THE REPUBLIC OF THE PHILIPPINES

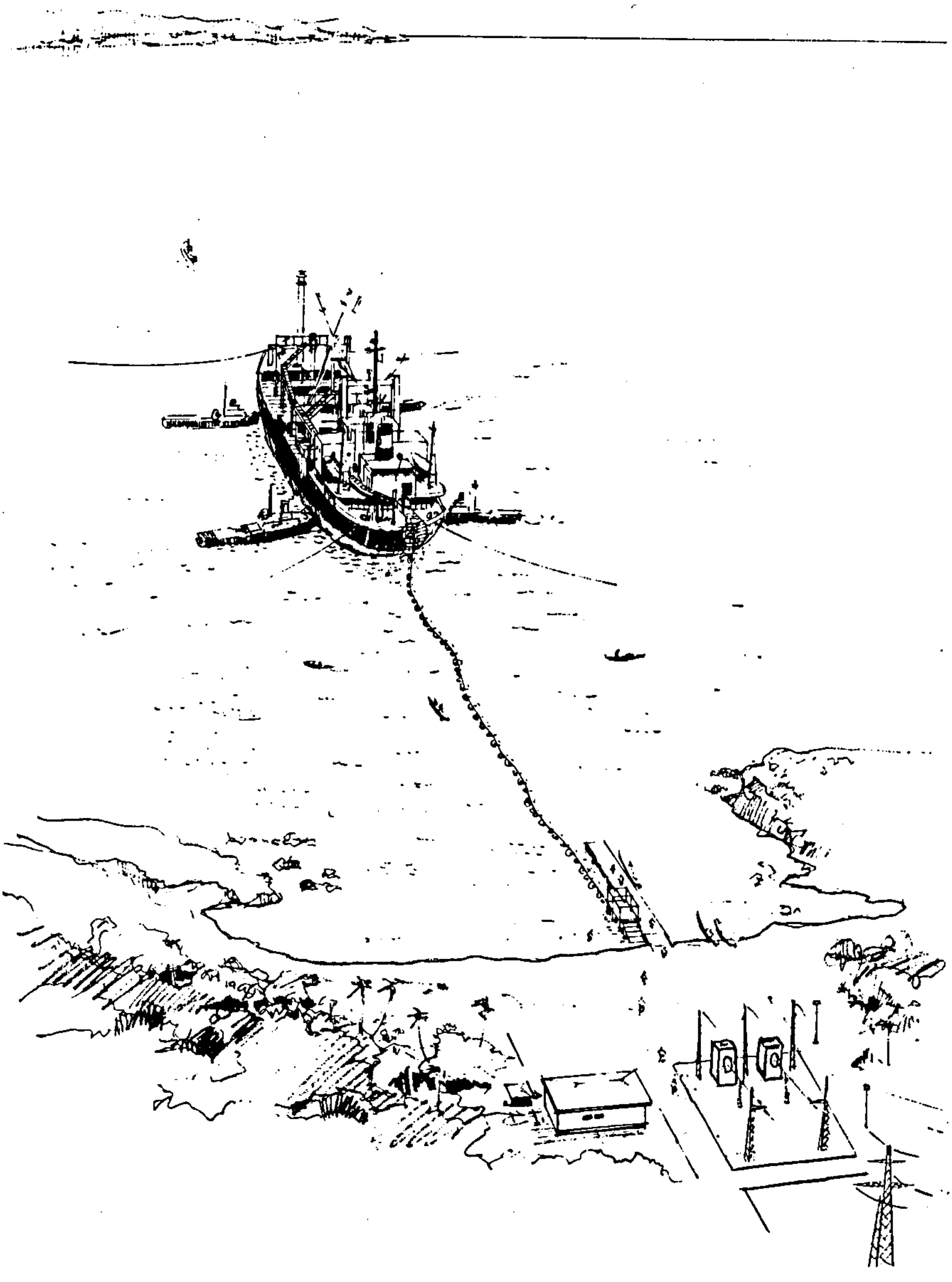
NATIONAL POWER CORPORATION

FEASIBILITY STUDY
REPORT
ON
LEYTE-MINDANAO POWER TRANSMISSION PROJECT

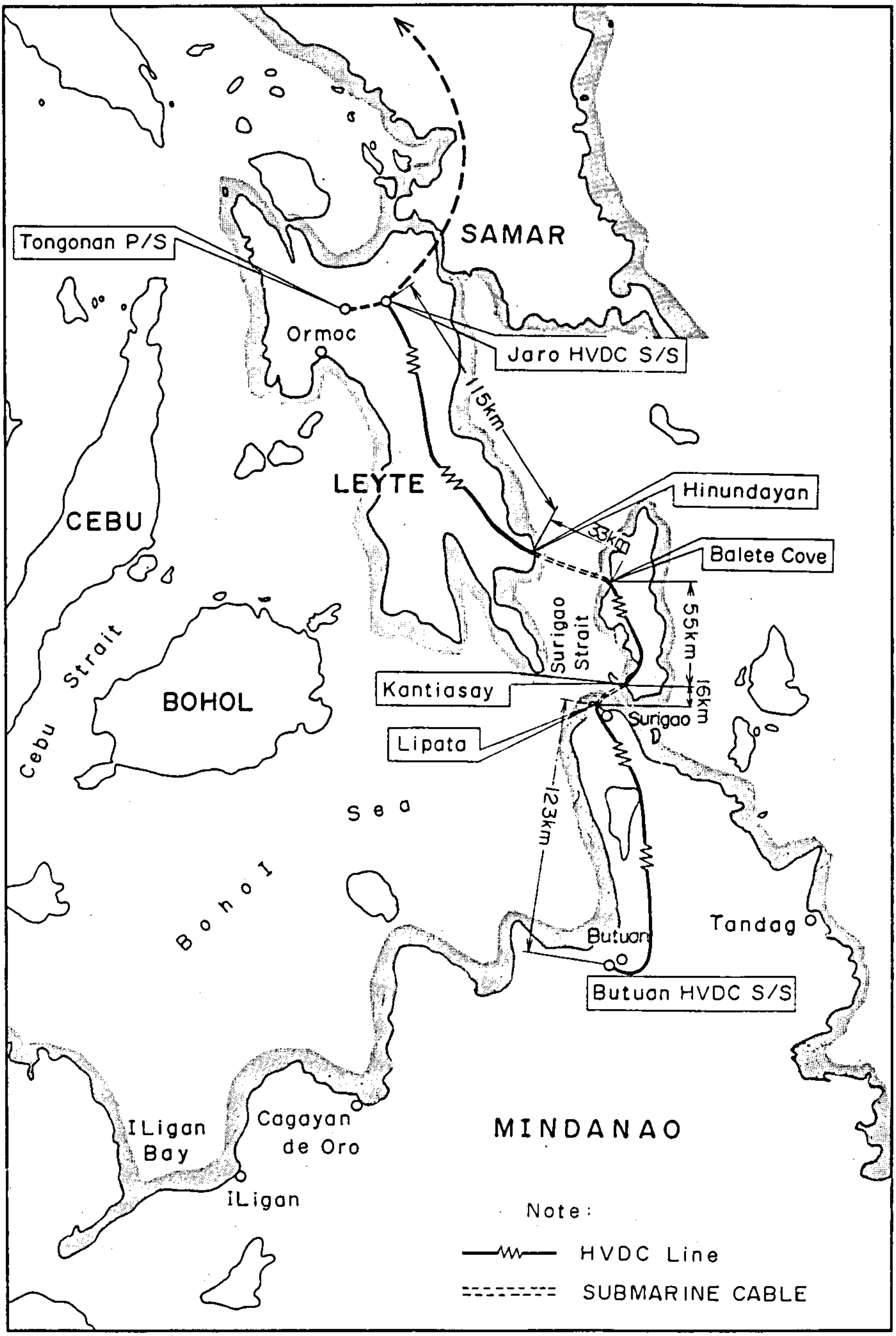
MARCH 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

