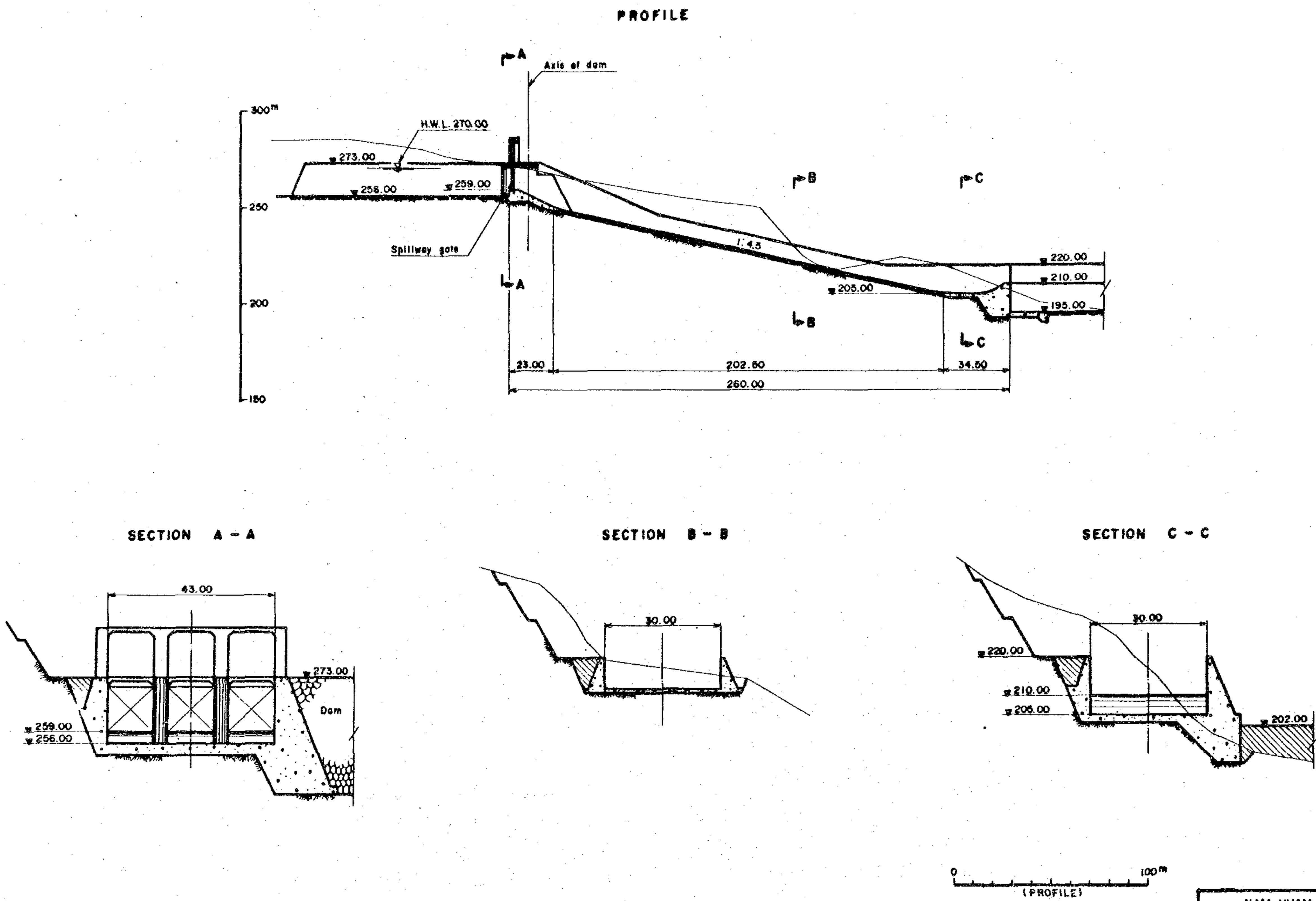
Fig. 6–5



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Rit Dam

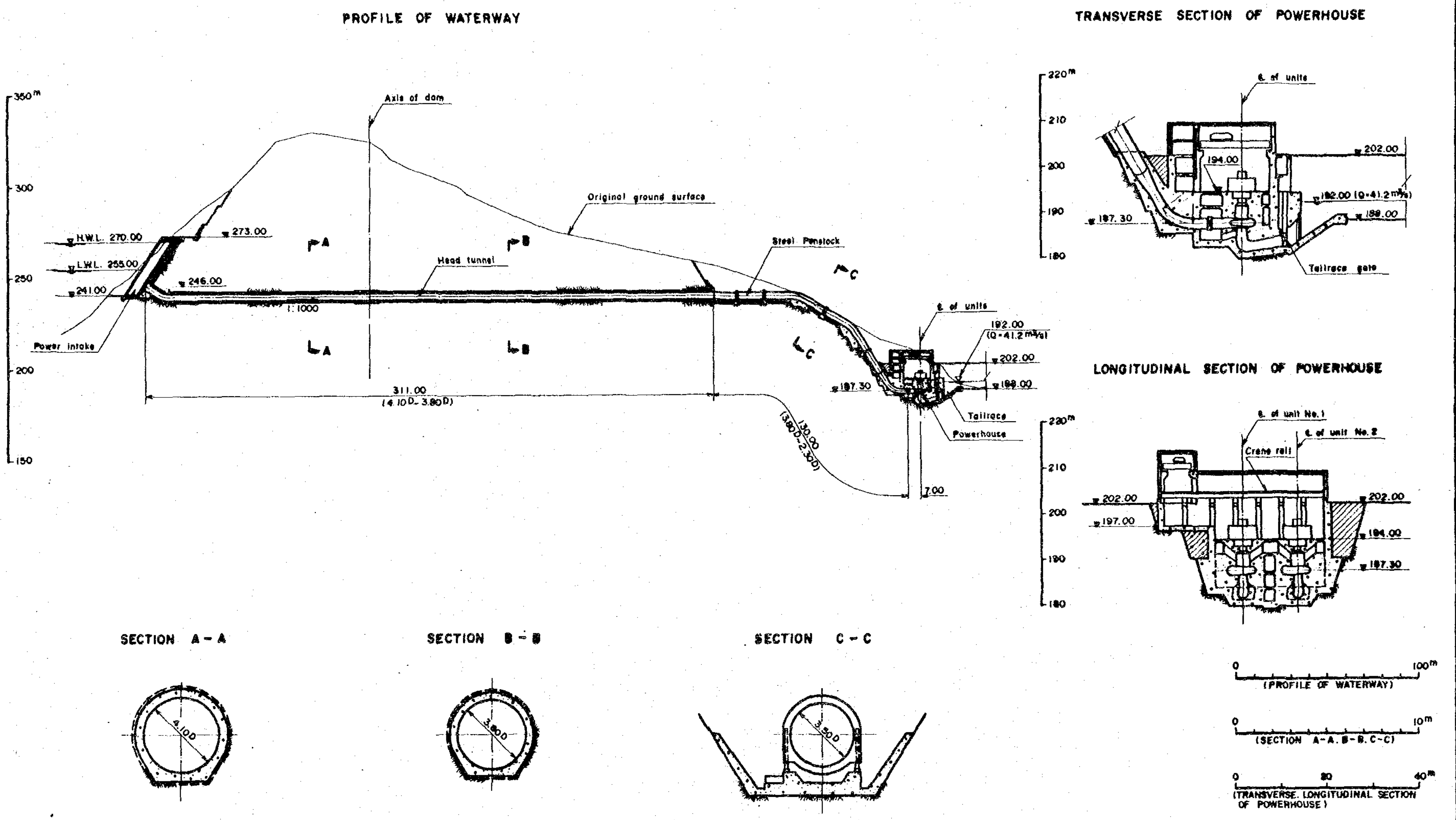
Fig. 6–6



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Rit Spillway

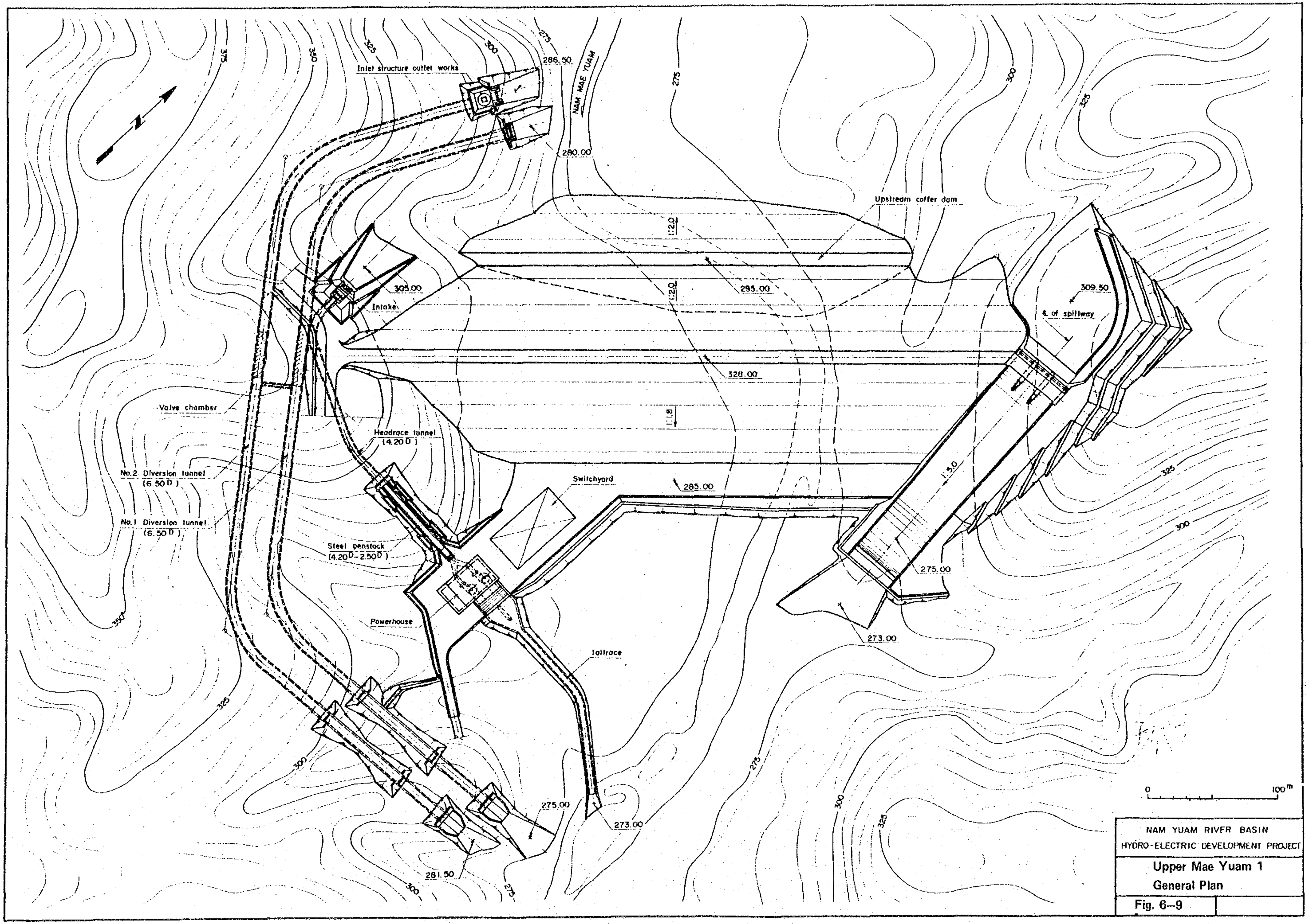
Fig. 6–7



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Rit Waterway

Fig. 6-8

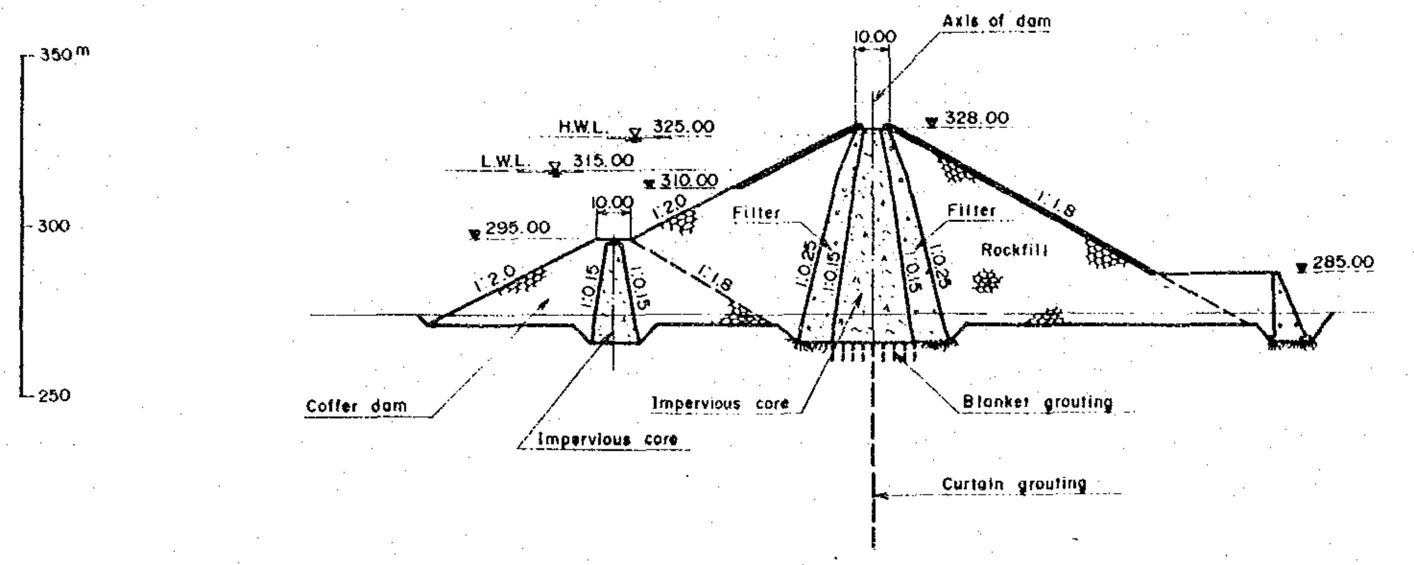


NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

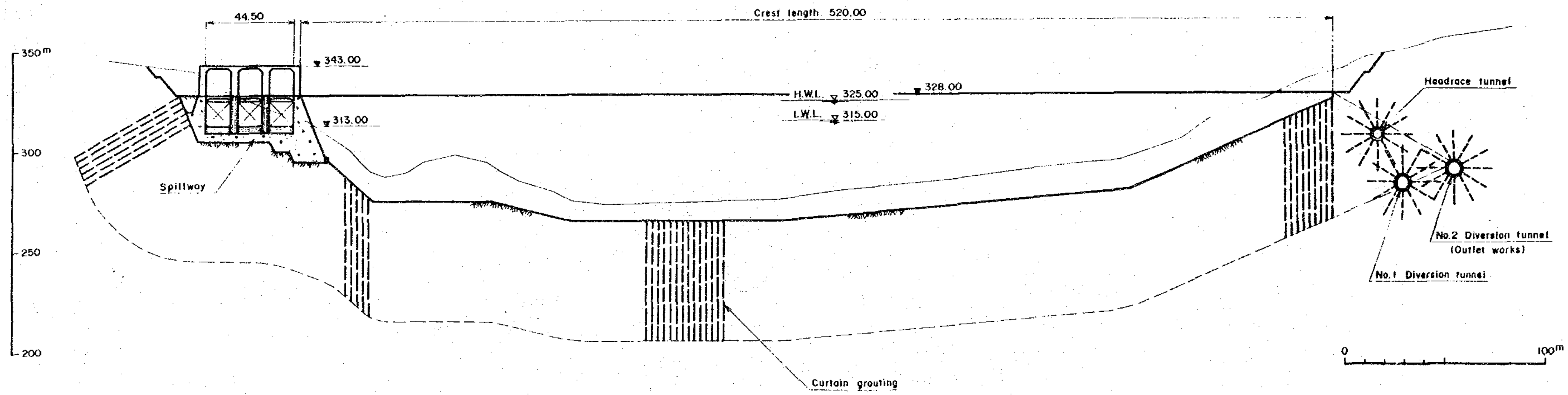
Upper Mae Yuam 1
General Plan

Fig. 6–9

TYPICAL SECTION OF DAM



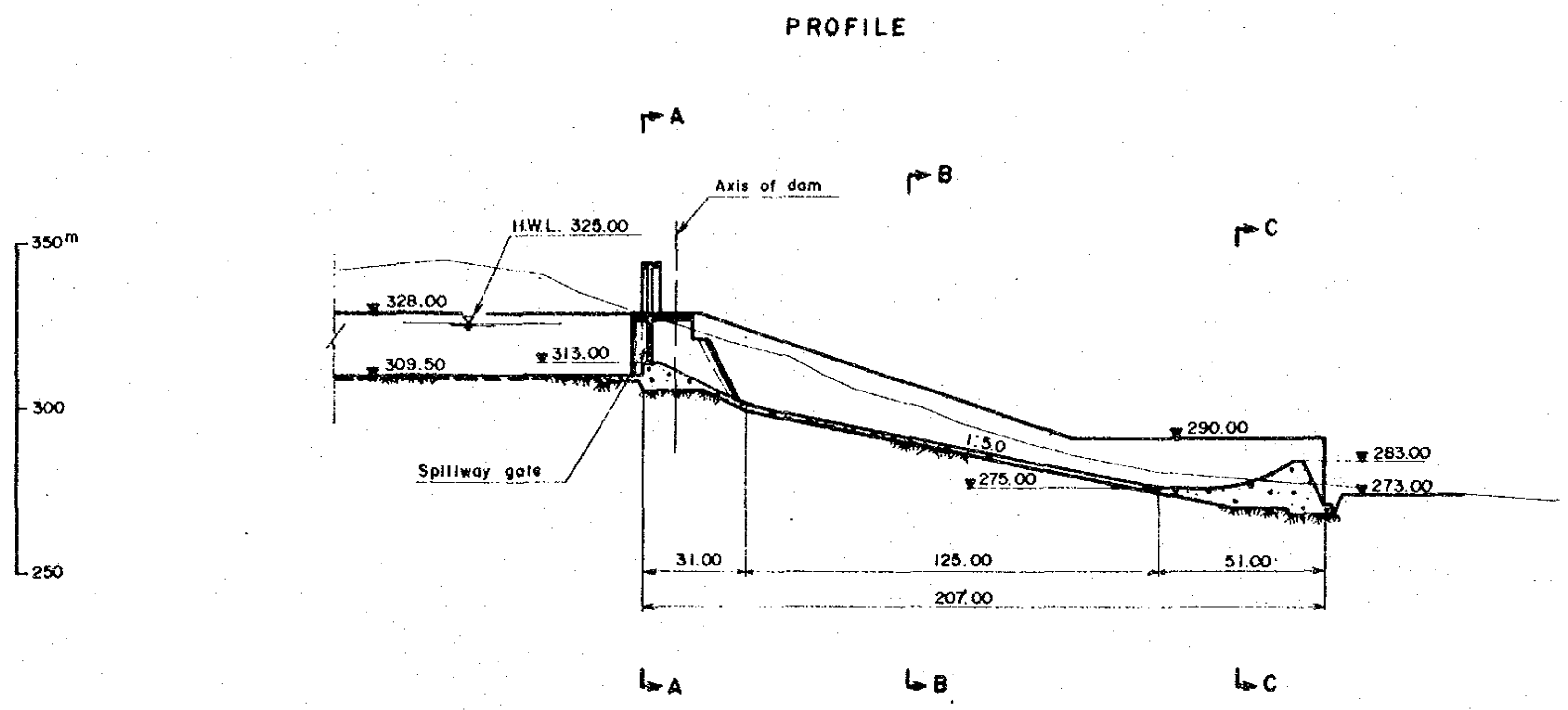
PROFILE OF DAM

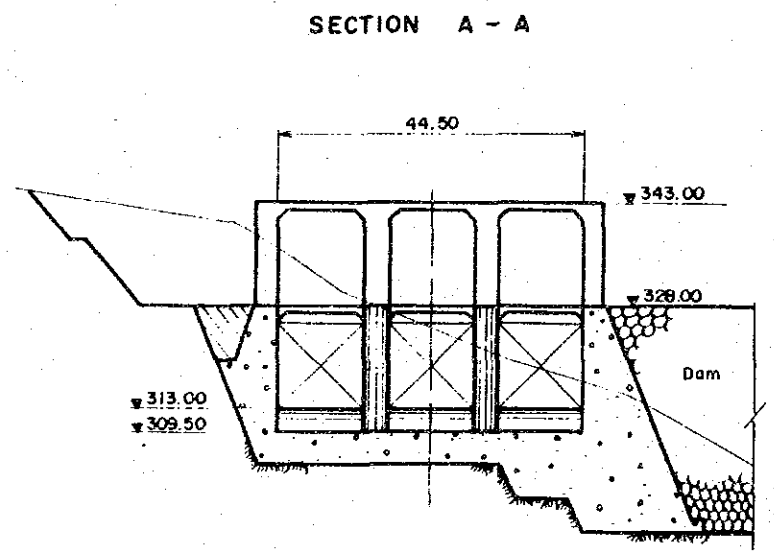


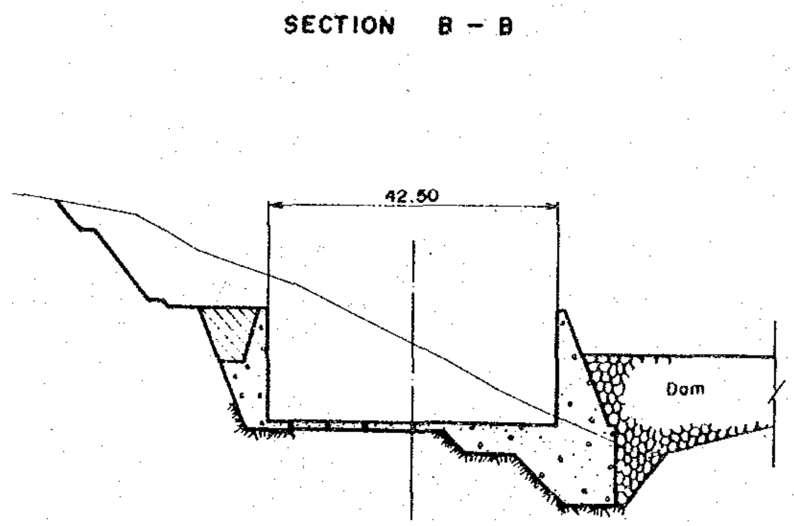
NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

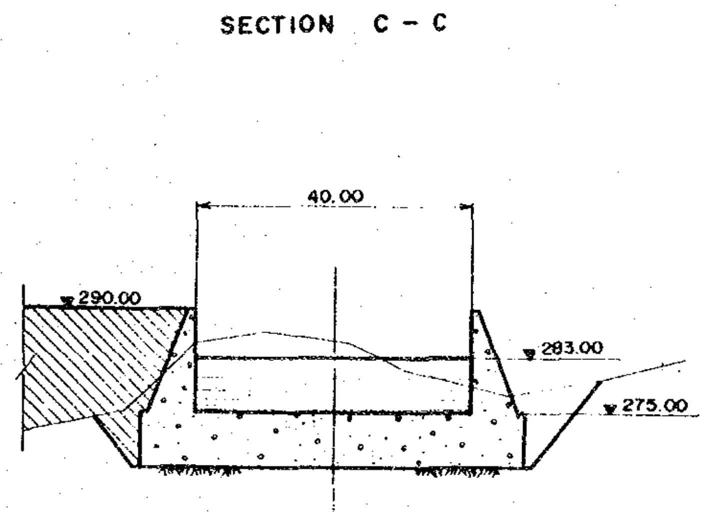
Upper Mae Yuam 1 Dam

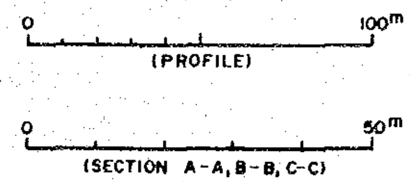
Fig. 6–10









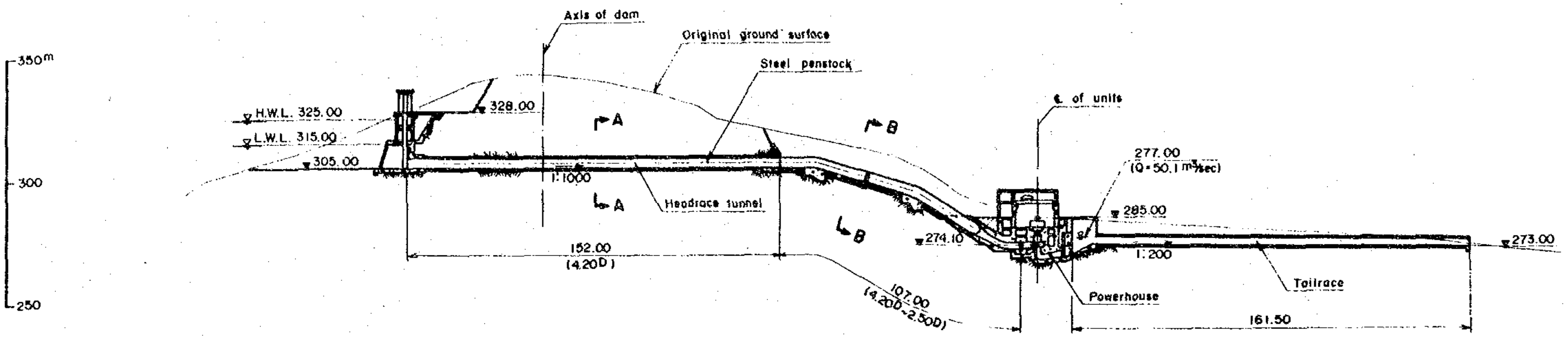


NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

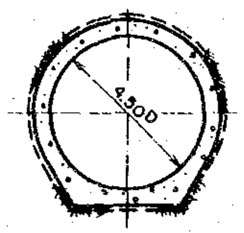
Upper Mae Yuam 1 Spillway

Fig. 6–11

PROFILE OF WATERWAY



SECTION A – A



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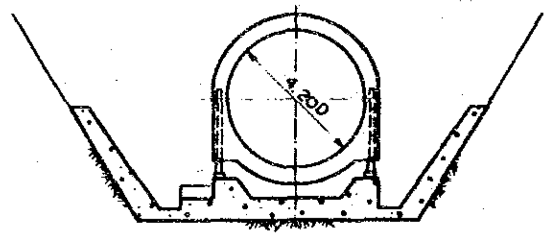
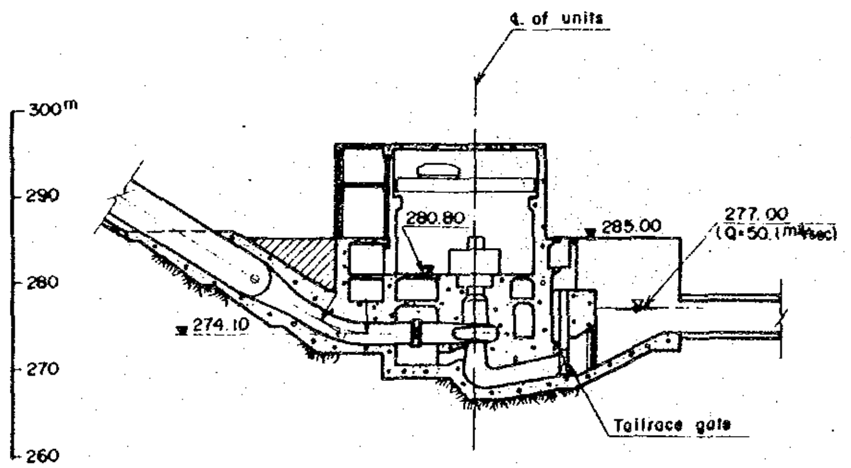
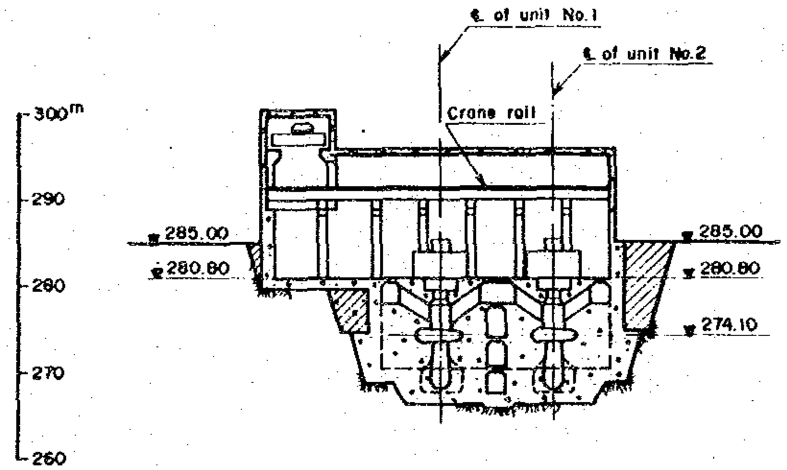
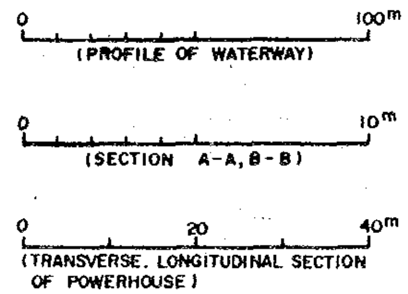