Artist's Imaginary View of Landing Point for DC ±350 kV Sumbarine Cables Transmission Line Route



Transmission Line Route



ABBREVIATIONS

EDC	:	Energy Development Corporation
GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
MECO	:	Manila Electric Company
MOE	:	Ministry of Energy
NAPOCOR	:	National Power Corporation
NEA	:	National Electrification Administration
OECF	:	Overseas Economic Cooperation Fund
PASAR	:	Philippine Associated Smelting and Refining Corporation
PHILPHOS	:	Philippine Phosphate Fertilizer Corporation
PHIVIDEC	:	Philippine Veterans Industrial Development Corporation
PNOC	:	Philippine National Oil Company

PREFACE

In response to the request of the Government of the Republic of the Philippines, the Government of Japan decided to carry out the feasibility study of the Leyte-Mindanao Power Transmission Project and commissioned the Japan International Cooperation Agency (JICA) for that purpose. JICA organized successive survey teams under the leadership of Mr. Nobuo Tago of Electric Power Development Co., which visited the Philippines for 3 times in the January 1983 - January 1984 period and carried out field survey in cooperation with authorities of the Government of the Republic of the Philippines and other related organizations. This report is prepared based on the field survey and on the results of the discussion and analysis of the collected data after the return of the survey team to Japan.

I am only too glad if this report can contribute to the promotion of the economic development of the Republic of the Philippines and to the friendship between Japan and the Philippines.

Finally, I express my gratitude to the authorities concerned of the Government of the Republic of the Philippines, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry of Japan and the Embassy of Japan in the Philippines for their invaluable cooperation and support.

March 1984

Keisuke Arita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Keisuke Arita
President,
Japan International Cooperation Agency

Dear Sir,

We are hereby pleased to submit you the survey report on the Leyte-Mindanao Power Transmission Project of the Republic of the Philippines.

This survey, commissioned by you, is aimed at studying and examining the technical and economic feasibility of the Leyte-Mindanao Power Transmission Project which proposes to construct a transmission line between the Leyte Island and the Mindanao Island in order to make possible the interconnection between the Luzon grid, the largest electric power system of the country, and the Mindanao grid, the second largest.

For this purpose Electric Power Development Co. (EPDC), and Nippon Koei Co., Ltd. formed a joint-venture which organized successive survey teams under the leadership of Mr. Nobuo Tago of EPDC. The Primary Survey Team consisting of 7 members visited the Philippines for 60 days from January 17 to March 17, 1983 to carry out the field survey consisting of the topographical survey and route survey of the overhead transmission lines, HVDC substations, electrodes, microwave repeater stations, etc., in addition to the collection of data of various kinds. The 5-member Secondary Survey Team carried out the submarine cable route survey for 60 days, from June 14 to August 12, 1983 and the 8-member Tertiary Survey Team carried out the detailed survey of the topography of the bottom of the sea.

The power demand and supply balance of the Luzon Grid, Leyte-Samar Grid and Mindanao Grid, the transmission line planning, the preliminary design, the power system analysis, the cost estimation, the construction schedule, the economic evaluation and the financial analysis are examined and discussed based on the aforementioned field surveys and the obtained results are presented in this report.

This project will operate interconnected with the Luzon-Leyte Power Transmission Project, whose survey was carried out in an earlier occasion with JICA cooperation, and is expected not only to contribute significantly to further development and exploitation of the abundant geothermal energy resources of Leyte Island but also to upgrade the power supply reliability of the Luzon Grid, Leyte-Samar Grid and Mindanao Grid. Therefore, the Team is sure that the completion of this project will make extraordinary contributions to the development of the Philippines.

In submitting this report the Team wish to express our gratitude to all those persons concerned of National Power Corporation and other related authorities of the Government of the Republic of the Philippines, the Ministry of Foreign Affairs, the Ministry of International Trade and Industry, the Embassy of Japan in the Philippines and the Japan International Cooperation Agency for their invaluable cooperation and support.

March, 1984

Nobuo Tago

Nobuo Tago, Team Leader
Survey Team for Feasibility Study on the Leyte-Mindanao Power Transmission Project

Contents

Page

Page

CHAPTER 7 PRELIMINARY DESIGN

Page

CHAPTER 8 CONSTRUCTION COST AND CONSTRUCTION SCHEDULE

CHAPTER 9 ECONOMIC EVALUATION AND FINANCIAL ANALYSIS

APPENDIX

FIGURE LIST

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

TABLE LIST

CHAPTER 3

CHAPTER 4

A - 1

A - 3

A - 4

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background

The Republic of the Philippines is an insular country with the largest number of islands in the world, totaling more than 7,000. In particular, the Luzon Island, where the capital city of Manila is located, is situated at the northern part of the archipelago and is the most important island of the country with the largest population, largest area and many industries. The Mindanao Island, second in terms of area, is located in the southern part of the country and has abundant hydro power resources. Many industries using hydroelectric power have been constructed of late years in this island as a consequence of the policy for encouragement of industry adopted by the government. They are concentrated particularly in the cities of Iligan and Cagayan de Oro located in northern Mindanao and as a consequence it became the second most important island of the country in terms of population and industry.

The Visayas Area consisting of the Samar, Leyte, Bohol, Cebu, Negros and Panay islands is located between the Luzon Island and the Mindanao Island.

The National Power Corporation (NAPOCOR), responsible for the supply of electric power in the Republic of the Philippines, has three independent areas of jurisdiction, i.e., Luzon, Visayas and Mindanao, which have independent grids operated without interconnection with each other.

The Luzon Grid consists of hydroelectric power stations located in the northern part, oil fired thermal power plants located in the central part and geothermal power plants developed of late years and located in the southern part. The Visayas Grid consists of independent electric power systems of each island whose principal power sources used to be diesel generators and small-sized hydroelectric power plants, but a geothermal power plant was constructed in Leyte Island and a coal fired thermal power plant was constructed in Cebu Island and were put in commercial operation of late years. In addition, a geothermal power plant is also under construction in the Negros Island. The power sources of the Mindanao grid consist principally of the hydroelectric power stations of the Agus river and the Aplaya diesel power plant, but the construction of new hydroelectric power stations are progressing at high pitch in the Agus river and Pulangi river in order to cope with the rapid increase of demand due to the industrial load.

The Philippines, which is a non-oil developing country, was no exception to the devastating effects of the oil shock of 1973 and the government promptly adopted measures to reduce the degree of reliance on imported petroleum and to develop domestic energy resources. In other words, the government decided to target the development of hydro-power, coal and geothermal energy as new sources of energy. In particular, geothermal energy was exploited in the most intensive way and played a dominant role in the replacement of petroleum. Fortunately, the geothermal energy of the Philippines has one of the highest potentials of development in the world. The exploitation of geothermal energy in this country commenced with the construction of a 3 MW test plant in 1977 which was put in commercial service in 1978. As things now stand the geothermal power plants of Tiwi and Mak-ban (220 MW each) are in operation in the Luzon Island and the Tongonan Geothermal Power Plant (112.5 MW) is in operation in the Leyte Island. Furthermore, the Palimpinon Geothermal Power Plant (112.5 MW) is under construction in the Negros Island. Geothermal energy resources are particularly abundant in the Leyte Island and besides the Tongonan area, which has the largest reserved energy potential of the Philippines, there are energy reserves in the Biliran, Burauen and Anahawan areas and successful test drilling have been concluded in Biliran, resulting into the confirmation of energy reserve potential surpassing 200 MW. Electricity generated by the Tongonan Geothermal Station will contribute not only to cope with the demand of power in the Leyte-Samar area, but after the completion of the third stage of development it will be able to sent power to the Manila area and the Luzon-Leyte Power Transmission Project was planned with the purpose of making contributions to minimize the consumption of petroleum in the country. This project intends to make the interconnection between Tongonan located in the Leyte Island and Naga located in the Luzon Island by means of a long-distance transmission line consisting principally of DC power transmission line and a 500 kV AC transmission line between Naga and San Jose Substation located in the outskirts of Manila and its total extension covers 800 km. The Government of the Republic of the Philippines asked the Government of Japan to carry out the feasibility study of the Luzon-Leyte Power Transmission Project for the DC transmission line and Japan International Cooperation Agency sent a survey team in March 1981. The survey report was submitted to the Government of the Philippines in March 1982. Based on this report, NAPOCOR is taking concrete measures for realization of this project.