TRANSVERSE SECTION OF POWERHOUSE



LONGITUDINAL SECTION OF POWERHOUSE

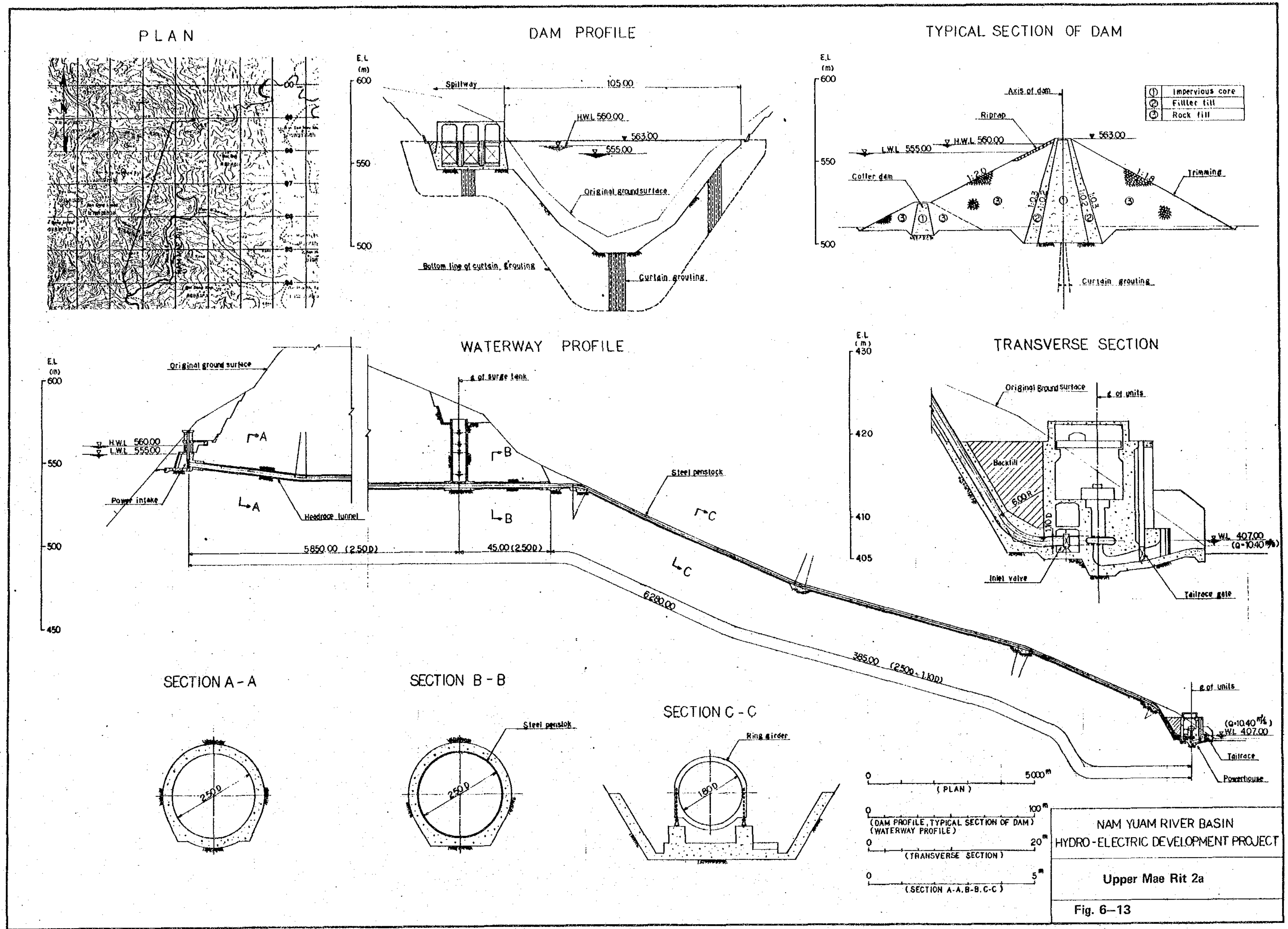




NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Upper Mae Yuam 1 Waterway

Fig. 6–12



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Upper Mae Rit 2a

Fig. 6–13

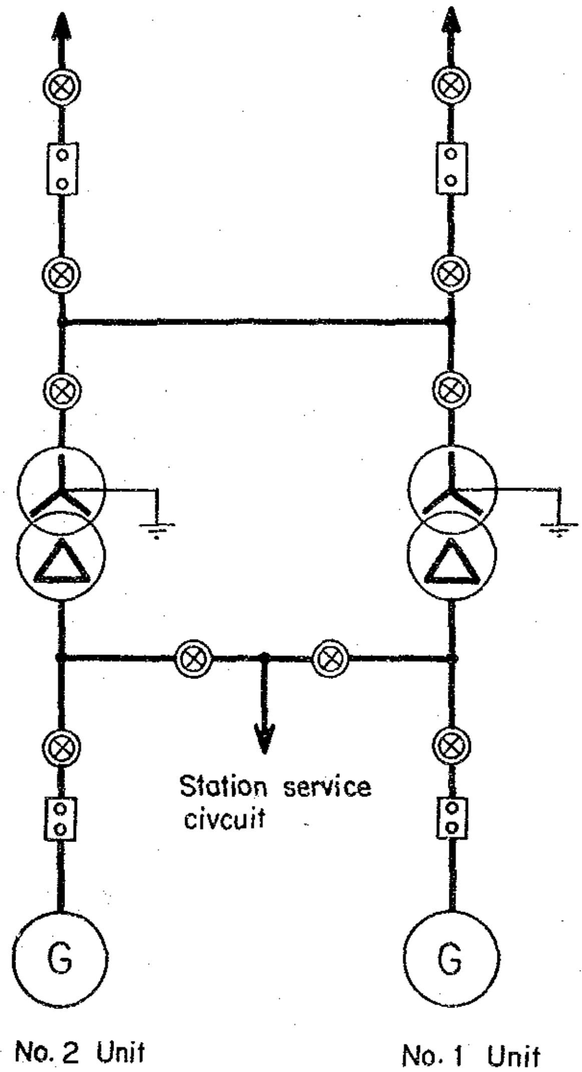


Fig. 6–14 Single Line Diagram. Ngao, Rit, Rit 2a

CHAPTER 7. POWER TRANSMISSION LINE SYSTEM PLAN

CHAPTER 7 POWER TRANSMISSION LINE SYSTEM PLAN

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CHAPTER 7. POWER TRANSMISSION LINE SYSTEM PLAN

7.1 Outline of Thailand Power System

1) Present Facilities

i) Generating Stations

As of October 1985, EGAT installed capacity is 6,464 MW, of which 1,817.9 MW is from hydro, 3,627.5 MW from oil/gas and lignite-fired thermal, 720 MW from combined cycle, 265 MW from gas turbine and 33.6 MW from diesel generations. Table 7-1 shows a detailed breakdown of the present installed capacity.

The supply area of Thailand power system is divided into 4 regions according to the EGAT definition.

The base load generation in Region 1 is provided by the north Bangkok oil-fired, South Bangkok and Bang Pakong oil/natural gas-fired thermal plants and also Bang Pakong combined-cycle power plants, while that in Region 4 is provided by the lignite-fired power plant at Mae Moh. For peaking generation, capacities are obtained from Bhumibol, Sirikit, Srinagarind, Kang Krachan, Khao Laem and Tha Thung Na hydroelectric plants. Additional supports for peaking power are available from gas turbines and diesel generators located at or nearby major load centers.

The power supply for base load in Region 2, the northeast, is mainly obtained from the interconnection with Region 4 through the 230 kV tie line and the 115 kV tie line for interconnection with Region 1.

Hydroelectric and gas turbine generations are used for peak load.

The base load generation in Region 3, the south, is provided by the barge-mounted thermal power plant at Khanom, lignite-fired power plant at Krabi and oil-fired power plant from the 115 kV Central-Southern tie line which has been in operation since Aug. 1980. The power system in Region 3 is also interconnected with its neighboring system in Malaysia via the 115/132 kV interconnector.

ii) Transmission lines and substation

The standard voltage for power transmission in EGAT system are 230, 115 and 69 kV at the frequency of 50 Hz. The EHV transmission voltage of 500 kV has been adopted as the next standard voltage. As of Oct. 1985, there are 26 (230 kV), 88 (115 kV), 18 (69 kV) substations, totalling 132 substations. The total installed transformer capacity, excluding station service transformer and generator units transformer, is 10,049 MVA.

2) The Power Development Plan

The EGAT Power Development Plan up to FY 2001, using September 1985 load forecast, and the list of power plants is tabulated in Table 7-2, Fig. 7-1.

At present there are three projects under construction, two of which are hydroelectric and one is thermal power plant. The hydroelectric projects under construction are: Srinagarind Unit 4 (Reversible pump turbine 180 MW) and Chiew Larn Units 1-3 (3 x 80 MW).

The thermal power project under construction is: Mae Moh Lignite-Fired Power Plant Unit 8 (300 MW). The total capacity of projects under construction including hydrto projects is 720.0 MW.

In term of regional planning for Region 3, the major projects to supply sufficient power and energy to this region are: Chiew Larn hydroelectric project (3 x 80 MW), Second Power Plant Barge at Khanom (75 MW), the second Central-Southern tie line (presumeably 300 MW), Kaeng Krung hydroelectric (2 x 40 MW), Krabi 2 coal-fired power plant of 3 x 150 MW and Sai Buri hydroelectric (2 x 23 MW).

As for the major electric system from FY 1988 to FY 2001 there will be additional generating capacity for future projects of 8,611 MW, of which 886 MW will be generation from hydroelectric projects, namely: Srinagarind Unit 5 (Reversible pump turbine 180 MW), Nam Chon Units 1-4 (4 x 145 MW), Kaeng Krung Units 1-2 (2 x 40 MW), and Sai Buri Units 1-2 (2 x 23 MW).

The other 7,725 MW will be thermal power plants development i.e., Khanom PPB Unit 2 (75 MW), Nam Phong Combined Cycle Blocks 1-2 (2 x 300 MW), Mae Moh Units 9-10 (2 x 300 MW), Bang Pakong Thermal Units 3-4 (2 x 600 MW), Krabi 2 Units 1-3 (3 x 150 MW), Ao Phai Thermal Units 1-4 (4 x 600 MW) and New Coal-Fired Units 1-4 (4 x 600 MW).

So far, in FY 2000-2001 hydro power is not planned except thermal plant above.

Due to the establishment of large-sized thermal power plants, the importance of developing hydroelectric power that has enough capacity to cope immediately with peak load is growing up in the future.

3) Demand-Supply Balance

In development plan, the commencement time of new projects should be determined based on the consideration of demand-supply balance which is estimated from load forecast and power development program as a whole.

Fig. 7-2, 3 is the prospect of EGAT and Region 4 development plan, and Fig. 7-4 shows the yearly EGAT development of reserved capacity ratio as its result. It is difficult to decide reserved capacity ratio, but it seems reasonable that the present ratio (25%) could be one standard to maintain.

Looking at the total reserved capacity ratio in peak balance, and even if 2 units of largest-class thermal power plant are lacking, the reserved capacity is overfull up to 1986 and thereafter gradually reduces.

If those which are planned as miscellaneous hydro would not be developed after FY 2000, the reserved capacity ratio overrides the present standard.

Therefore, it seems to be a proper schedule to include the Nam Yuam River Basin Project during FY 2000 - 2006. Based on this fact, the final economic evaluation goes, on assumption that they will start in FY 2000, and that all dependable capacity will be effective.

7.2 Outline of Power Transmission Line System Plan

In case Nam Yuam Project is put into the power transmission system, the various items considered in examining the required transmission system are as follows.

7.2.1 Selection of Power Transmission Scheme

1) The power transmission line system plans formulated under this project are for the purpose of transmitting electric power generated at the hydroelectric power stations of Nam Mae Ngao (116.9 MW), Nam Mae Rit (24.0 MW), Upper Mae Rit 2a (11.2 MW), Upper Mae Yuam 1(18.5 MW) and Lower Yuam (162 MW) to the Region 4 power system.

2) The transmission line should be the most advantageous taking its construction cost, convenience of maintenance and inspection, and transmission losses into consideration. Moreover, it is essential that power can be transmitted even during faulting outage of a single-circuit.

3) The transmission distance, assuming that the transmission line from Nam Yuam Project is connected to the nearest power station or substation existed or planned, is more than 200 km to Lamphun 2 substation, and more than 185 km to Tak 2 substation. For assuring highly reliable transmission, it is judged necessary to construct a 230 kV, 115 kV, two-circuit, ACSR 1272 MCM (Mile Circular Mils), 795 MCM, 477 MCM transmission line after the various studies concerning optimum transmission voltage, corona disruptive critical voltage, conductor size, number of circuit, etc. as described in cause 7.5. later.

4) Assume that the transmission line for Lower Yuam (230 kV, two-circuit, 1272 MCM) is existing already, the transmission line

for Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a and Upper Mae Yuam 1 connect to a Lower Yuan power station or new substation (230/115 kV) or new switching station.

5) Lamphun 2, Tak 2 substation (230/115 kV) should be completed before Nam Yuam Project is put into power transmission system.

In consideration of construction of 230 kV, two-circuit transmission line, the following six alternatives were examined. (see Table 7-3)

A. Northern route

a) Case-1

i) Construction of a 230 kV (22 km), two-circuit, ACSR 1272 MCM transmission line from Nam Mae Ngao to Lower Yuam Power Station.

ii) Construction of a 230 kV (17 km), two-circuit, ACSR 1272 MCM transmission line from Nam Mae Rit to Nam Mae Ngao Power Station.

iii) Construction of a 230 kV (22 km), two-circuit, ACSR 1272 MCM transmission line from Upper Mae Rit 2a to Nam Mae Rit Power Station.

iv) Construction of a Mae Sariang Switching station (230 kV) and a 230 kV (29 km), two-circuit, ACSR 1272 MCM transmission line from Upper Mae Yuam 1 power station to this switching station.

b) Case 2-A

i) Construction of a 230 kV (22 km), two circuit, ACSR 1272 MCM transmission line from Nam Mae Ngao power station to Lower Yuam power station.

ii) Construction of 230 kV (17 km), two-circuit, ACSR 1272 MCM transmission line from Nam Mae Rit Power Station to Nam Mae Ngao Power Station.

iii) Construction of a Mae Sariang Switching station and a 230 kV (22 km), two-circuit, ACSR 1272 MCM transmission line from Upper Mae Rit 2a Power Station to this switching station.

iv) Construction of a 230 kV (29 km), two-circuit, ACSR 1272 MCM transmission line from Upper Mae Yuam 1 power station to this switching station.

c) Case 2-B

i) Construction of a 230 kV (22 km), two-circuit, ACSR 795 MCM transmission line from Nam Mae Ngao Power Station to Lower Yuam Power Station.

ii) Construction of a 230 kV (17 km), two-circuit, ACSR 795 MCM transmission line from Nam Mae Rit Power Station to Nam Mae Ngao Power Station.

iii) Construction of a Mae Sariang Switching Station (230 kV) and a 230 kV (22, 29 km), two-circuit, ACSR 795 MCM transmission line from Upper Mae Rit 2a, Upper Mae Yuam 1 Power Station to this switching station.

d) Case-3

i) Construction of a Lower Yuam Substation (230/115 kV) and a 115 kV (22 km), two-circuit ACSR 795 MCM transmission line from Nam Mae Ngao Power Station to this substation.

ii) Construction of a 115 kV (17 km), two-circuit, ACSR 795 MCM transmission line from Nam Mae Rit power station to Nam Mae Ngao power station.

iii) Construction of a Mae Sariang Substation (230/115 kV) and a 115 kV (29 km), two-circuit, ACSR 477 MCM transmission line from Upper Mae Rit 2a, Upper Mae Yuam 1 Power Station to this substation.

B. Southern route

a) Case 4-A

i) Construction of a 230 kV (22 km), two circuit, ACSR 1272 MCM transmission line from Nam Mae Ngao Power Station to Lower Yuam Power Station.

ii) Construction of a 230 kV (185 km), single-circuit, ACSR 1272 MCM transmission line from Lower Yuam Power Station to Tak 2 and a 230 kV (17 km), two-circuit, ACSR 1272 MCM transmission line from Nam Mae Rit Power Station to Nam Mae Ngao Power Station.

iii) Construction of a 230 kV (22 km), two-circuit, ACSR 1272 MCM transmission from Upper Mae Rit 2a to Nam Mae Rit Power Station.

iv) Construction of a 230 kV (74 km), two-circuit, ACSR 1272 MCM transmission line from Upper Mae Yuam 1 Power Station to Lower Yuam Power Station.

b) Case 4-B

i) Construction of a 230 kV (22 km), two-circuit, ACSR 795 MCM transmission line from Nam Mae Ngao Power Station to Lower Yuam Power Station.

ii) Construction of a switching station and a 230 kV (17 km), two-circuit, ACSR 795 MCM transmission line from Nam Mae Rit Power Station to Nam Mae Ngao Power Station, and construction of a 230 kV (22 km), two-circuit, ACSR 795 MCM transmission line from Upper Mae Rit 2a to Nam Mae Rit Power Station.

iii) Construction of a 230 kV (74 km), two-circuit, ACSR 795 MCM transmission line from Upper Mae Yuam 1 Power Station to Lower Yuam Power Station.

7.3 Economic Comparison of Power Transmission Scheme

The result of economic comparisons made for the various system's case, i.e., 1, 2-A, 2-B, 3, 4-A, 4-B, Schemes, for the northern route and the southern route are as shown in Table 7-3.

Comparing the respective scheme with the annual cost including the transmission losses, the scheme 2-B (Northern Route) will be the most economical.

Even if comparing the respective scheme with the construction cost, the scheme 2-B will be the most economical.

7.4 Power System Analysis

Reinforcement for transmission of the electric power generated by Nam Yuam Project requires to construct the transmission line of nominal voltage of 230 kV as mentioned above. However, according to the result of stability study or loss of whole EGAT power system's power loss, the northern route plan can not necessarily say to be advantageous compared with the southern route plan. Therefore, the power system analysis for each route were carried out.

1) Power flow and voltage regulation

Power flow calculation were carried out based on EGAT's Power development plan and load forecast in FY 2000. The results are indicated in Fig. 7-5.

Regarding power flow calculation, the load side voltage of each power station and substation were mainly examined to be kept in 95 to 105% of nominal voltage on major power transmission system of Region 4 and Region 1, but the load power factor of substation is 85%.

a) Peak time

In case the load-side voltage of transformer sets to 95%, except that some substation are necessary to equip power capacitor, the generator voltage and bus voltage of each power station and substation are kept at 95 to 105% of nominal voltage 230 kV.

The voltage regulation of the entire power system in Thailand was not throughly studied because the study is out of the scope of works. The voltage regulation of the entire power system should be separately studied.

The all scheme will not have parts which will become overload at 230 kV.

2) Power loss of EGAT system

In each scheme, the power loss of Region 1,4 power system are indicated on Table 7-4.

In scheme 2-B (Northern Route), the power loss is 402.5 MW, comparing with the respective schemes, the scheme 2-B (Northern Route) will be the best.

3) Stability study

Transient stability calculation was carried out for the scheme 2-B, 4-B at peak time in FY 2000. The study led to the conclusion that scheme 2-B have no generator stepping-out and have no problem as to stability.

In the transient stability calculation, a change of an angular position of each rotor succeeding to a disturbance in the power system were calculated as follows. The severest effect to transient stability is thought to be given by a time when a three phase fault of one-circuit with a fault-clearing time of 6 cycles occurs. The fault points are assumed at the 230 kV bus of power station side and substations. The results are shown on Table 7-6 and Fig. 7-6.

4) Conclusion

As mentioned above, the scheme 2-B will be the best as the result of economic comparisons and power system analysis, and the following plans (scheme 2-B) are recommended measures for the necessary strengthening of the system related to the development of Nam Yuam Project.

i) Construction of a 230 kV, two-circuit, ACSR 795 MCM transmission line from Nam Mae Ngao Power Station to Lower Yuam Power Station.

ii) In the development of Nam Mae Rit, Construction of a 230 kV, two-circuit, ACSR 795 MCM transmission line from Nam Mae Rit power station to Nam Mae Ngao Power Station, and when Upper Mae Rit 2a or Upper Mae Yuam 1 Project be develop, construct of a switching station.

iii) It is preferable that the generator of Lower Yuam, Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, Upper Mae Yuam 1 Power Station have a automatic voltage regurator with PSS (power system stabilizer).

iv) In order to transmit stably the power generated by Lower Yuam, Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, Upper Mae Yuam 1 via 200 km, 230 kV, two-circuit line is not sufficient, a switching station is required in this system.

7.5 Preliminary Design of Transmission Line

1) Transmission line route

For transmitting the electric power generated by Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, and Upper Mae Yuam 1 to the Region 4, as stated hereinbefore, the northern route has been taken as the object of examination, and it has been ascertained that the northern route connected to Lamphun 2 substation is more advantageous.

The northern route to be constructed in this project is outlined hereunder. Reference is to be made to Fig. 7-7.

When constructing the transmission line, the availability of the existing roads which can be utilized for transporting the machines and materials has great effect on the construction costs. Nam Mae

Ngao, Nam Mae Rit, and Upper Mae Rit 2a power stations are situated in the less developed mountaineous area northwest in Thailand and the access conditions are poor. Following about 150 km from Lamphun 2 substation to Mae Sariang and about 29 km from Mae Sariang to upper Mae Yuam 1 site, the route runs in parallel with the well paved national highway. No difficulty in the construction will be encountered in this section.

Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a projects are situated in the less developed mountaineous area, therefore, it is recommended that the implementing agency of the feasibility study of the Nam Mae Ngao, Nam Mae Rit, and Upper Mae Rit 2a project should be familiarized with the actual condition of the said road project and reflect the results of such informations in the selection of transmission line route.

In selecting Mae Sariang Switching Station site, it is essential that deliverate considerations be given to the coordination of the proposed 230 kV transmission line of the Lower Yuam Project with the residential areas etc.

2) Transmission line voltage and number of circuits

Reinforcement for transmission of the electric power generated by Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, Upper Mae Yuam 1 Power Station requires to construct the transmission line of nominal voltage of 230 kV mentioned above.

The two-circuits would be required by reference to the criteria currently adopted by EGAT inconnection with operation of their transmission line facilities.

3) Phase conductor

The size of conductor is determined in view of ampacity which corresponds with the power of Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, and Upper Mae Yuam 1, stability and corona disruptive critical voltage etc.

In order to transmit the power by 230 kV, 1272 MCM or 795 MCM was selected, and in order to transmit the power by 115 kV, 795 MCM or 477 MCM was selected upon examination of the EGAT's standards.

However, in selecting 795 MCM (230 kV), it is recommended that deliverate consideration be taken to the design of transmission line steel tower etc., at feasibility study level.

7.6 Additional Study

For transmitting the electric power generated by Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, and Upper Mae Yuam 1 to the Region 4, it has been ascertained that the northern route connected to Lamphun 2 substation is more advantageous. The additional case was examined based on the following conditions.

(1) Nam Mae Ngao Project is developed individually prior to the construction of Lower Yuam Project.

(2) The electric power generated by Nam Mae Ngao is directly transmitted to Lamphun 2-substation. In particular, the electric power can be transmitted even during faulting outage of a single line circuit.

7.6.1 Transmission Line Route

The transmission line route was selected along the existing well paved national highway Route No. 108. (Fig. 7-12) The distance from Nam Mae Ngao power station to Lamphun 2 substation is about 175 km.

7.6.2 Transmission Line Voltage and Number of Circuits

Transmission of the electric power (116.9 MW) generated by Nam Mae Ngao power station requires the construction of the 230 kV, two circuit transmission line for the stability. (Fig. 7-13)

7.6.3 Phase Conductor

The size of conductor is determined to be ACSR 1272MCM based on the EGAT standards.

Table 7-1 Existing Power Plants

Plants	Power (MW)		Energy (GWh)		Re-gion
	Installed	Dependable	Average	Firm	
HYDRO POWER PLANTS					
Bhumibol Dam Units 1~7	535.0	441.1	1,414.1	891.4	R4
Sirikit Dam Units 1~3	375.0	280.5	1,005.3	644.9	R4
Ubolratana Dam Units 1~3	25.0	20.3	56.1	35.0	R2
Sirindhorn Dam Units 1~3	36.0	33.3	59.3	35.0	R2
Chulabhorn Dam Units 1~2	40.0	39.5	76.4	56.2	R2
Kang Krachan Dam Units 1	19.0	13.5	77.2	48.4	R1
Nam Pung Units 1~2	6.0	5.7	15.1	7.0	R2
Srinagarind Dam Units 1~3	360.0	360.0	1,162.0	861.0	R1
Bang Lang (Pattani) Units 1~3	72.0	53.5	208.8	116.8	R3
Khao Laem #1~3	300.0	245.0	756.0	523.6	R1
Tha Thung Na Units 1~2	38.0	38.0	166.6	127.3	R1
Buai Kum	1.3	1.3	3.0	-	R2
Ban Yang	0.125	0.125	0.3	-	
Ban Santi	1.3	1.3	6.1	-	
Klong Chong Klum	0.02	0.02	0.1	-	
Ban Khun Klang	0.18	0.18	0.7	-	
Mae Ngat Units 1~2	9.0	-	29.0	15.5	R4
Total	1,817.9	1,533.3	5,036.1	3,362.1	
THERMAL POWER PLANTS					
North Bangkok Units 1~3	237.5	225.6	1,660.0	1,660.0	R1
South Bangkok Units 1~5	1,300.0	1,235.0	8,713.0	8,713.0	R1
Krabi Power Plant Units 1~3	60.0	54.0	300.0	300.0	R3
Surat Thani Power Plant Units 1	30.0	28.5	210.0	210.0	R3
Mae Moh Units 1~3	225.0	213.9	1,477.0	1,477.0	R4
Mae Moh Units 4~7	600.0	570.0	3,940.0	3,940.0	R4
Khanom PPB Unit 1	75.0	71.3	525.0	525.0	R3
Bang Pakong Thermal Units 1~2	1,100.0	1,045.0	6,744.0	6,744.0	R1
Total	3,627.5	3,443.3	23,569.0	23,569.0	

Plants	Power (MW)		Energy (GWh)		Region
	Installed	Dependable	Average	Firm	
COMBINED CYCLE POWER PLANTS					
Bang Pakong Combined Cycle Blocks I & II	720.0	684.0	3,780.0	3,780.0	R1
Total	720.0	684.0	3,780.0	3,780.0	
GAS TURBINE POWER PLANTS					
Nakhon Ratchasima Unit 1	15.0	13.5	13.0	13.0	R2
Udon Thani Unit 1	15.0	13.5	13.0	13.0	R2
Bat Yai Units 1~3	45.0	40.5	39.0	39.0	R3
Surat Thani Units 3~5	45.0	40.5	39.0	39.0	R3
South Bangkok Gas Turbine Unit 1	25.0	20.0	38.3	38.3	R1
Lan Krabu Units 1, 2, 3	45.0	40.5	295.8	295.8	R4
Lan Krabu Units 5, 6, 7	75.0	60.0	492.8	492.8	R4
Total	265.0	218.5	930.9	930.9	
DIESEL POWER PLANTS					
Pnuket Units 1~4	10.6	8.5	9.0	9.0	R3
Chiang Mai Unit 1	1.0	0.8	1.0	1.0	R4
Mae Moh Units 1~8	8.0	6.4	7.0	7.0	R4
Nakhon Si Thammarat Units 1~2	2.0	1.6	2.0	2.0	R3
Bang Lang Units 1~5	5.0	4.0	4.0	4.0	R3
Khao Laem Units 1~5	5.0	4.0	4.0	4.0	R1
Krabi Units 1~2	2.0	1.6	2.0	2.0	R3
Total	33.6	26.9	29.0	29.0	
TOTAL EXISTING PLANTS	6,464.0	5,906.0	33,345.0	31,671.0	

Reference: System planning department November, 1985

Table 7-2 Power Development Plan (Whole EGAT)

Year	Plants	commis-sioning date	Power (MW)		Energy (GWh)		Re-gion
			Install-ed	Depend-able	Average	Firm	
1985	A. Hydro						
	Srinagarind #4	Nov.	180	180	54.6	35.7	R1
	B. Gas Turbine						
	Songkhla #1	Nov.	25	20	38.3	38.3	R3
1987	A. Hydro						
	Chiew Larn #1 ~ 3	Jul.	240	177.9	553.7	236.9	R3
1988	A. Thermal						
	Khanom PPB #2	Jun.	75	71.3	525.0	525.0	R3
1989	A. Thermal						
	Mae Moh #8	Jul.	300	285.0	1,970.0	1,970.0	R4
1990	A. Hydro						
	Srinagarind #5	Oct.	180	180	54.6	35.7	R1
	B. Thermal						
	Mae Moh #9	Jun.	300	285	1,970	1,970	R4
	Nam Phong Combined Cycle #1	Nov.	300	285	1,575	1,575	R2
1991	A. Thermal						
	Mae Moh #10	Jun.	300	285	1,970	1,970	R4
	Bang Pakong #3	Oct.	600	570	3,680	3,680	R1
1992	A. Retired (diesel)	Dec.					
	Chaing Mai #1		-1.0	-0.8	-1.0	-1.0	R4
	Mae Moh I #1 ~ 8		-8.0	-6.4	-7.0	-7.0	R4
	Nakhan Si Thammanrat #1, 2		-2.0	-1.6	-2.0	-2.0	R3
	Bang Lang #1 ~ 5		-5.0	-4.0	-4.0	-4.0	R3
	Khao Laem #1 ~ 5		-5.0	-4.0	-4.0	-4.0	R1
	(Total)		(-21.0)	(-16.8)	(-18.0)	(-18.0)	

Year	Plants	commis-sioning date	Power (MW)		Energy (GWh)		Re-gion
			Install-ed	Depend-able	Average	Firm	
1993	A. Thermal						
	Nam Phong Combined Cycle #2	Jan.	300	285	1,575	1,575	R2
	Bang Pakong #4	Oct.	600	570	3,680	3,680	R1
	B. Hydro						
	Nam Chon #1, 2	Nov.	290	290	599.2	432.7	R1
1994	A. Hydro						
	Nam Chon #3, 4	May.	290	290	599.2	432.7	R1
	Kaeng Krung #1, 2	Oct.	80	77	177.9	156.1	R3
	B. Thermal						
	Krabi 2 #2	Nov.	150	142.5	920	920	R3
	C. Retired (Thermal)						
	North Bangkok (oil)	Dec.	-237.5	-225.6	-1,660	-1,660	R1
1995	A. Thermal						
	Ao Phai Thermal #1	Oct.	600	570	3,680	3,680	R1
	B. Retired (Thermal)						
	Krabi (Lignite) #1 ~ 3	Aug.	-60	-54	-300	-300	R3
1996	A. Thermal						
	Ao Phai #2	Oct.	600	570	3,680	3,680	R1
	Krabi 2 #2	Nov.	150	142.5	920	920	R3
	B. Retired (Thermal)						
	South Bangkok #1 (oil)	Dec.	-200	-190	-1,340.5	-1,340.5	R1
1997	A. Thermal						
	Ao Phai #3	Oct.	600	570	3,680	3,680	R1
	Krabi 2 #3	Nov.	150	142.5	920	920	R3
	B. Retired (Thermal)						
	South Bangkok #2 (oil)	Dec.	-200	-190	-1,340.5	-1,340.5	R1

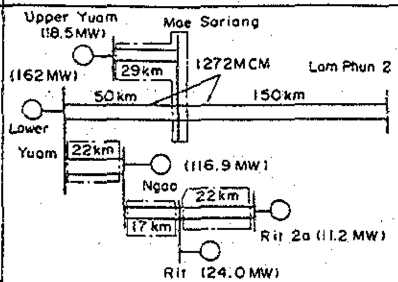
Year	Plants	commis-sioning date	Power (MW)		Energy (GWh)		Re-gion
			Install-ed	Depend-able	Average	Firm	
1998	A. Hydro						
	Sai Buri #1, 2	Nov.	46	40	119	78.3	R3
	B. Thermal						
	Ao Phai #4	Oct.	600	570	3,860	3,860	R1
	C. Retired (Thermal)						
	Surat Thani #1 (oil)	Mar.	-30	-28.5	-210	-210	R1
1999	A. Thermal						
	Coal-Fired #1	Oct.	600	570	3,860	3,860	R1
	B. Retired (Thermal)						
	South Bangkok #3 (oil)	Jun.	-300	-285	-2,010.7	-2,010.7	R1
2000	A. Thermal						
	Coal-Fired #2	Apr.	600	570	3,680	3,680	R1
	Coal-Fired #3	Oct.	600	570	3,680	3,680	R1
	B. Retired (Thermal)						
	South Bangkok #4 (oil)	Aug.	-300	-285	-2,010.7	-2,010.7	R1
	(Gas Turbine)	Nov.					
	Nakhon Ratchasima #1		-15	-13.5	-13.0	-13.0	R2
	Udon Thani #1		-15	-13.5	-13.0	-13.0	R3
	Hat Yai #1 ~ 3		-45	-40.5	-39.0	-39.0	R3
	Surat Thani #3 ~ 5		-45	-40.5	-39.0	-39.0	R3
	Lan Krabu #1 ~ 3	Dec.	-45	-40.5	-295.8	-295.8	R4
2001	A. Thermal						
	Coal-Fired #4	Apr.	600	570	3,680	3,680	R1
	B. Retired (Diesel)						
	Phuket #1 ~ 4	May.	-10.6	-8.5	-9.0	-9.0	R3
	(Gas Turbine)						
	Songkhla #1	Aug.	-25	-20	-38.3	-38.3	R3
	Lan Krabu #5 ~ 7	Sep.	-75	-60	-492.8	-492.8	R4

Reference: System planning department November, 1985

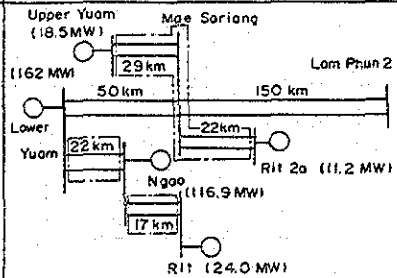
Table 7–3–1 Economic Comparison for the Selection of Power System for Nam Yuam River Basin Project

Power System Diagram

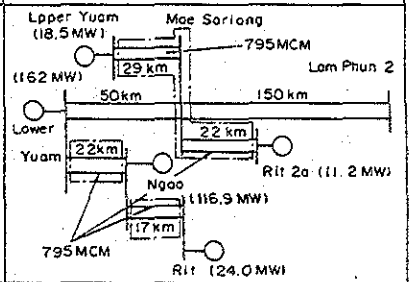
Scheme 1



Scheme 2-A



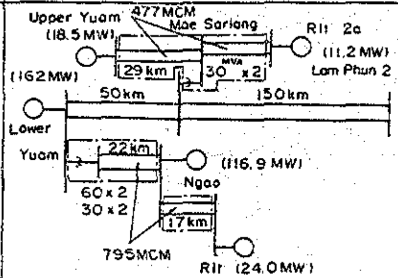
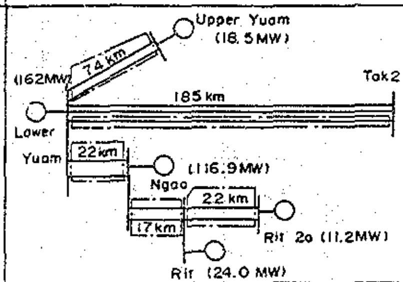
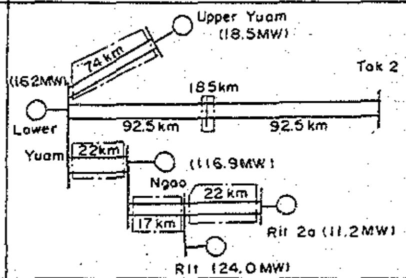
Scheme 2-B



Items \ Scheme	1	2-A	2-B
Transmission Line			
Voltage kV	230	230	230
Number of circuit	2	2	2
Conductor size	1272 MCM	1272 MCM	795 MCM
Total distance km	90	90	90
1 Construction Cost (M฿)			
(1) Lines *7	200	200	162.9
(2) Equipment of station *8	68.4	65.8	65.8
(3) Total	268.4	265.8	228.7
2 Annual Cost (M฿)	36.4	36.0	31.1
3 Line Losses			
(1) Power $\times 10^3$ (kW)	12.7	12.1	12.1
(2) Annual energy $\times 10^3$ (kWh)	6759	6431	6510
4 Cost of losses (M฿)			
(1) Power	22.3	21.22	21.22
(2) Annual energy	10.6	9.84	9.96
(3) Total	32.6	31.06	31.18
Total Annual Cost Including Line Losses (M฿)			
2 + 4(3)	69.0	67.06	62.28
2 + 4(2)	47.0	45.84	41.06

Note:
1 Planned transmission line and or substation for Nam Yuam
2 Annual Cost Factor for lines = 0.1313, for equipment = 0.1475
3 Cost of Losses 1.53 ฿/kWh, 1754 ฿/kW
4 Annual load factor is 15 (%)
5 Line Losses for the increased lines of Lower Yuam is not included
6 Discount rate = 12 (%)
*7 Cost is included the engineering fee (4%), interest (7%)
*8 Cost isn't included the telecommunication system and Line protection system

Table 7–3–2 Economic Comparison for the Selection of Power System for Nam Yuam River Basin Project

Items \ Scheme	3	4-A	4-B
Power System Diagram			
Transmission Line			
Voltage kV	115	230	230
Number of circuit	2	2	2
Conductor size	795 MCM, 477 MCM	1272 MCM	795 MCM
Total distance km	90	135	135
1 Construction Cost (M฿)			
(1) Lines *7	124.9	562.5	244.4
(2) Equipment of station *8	140.6	63.27	70.8
(3) Total	265.5	625.8	315.2
2 Annual Cost (M฿)	37.1	83.2	42.5
3 Line Losses			
(1) Power $\times 10^3$ (kW)	12.6	8.0	12.2
(2) Annual energy $\times 10^3$ (kWh)	6693	4279	6379
4 Cost of losses (M฿)			
(1) Power	22.1	14.0	21.4
(2) Annual energy	10.24	6.55	9.76
(3) Total	32.34	20.55	31.16
5 Total Annual Cost Including Line Losses (M฿)			
2 + 4(3)	69.44	103.75	73.66
2 + 4(2)	47.34	89.75	52.26

Note: 1 Planned transmission line and or substation for Nam Yuam

2 Annual Cost Factor for lines = 0.1313
for equipment = 0.1475

3 Cost of Losses 1.53 ฿/kWh, 1754 ฿/kW

4 Annual load factor is 15 (%)

5 Line Losses for the incrcased lines of Lower Yuam is not included

6 Discount rate = 12 (%)

*7 Cost is included the engineering fee (4%), interest (7%)

*8 Cost isn't included the telecommunication system and Line protection system

Table 7-4 Power Loss at Peak Time in 2000

Scheme	Power loss of Region 1, 4 (MW)
2-B	402.5
4-B	415.7
4-A	411.7

Table 7-5 Short Capacity (Scheme 2-B)

Substation	Voltage (kV)	Short capacity (MVA)	Fult current (kA)
Lamphun 2	230	2,630	6.6
Upper Yuam	230	1,530	3.8
Rit 2a	230	1,550	3.9
Lower Yuam	230	1,570	3.9
Ngao	230	1,510	3.8
Rit	230	1,450	3.6

Table 7–6 The Result of the Stability Analysis

Scheme	Fault point	With switch station	Without switch station	
		Without PSS	With PSS	Without PSS
2-B	Lower Yuam	Stable (Fig. 8-6-1)	–	–
	Switch station	Stable (Fig. 8-6-2)	–	–
	Upper Mae Yuam	Stable (Fig. 8-6-3)	–	–
	Nam Mae Rit	Stable (Fig. 8-6-4)	–	–
	Upper Mae Rit 2a	Stable (Fig. 8-6-5)	–	–
	Mae Moh (500 kV)	Stable (Fig. 8-6-6)	–	–
	Tha Tako	Stable (Fig. 8-6-7)	–	–
	Nohg Chok	Stable (Fig. 8-6-8)	–	–
	Sai Noi	Stable (Fig. 8-6-9)	–	–
	Mae Moh (115 kV)	Stable (Fig. 8-6-10)	–	–
2-B-X*1	Lower Yuam	Stable (Fig. 8-6-12)	Stable (Fig. 8-6-12)	Unstable (Fig. 8-6-12)
4-B	Lower Yuam	Stable (Fig. 8-6-13)	Unstable (Fig. 8-6-13)	Unstable (Fig. 8-6-13)

*1 Nam Mae Rit, Upper Mae Rit 2a, Upper Yuam Power Station doesn't operate.

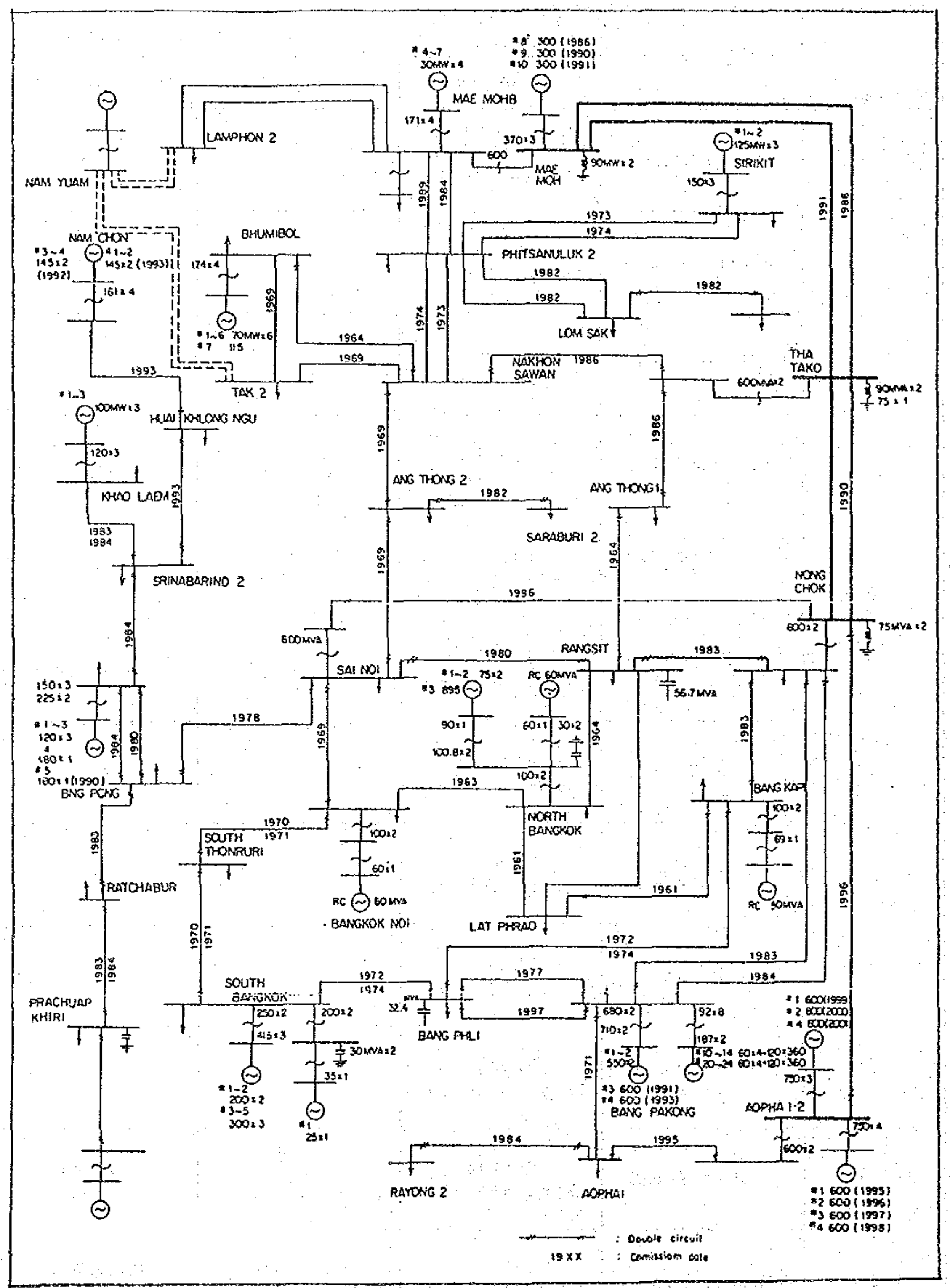


Fig. 7–1 EGAT Power System Development Plan

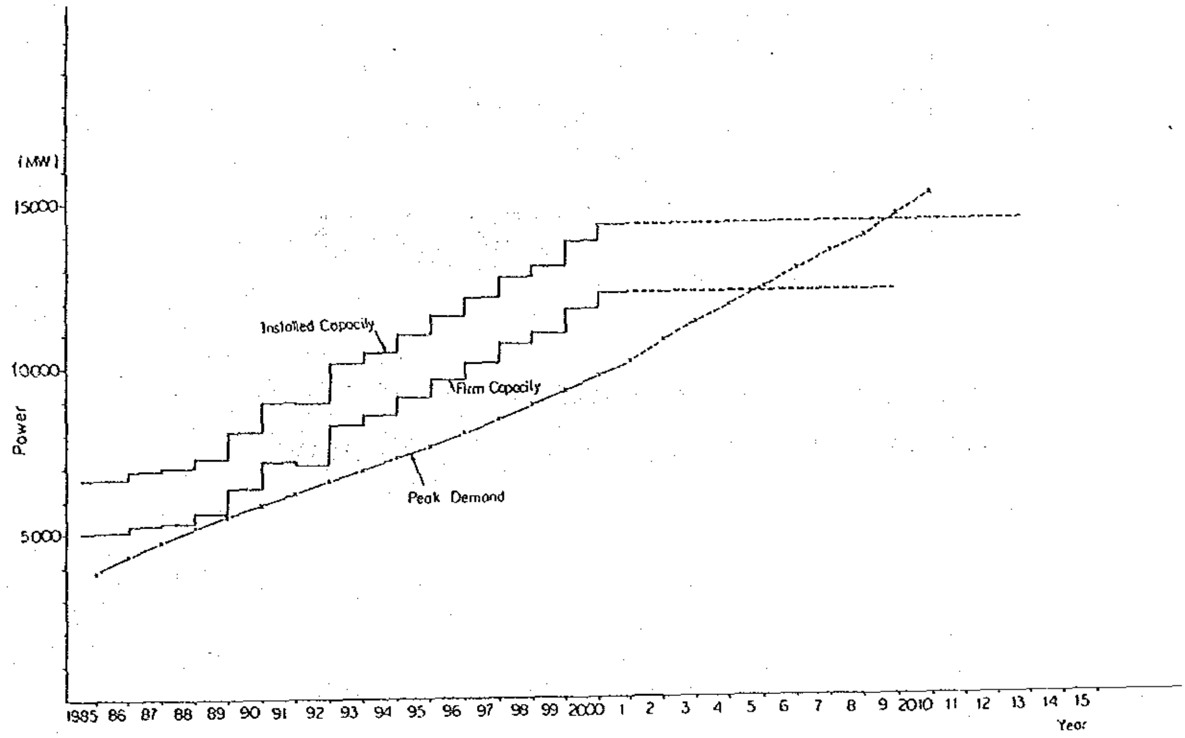


Fig. 7–2–1 Power Development Plan (Power)

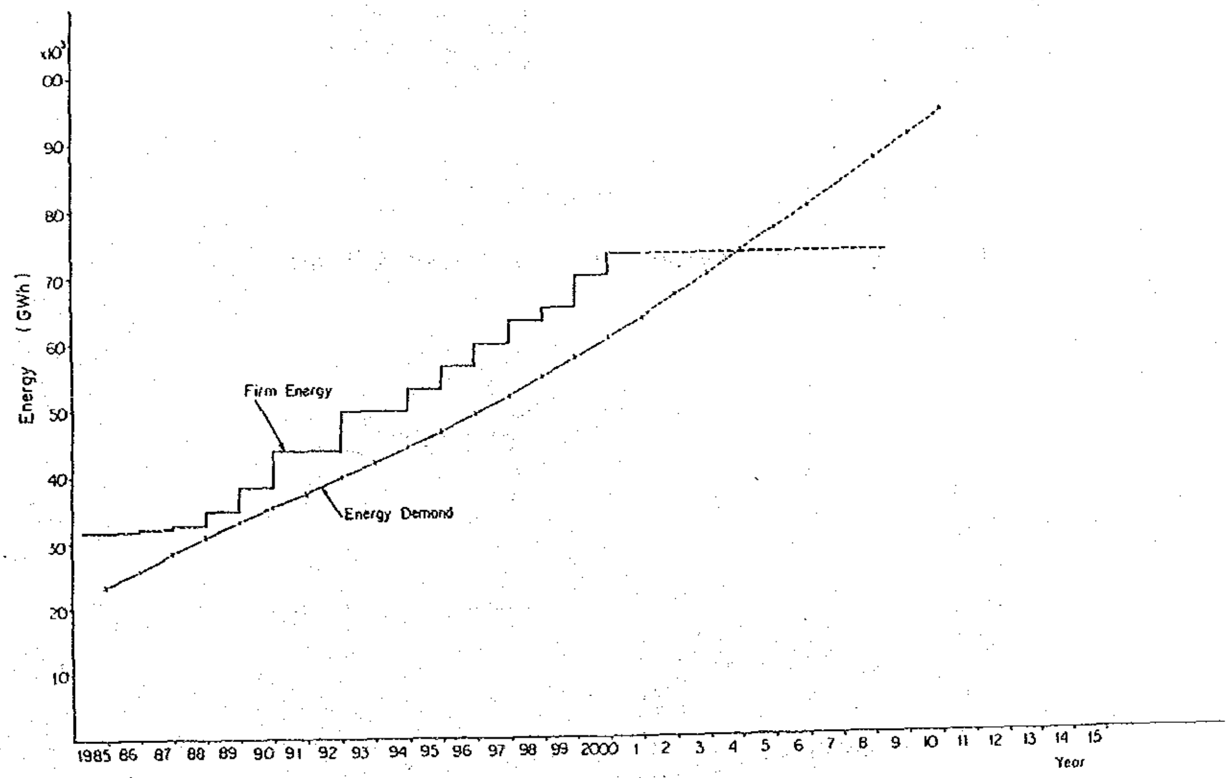


Fig. 7–2–2 Power Development Plan (Energy)

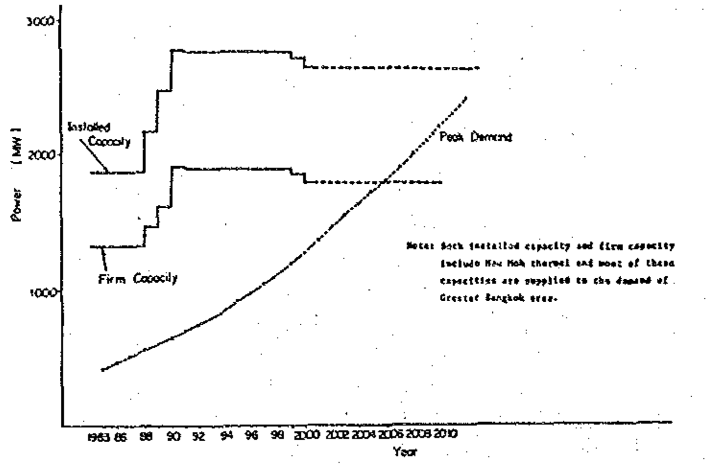


Fig. 7–3–1 Power Development Plan Region 4 (Power)

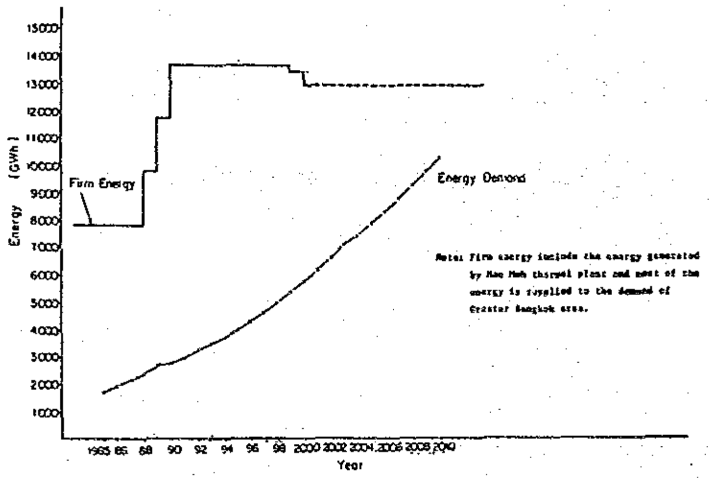


Fig. 7–3–2 Power Development Plan Region 4 (Energy)

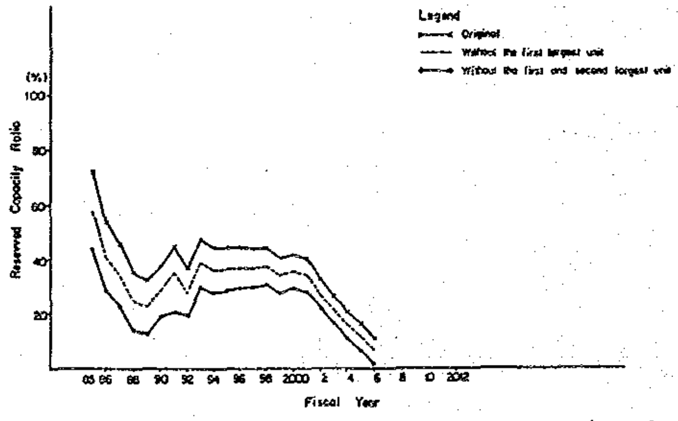


Fig. 7–4 Reserved Capacity Ratio in Peak Balance (Whole Thailand)