This time the Government of the Philippines drew up the plan of the power transmission project interconnecting between Leyte Island and Mindanao Island, which has the second largest power demand in the country, and asked the Government of Japan to carry out the relevant feasibility study. In response to that request the Government of Japan commissioned the Japan International Cooperation Agency which sent a preliminary survey team to the Philippines in July 1982. The preliminary survey team held talks with NAPOCOR about the full-scale survey, signed the "Implementing Arrangement" and as a consequence the primary survey team was sent in January 1983.

Broadly speaking the electric power system of the Philippines consists of three grids, i.e., Luzon, Visayas and Mindanao. The aforementioned Luzon-Leyte Power Transmission Project will interconnect the Luzon Grid with the Leyte-Samar Grid which is part of the Visayas Grid and the implementation of the Leyte-Mindanao Power Transmission Project will result into the completion of the power transmission trunk line interconnecting Luzon, Leyte and Mindanao. The interconnection of the Luzon Grid with the Mindanao Grid will make possible the power interchange operation between them, which will bring about a substantial improvement in the power supply reliability.

1.2 Purposes and Scope of the Study

This study is aimed at preparing the optimum development plan and to draw up the relevant report in conformity with the "Implementing Arrangement" signed by the preliminary survey team and by referring to the "Preliminary Survey Report on the Leyte-Mindanao Power Transmission Project" submitted by the preliminary survey team. The contents of the field survey are as follows.

1.2.1 Primary survey

(1) Collection of data

Data on the forecast of demand, data on the existing facilities and future plans related to the grid analysis, data on the meteorology.

(2) Survey of the HVDC substation sites

Survey of Jaro site of the Leyte Island and Butuan and Kirahon sites of the Mindanao Island proposed for HVDC substations.

(3) Survey of electrodes and electrode lines

Survey for selection of the grounding electrodes sites, and of the electrode line routes by means of vehicles and helicopter and collection of data on water level at ebb tide at the grounding electrode sites.

(4) Survey of the overhead transmission line route

Survey of the overhead transmission line route from Jaro to Davao via Kirahon by means of helicopter and vehicles.

(5) Survey of the submarine cable route and landing site

Survey of the Surigao Strait section located between Leyte Island and Dinagat Island and Hinatuan Passage section located between Hanigad Island and Mindanao Island of the planned submarine cable route by means of helicopter.

Survey of the proposed submarine cable landing sites of Hinundayan in Leyte Island, Balete Cove in Dinagat Island, Hanigad in Hanigad Island and Bilan-bilan in Mindanao Island, by means of vehicles, boats and helicopter.

(6) Survey of the microwave repeater station sites

Rough survey of the sites planned in the map by means of helicopter and vehicles.

(7) Survey for expansion of the existing substations

Survey of the existing Butuan Substation, Tagoloan Substation and Davao Substation that will be used as lead-in substations of this project.

1.2.2 Secondary survey

(1) Survey of the submarine cable

Survey of the topography and geology of the bottom of the sea, speed of tide current and number of ships sailing in the Surigao Strait located between Leyte Island and Dinagat Island and Hinatuan Passage located between Hanigad Island, Nonoc Island and Mindanao Island.

(2) Survey of submarine cable landing sites

Rough survey from the cable landing sites to the cable head installing sites.

(3) Collection of data

Collection of data about the state of things of the navigation of vessels, possibility of anchorage, state of things of fishing and marine meteorology such as tide current, ebb and flow of tide, etc., related with the laying of the submarine cable, by contacting the local authorities in charge of the matter.

1.2.3 Tertiary survey

(1) Survey of the submarine cable route

Survey of the topography and speed of tide current of the bottom of the sea for selection of the best route to lay the submarine cable in the Surigao Strait and in the Hinatuan Passage.

1.3 Formation of Survey Team

(1) Participant firms of the survey team

The Electric Power Development Co. and Nippon Koei Co., Ltd. joint-venture, which carried out the feasibility study of the Luzon-Leyte Power Transmission Project and had submitted the relevant report the last occasion, was commissioned again this time to carry out the feasibility study of the Leyte-Mindanao Power Transmission Project. Nippon Koei Co., Ltd. would be in charge of the submarine cable, AC transmission line, power demand forecast, economic & financial analysis, etc., and Electric Power Development Co. would be in charge of the other sectors consisting principally of the HVDC technology.

(2) Members of the survey team

The members and the duties of the survey team are as follows.

Leader	Mr. Nobuo Tago	EPDC	General Affairs	① (In) (En)
	Mr. Makoto Yabuki	EPDC	HVDC transmission line	①
	Mr. Hiroshi Kagami	EPDC	Power system	(In) (En)
	Mr. Tetsuro Inoue	EPDC	System analysis	① (In)
	Mr. Masanori Ueda	EPDC	Communication	①
	Mr. Takayoshi Sano	EPDC	HVDC Substation	①

Sub-leader	Mr. Sumio Tsukahara	Nippon Koei	Assistant coordinator, AC transmission line ① ② ③
	Mr. Kimihiko Yanagisawa	Nippon Koei	Power demand forecast and economic & financial analysis ①
	Mr. Yuzo Yamaguchi	Nippon Koei	Submarine survey ② ③
	Mr. Teruo Ohmura	Nippon Koei	" ② ③
	Mr. Ei-ichi Shimura	Nippon Koei	" ②
	Mr. Keishi Shimo	Nippon Koei	" ② ③
	Mr. Yoshito Watanabe	Nippon Koei	" ③
	Mr. Akio Kuroda	Nippon Koei	" ③
	Mr. Kiyotaka Umezu	Nippon Koei	" ③
	Mr. Masanao Yagi	Nippon Koei	Submarine survey analysis of data
	Mr. Yoshihiro Ohta	Nippon Koei	Survey of submarine cable route ③

Note: ① ② ③ represent first study visit, second study visit and third study visit, respectively.

Ⓘⓝ Ⓔⓝ represent the intermediate visits for the project study to discuss the inception report and the system engineering report.

1.4 Schedule of the Field Survey

The field survey was divided in 2 distinct stages, i.e., the Primary Survey and the Secondary Survey, with the former one covering the land transmission lines, HVDC substations, communication, power demand forecast, power system analysis, etc., in other words, all sectors with exception of the submarine cable routes. The Secondary Survey covered aspects related to the submarine cable routes crossing the Hinatuan Passage and the Surigao Strait.

The results of the Secondary Survey revealed that there are pronounced undulations in part of the submarine cable route, with some sections with some problems with regard to the laying of the submarine cable. Under the circumstances, it was decided to carry out the Tertiary Survey in additional character, which will use equipment able to observe in further details the state of things at the bottom of the sea, in order to provide data to decide if the laying of the submarine cable is possible.

- Primary survey — 60 days from 17 January to 17 March, 1983

  Participants: 7 members under the direction of the leader

- Secondary survey		60 days from 14 June to 12 August, 1983
	Participants:	5 members under the directions of the sub-leader
- Tertiary survey		60 days from 28 November, 1983 to 26 January, 1984
	Participants:	8 members under the direction of the sub-leader.

Prior to the field survey, 3 members of the survey team under the direction of the leader visited the NAPOCOR from 20 November to 4 December, 1982 to explain about the Inception Report and held detailed conferences about the plan of the field survey. The field survey was implemented with full cooperation of NAPOCOR, based on the planned schedule. Meetings for explanations about the System Engineerig Report were held from 12 to 26 October, 1983 with participation of the leader and one member more from the Japanese side and NAPOCOR considered it satisfactory.

1.5 Fundamental Consideration in Preparation of the Report

The basic course to study the technical and economic feasibility of the Leyte-Mindanao power transmission facilities and to draw up the relevant report was determined in conformity with the matters discussed and decided by NAPOCOR and the survey team. The following fundamental considerations were established for the Leyte-Mindanao Power Transmission Project.

1.5.1 Power demand projection

In this study, power demand projection will be made for the power grids of Mindanao, Luzon and Leyte-Samar up to the year 2000.

For the Mindanao and Luzon power grids, the demand projection will be made through the projected GRDP elasticity of power consumption based on the historical trend of power consumption and thereafter the projected demand will be compared with the NAPOCOR projection.

For the Leyte-Samar power grid, the power demand projection will be made not based on the historical trend of power consumption but based on the industrial development plan in the Leyte-Samar region and on the regional development plan prepared by the government. This is due to the fact that, in this Leyte-Samar region despite the low growth of power consumption in the past, the power demand is anticipated to increase rapidly in the near future after the on-going industrial development projects located at Isabel in the northern Leyte are commissioned.

1.5.2 Power system analysis and determination of the interconnected capacity

The power flow, three-phase short-circuit capacity and stability of the Mindanao Grid in 1990 and 1995 are calculated in the first place. Next, the reserve capacities of the Luzon Grid, and Mindanao Grid in 1990, 1995 and 2000 are calculated in order to determine the extent of reduction of reserve power. The interconnected power transmission capacity is estimated from the said extent of reduction of reserve power.

The location of the HVDC substation of the Mindanao Island is determined from the results of the said power system analysis, from the technical and economic standpoint.

1.5.3 Analysis of stability of the AC/DC interconnection

(1) Examination of the independent Mindanao Grid

- The necessity of reinforcing the facilities and other relevant aspects are examined by carrying out the power flow calculation and the stability calculation for 1990 and 1995.
- The power flow calculation is carried out by assuming the interconnection between Luzon-Mindanao and the system is examined for existence of any transmission line element that might become overloaded.
- The short circuit capacity is calculated to check the existing circuit breaker for any problem related to interrupting capacity.

(2) Analysis of stability of AC/DC interconnection grids

The stability analysis of the AC interconnection and DC interconnection (2-terminal and 3-terminal) is carried out for 200 MW in 1990 (1st stage) and 400 MW in 1995 (2nd stage).

The following stability conditions are found as a result of these analysis.

- AC interconnection

  In the most severe case of 1-circuit line fault 3LG-0 of the interconnecting transmission line, the swing curve (transient stability) of the generators of the Tongonan and Mindanao power system should present attenuation tendency and furthermore the voltage should not present large variations.

- DC interconnection (2-terminal and 3-terminal)

  The swing curve of the interconnected AC system should present attenuating tendency and furthermore the voltage should not present large variations even when the operation of the AC-DC converter is resumed after stopping it once, with 1-circuit 3LG-0 (2-terminal and 3-terminal) in a transmission line at the vicinity of the Butuan HVDC Substation of the Mindanao Grid and 1-circuit 3LG-0 in the 500 kV transmission line (3-terminal only) at the vicinity of the Naga HVDC Substation of the Luzon Grid.

  Should any problem occur with regard to the voltage stability, the analysis will be carried out by installing a synchronous rotary condenser or a SVC (Static Var Compensator) in the HVDC Substation.

1.5.4 Preliminary design and construction cost

This is a long-distance power transmission project including 2 sections of submarine cable with total distance of 49 km. This project in totality covers 342 km from Jaro (HVDC Substation at the Leyte side) to Butuan (site proposed for HVDC Substation at the Mindanao side) and 437 km up to Kirahon in the latter island.

As for the power transmission system, which will be interconnected with the Luzon-Leyte power transmission project examined previously and will be closely related with the interchange power generated by the Tongonan geothermal power station located in the Leyte Island, the survey team will study comparatively from the technical and economic standpoints the three proposed alternatives, i.e., (i) the DC 3-terminal power transmission alternative to be operated in coordination with the Naga & Jaro HVDC Substations of the Luzon-Leyte Power Transmission Project and the HVDC Substation of the Mindanao side, (ii) the DC 2-terminal alternative to be operated by both the new HVDC substation adjacent to the Jaro HVDC Substation and the Mindanao-side HVDC substation and (iii) AC power transmission alternative, in order to select the alternative best suited for this project, and subsequently the survey team will calculate the construction cost of the selected alternative by carrying out the preliminary design of the overhead transmission line, submarine cable, HVDC substation (including the expansion of the facilities of the existing substations) and communication facilities.

1.5.5 Stages of execution of the construction work

The conclusion of this project can be in 1990 at the earliest, in view of the period of time for detailed design, raising of funds for construction, tender, construction work, etc. Therefore, the most effective time for start of operation after 1990 will be examined in the first place and then the time schedule of work for execution of the survey, design, manufacturing, construction and test in the most rational and economical way will be prepared, by setting the goal at the said date of start of operation.

1.5.6 Economic evaluation

The economic evaluation of this project consists of the comparison of the construction cost of the project with the merits brought about as a consequence of the completion of the project, i.e., reduction of reserve power, economic interchange of power and reduction of power transmission loss. The overall economic evaluation covering not only this project but also the Luzon-Leyte Power Transmission Project is also made in this study.

1.5.7 Financing schedule and financial analysis

Financing schedule will be prepared comprising both the yearly disbursement schedule of capital cost and the assumptions on terms of foreign loan.

Financial analysis will be made through comparing the energy sales revenue to be realized by the Tongonan geothermal power generation project and by the Leyte-Mindanao power transmission project with the corresponding capital and recurrent costs which are required for the abovementioned two projects.

Financial internal rate of return (FIRR) of the Project will be computed not only for the Leyte-Mindanao power transmission project (independent analysis) but also for the combination of both the Leyte-Mindanao and the Luzon-Leyte power transmission projects (integrated analysis).

CHAPTER 2

CONCLUSION AND RECOMMENDATION

CHAPTER 2 CONCLUSION AND RECOMMENDATION

The following are the conclusions and recommendations drawn as a result of the survey and investigation about the Leyte-Mindanao power transmission project.

Principal features of the Project are as follows:

(1) HVDC S/S

Name	:	Butuan HVDC S/S
Site	:	Adjacent to the existing 138 kV Butuan S/S
Capacity	:	200 MW at 1st stage 200 MW at 2nd stage 400 MW in total

(2) Transmission facilities

- DC overhead transmission line

Voltage	:	DC +350 kV at 1st stage
	:	DC ±350 kV at 2nd stage
Distance	:	293 km

- DC submarine cable

Distance	:	49 km

- Electrode line

Jaro HVDC S/S to Managasnas	:	28 km
Butuan HVDC S/S to Carmen	:	30 km

(3) Telecommunication facilities

Distance of microwave circuit	:	289.5 km
No. of microwave repeater stations	:	4
Distance of VHF circuit	:	121.5 km
No. of VHF terminal stations	:	4

2.1 Conclusion

(1) The final power transmission power will be 400 MW

This project is appropriate to start the operation in 1992 in view of the results of the study carried out by NAPOCOR about the power demand and supply balance of the Luzon and the Mindanao power development projects.

This project will be developed by dividing it in 2 distinct stages in view of the power demand and supply balance of the two power systems, with the operation of the first stage starting early 1992 and the second stage early 1997.

The power transmission capacity of the first stage is 200 MW, with 100 MW for power transmission and 100 MW for reserve power interchange. The power transmission capacity of the second stage is 400 MW, with 200 MW for power transmission and 200 MW for reserve power interchange.

(2) As for the power transmission system, the DC 3-terminal system is the most advantageous alternative, with the point of interconnection with the Mindanao Grid located at Butuan.