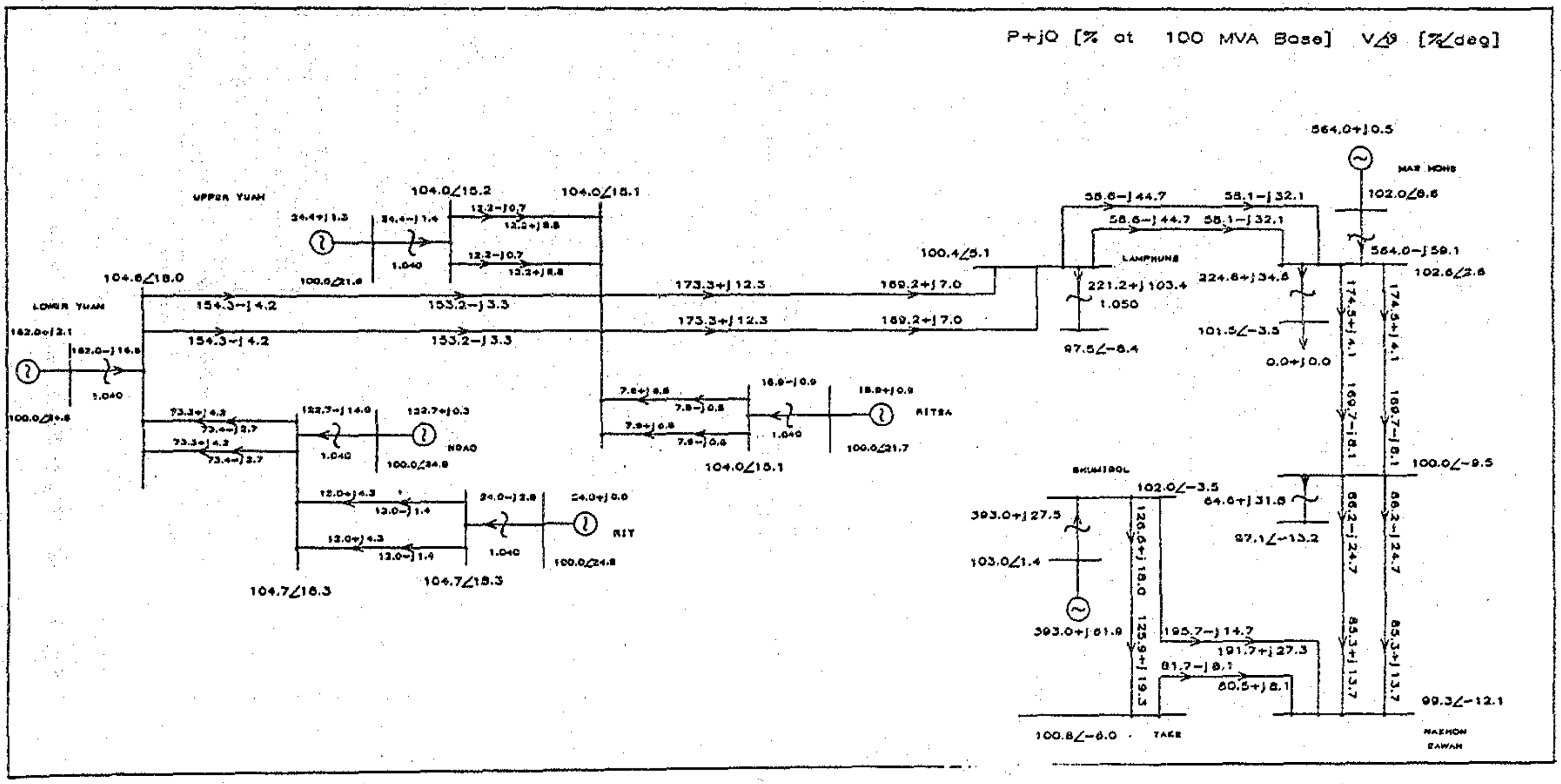


Fig. 7–5–1 Power Flow Diagram: 2–B

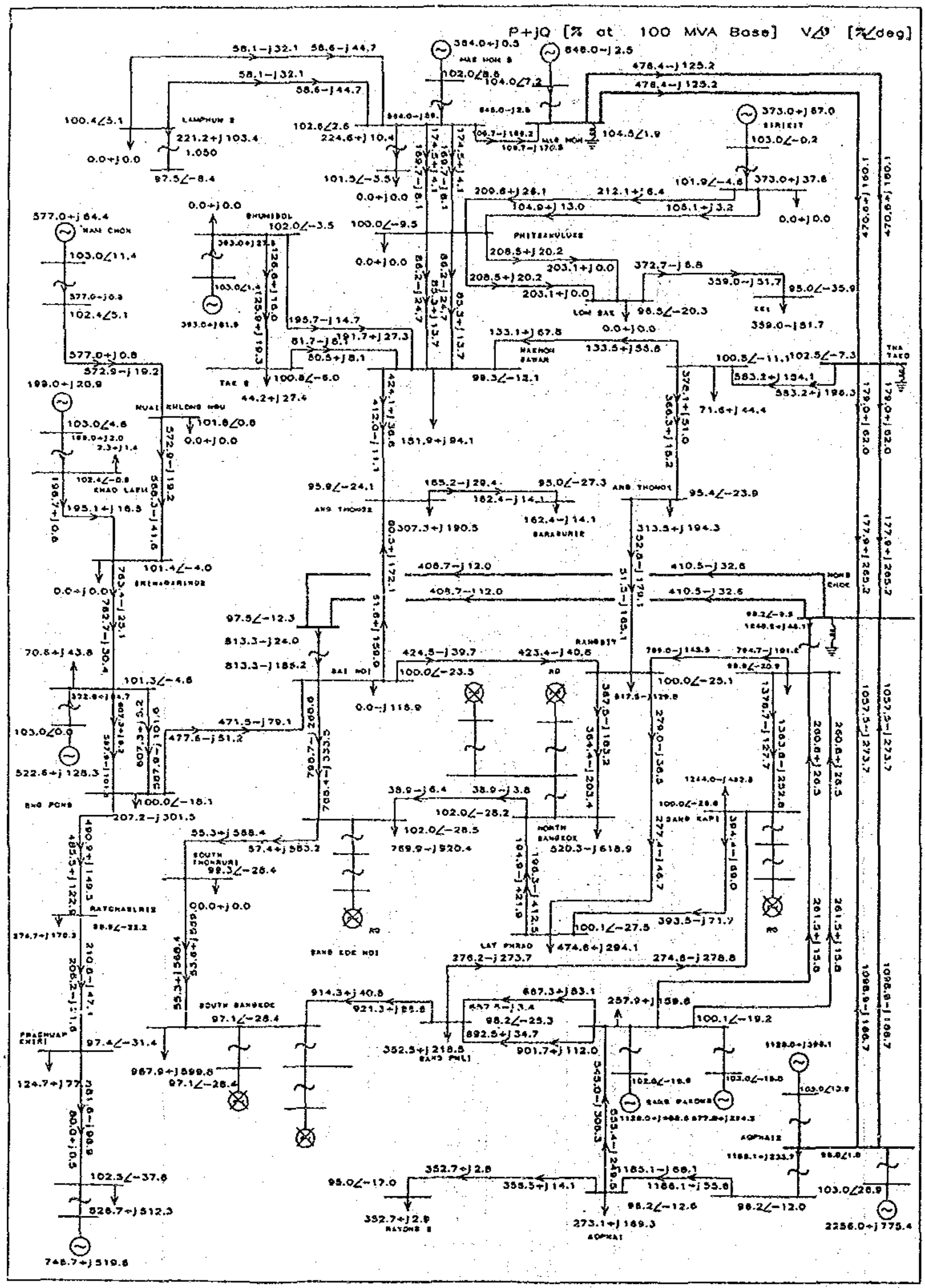


Fig. 7–5–2 Power Flow Diagram: 2–B

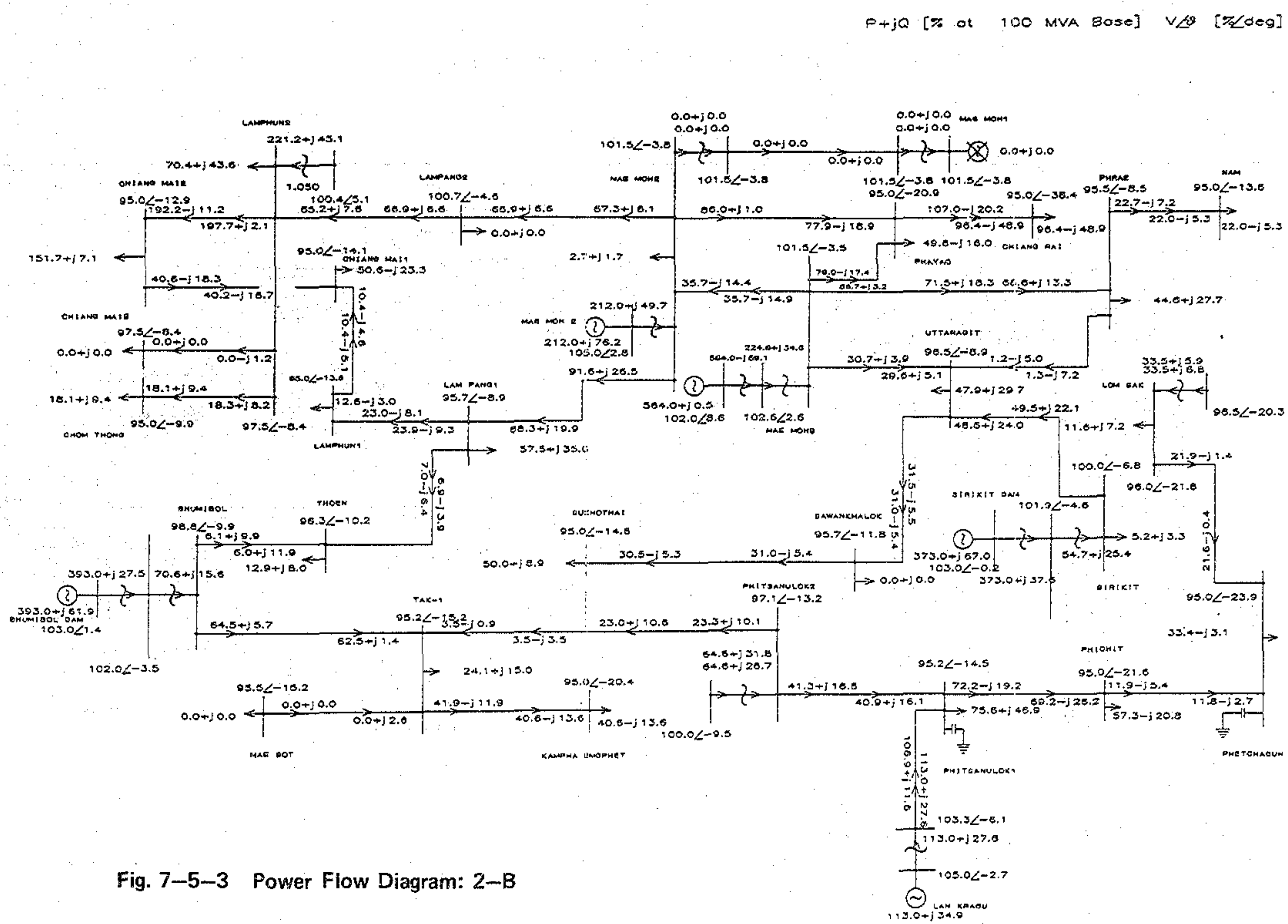


Fig. 7–5–3 Power Flow Diagram: 2–B

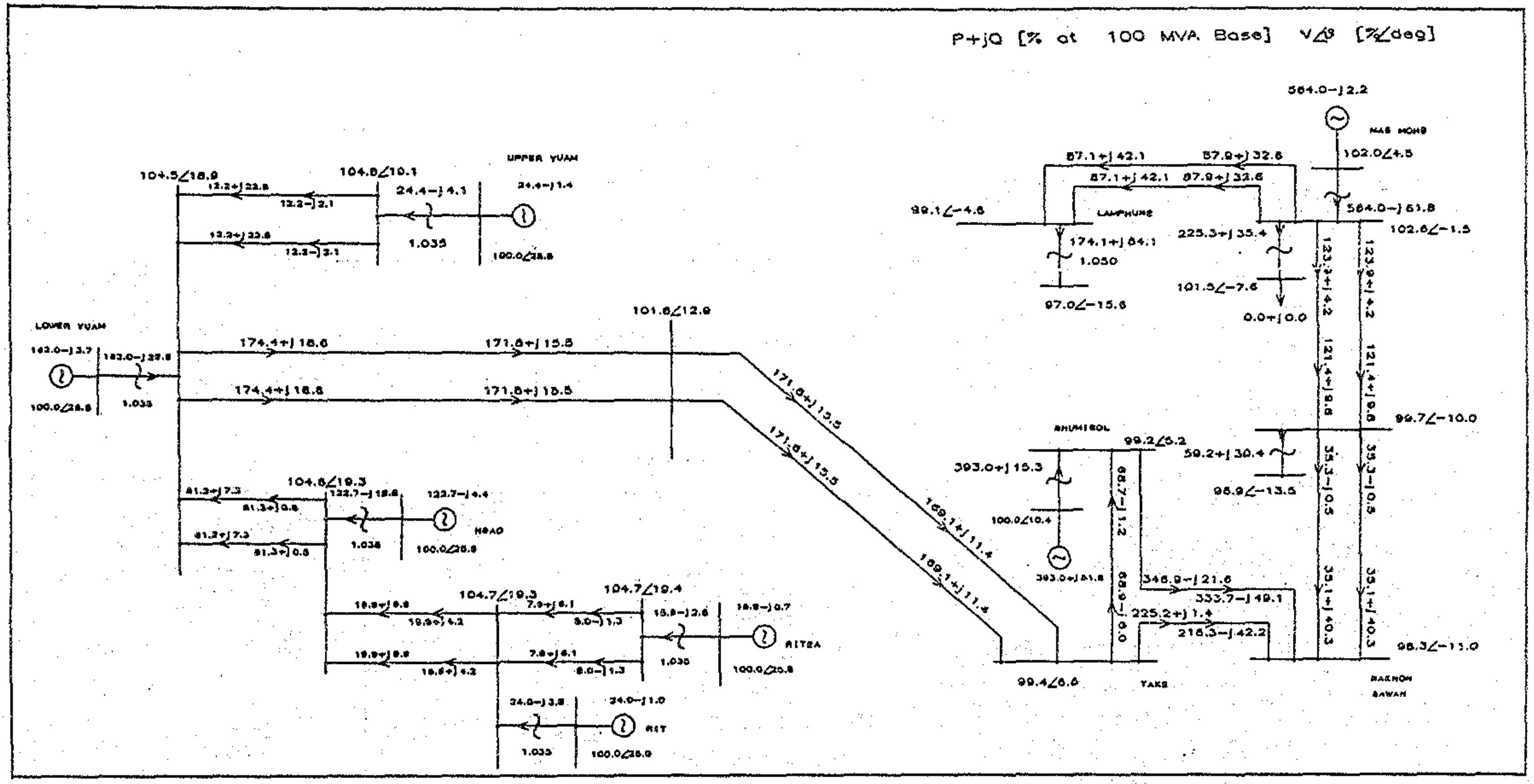


Fig. 7–5–4 Power Flow Diagram: 4–B

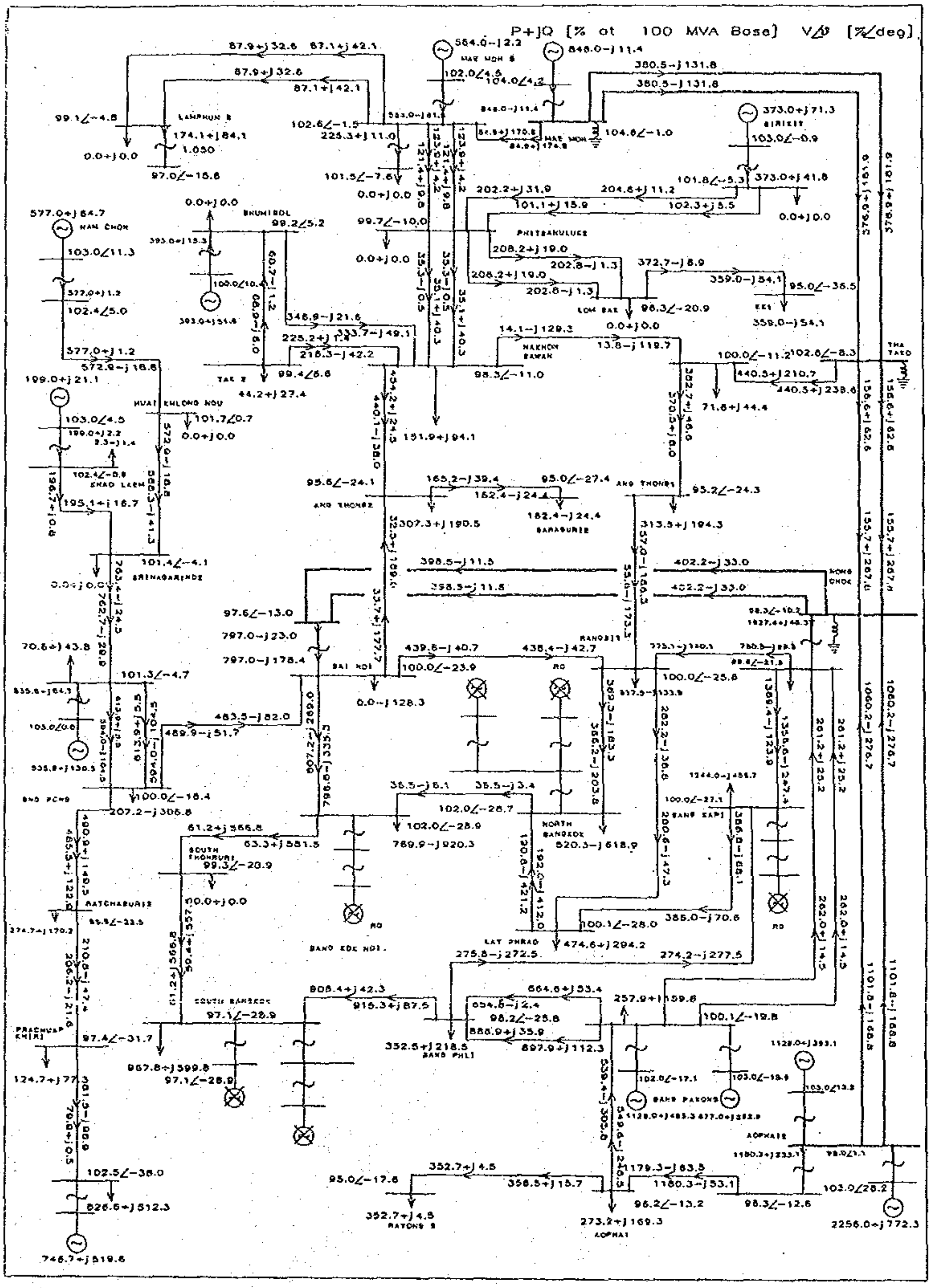


Fig. 7–5–5 Power Flow Diagram: 4–B

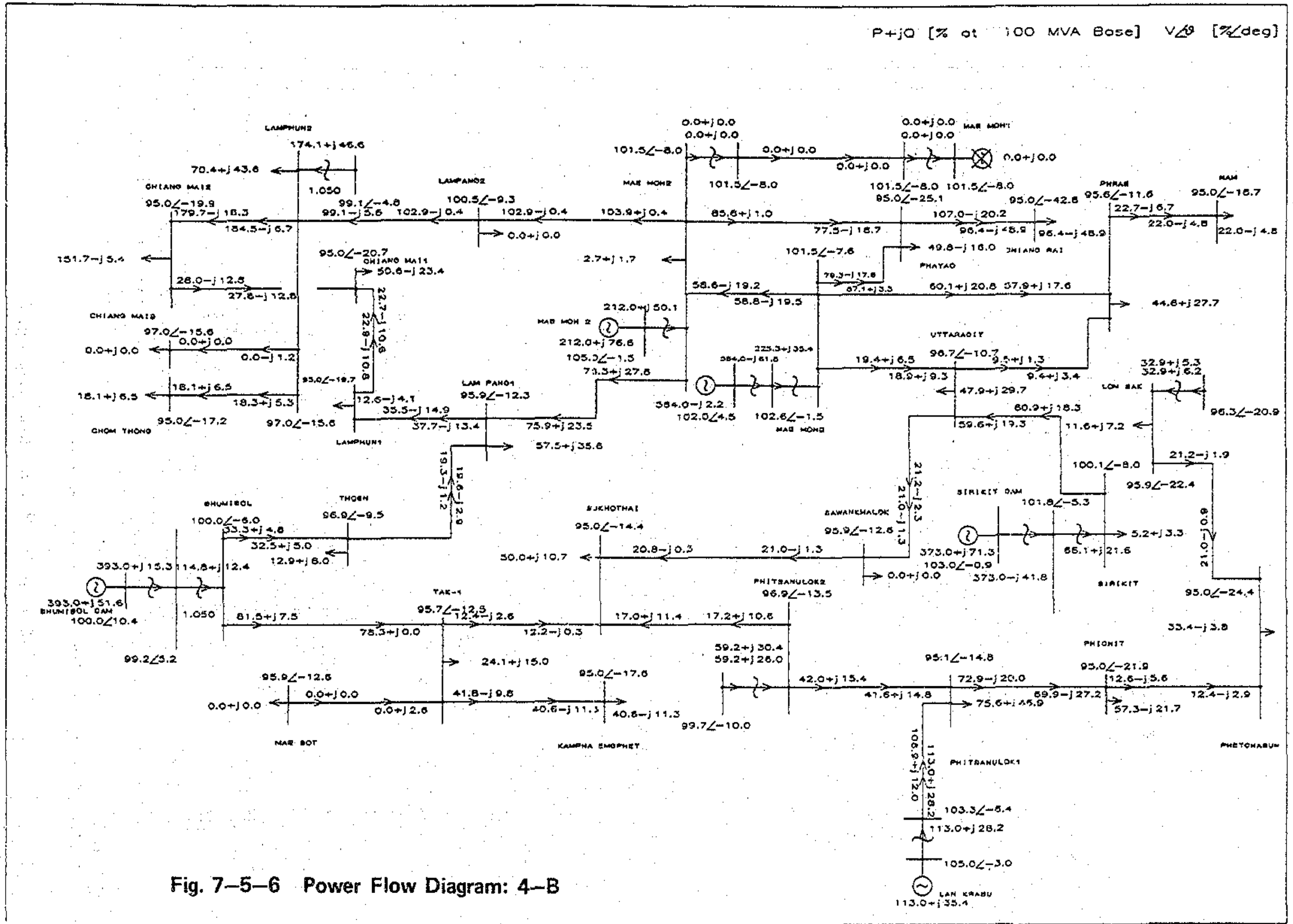


Fig. 7–5–6 Power Flow Diagram: 4–B

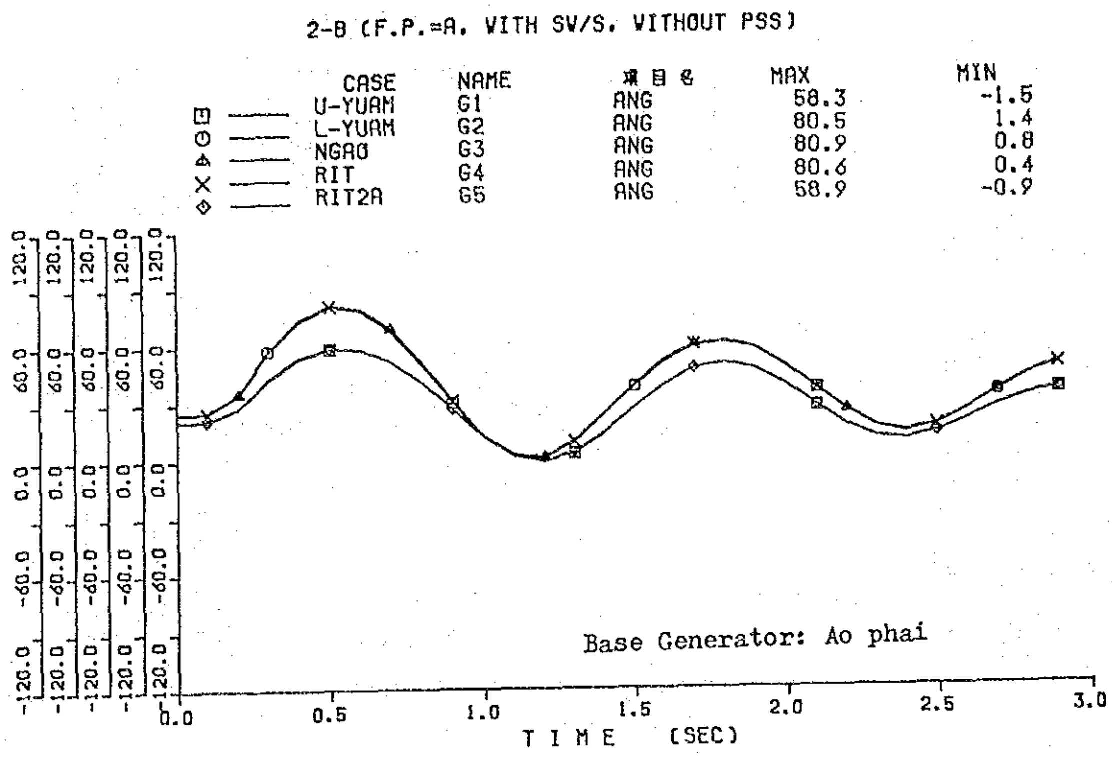


Fig. 7–6–1 Stability Analysis: 2B–1–1

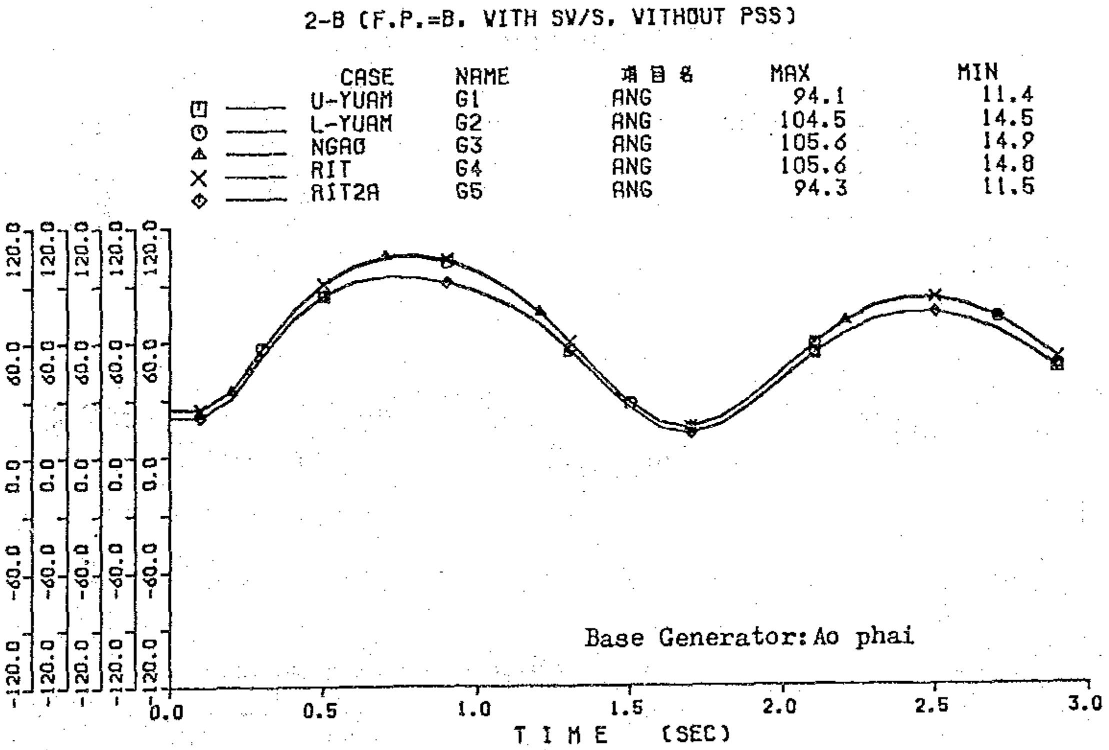


Fig. 7–6–2 Stability Analysis: 2B–1–2

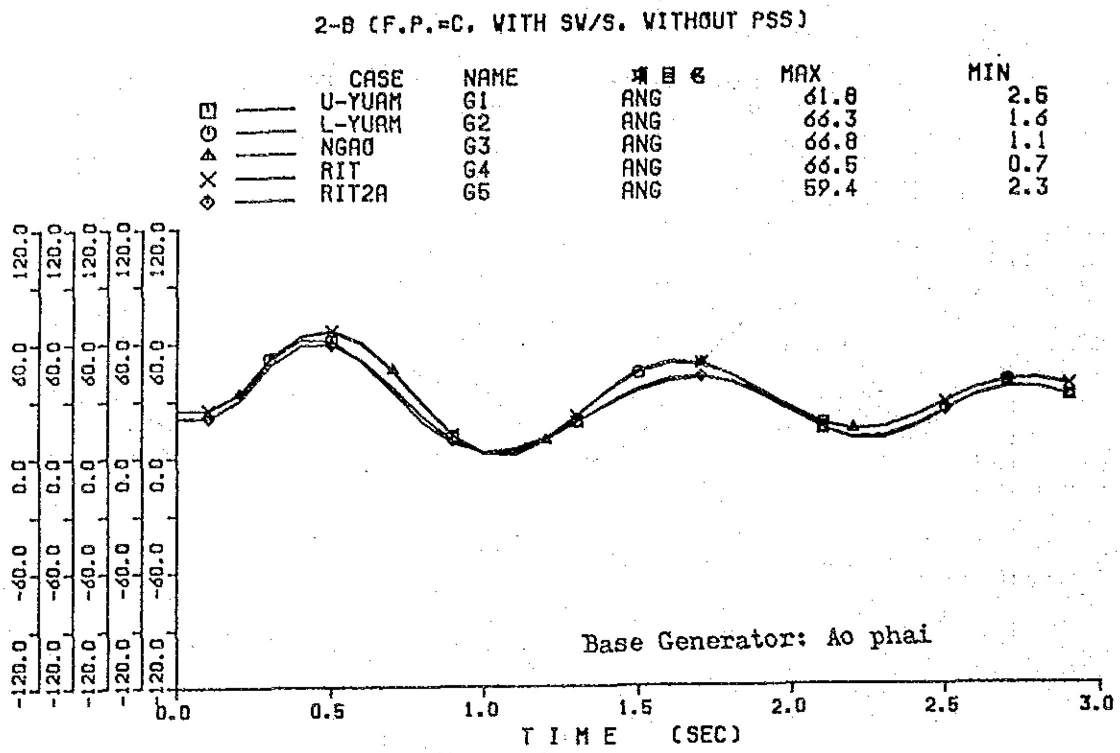


Fig. 7–6–3 Stability Analysis: 2B–1–3

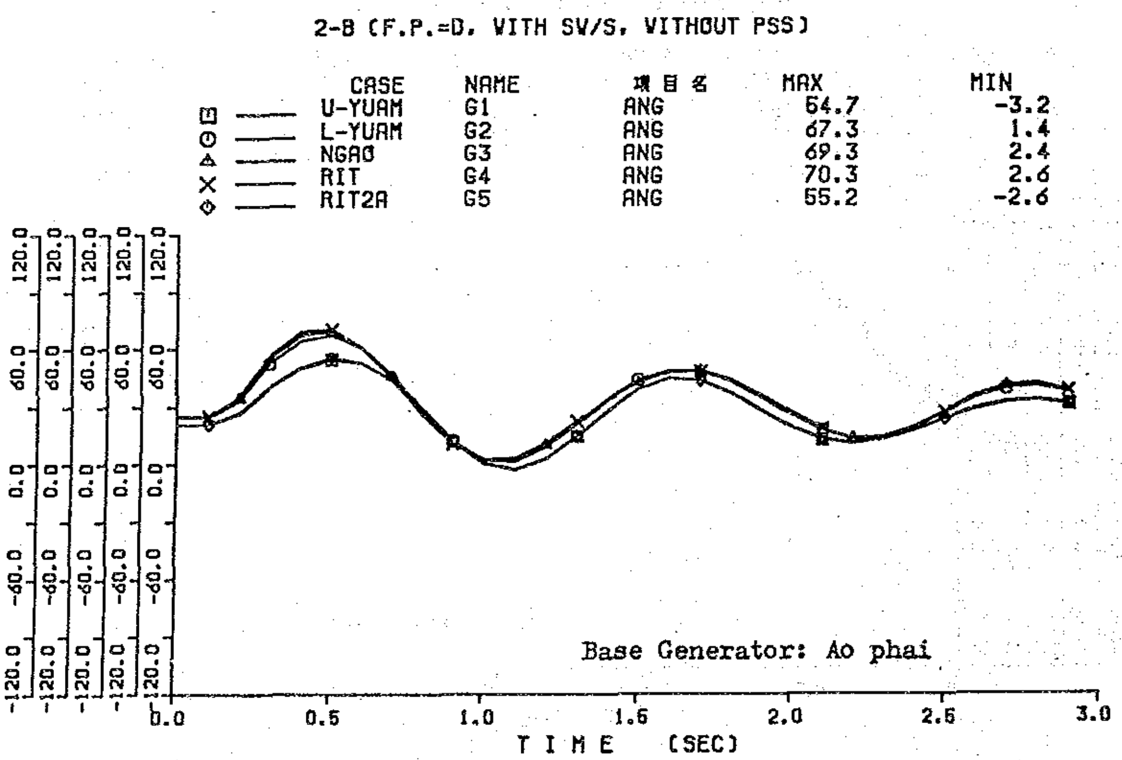