The final power transmission capacity is 400 MW and the Tagoloan S/S (HVDC substation to be constructed in Kirahon) and the Butuan S/S (HVDC substation to be constructed adjacent to the substation) are selected at the Mindanao side as points of interconnection with the Jaro HVDC S/S. As for the power transmission system, three distinct alternatives, i.e., DC ±350 kV 3-terminal power transmission system, DC ±250 kV 2-terminal power transmission system and AC 230 kV power transmission system are submitted to a comparative study. The results of the said comparative study indicate that the DC 3-terminal power transmission system presents the cheapest construction cost because it can use in common the Jaro HVDC S/S which will be constructed in the Luzon-Leyte power transmission project. Furthermore, this alternative is more advantageous from the standpoints of operation and maintenance and as a consequence it results more economical compared with the other two power transmission systems taken into consideration.

The construction of DC ±350 kV, 900 MW facilities is expected to be concluded early 1991 in the second stage of the Luzon-Leyte power transmission project. Therefore, the start of operation of this project in 1992 is appropriate also from the standpoint of coordination with that project and the adoption of the DC 3-terminal power transmission system is possible.

Calculations of power flow, stability and short-circuit capacity of the Mindanao Grid are carried out with the purpose of selecting the most appropriate site for the point of interconnection at the Mindanao side among the two proposed sites, i.e., Tagoloan S/S and Butuan S/S. The latter site is selected from the technical and economic standpoints and the area adjacent to the substation is selected for construction of the HVDC substation.

However, the installation of synchronous rotary condenser might be necessary in the Butuan HVDC S/S in the second stage of this project, in order to secure the stability of the DC power transmission system.

(3) The most appropriate HVDC system is of bipolar composition which will be firstly composed of monopolar at the first stage. Results of the comparison of the various patterns for extension of the DC ±350 kV 3-terminal power transmission system from the economical standpoint indicate that in the first stage of 1992 it is recommendable to construct the 200 MW monopolar system in the Butuan S/S, with installation of the additional facilities with

200 MW capacity corresponding to the other pole in the second stage of 1997, in order to realize the converter facilities with the final capacity of 400 MW.

(4) Selection of the submarine cable route and cable

The shortest course for interconnection between Leyte Island and Mindanao Island is via Panaon Island. However, there is a section with more than 500 m water depth between Panaon Island and Mindanao Island and therefore it is not an appropriate submarine cable route. Under the circumstances, the roundabout route via Dinagat Island and Nonoc Island is selected in this project and as a consequence the submarine cable extends over two sections with total distance of 49 km.

The first section of the submarine cable route with 33 km distance crosses the Surigao Strait between Hinundayan in Leyte Island and Balet Cove in Dinagat Island. The second section with 16 km distance crosses the Hinatuan Passage between Kantiasay in Nonoc Island and Lipata in Mindanao Island. The OF cable with 600 mm^2 section is selected from the technical and economical standpoints.

(5) Communication circuit

A microwave circuit will be constructed among Naga HVDC S/S, Jaro HVDC S/S and Butuan HVDC S/S, because high-speed and high-reliability transmission of information is required to operate the HVDC system.

Four repeater stations will be installed for the microwave circuit between Jaro HVDC S/S and Butuan HVDC S/S. Furthermore, VHF stations will be installed at the submarine cable terminals in order to transmit information required for sake of supervision.

(6) Cost and time schedule of the construction work

The first stage of the work will be started in 1988 and finished in 1991, and the second stage will be started in 1994 and finished in 1996. The construction costs in terms of prices prevailing in 1983 are the following.

Unit: US$$10^3$

	Foreign currency	Domestic currency	Total
1st stage	122,637	33,498	156,135
2nd stage	32,677	7,636	40,313
Total	155,314	41,134	196,448

(7) Economic evaluation and financial analysis

The economic evaluation and the financial analysis are carried out for two distinct cases, i.e., independent evaluation referring exclusively to this project and the integrated evaluation taking into consideration the totality of the DC power transmission facilities making the interconnection extending from the Luzon Island to the Mindanao Island. In making the evaluation particular attention is paid to make a clear distinction of the benefits of the Luzon-Leyte power transmission and the benefits of this project in order to prevent from being summed up twice.

a) Economic evaluation

Three principal benefits are taken into consideration for independent evaluation of this project, i.e., reduction of reserve power capacity, economical power interchange and reduction of power loss in the transmission lines as a result of the interconnection of the two power systems. On the other hand, the cost taken into consideration to make the economic evaluation of this project are the construction cost and the operation & maintenance cost during the life time of the project.

The benefit for the sake of integrated evaluation consists of the difference between the cost of power transmitted from the Tongonan geothermal power station to the Luzon Grid and the incremental fuel cost in the oil-fired thermal power plant of the Luzon Grid. On the other hand, the benefit related to the power transmitted from the Tongonan geothermal power station to the Mindanao Grid is the difference of power generating cost with regard to the coal fired thermal power stations of the Mindanao Grid. The cost comprises the total construction cost of the power transmission facilities from Naga HVDC S/S to Butuan HVDC S/S via Jaro HVDC S/S, the operation and maintenance costs during the life time of the project, the construction cost and the operation & maintenance cost of the units No. 7 to No. 22 of the Tongonan geothermal power station and the cost of steam purchased from PNOC.

b) Financial analysis

The benefit for independent evaluation is the revenue due to energy sales from Tongonan geothermal power stations to Mindanao power grid through the Leyte-Mindanao Power Transmission Project. On the other hand, the cost for the independent evaluation are the construction costs of the Project and Tongonan geothermal power plants and their steam cost and, respective operation and maintenance cost of them.

The benefit for integrated evaluation is the revenue due to energy sales from Tongonan geothermal power stations to both Luzon and Mindanao power grids through HVDC power transmission system (Naga-Jaro-Butuan 3-terminal HVDC system). Concerning the cost for integrated evaluation, the construction costs of the Project, the units of No. 7 to No. 22 of the Tongonan geothermal power stations and their steam cost and respective operation and maintenance cost are considered.

The results of the evaluation by means of the cash flow discount method based on the aforementioned benefits and costs are as follows.

	Economic evaluation (EIRR)	Financial evaluation (FIRR)
Independent evaluation	21.3 %	7.8 %
Integrated evaluation	14.4 %	12.6 %

According to the World Bank (IBRD) the economic internal rate of return desirable for the Philippines from the standpoint of opportunity cost of capital is 14% or more.

The economic internal rate of return of this project is 21.3% in the case of independent evaluation and 14.4% in the case of integrated evaluation, and as a consequence it is regarded as pertinent, because the EIRR surpasses 14% in both cases.

On the other hand, the result of the financial analysis indicates a quite low financial internal rate of return of 7.8% in the case of independent evaluation. Therefore, in the case of raising funds for implementation of this project it is recommendable to make use of low interest rate financing sources.

(8) The 230kV power transmission project from Kirahon HVDC S/S to Davao S/S is regarded as unnecessary as a result of the analysis of the power system. In other words, the 138kV transmission lines which are being planned by NAPOCOR at the present time are sufficient for the sake of extension of the Mindanao Grid.

2.2 Recommendations

The following recommendations are made on the basis of the conclusions mentioned in the section 2.1.

This project is pertinent from the technical and economic standpoints and NAPOCOR should take actions to realize the project. The operation of this project is to be started in 1992 and therefore the various kinds of survey such as the detailed study (D/S), etc., should be commenced in 1988. Therefore, attension should be paid to the following points.

(1) Relationship between this project and other projects

This project is closely related with the geothermal power development projects of Tongonan and other places in the Leyte Island and with the Luzon-Leyte power transmission project. Therefore, in executing this project attention should be paid to the state of progress of the work of the said projects.

(2) Expropriation of land

The southern part of the Dinagat Island and the Nonoc Island belong to the nickel ore exploitation area of the Marinduque Mining and Industrial Corporation (MMIC). The definitive route of the overhead transmission lines should be decided after consultations with MMIC about expropriation of land, because it will be located in this mining area.

The sites for construction of the HVDC substations, transmission lines, microwave repeater stations, etc., should be expropriated in advance in order to make possible the smooth progress of the construction in accordance with the time schedule.

(3) Further field survey

a) Survey to lay the submarine cable

It is indispensable to carry out in advance a complete survey of the submarine cable routes, including the meteorology, marine meteorology and restrictions related to the sailing of vessels, particularly at the Nonoc Island side of the Hinatuan Passage, because it has a very rapid tide flow speed and furthermore this passage has heavy traffic of vessels and the operation of fishing boats is very frequent.

b) Survey of salt contamination

Salt contamination is a serious problem in the case of the HVDC system. Therefore, it is indispensable to prepare data about the matter by measuring the extent of deposition of salt throughout the totality of the project area.

c) Survey of the grounding electrode site

It is necessary to carry out the survey about the topography, geology, sea water level at the ebb and flow of tide and other details of the grounding electrode sites. Furthermore, it is also necessary to carry out the survey about burried facilities of nearby private houses and factories which could be influenced by the electrolytic corrosion caused by the ground current.

d) Microwave circuits

The negotiations about the frequency band to be used in the microwave circuit and VHF circuit should be held in advance with the competent authorities. Furthermore, the selection of exact sites of the repeater stations should be surveyed at the detailed study stage.

It is also necessary to hold negotiations with the competent authorities about the use of military microwave circuit as stand-by circuit.

CHAPTER 3

POWER INDUSTRY IN THE PHILIPPINES

CHAPTER 3 POWER INDUSTRY IN THE PHILIPPINES

3.1 Power Market

3.1.1 Organization

The power sector in the Philippines is comprehensively administered by the Ministry of Energy (MOE). There are two major Government agencies which share the responsibilities for stable electric power supply: (i) the National Power Corporation (NAPOCOR) who is largely responsible for power generation and transmission under the MOE and (ii) the National Electrification Administration (NEA) who is responsible for power distribution under the Ministry of Human Settlement. The Philippine Atomic Energy Commission and the Philippine National Oil Corporation (PNOC) are the other two agencies administered under the MOE.

The electric power in the Philippines is supplied through electric utilities such as NAPOCOR, the Manila Electric Company (MECO), other privately owned utilities and 116 electric cooperatives as of the beginning of 1980. Out of them, MECO had the largest generating capacity which considerably exceeded that of NAPOCOR. Aiming at promoting efficient utilization and accelerated development of the power facilities, NAPOCOR and MECO have negotiated their integration since 1975. Finally on July 11, 1978, they reached the agreement that MECO would sell its power plants to NAPOCOR. On November 1, 1978, operations of these plants with total installed capacity of 1,150 MW had been turned over to NAPOCOR.

3.1.2 Supply and Demand of Power

The installed capacity of the NAPOCOR amounted to 4,324 MW in 1982. The generation mix was 57% oil-based power plant, 29% hydro power plant, 13% geothermal power plant and 1% coal-oil dual fired power plant. In terms of geographical location, 81% of the total system capacity provides for Luzon's power requirements and the remaining capacity is shared by Visayas (6%) and Mindanao (13%). Over the past five years of 1978 to 1982, the system capacity of NAPOCOR increased at an annual rate of 19%. The historical data on installed capacity of NAPOCOR is shown in Table 3-1.

The energy generation of NAPOCOR in the period from 1977 to 1982 grew at a rate of 9% per annum. Of the 17,413 GWh generation in 1982, 58% was produced by oil-based power plant, 21% by hydro power plant and another 21% by geothermal power plant (Table 3-2). According to the data of MECO, energy sales for industrial use in 1980 amounted to 39% of the total energy sales, for commercial use 32% and for residential use 27%. The industrial power use increased at an annual rate of 6% in the period from 1975 to 1980 and the residential power use at 10% in the same period (Table 3-3).

In 1980, about 39% of the total household in the Philippines was served by electricity. Geographically, about 54% of the total household was served by electricity in Luzon, 21% in Visayas and 22% in Mindanao (Table 3-4).

In 1982, the average power rates of NAPOCOR were 46.70 centavos/kWh in Luzon, 54.44 centavos/kWh in Visayas and 18.59 centavos/kWh in Mindanao, the country-wide average being 42.99 centavos/kWh (Table 3-5). In the period from 1977 to 1982, the average power rates of NAPOCOR increased at the annual rate of 21% in Luzon, 13% in Visayas and 34% in Mindanao, the country-wide average being 24%.

3.2 Present State and Development Plans of Geothermal Energy in Leyte Island

3.2.1 Background

Exploration of the geothermal resources in the Leyte Island had commenced in 1973 at Tongonan. The Tongonan geothermal field is located on the southwestern slopes of the mountains of northwest Leyte and lies within the catchment area of the Upper Mahiao and the Sambaloran rivers. The production field is situated between elevations of 400 m and 700 m above sea level and has a minimum surface area of 4 km^2.

The scientific studies and development of the Tongonan Geothermal Power Project has been carried out under the technical cooperation of the Government of New Zealand and the Tongonan geothermal project has been promoted by the joint efforts of three Government agencies of the Philippines i.e. NAPOCOR, PNOC and EDC. On October 21, 1976, the first deep exploratory production well was drilled at the Mahiao area and in July 1977, the first 3 MW geothermal pilot plant started to supply the power to Ormoc city.

The construction of the 112.5 MW (=3 units × 37.5 MW) geothermal power plant was completed and commercial operation commenced in May, 1983 for the plant No.1, in July, 1983 for the plant No.2 and in September, 1983 for the plant No.3. These three plants is planned to supply power required in the PASAR copper smelter project undertaken at Isabel in Leyte.

The present Leyte-Mindanao Power Transmission Project aims at utilizing effectively the above exploited Tongonan geothermal power by connecting the Leyte-Samar power grid with the Mindanao power grid. Meanwhile, the Luzon-Leyte Power Transmission Project which aims at transmitting Tongonan geothermal power from Leyte to Luzon is now under its detailed design stage administered by NAPOCOR and financed by OECF of Japan.

3.2.2 Technical and economic features of Tongonan geothermal power project

(1) Current development

The feasibility study together with preliminary design of the Tongonan Project was conducted in 1978 by a New Zealand consultant in association with NAPOCOR, PNOC and EDC[/1]. The said study had identified and proved the technical and economic feasibility of the first stage development of geothermal resources with the capacity of 112.5 MW.

According to NAPOCOR[/2], the technical features of Tongonan 112.5 MW Project are as shown below.

(i) Area of geothermal field reservation: 107,625 ha

(ii) Heat energy: minimum 200°C

/1 Tongonan Geothermal Power Station, Preliminary-Design Report, KRTA, October 1978

/2 Capsule Report, Tongonan Geothermal Power Project, NAPOCOR, 1979

(iii) Steam wells:

Having been drilled	:	17 wells
To be utilized for steam production for 112.5 MW	:	11 "
Standby	:	3 "
For re-injection	:	3 "

(iv) Depth of steam wells : 3,700 - 6,600 ft.

(v) Power plant capacity : 112.5 MW (=3 × 37.5 MW)

(vi) Transmission lines:

Tongonan - Isabel (33.9 km)	:	138 kV (Double)
" - Tunga (43.9 km)	:	69 kV
" - Wright (110.0 km)	:	138 kV

The project cost of NAPOCOR for 112.5 MW installation is estimated at P491 million covering civil works, electro-mechanical supply, erection works, consulting services etc. and that of EDC is estimated at P270 million covering steam collection and effluent-disposal system, well drilling costs, site expenses and geoscientific overhead etc.

(2) Future development

According to the most up-to-date information obtained from NAPOCOR, the future development of Tongonan geothermal power is scheduled as shown below.