Fig. 7–6–4 Stability Analysis: 2B–1–4

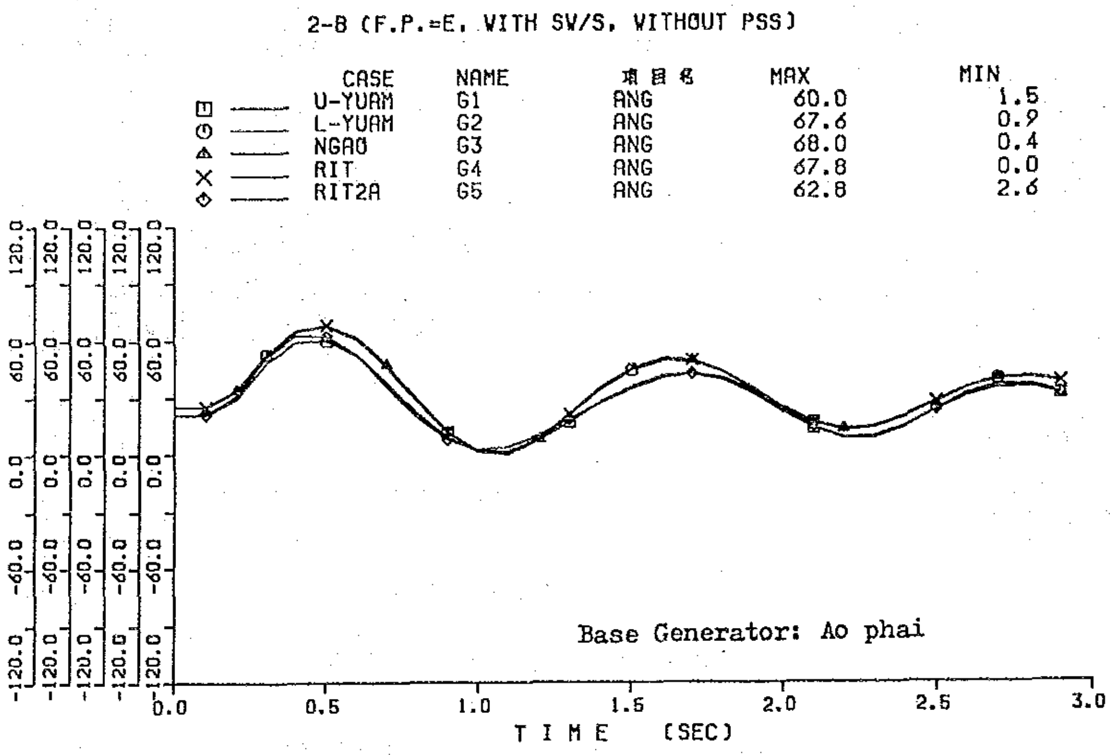


Fig. 7–6–5 Stability Analysis: 2B–1–5

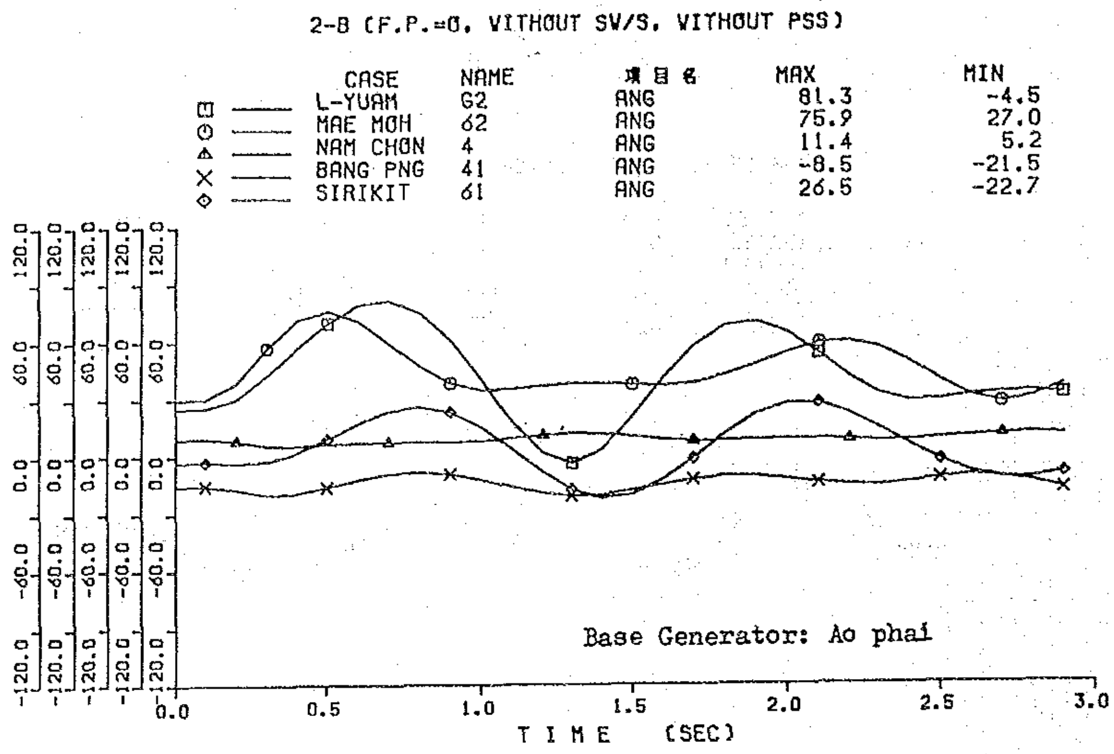


Fig. 7–6–6 Stability Analysis: 2B–4–1

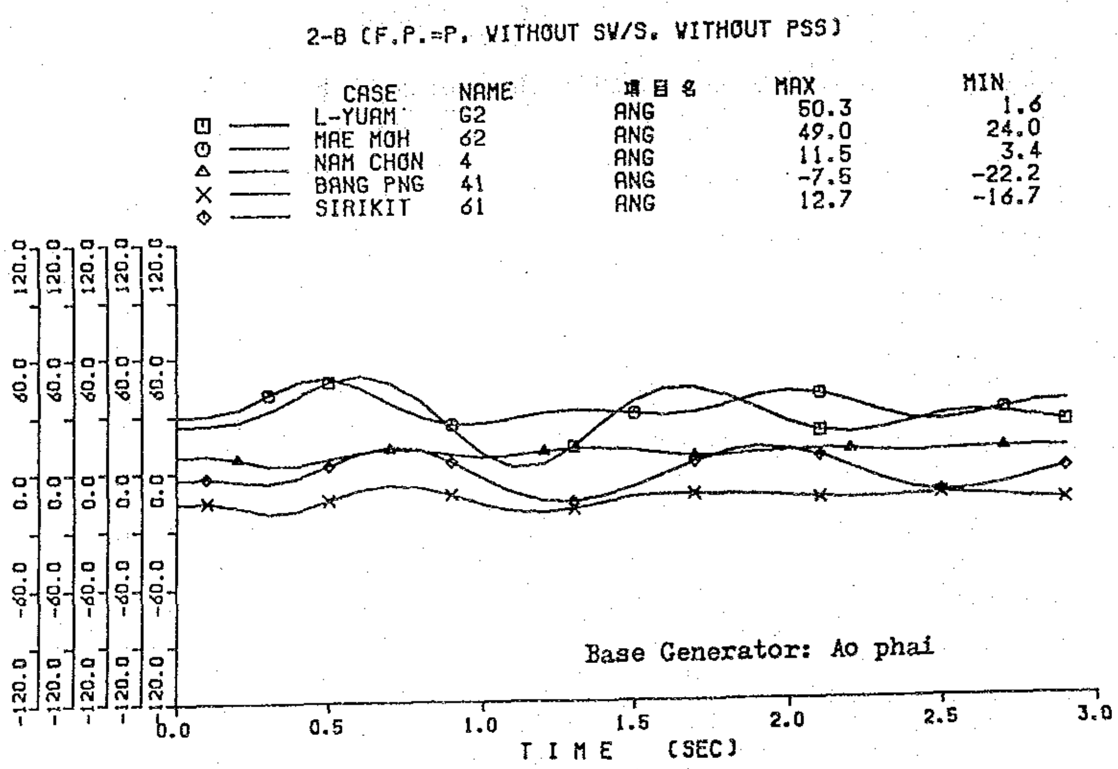


Fig. 7–6–7 Stability Analysis: 2B–4–2

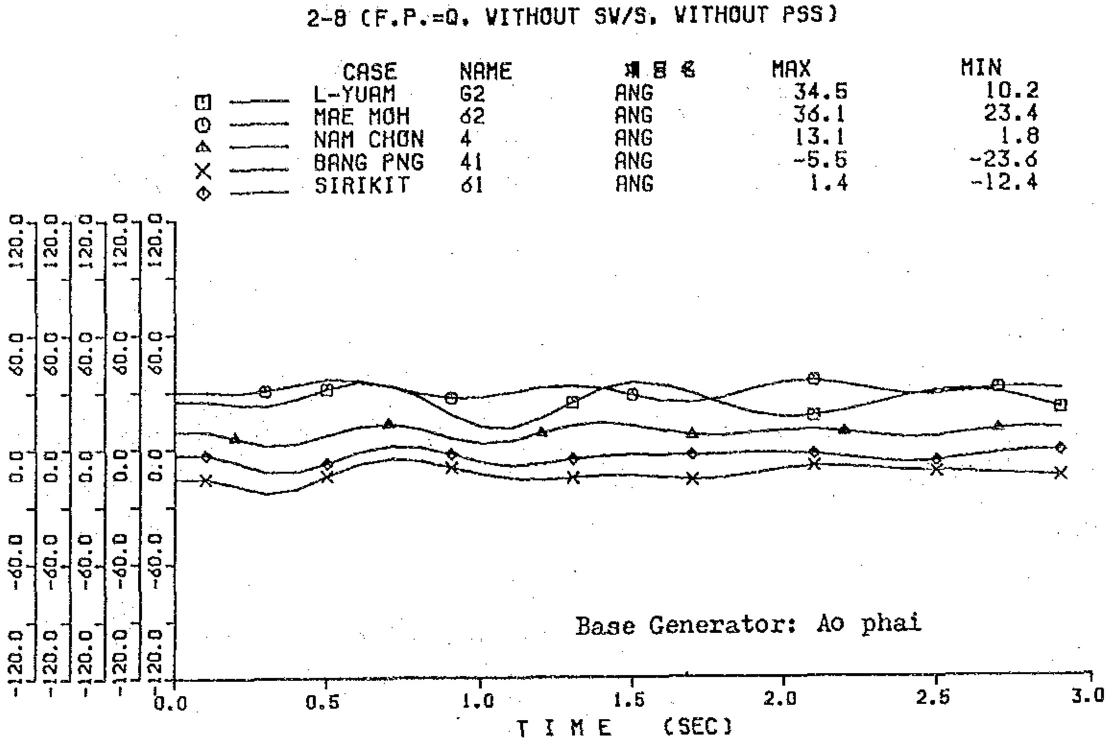


Fig. 7–6–8 Stability Analysis: 2B–4–3

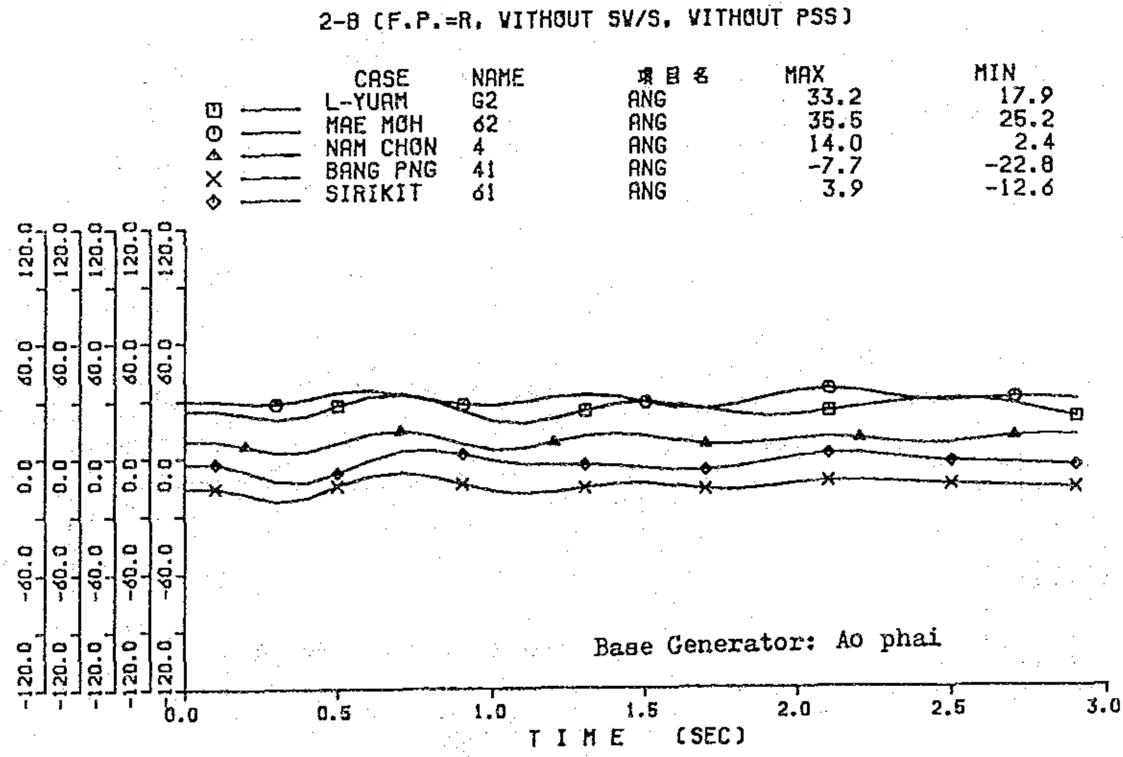


Fig. 7–6–9 Stability Analysis: 2B–4–4

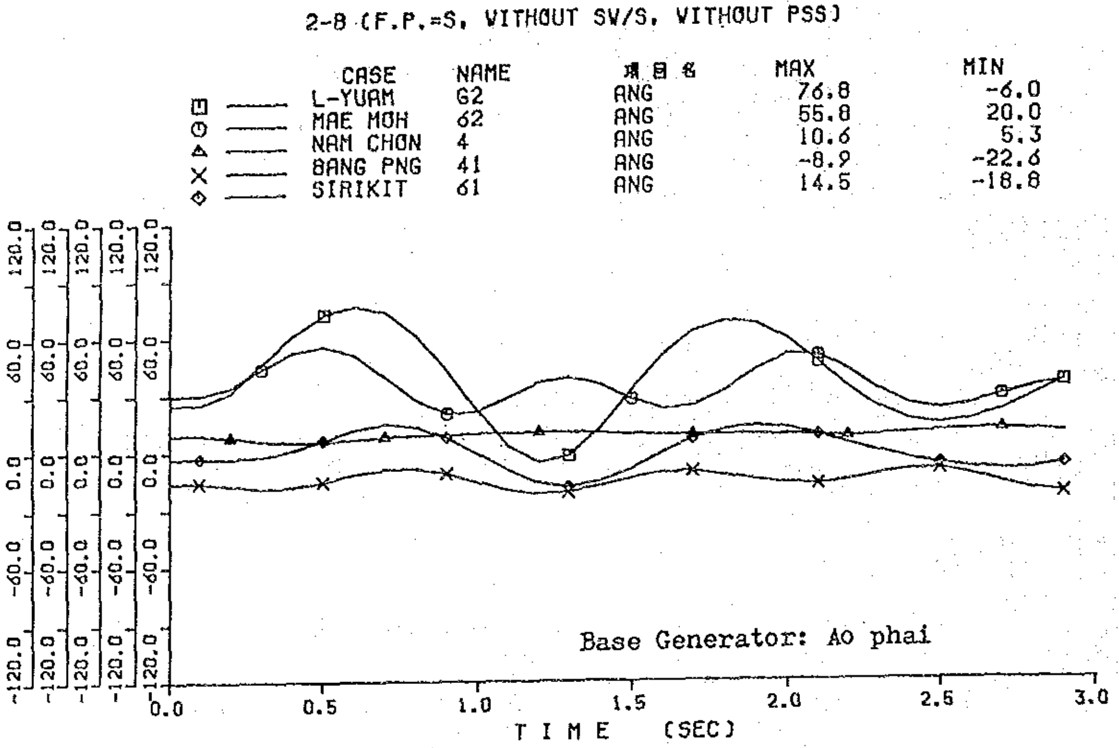


Fig. 7–6–10 Stability Analysis: 2B–4–5

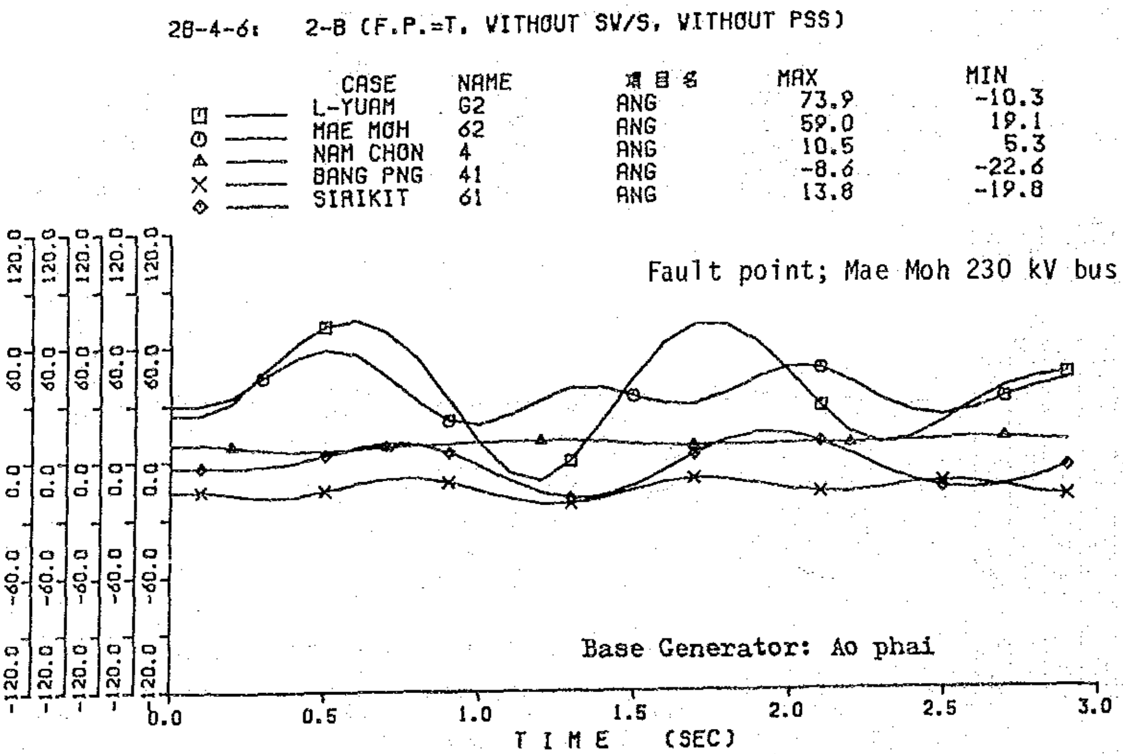


Fig. 7–6–11 Stability Analysis: 2B–4–6

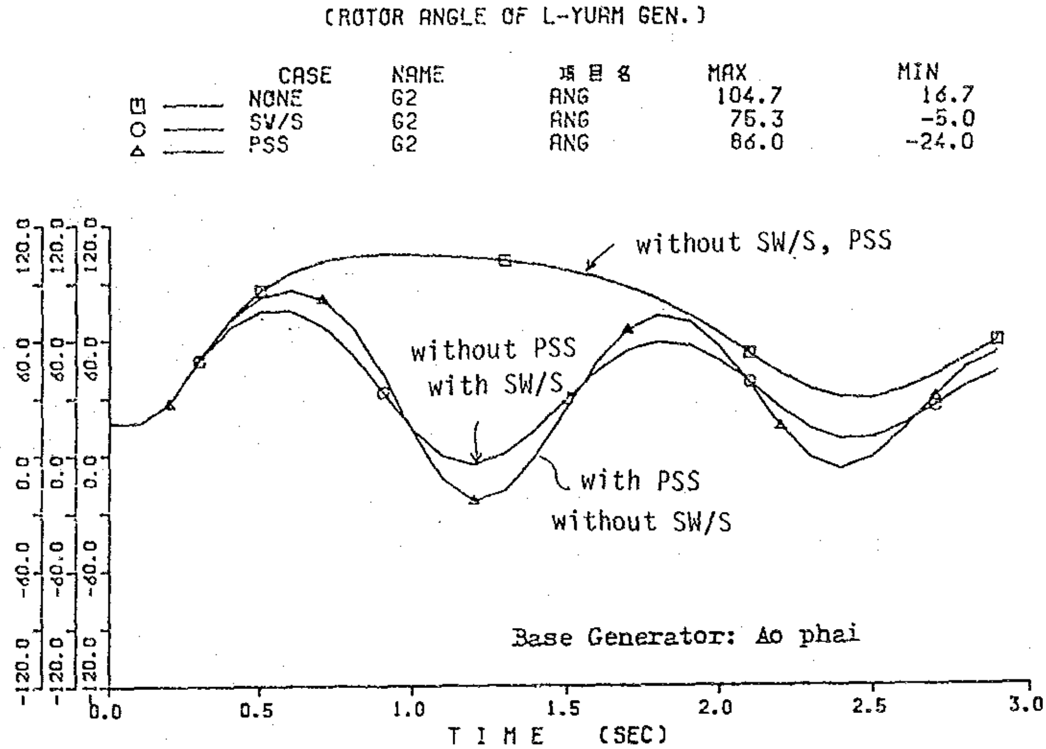


Fig. 7–6–12 Stability Analysis: Comparison 2–B–X

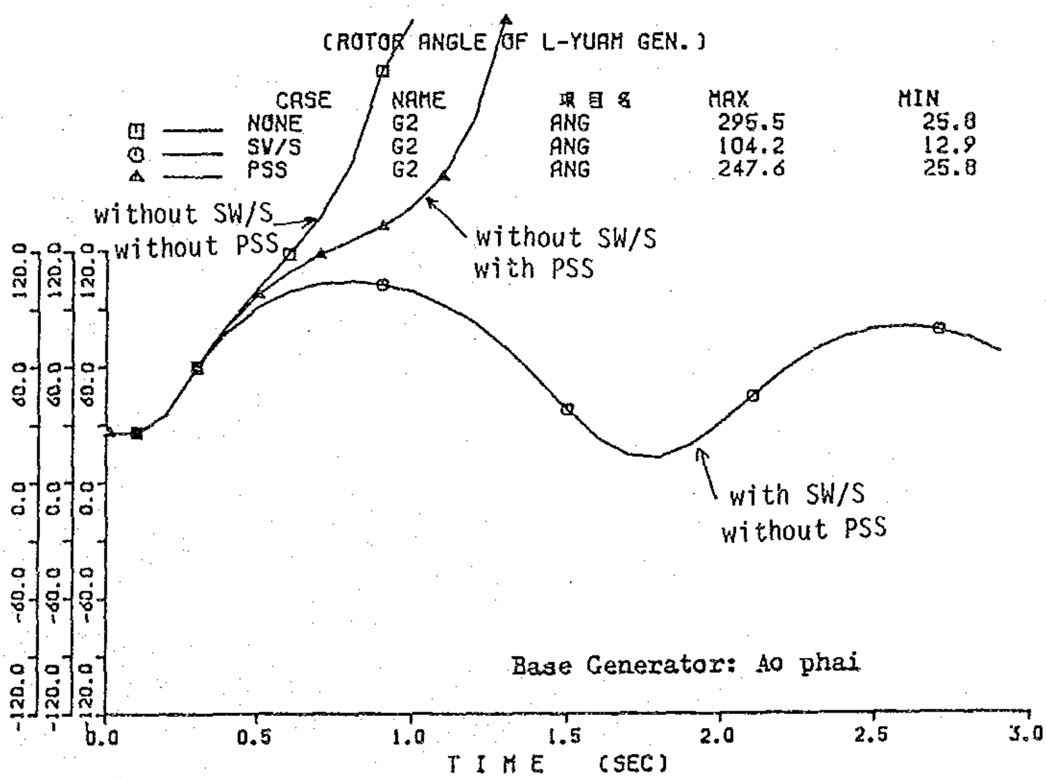
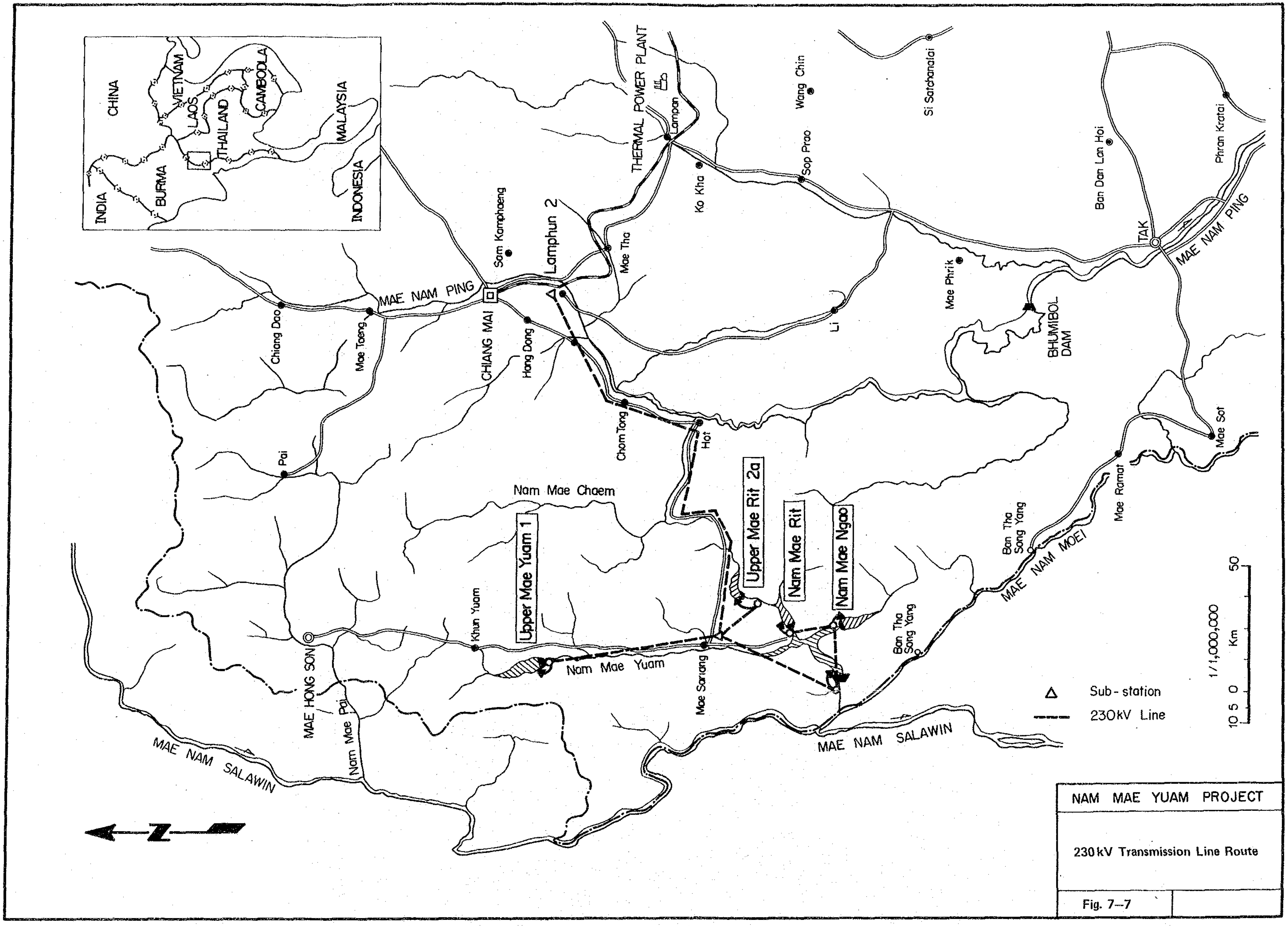


Fig. 7–6–13 Stability Analysis: Comparison 4–B



NAM MAE YUAM PROJECT

230kV Transmission Line Route

Fig. 7–7

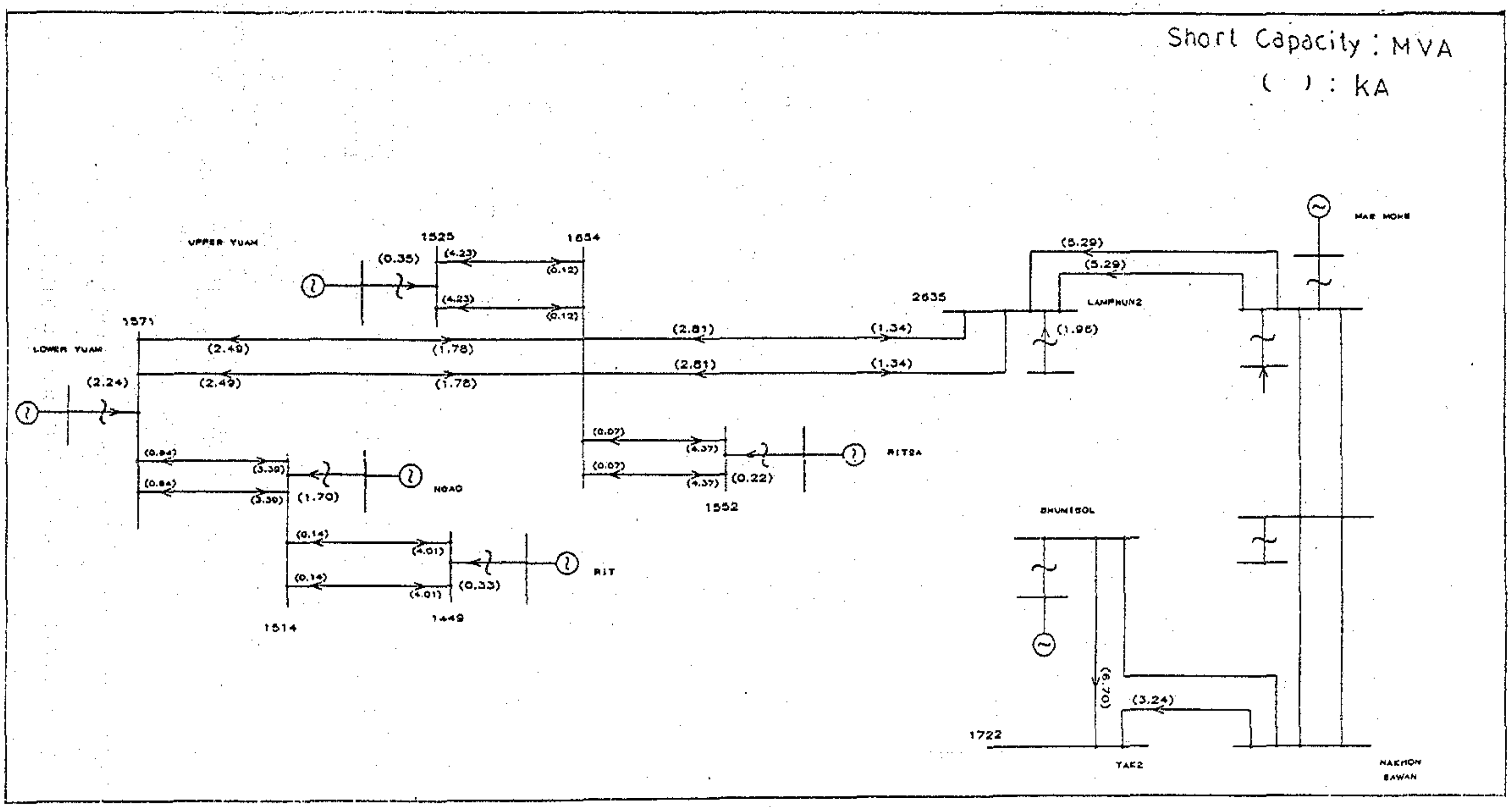


Fig. 7–8–1 Short Circuit Current: 2–B

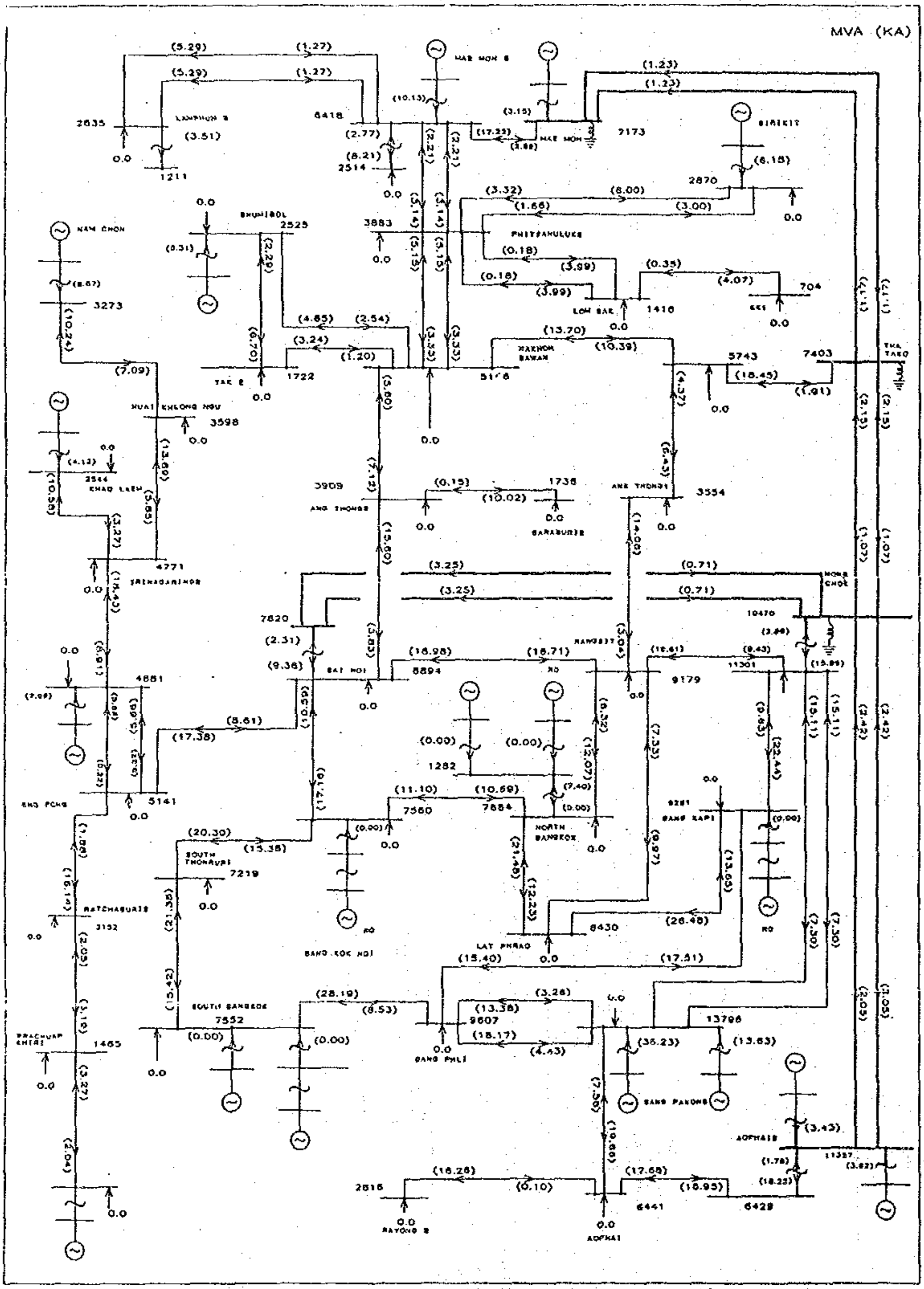


Fig. 7–8–2 Short Circuit Current: 2–B

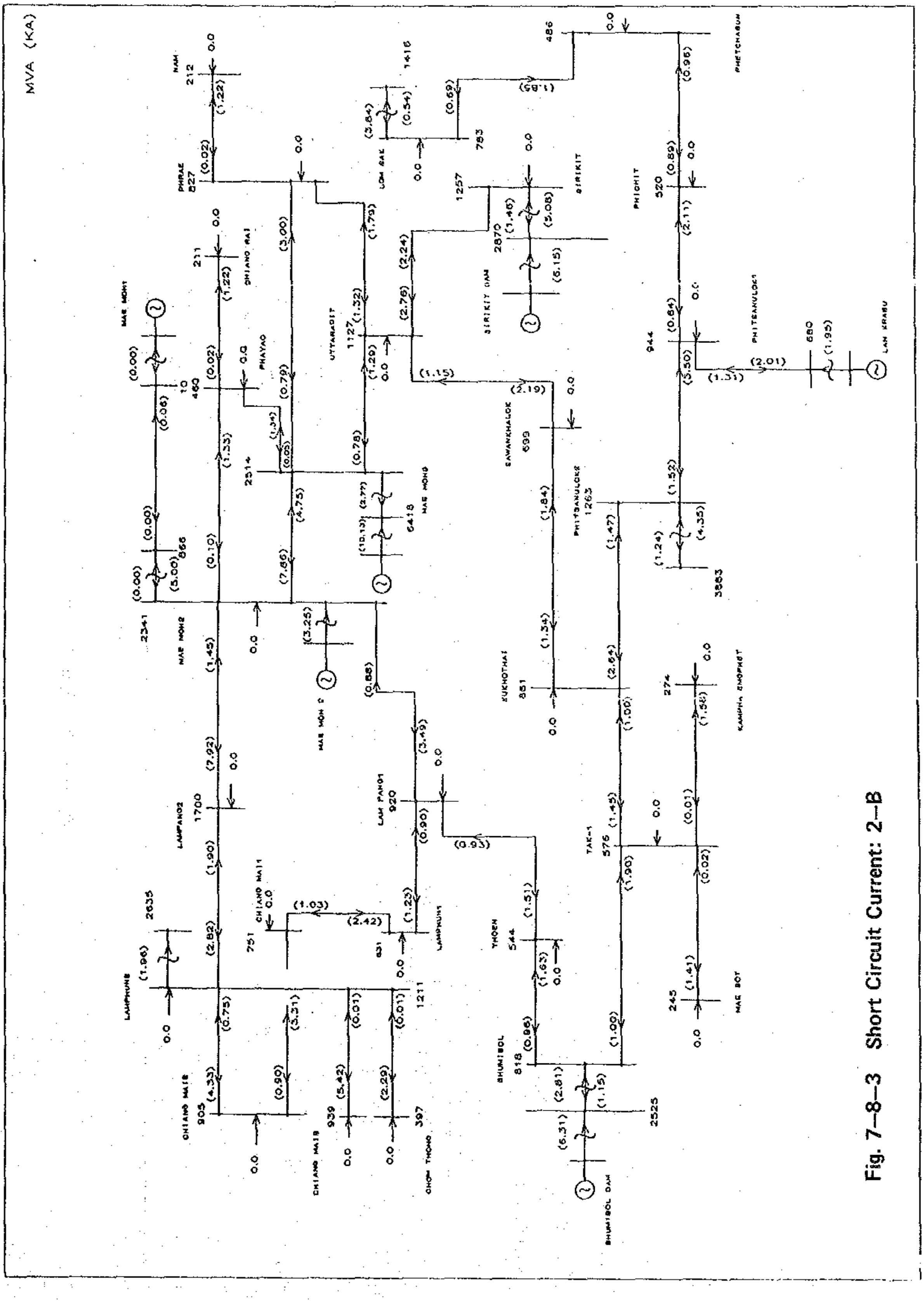


Fig. 7–8–3 Short Circuit Current: 2–B

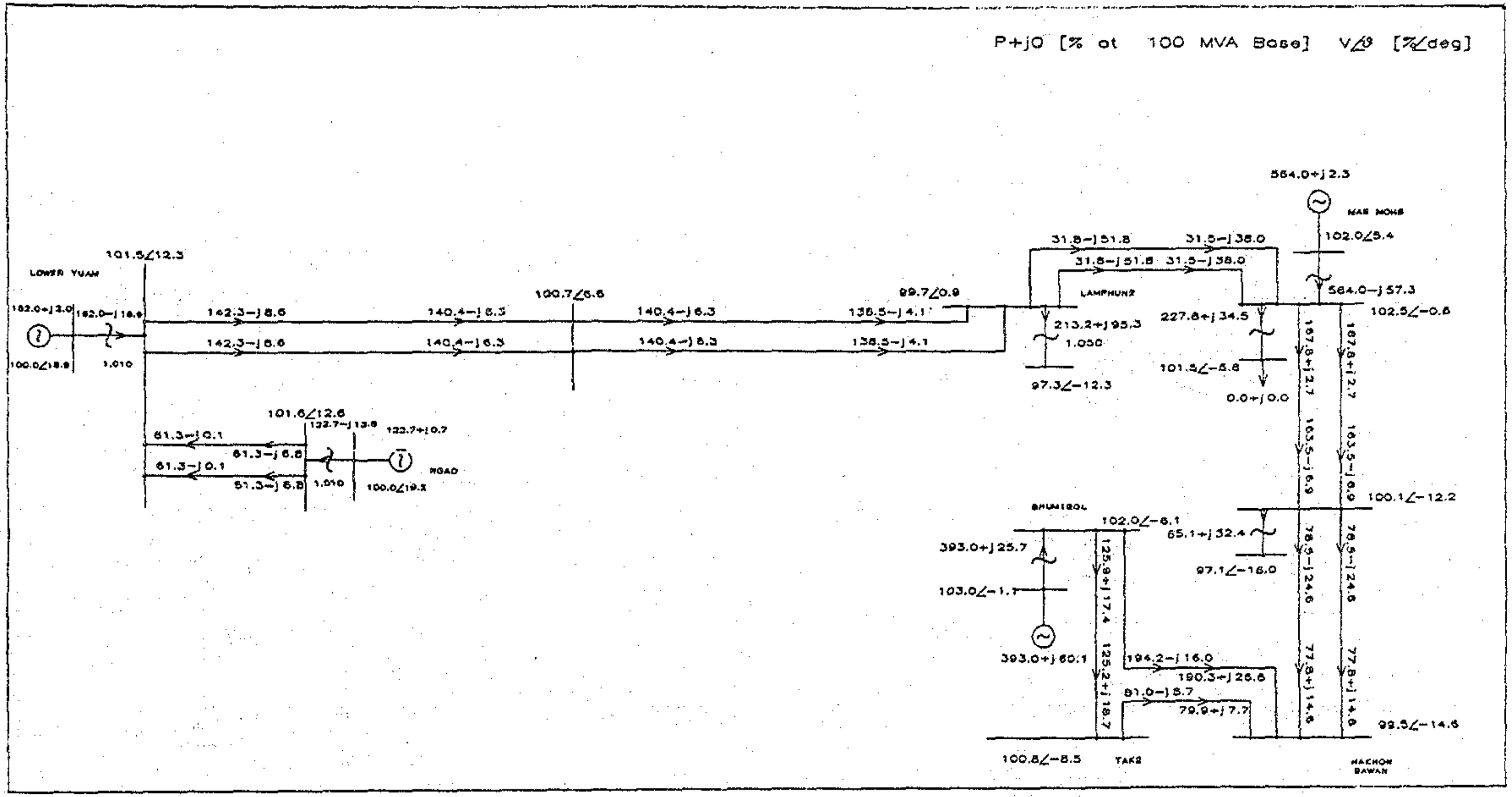


Fig. 7–9–1 Power Flow Diagram: 2–B–X

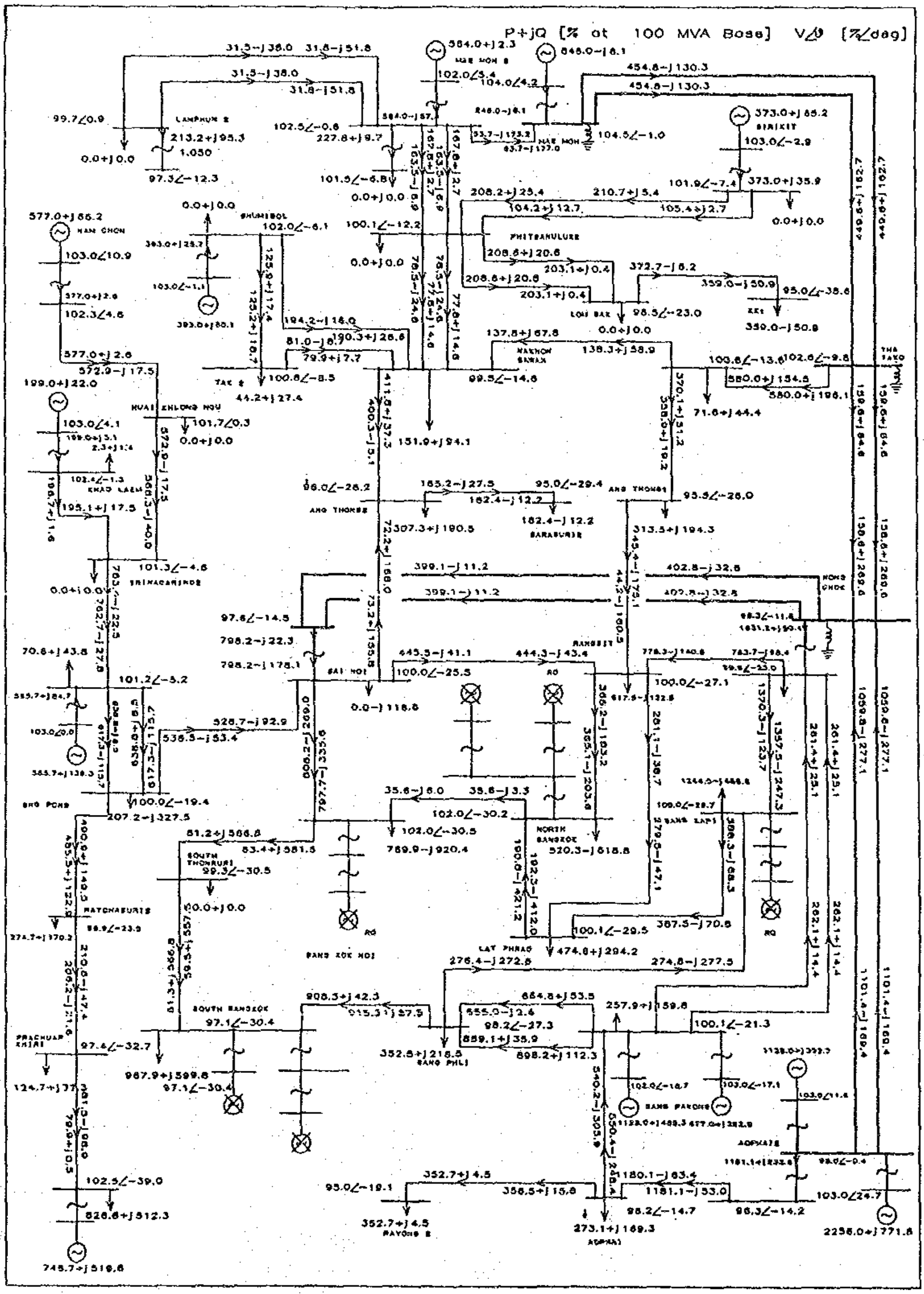


Fig. 7–9–2 Power Flow Diagram: 2–B–X

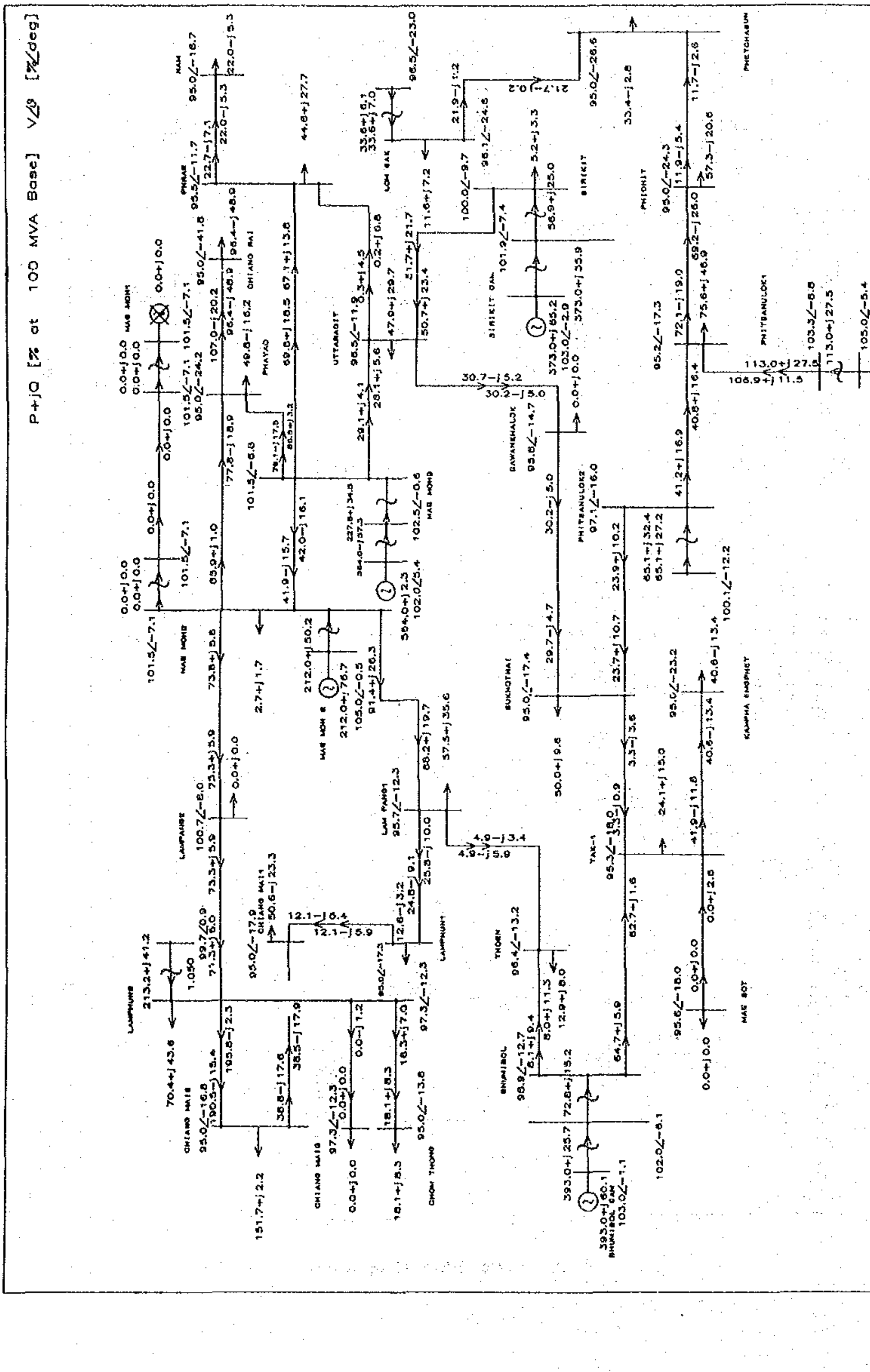


Fig. 7–9–3 Power Flow Diagram: 2–B–X

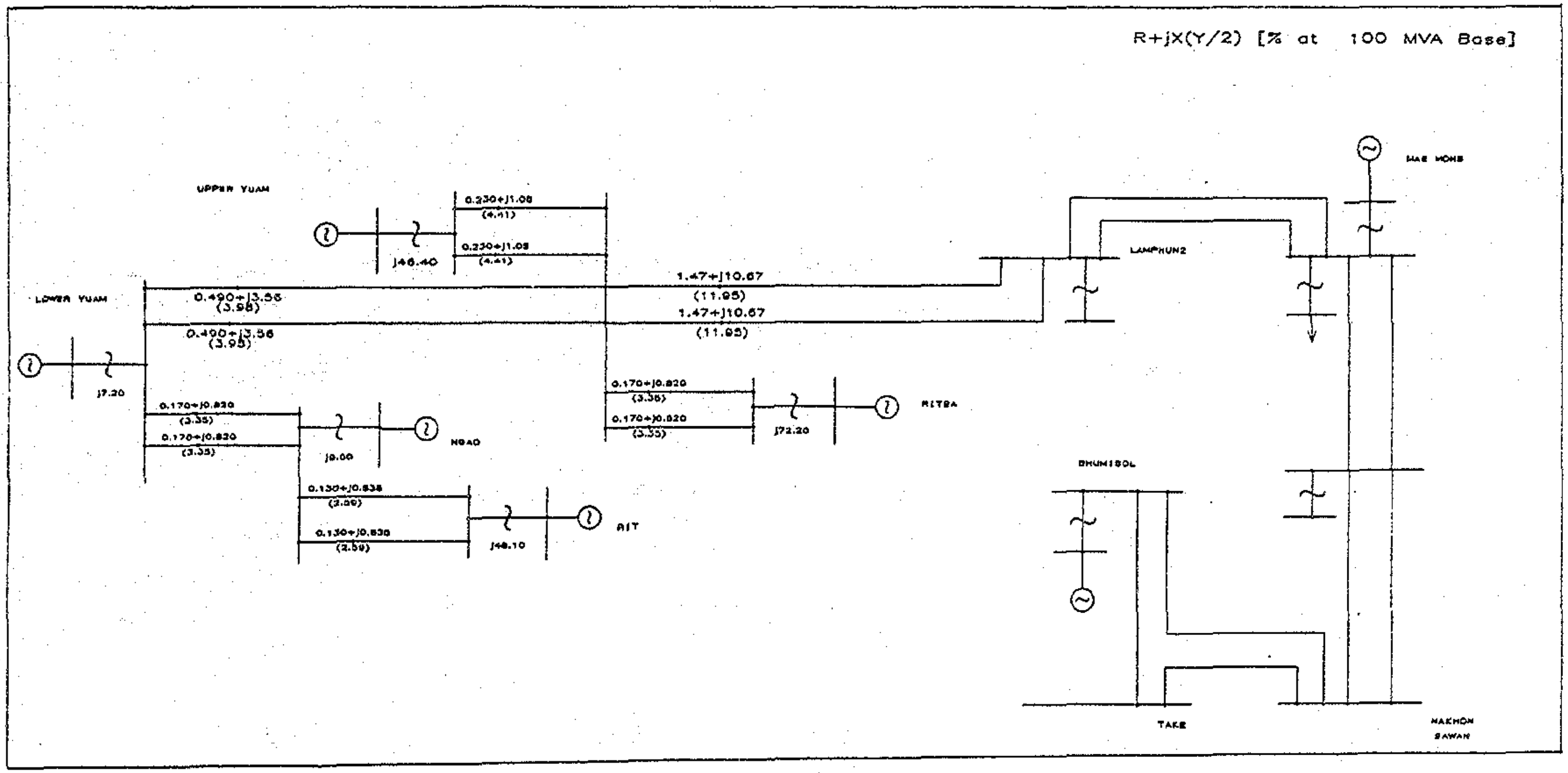


Fig. 7–10–1 Impedance Map: 2–B

R+jX(Y/2) [% at 100 MVA Base]