Tongonan Power Plant	Capacity	Year of Commission
No.1 - No.3	3 × 37.5 MW = 112.5 MW	1983
No.4 - No.6	3 × 37.5 MW = 112.5 MW	1986
No.7 - No.8	2 × 55 MW = 110 MW	1988
No.9 - No.12	4 × 55 MW = 220 MW	1989
No.13 - No.16	4 × 55 MW = 220 MW	1991
No.17 - No.20	4 × 55 MW = 220 MW	1992
No.21 - No.22	2 × 55 MW = 110 MW	1993
Total	1,105 MW	

As shown above, the final exploitation of Tongonan geothermal energy is expected to amount to as much as 1,105 MW.

It is noted that the power potential of the Tongonan geothermal field which has been unofficially informed to exceed 1,000 MW could not be officially confirmed during the field survey of the present study. Such being the situation, the development plan of the Tongonan geothermal power prepared by NAPOCOR was adopted as it was in this Study.

3.2.3 Other geothermal energy sources in Leyte

Since the Philippines lies on a high-heat flow region that is a part of the "Circumpacific Fire Belt", geothermal potential has long been identified as a viable economic source of energy. According to "the Five-Year Energy Program 1981 - 85" prepared by the Ministry of Energy, twenty two sites are designated as geothermal potential areas (Table 3-6). Tongonan is listed as one of the four "proven potential areas". In the Leyte Island, the three potential sites, other than Tongonan, are listed as "possible potential areas"; they include Biliran Island, Burauen in northern Leyte and Anahawan in southern Leyte. Their locations are shown in Fig. 3-1.

According to the information obtained during field survey of the present study, the most up-to-date status of three geothermal potential sites are briefed as follows: At the Biliran geothermal field, three wells had been drilled but, although their potential capacities were informed to amount to some 200 MW, they are not confirmed yet. At the Burauen geothermal field, test boring is planned to be conducted within the year of 1983. At the Anahawan geothermal field, an initial survey alone is scheduled to be done in the near future.

However, since there are still many uncertainties about geothermal potentials at these geothermal areas, no areas of the above three were taken up in this Study as the source of power supply.

Table 3-1 Installed Capacity by Geographical Location and by Plant Type, 1977 to 1982

Unit: MW

Item	1977	1978	1979	1980	1981	1982	(%)
LUZON	752	1,902	2,994	3,226	3,156	3,511	(81)
Hydro	521	527	544	556	556	856	
Oil-Based	231	1,375	2,230	2,230	2,105	2,105	
Geothermal	-	-	220	440	550	550	
VISAYAS	42	73	93	103	224	263	(6)
Hydro	2	2	2	2	2	2	
Oil-Based	37	68	88	95	166	202	
Geothermal	3	3	3	6	6	9	
Coal-Oil Dual Fired	-	-	-	-	50	50	
MINDANAO	213	213	429	487	523	550	(13)
Hydro	202	202	382	382	382	409	
Diesel	11	11	47	105	141	141	
PHILIPPINES	1,007	2,188	3,516	3,816	3,903	4,324	(100)
Hydro	725	731	928	940	940	1,267	(29)
Oil-Based	279	1,454	2,365	2,430	2,412	2,448	(57)
Geothermal	3	3	223	446	501	559	(13)
Coal-Oil Dual Fired	-	-	-	-	50	50	(1)

Source: "1982 Annual Report" NAPOCOR

Table 3-2 **Gross Energy Generation by Geographical Location and by Plant Type, 1977 to 1982/1**

Unit: GWh

Item	1977	1978	1979	1980	1981	1982 (%)
LUZON	10,380/2	11,222/2	12,504/2	13,115	13,666	14,398(83)
Hydro	1,270	1,755	1,731	1,873	2,033	1,832
Oil-Based	9,110	9,467	10,120	9,173	8,894	9,011
Geothermal	-	-	653	2,069	2,739	3,555
VISAYAS	55	230	243	321	503	777(4)
Hydro	12	11	8	9	8	10
Oil-Based	42	216	231	304	464	676
Geothermal	1	3	4	8	31	31
Coal-Oil Dual Fired/3	-	-	-	-	-	60
MINDANAO	901	1,045	1,146	1,650	1,819	2,238(13)
Hydro	899	1,026	1,129	1,620	1,683	1,909
Oil-Based	2	19	17	30	136	329
Geothermal	-	-	-	-	-	-
PHILIPPINES	11,336	12,497	13,893	15,086	15,988	17,413(100)
Hydro	2,181	2,792	2,868	3,502	3,724	3,751(21)
Oil-Based	9,154	9,702	10,368	9,507	9,494	10,016(58)
Geothermal	1	3	657	2,077	2,770	3,586(21)
Coal-Oil Dual Fired/3	-	-	-	-	-	60(-)

/1: Includes generation of power plants under test run

/2: Includes energy generation of MECO plants

/3: Generation of Cebu Coal Thermal Plant broken down into: 60 GWh Coal and 186 GWh Oil-based

Source: "1982 Annual Report" NAPOCOR

Table 3-3 Energy Sales of MECO by Customers

Unit: GWh

Customers	1975	1976	1977	1978	1979	1980	Growth p.a. '75/'80 (%)
Residential	1,418	1,486	1,623	1,786	2,015	2,228 (27)	9.5
Commercial	1,812	1,958	2,177	2,323	2,508	2,617 (32)	6.7
Industrial	2,386	2,571	2,764	2,990	3,349	3,259 (39)	6.4
Street Lights	45	47	49	51	52	55 (1)	4.1
Resale	228	255	281	187	63	57 (1)	-24.2
Total	5,889	6,317	6,894	7,337	7,987	8,216(100)	6.9

Source: "1980 Statistical Yearbook on the Philippine Electric Power Industry", NAPOCOR Corporate Planning

Table 3-4 Status of House Connection in 1978 and 1980

Unit: 10^3

Region	1978			1980		
	With (%)	Without (%)	Total	With (%)	Without (%)	Total
Luzon	1,661 (43.5)	2,154 (56.5)	3,815	2,163 (54.1)	1,834 (45.9)	3,997
Visayas	241 (14.5)	1,412 (85.5)	1,653	369 (21.3)	1,362 (78.7)	1,731
Mindanao	205 (13.4)	1,327 (86.6)	1,532	350 (21.8)	1,255 (78.2)	1,605
Total	2,107 (30.1)	4,893 (69.9)	7,000	2,882 (39.3)	4,451 (60.7)	7,333

Source: Processed from "1980 Statistical Yearbook on the Philippine Electric Power Industry," NAPOCOR Corporate Planning

Table 3-5 Average Power Rates of NAPOCOR by Region

Unit: centavo/kWh

Region	1977	1978	1979	1980	1981	1982
Luzon	18.10	18.16	22.77	36.40	44.80	46.70
Visayas	29.21	29.49	30.80	40.62	49.82	54.44
Mindanao	4.26	11.00	13.66	16.51	18.00	18.59
Philippines	14.41	17.23	22.12	34.22	41.66	42.99