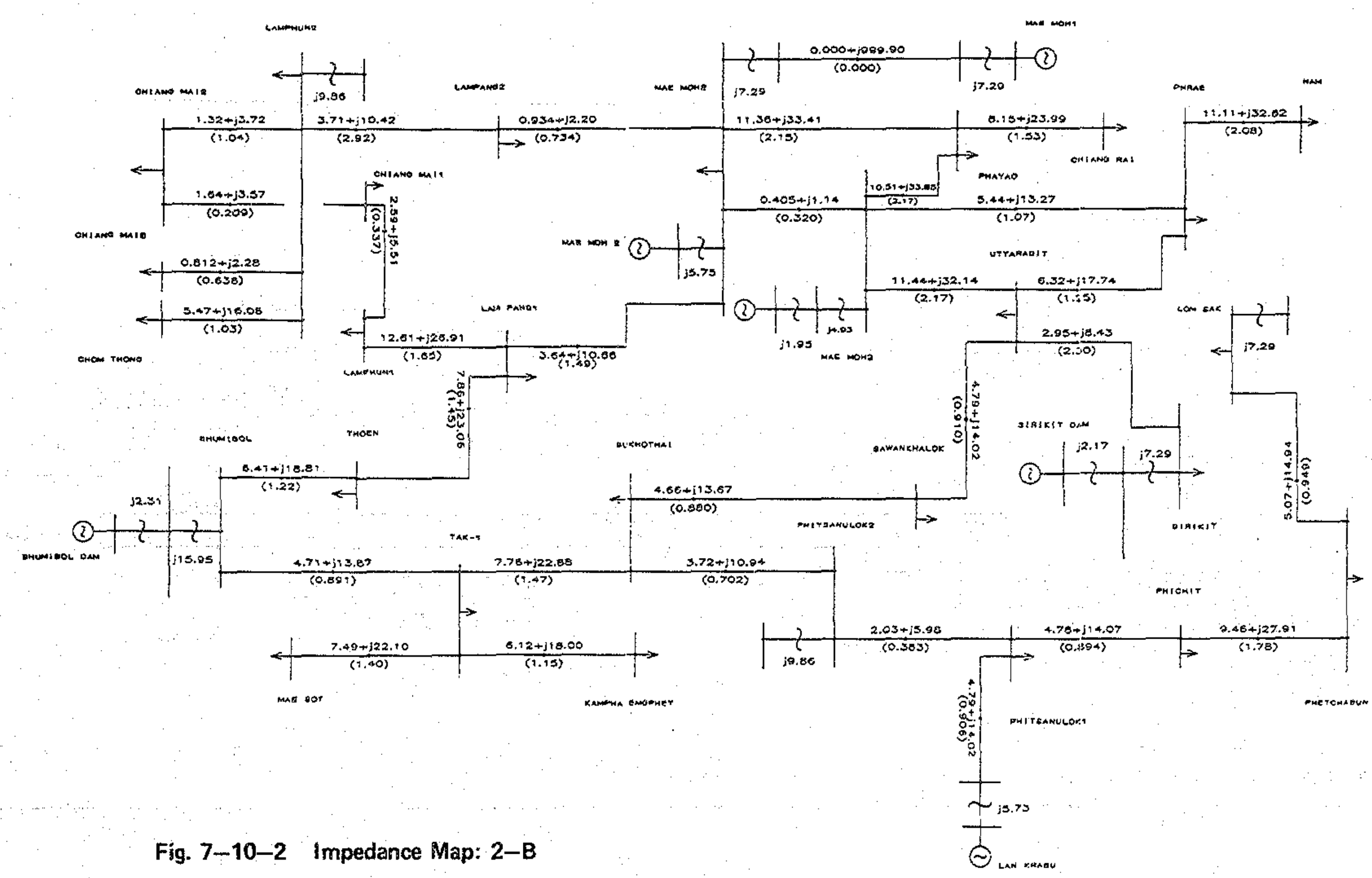


Fig. 7–10–2 Impedance Map: 2–B

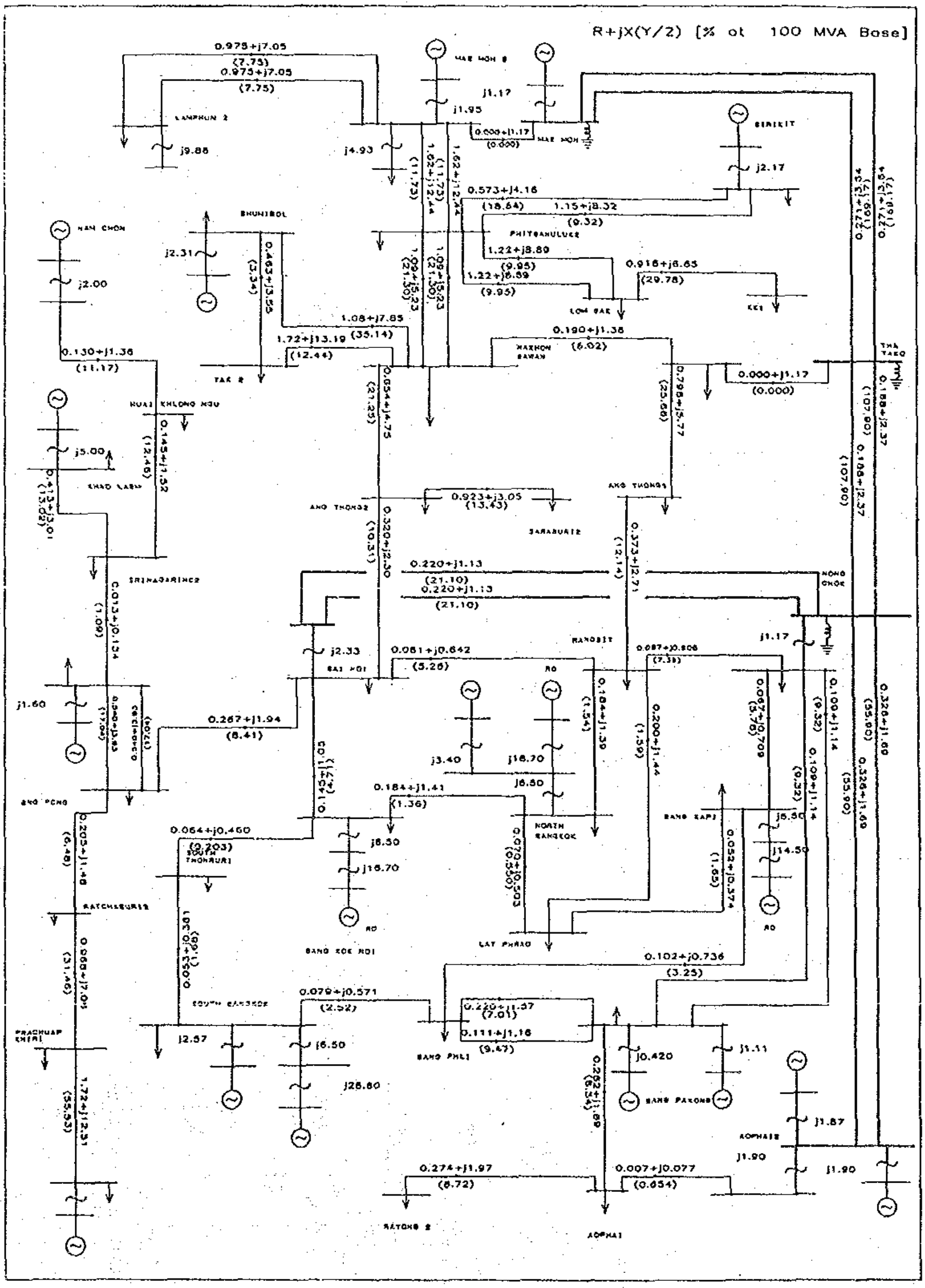


Fig. 7–10–3 Impedance Map: 2–B

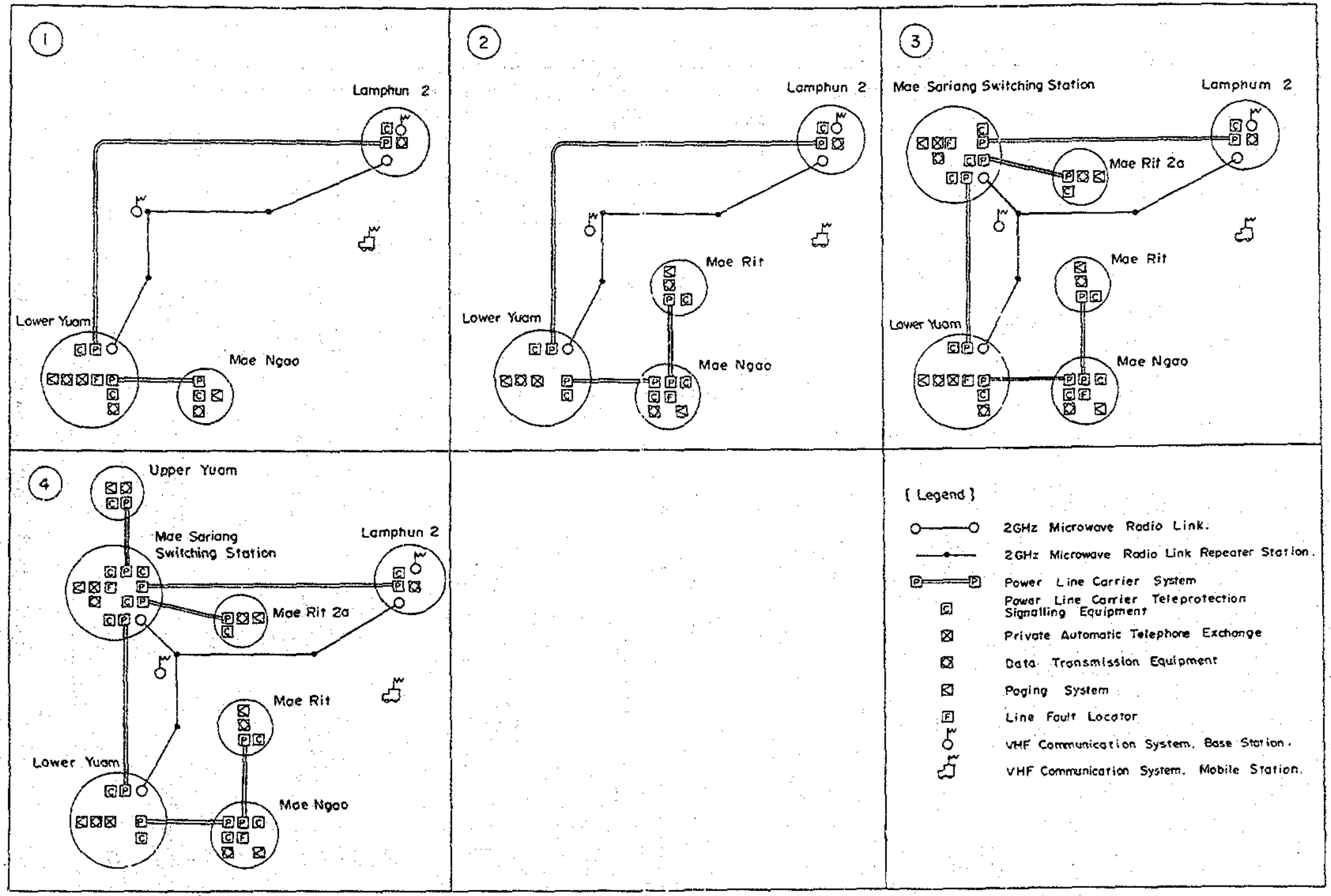
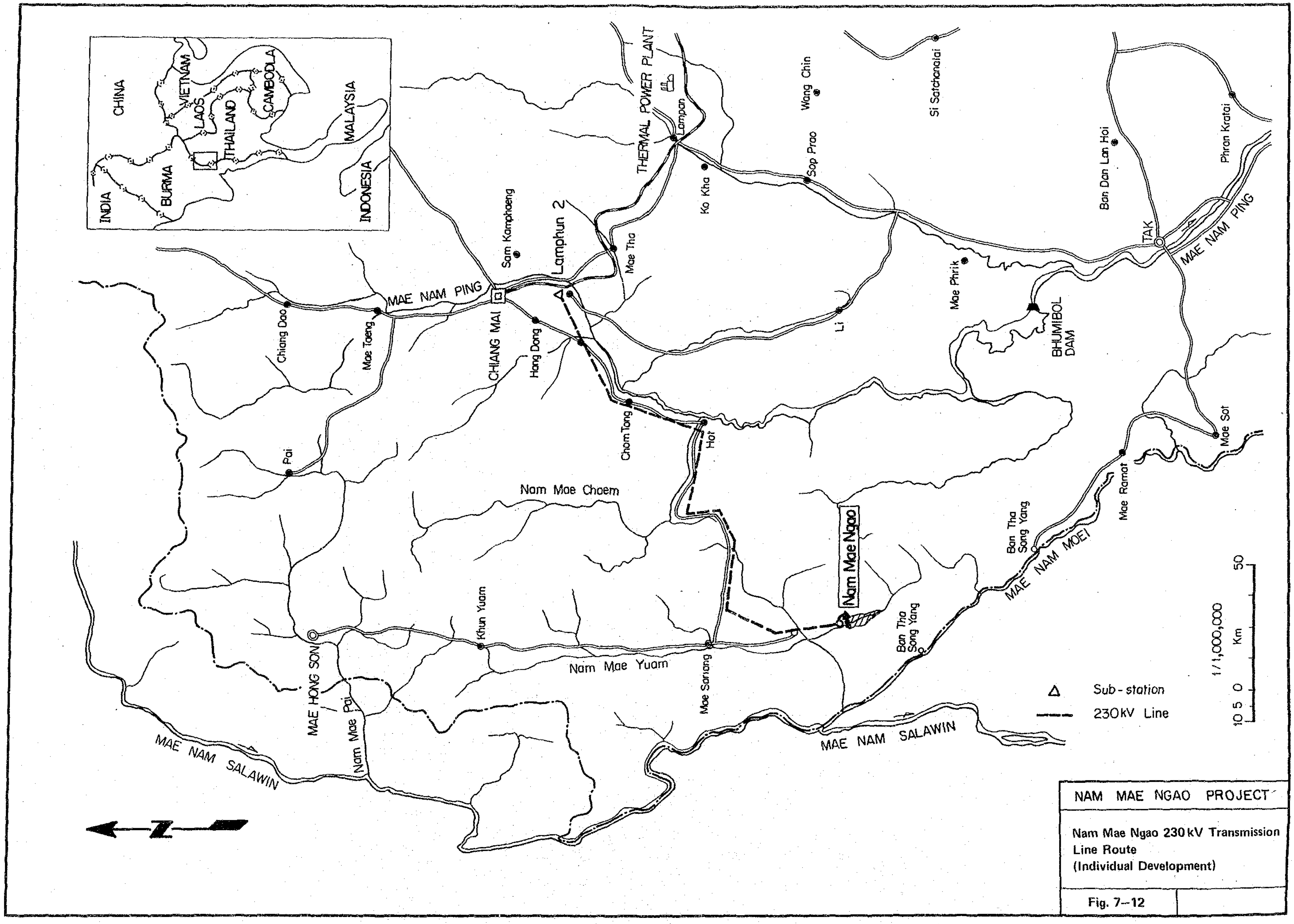


Fig. 7–11 Telecommunication System



NAM MAE NGAO PROJECT

Nam Mae Ngao 230kV Transmission Line Route (Individual Development)

Fig. 7–12

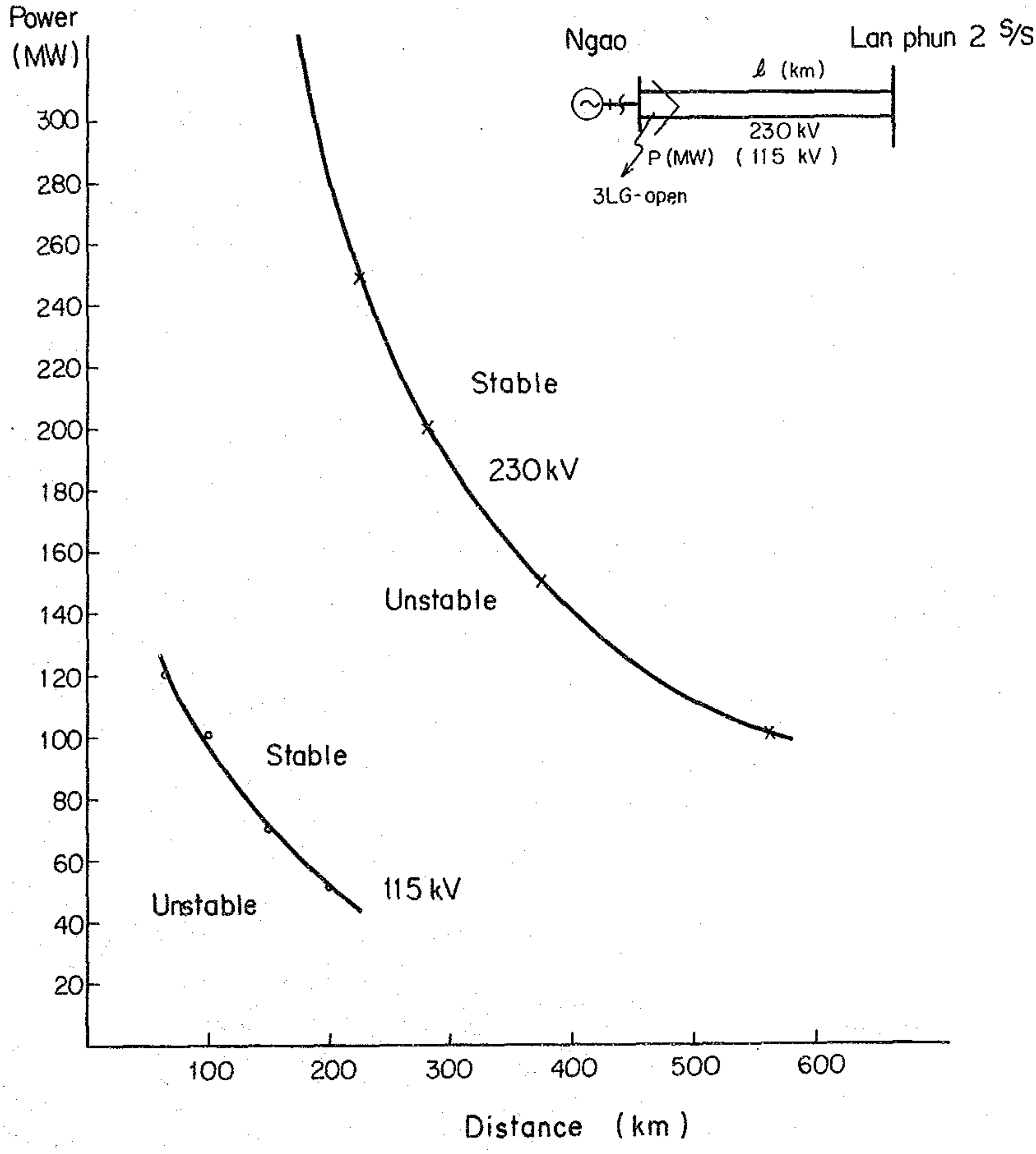


Fig. 7–13 Transient Stability Limit

CHAPTER 8. CONSTRUCTION PLANNING AND COST ESTIMATION

CHAPTER 8 CONSTRUCTION PLANNING AND COST ESTIMATION

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CHAPTER 8. CONSTRUCTION PLANNING AND COST ESTIMATION

8.1 Construction Planning

Fig. 8-1 to Fig. 8-4 show the construction schedules of each project. These were made, taking into consideration the construction scales, methods, weather conditions, etc.

The condition for carring out these schedules is that preparing roads for construction and arranging camping facilities should be completed beforehand.

The following is the outline of construction of each project.

1) Mae Mae Nago

Construction road from highway to the site has been already constructed. However, the route is to be changed in order to improve the alignment and longitudinal gradient for transportation of heavy equipment.

Diversion tunnel construction works are to be started at the beginning of the dry season, and be completed by the beginning of the dry season of the second year. After that, the river flow is diverted to the diversion tunnel. Excavation of dam foundation is to be started from the upper part, and after diverting the river flow, excavation of the river bed is to be started. Embankment of the dam is to be started from upstream cofferdam, and successively moves to the main body of the dam. About twenty eight months are estimated for the dam embankment and it is to be completed by the beginning of the dry season of the fifth year.

During this period, foundation treatment of the dam and construction of spillway are proceeded in parallel.

Immediately after the dam is completed, the installation of the outlet works is to be started and be completed by the end of the dry season of the fifth year.

Impounding of reservoir is to be started from July and water level will be raised to the NHWL by the end of September. Construction works for intake, penstock, etc. are to be started from the third year and be carried out in parallel. As for the construction of power station, after the installation of overhead crane, the installation works of turbine and generator are to be started and completed within about one year and a half. After various tests which are to be performed while reservoir impounding, the operation of power plants can be in service by the end of October of the last year.

It is planned that the construction works of power transmission lines and switchyard are to be carried out during the installation works of turbine and generator and completed before the various tests for the commencement of operation.

2) Nam Mae Rit

Though the access road from highway to the site has been constructed already, the route is to be changed in order to improve the alignment and longitudinal gradient for transportation of heavy equipments.

Diversion tunnel construction works are to be started at the beginning of the dry season, and be completed by the beginning of the dry season of the second year. After that, the river flow is diverted to the diversion tunnel. Excavation of dam foundation is to be started from the upper part, and after diverting the river flow, excavation of the river bed is to be started. The embankment of dam is to be started from upstream cofferdam, and successively moves to the main body of the dam. About two years are estimated for dam embankment, and it is to be completed by the beginning of the dry season of the fourth year.

Immediately after the dam is completed, the installation of the outlet works is to be started and be completed by the end of the dry season of the fifth year.

Impounding of reservoir is to be started from April, and water level will be raised to the NHWL by the end of July. Construction works for spillway are to be started from the first year and be completed at the same time of the dam completion. Construction works for intake, penstock, etc. are started from the second year and be carried out in parallel. As for the construction of power station, after the installation of overhead crane, the installation works of turbine and generator are to be started and be completed within about one year and a half. After the various tests which are to be performed while reservoir impounding, the operation of power plants can be in service by the end of July of the last year.

It is planned that the construction works of power transmission lines and switchyard are to be carried out during the installation works of turbine and generator and completed before the various tests for the commencement of operation.

3) Upper Mae Yuam 1

Existing road from highway to Ban Wan Khan is to be improved for construction and new construction road is to be constructed from Ban Wan Khan to the site.

Diversion tunnel construction works are to be started at the beginning of the dry season of the first year, and be completed by the beginning of the dry season of the second year. After that, the river flow is diverted to the diversion tunnels and construction of cofferdam is to be immediately started.

Excavation of dam foundation is to be started from upper parts, and after diverting the river flow, excavation of river bed is to be started.

Embankment of the dam is to be started from upstream cofferdam, and successively moves to the main body of the dam. About two years are estimated for dam embankment, and it is to be completed by January of fifth year.

Immediately after the dam completed, the installation of outlet works is to be started and be completed by the end of dry season of the fifth year.

Impounding of reservoir is to be started from June, and water level will be raised to NHWL by the end of September.

Construction works for spillway, powerhouse, tailrace, etc. are to be started from the second year and are to be carried out in parallel. As for the construction of power station, after installation of overhead crane, the installation works of turbine and generator are to be started and be completed within about one year and a half.

After various tests which are to be performed while reservoir impounding, the operation of power plants can be in service in the middle of October of the fifth year.

It is planned that the construction works of power transmission lines and switchyard are to be carried out during the installation works of turbine and generator and completed before the various tests for the commencement of operation.

4) Upper Mae Rit 2a

Judging from 1:50,000 map, two new-construction roads to the site are to be constructed from Ban Mae Chang. One is for approaching to dam site and the other is to power station site.

As this project has a long headrace tunnel, the construction works of headrace tunnel will governs the entire construction schedule of this project. The construction of headrace tunnel is to be started from both portals of upstream and downstream at the dry season of the first year.

The construction of the upstream portal of headrace tunnel is to be started after excavation of intake portion.

Three and a half years are estimated for headrace tunnel construction.

Construction works for dam, surge tank, penstock, power station, tailrace, etc. are to be carried out in parallel with the headrace construction works.

After the various tests which are to performed while reservoir impounding, the operation of powr plants can be in service by the end of April of the last year.

It is planned that the construction works of power transmission lines and switchyard are to be carried out during the installation works of turbine and generator and be completed before the various tests for the commencement of operation.

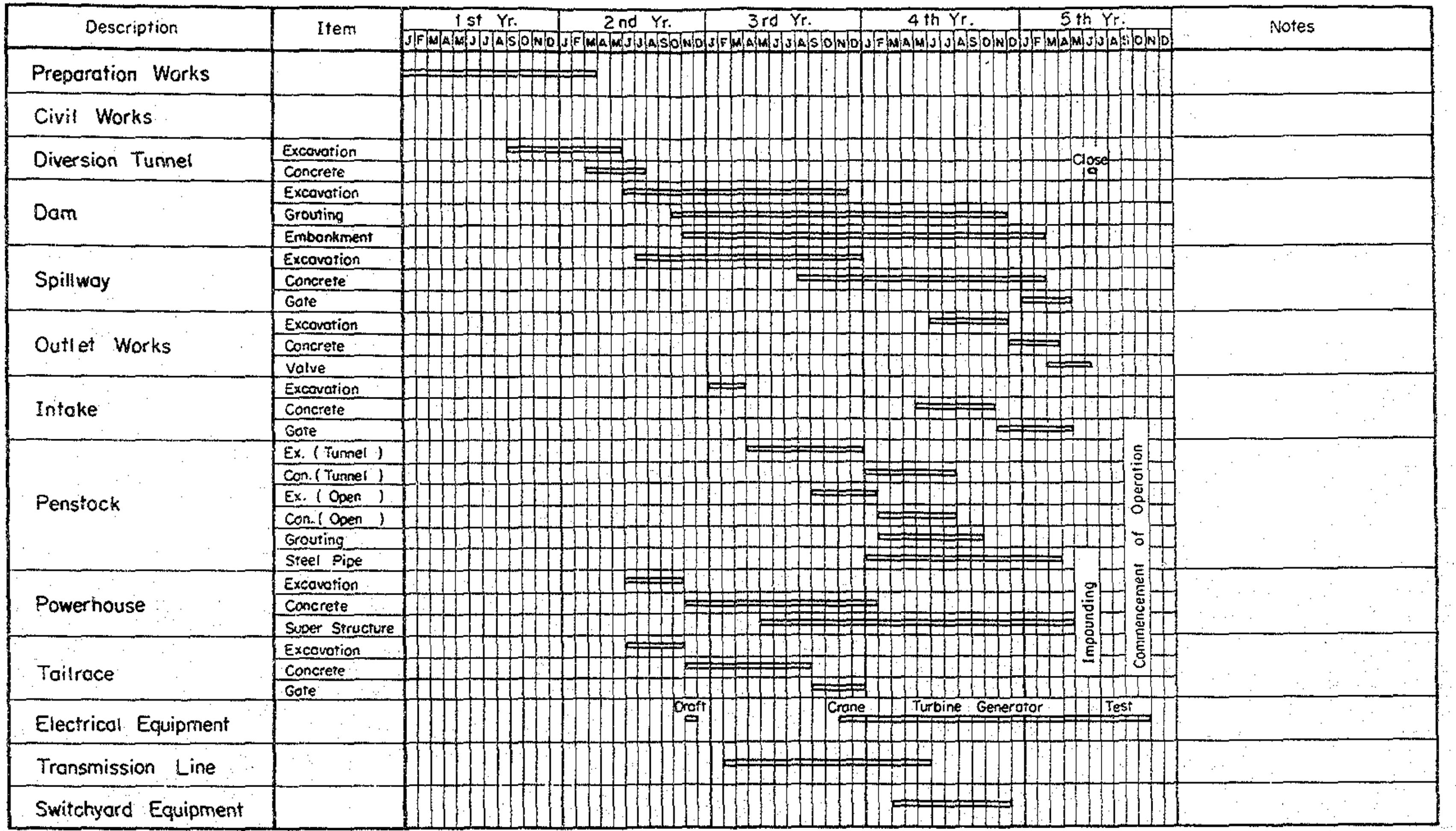

Fig. 8–1 Construction Schedule Nam Mae Ngao

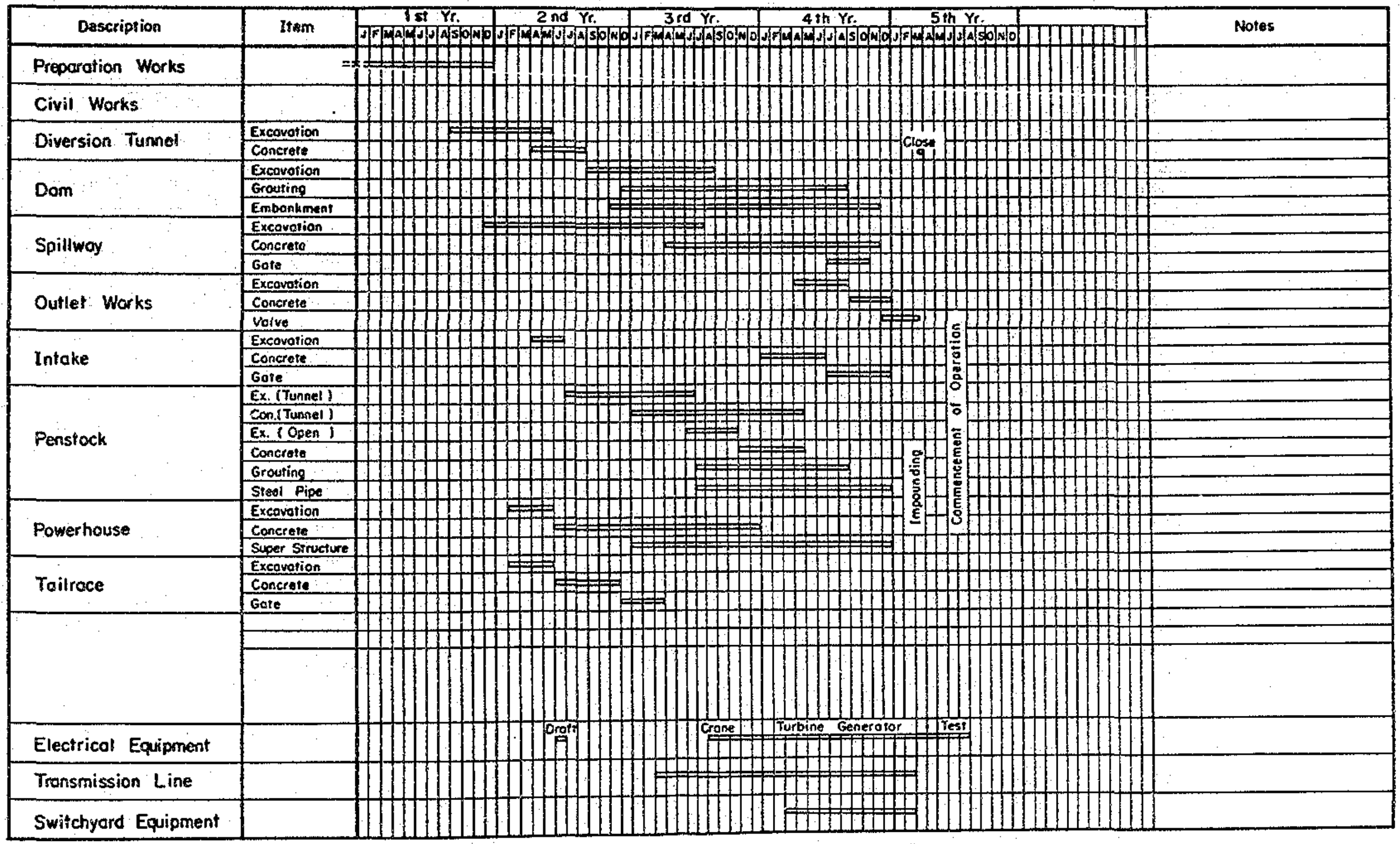

Fig. 8–2 Construction Schedule Nam Mae Rit

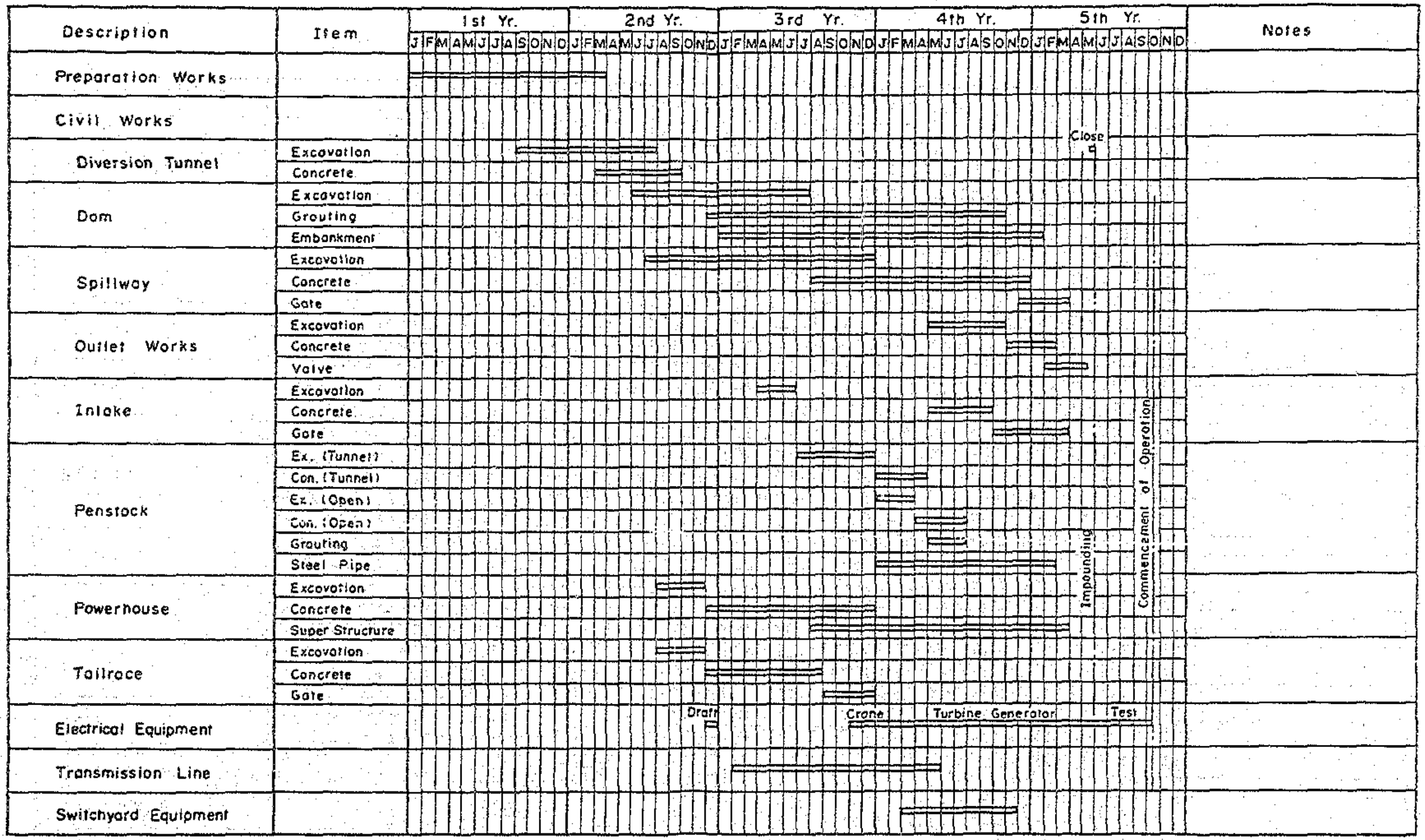

Fig. 8–3 Construction Schedule Upper Mae Yuam 1

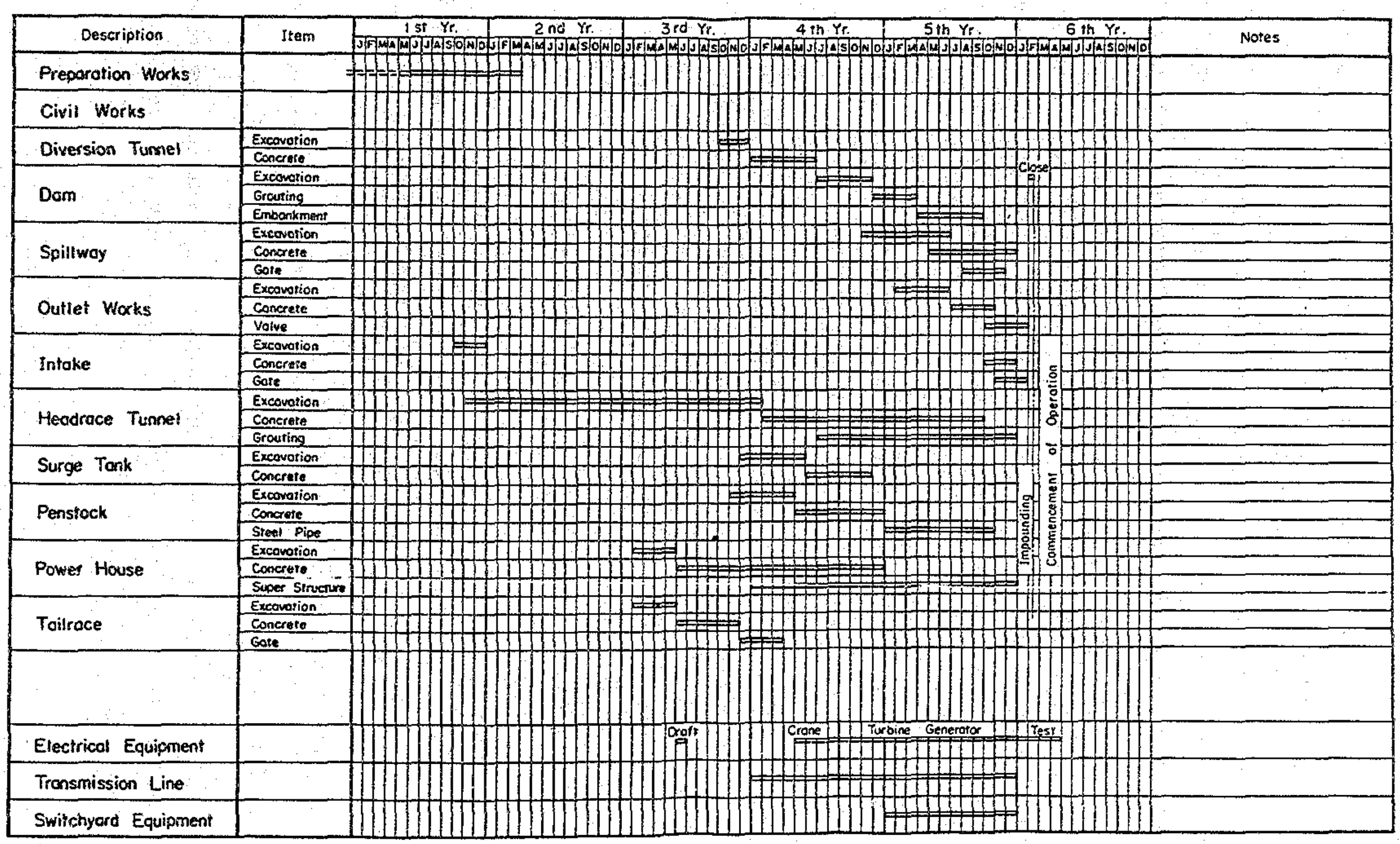

Fig. 8–4 Construction Schedule Upper Mae Rit 2a

8.2 Construction Cost and Financial Program

The total project cost of the individual project is calculated by the following procedure.

The approximate calculation formula prepared on the basis of the results of construction of many dams and power stations implemented in the past is used for the calculation of the volume of construction works.

The unit prices of the construction works at the first and the second stage were estimated based on August 1985 price level. These prices were referred to the construction cost of the similar projects implemented in Thailand. At the additional stage, the unit prices were estimated at the price level of July 1986.

The calculated total project costs cover preparation works, compensation, civil works, hydraulic equipment, electric equipment, transmission line, engineering fee, EGAT administration cost and interest during construction. The import duties and taxes are not taken into consideration on the second stage study of Nam Mae Rit, Upper Mae Yuam 1 and Upper Mae Rit 2a. On the additional stage of Nam Mae Ngao, the import duties and taxes are taken into account. The price contingency is not taken into consideration.

The total project costs are shown on Table 8-1 to 8-4 corresponding to the selected projects with distinction between the foreign and local currencies. The exchange rate of US dollar to Baht is taken at 27 ฿/$.

Financial programs in accordance with the construction schedule are given on Table 8-5 to 8-8.

The costs for engineering service and EGAT administration have been estimated at 5 percent and 3 percent respectively of the direct construction cost.

The interest during construction period is considered only for the foreign loan at the rate of 10 percent per year.

The costs are divided into foreign currency and local currency, considering the possibility of procurement of construction materials and equipments in Thailand.

In the studies of the incremental benefit of Lower Yuam Project, the construction cost has been re-evaluated by applying the same unit prices estimated at July 1986 price level.

Table 8–1 Construction Cost of Nam Mae Ngao Project

Unit: M฿

Item	Total	Currency	
		Foreign	Local
Preparation Works	144.2	0	144.2
Compensation	0.2	0	0.2
Civil Works	1,834.5	1,009.0	825.5
Hydraulic Equipment	152.3	114.2	38.1
Electrical Equipment	698.9	594.1	104.8
Telecommunication & Transmission line	89.5	62.8	26.7
Duties & Taxes	220.4	0	220.4
Sub-total	3,140.0	1,780.1	1,359.9
Engineering Fee	157.0	94.2	62.8
EGAT Administration	94.2	0	94.2
Interest during Construction	442.2	0	442.2
Grand Total	3,833.4	1,874.3	1,959.1

(Based on Case No.3 at the second stage study)

(As of July 1986 price level)

Table 8-2 Construction Cost of Nam Mae Rit Project

Unit: M฿

Item	Total	Currency	
		Foreign	Local
A) Generating Facilities			
1. Preparation Works	74.1	0	74.1
2. Civil Works	740.8	407.4	333.4
3. Hydraulic Equipment	92.9	69.7	23.2
4. Electrical Equipment	270.8	230.2	40.6
Sub-total	1,178.6	707.3	471.3
B) Transmission Line	39.1	27.4	11.7
C) Engineering Fee	60.9	36.5	24.4
D) EGAT Administration	36.5	0	36.5
E) Interest during Const.	138.2	0	138.2
Grand Total	1,453.3	771.2	682.1

(Base on Case No.2 at the second stage study)

(As of August 1985 price level)

Table 8-3 Construction Cost of Upper Yuam I Project

Unit: M฿

Item	Total	Currency	
		Foreign	Local
A) Generating Facilities			
1. Preparation Works	59.5	9.6	49.9
2. Civil Works	1,183.1	373.6	809.5
3. Hydraulic Equipment	90.3	67.4	22.9
4. Electrical Equipment	274.6	233.4	41.2
Sub-total	1,607.5	684.0	923.5
B) Telecommunication & Transmission Line	78.9	55.2	23.7
C) Compensation	44.8	7.3	37.5
D) Engineering Fee	86.6	51.9	34.7
E) EGAT Administration	51.9	0	51.9
F) Interest during Const.	187.7	0	187.7
Grand Total	2,057.4	798.4	1,259.0

(Base on Case No.1 at the second stage study)

(As of August 1985 price level)

Table 8–4 Construction Cost of Upper Mae Rit 2a Project

Unit: M฿

Item	Total	Currency	
		Foreign	Local
A) Generating Facilities			
1. Preparation Works	51.7	0	51.7
2. Civil Works	383.3	210.8	172.5
3. Hydraulic Equipment	57.4	43.1	14.3
4. Electrical Equipment	155.2	131.9	23.3
Sub-total	647.6	385.8	261.8
B) Transmission Line	45.0	31.5	13.5
C) Engineering Fee	34.6	20.8	13.8
D) EGAT Administration	20.8	0	20.8
E) Interest during Const.	86.3	0	86.3
Grand Total	834.3	438.1	396.2

(Base on Case No.3 at the second stage study)

(As of August 1985 price level)

Table 8-5 Financial Program of Nam Mae Ngao

Unit: M฿

Year	Total	Foreign	Local	Remarks
1st Yr.	342.5	133.8	208.7	
2nd Yr.	780.0	427.4	352.6	
3rd Yr.	1,037.7	528.4	509.3	
4th Yr.	2,202.1	611.0	591.1	
5th Yr.	471.1	173.7	297.4	
Total	3,833.4	1,874.3	1,959.1	

These amount are based on the price level as of July, 1986.

Table 8-6 Financial Program of Nam Mae Rit

Unit: M฿

Year	Total	Foreign	Local	Remarks
1st Yr.	188.4	58.9	129.5	
2nd Yr.	196.3	106.2	90.1	
3rd Yr.	430.7	236.7	194.0	
4th Yr.	492.9	284.7	208.2	
5th Yr.	145.0	84.7	60.3	
Total	1,453.3	771.2	682.1	

These amount are based on the price level as of August, 1985.

Table 8-7 Financial Program of Upper Mae Yuam I

Unit: M฿

Year	Total	Foreign	Local	Remarks
1st Yr.	243.2	62.7	180.5	
2nd Yr.	372.5	172.0	200.5	
3rd Yr.	565.9	221.0	344.9	
4th Yr.	693.2	267.8	425.4	
5th Yr.	182.6	74.9	107.7	
Total	2,057.4	798.4	1,259.0	

These amount are based on the price level as of August, 1985.

Table 8-8 Financial Program of Upper Mae Rit 2a

Unit: M฿

Year	Total	Foreign	Local	Remarks
1st Yr.	88.6	25.6	63.0	
2nd Yr.	59.4	20.6	38.8	
3rd Yr.	68.1	34.9	33.2	
4th Yr.	178.8	103.8	75.0	
5th Yr.	387.0	223.0	164.0	
6th Yr.	52.4	30.2	22.2	
Total	834.3	438.1	396.2	

These amount are based on the price level as of August, 1985.

CHAPTER 9. ECONOMIC EVALUATION

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9.1 Basic Concept and Methodology adopted in the Study

1) Notation and Definitions

There seems to have been much confusion in definitions applied to the various classes of power and energy. Following definitions will therefore be employed in this study.

A continuous firm discharge of a hydro power plant is defined to be a discharge that is equalled or exceeded 100 percent[1] of time, i.e. the continuous firm discharge is a discharge available for 24 hours continuously in every day throughout the entire period of the plant life.

In case of a storage type hydro power plant, the continuous firm discharge in off-peak hours is stored and accumulated in a reservoir in order to discharge it concentratedly within peak demand hours. A firm discharge of the storage type hydro power plant is a mean discharge of the discharges in the peak demand hours.

Hence the firm discharge is available for every peak demand hour in every day throughout the entire period. It is also given by the formula:

$$\text{Firm discharge} = \frac{\text{Continuous firm discharge}}{\text{Daily plant factor}} \qquad (1)$$

where the daily plant factor is the ratio of the peak duration hours to the number of hours in a day. Although, it should be estimated at the ratio of the day when the daily demand is equal to the average value of the demands of all the days in the entire peiod, the daily plant factor is in this study estimated at the ratio of the maximum demand day because of the relative easiness in obtaining the data. (The result will be in the safety side in

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1) A value of 95% or 90% is employed in some practical applications. In this study 95% firm discharge is adopted.

the sense that the plant capacity will not fail to meet the demand.)

Since the peak duration hours vary with the charactor of demand, the daily plant factor depends on it too.

On the other hand, the daily plant factor of the hydro power plant is also dependent on a composition of the power supply system (a proportion of a total capacity of peak load taking power plants to that of base load taking power plants in the system) to which the proposed hydro power plant belongs.

Suppose that the system is mostly composed of the base load taking thermal power plants. Then the power and energy of the proposed hydro power plant will be fitted to the very peak portion of the demand, therefrom resulting in a low plant factor of the hydro power plant. On the other side, if a certain part of the peak portion is already supplied by existing hydro power plants in the system, then the newly proposed hydro power plant and the existing hydro power plants will cooperatively supply the relatively broad peak portion, hence resulting in a higher plant factor.

Thus the daily plant factor of the proposed hydro power plant can not be determined arbitrarily. Given the charactor of the demand and the compostion of the power supply sytem it is determined almost uniquely.

A continuous firm capacity of the hydro power plant is a capacity calculated upon using the continuous firm discharge under the condition that the reservoir water level is at its lowest elevation. Consequently, the continuous firm capacity can be secured by the plant for 24 hours continuously in every day in the entire period.

A firm capacity of the hydro power plant is calculated under the same condition as the above except the continuous firm discharge is replaced by the firm discharge, hence the firm capacity of the hydro power plant can be available in every peak demand hour in every day in the entire period.

It is thus seen that a frequency of an occurrence of the day when the output capacity of the hydro power plant is just equal to the firm capacity, is extremely small. But the fact that the conventional method for evaluating the benefit of the hydro power plant employ the firm capacity as one of the basic parameters, means that the benefit of the hydro power plant stands on this extreme value.

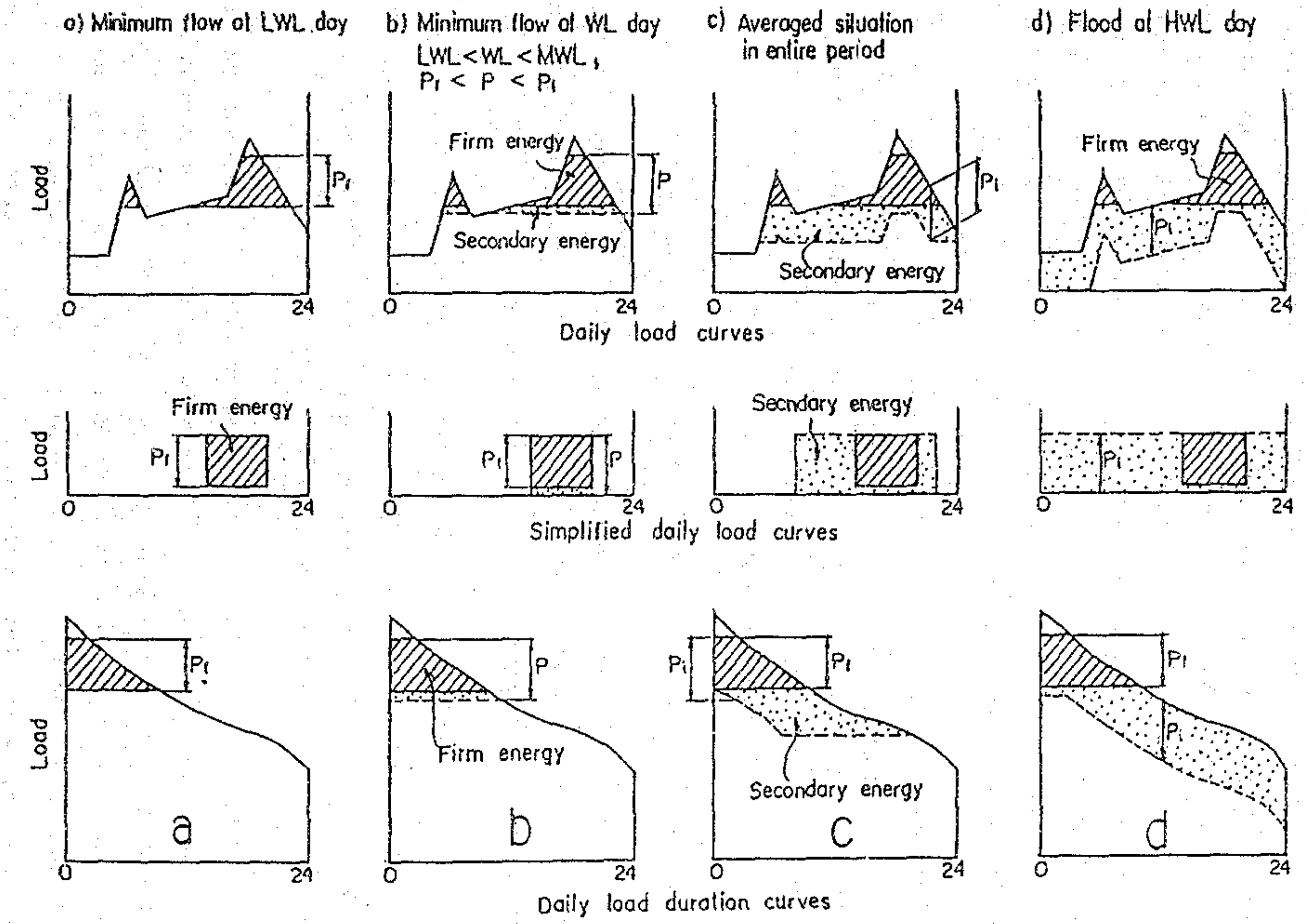
Usually, a capacity benefit of the hydro power plant is evaluated at a fixed cost of an appropriate alternative thermal power plant which has the equivalent capacity to the firm capacity of the hydro power plant, and an energy benefit is taken to be equal to a variable cost of the alternative thermal power plant which produces the equal amount of energy.

2) Position of Hydro Power and Energy under Load Duration Curve

River runoff varies with seasons. On a day when a reservoir water level is at the lowest elevation and an inflow to the reservoir is minimum, the hydro power plant outputs the firm capacity only and the generation is limited solely to the peak demand hours. The situation is conceptually illustrated on Fig. 9-1(a) where the firm power and energy supplies the hatched portion i.e. the peak demand hours only.

On the other hand, when the river runoff is so large that spillage over a dam is continued all day long, the hydro power plant is usually operated with the full installed capacity throughout 24 hours as illustrated on Fig. 9-1(d). On this day therefore all the extra power and energy that the hydro power plant has generated will be used to supply a portion of demand that otherwise would be supplied by a base load taking thermal power plant.

The above two extreme days, however, occur very rarely. On usual days, the situations are between the two. These are illustrated on Fig. 9-1(b) and (c). Of these, Fig. 9-1(b) shows the drier day and Fig. 9-1(c) represents the averaged situation (i.e. the average discharge day occurs on the average demand day) in the entire period. The secondary energies (shown by the dotted portion) produced by the hydro power plant, are fitted to and near the peak demand hours. As the result, the shape of the residual load curve (i.e. the curve after the hydro fitted portion is removed) approaches to that of a flat load curve which enable the base load taking thermal power plant to operate most economically.



WL: Water level, LWL: Low water level, MWL: Mean water level, HWL: High water level
P : Power output, P_f : Firm capacity, P_i : Installed capacity

Fig. 9–1 Daily Load Curve & Positions of Hydro Power Plant

On the lowest row on Fig. 9-1, daily load duration curves of the days corresponding to (a), (b), (c) and (d) as above described, are schematically depicted with the hydro power and energy, being fitted to the corresponding positions under the curves. Since the installed capacity (shown by P_i), firm capacity (shown by P_f), daily firm energy and daily average secondary energy of the given hydro power plant are constant (given) values, the positions where these capacities and energies occupy under the load duration curve, are almost uniquely determined. Thus, under the load duration curve on the averaged situation, (the lowest figure of Fig. 9-1(c)), the hatched area is equal to the amount of the daily firm energy production and the dotted area represents the daily average secondary energy generation.

Simultaneously, the height of the hatched area coincides with the firm capacity P_f, and the overall height of the hatched and dotted area at any time point never exceeds the installed capacity P_i. Due to these two way constraints (area and height) the hydro position is determined almost uniquely.

3) Optimal Combination of Thermal Power Plants

Several types of thermal power plants, such as a gas turbine plant, a combined cycle plant, an oil-fired or coal-fired steam thermal power plant, etc. are to be considered.

As is well known, these thermal power plants have their own charactors. In case of the gas turbine, for example, a capital cost per KW is the lower but a fuel cost per KWH is the higher, so it is usually suited for supplying the peak energy.

On the contrary in case of the high efficiency thermal power plant, the cost relationship is reversed, hence it is generally committed to assume the base load portion. The combined cycle plant stands between these two. In addition, these thermal power plants should be operated within certain specified ranges of capacity factors, where the capacity factor of the power plant is defined by the formula:

$$\text{Capacity factor} = \frac{\text{Annual energy production}}{\text{Installed capacity x number of hours in a year}} \quad (2)$$

In other words, each type of the thermal power plants has its own range of allowable operation hours in a year (hence in its whole life length) within which the most economical operation of the plant will be attained. For reference, standard range of the capacity factor in usual practice is less than 10% for the gas turbine, between 40% and 90% for the steam turbine thermal plant, and so on. It is important to note that an excessive operation of the thermal plant beyond the specified range of the capacity factor would virtually result in the shortening of the economic life length of the plant.

An optimal combination of these thermal power plants should then be searched for basing on such information as charactors of demands, site conditions, availabilities and costs of fuels, allowable ranges of capacity factors of the thermal power plants, etc.

In the following, however, only the problem of finding an optimal time point of inputting each thermal plant to the system will be discussed.

To that end, a so-called "screening curve method"[2] will be adapted because of its simplicity. Further to simplify the matter, it is assumed that only two types of thermal power plants, type I and type II are given for combination, where the fixed cost of the type I plant is lower than that of the type II plant but the variable cost of the former is higher than the latter.

Now, let t be time in hours and c be total annuitized fixed and variable costs per KW of a thermal power plant. Then within each range of the capacity factors, the c's can be approximated by the following linear equations:

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2) IAEA: Expansion Planning for Electrical Generating Systems, Vienna, 1984, pp.230 - 235.

$$C_I = f_I + V_I t$$
$$C_{II} = f_{II} + V_{II} t \qquad (3)$$

where f's denote the annuitized fixed costs in \$/KW.a, v's represent the variable costs in \$/KWH, and subscripts I and II stand for the type I and type II thermal plant respectively. Moreover by the assumption,

$$f_I < f_{II}, \quad V_I > V_{II} \qquad (4)$$

The equation (3) is represented by the two lines on Fig. 9-2. It is seen that when the operation time length t is longer than t_p, the cost c_{II} of the type II plant is lower than the cost c_I, but c_I is lower when t is shorter than t_p.

The boundary point between these two teritories is the intersection point c_p of the two lines. Projections of this point onto the respective axes can be obtained by solving the equation (3) as follows:

$$c_p = \frac{f_{II} v_I - f_I v_{II}}{v_I - v_{II}} \qquad (5)$$

$$t_p = \frac{f_{II} - f_I}{v_I - v_{II}} \qquad (6)$$

Consequently it is concluded that if the operation time length t is more than t_p hours, then the type II plant should be, but if it is less than t_p hours, then the type I plant should be input to the power supply system. Note that in the off-peak hours, type II plant alone is operated but in the peak demand hours both type I and type II plants are operated together.

Next step to be taken is to estimate the cost of the power and energy generated by these thermal power plants.