Source: "1982 Annual Report" NAPOCOR

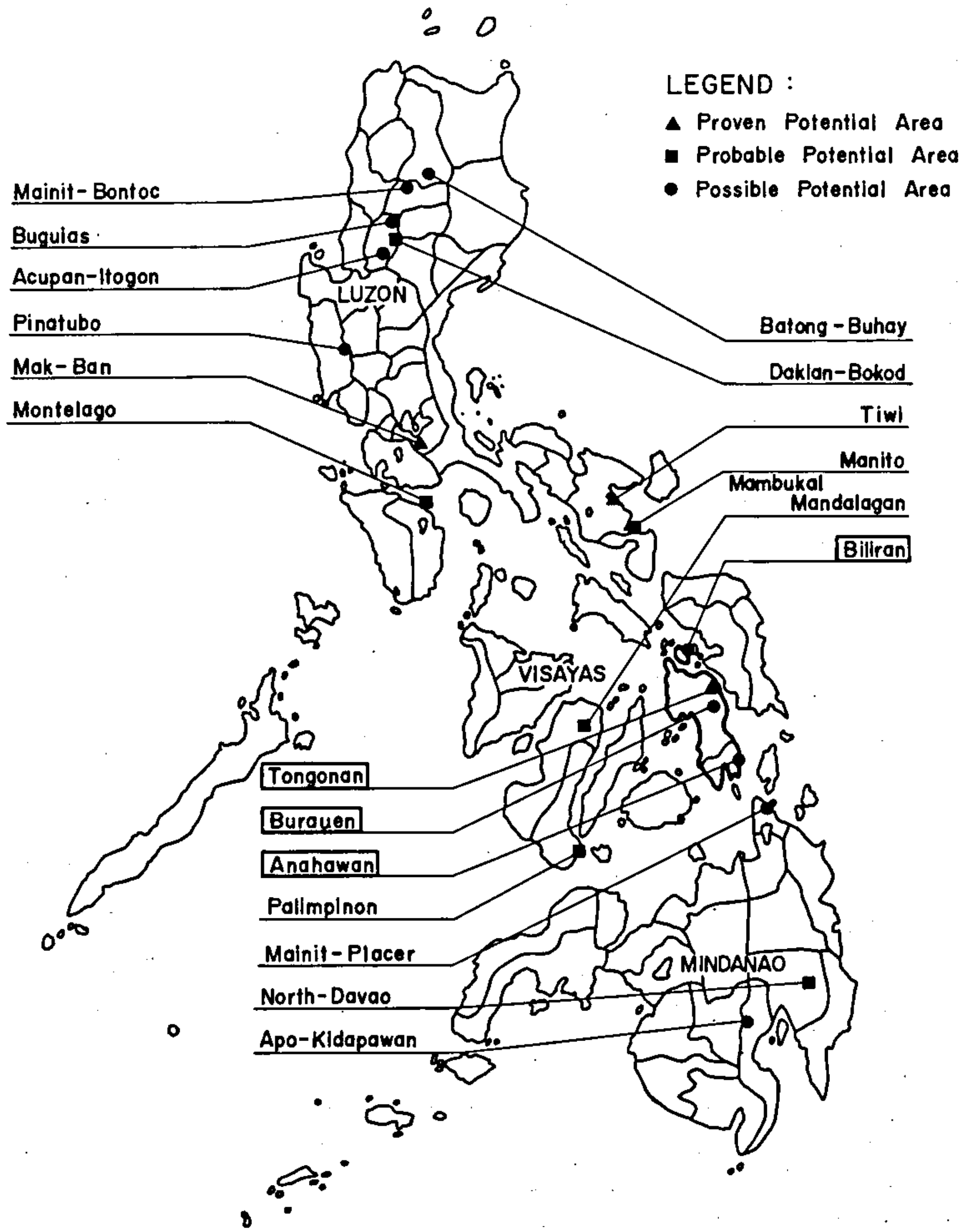
Table 3-6 Potential Geothermal Areas in the Philippines

Region	Geothermal area/location	Proven potential area	Probable potential area	Possible potential area	Entities involved
4	Makiling-Banahaw, Laguna	x			NPC/Union Oil (PGI)
5	Tiwi, Albay	x			NPC/Union Oil (PGI)
7	Palimpinon-Dauin, Negros Oriental	x			PNOC-EDC/KRTA
8	Tongonan, Leyte	x			PNOC-EDC/KRTA/ NAPOCOR
1	Daklan-Bokod, Benguet		x		BED/ELC
4-A	Naujan-Montelago, Oriental Mindoro		x		BED/ELC
5	Manito, Albay		x		PNOC-EDC (under negotiation by PGI)
6	Mambucal-Mandalagan, Negros Occidental		x		PNOC-EDC
11	Manat-Masara, North Davao		x		PNOC-EDC
1	Acupan-Itogon, Benguet			x	BED/ELC
1	Buguias, Benguet			x	BED/ELC
1	Mainit-Bontoc, Mt. Province			x	BED/ELC
2	Batong Buhay, Kalinga-Apayao			x	BED/ELC
2	Cagua, Cagayan			x	BED/ELC
3	Pinatubo, Zambales			x	BED/ELC
4	Mabini, Batangas			x	BED/ELC
5	Bulusan, Sorsogon			x	BED/ELC
8	Biliran Island, Northern Leyte			x	PNOC-EDC/BED ELC
8	Burauen, Northern Leyte			x	PNOC-EDC/KRTA
8	Anahawan, Southern Leyte			x	BED/ELC
10	Mainit-Placer, Agusan Norte			x	BED/ELC
12	Apo-Kidapawan, North Cotabato			x	

NAPOCOR - National Power Corporation
PGI - Philippine Geothermal, Inc.
PNOC-EDC - Philippine National Oil Company - Energy Development Corporation
KRTA - Kingston, Reynolds, Thom and Allardice, Ltd.
BED - Bureau of Energy Development
ELC - Electroconsult
Proven - Sufficiently explored by drilling, thereby establishing certainty as to presence of economic geothermal potential
Probable - Sufficient exploratory and production well.
Possible - Geological reserves.

Source: Five-Year Energy Program 1981 - 85, MOE, July 1980.

Fig. 3-1 Potential Geothermal Areas in the Philippines



3.3 Power Systems of the Philippines

3.3.1 General

The power system of the Philippines consists of 3 blocks, i.e., the Luzon Grid located in the Luzon Island, the Visayas Grid covering the Leyte Island, Samar Island, Cebu Island, etc., and the Mindanao Grid located in the Mindanao Island, and the following classes of voltage are adopted in each grid.

Luzon Grid:	230 kV, 115 kV, 69 kV
Visayas Grid:	138 kV, 69 kV
Mindanao Grid:	138 kV, 69 kV

In the Luzon Grid the 230 kV system was expanded and furthermore the construction of 500 kV power transmission facilities is being planned concurrently with the development of geothermal power sources in the southern part and hydroelectric power sources in the northern part of the island.

On the other hand, the Visayas Grid consists of 138 kV power transmission system because the area it covers is limited and the demand is small.

In addition to the aforementioned facilities, NAPOCOR is planning the transmission of power generated by the abundant geothermal energy resources of Leyte Island to the Luzon Grid by means of HVDC power transmission line.

The outline of the Luzon, Leyte-Samar and Mindanao power systems is described in Figs. 3-2 & 3-3 and Tables 3-7 & 3-8.

3.3.2 Power system of the Luzon Island

In the Luzon Island there is large concentration of population in Manila and its environs and there are many factories in the city and its vicinity. The power demand in the Manila area is covered by transmitting power from relatively distant power plants such as the hydroelectric power stations located in the northern part and geothermal power stations located in the southern part of the Luzon Island, in addition to power plants located at the center of the island, consisting principally of oil-fired thermal power stations.

The power demand in Luzon Island is expected to expand further in the future, principally in the Manila area. Under the circumstances, the 230 kV trunk transmission system consisting of 230 kV trunk transmission lines aimed at transmitting power from remote power sources to Manila, 230 kV trunk lines for electrification of local districts and 230 kV circular transmission line surrounding the suburbs of Manila and interconnecting the substations and the nuclear, coal-fired thermal and pumped-storage power stations under construction in this area are in course of construction in nationwide scale, and this system is expected to contribute for an efficient operation of the north-south interconnected system under the control of the new central load dispatching center which is in partial operation at the present time.

The 230 kV trunk transmission system is sufficient to cope with the demand of electricity and development of power sources up to the mid '80s but its capacity is expected to become insufficient to cope with the development of power sources of the southern part of the Luzon Island and to receive power generated by the geothermal energy sources of Leyte Island.

Under the circumstances, NAPOCOR carried out the study of the power system of the southern part of Luzon Island and as a result it has drawn up the plan for construction of the AC 500 kV transmission line from San Jose at the environs of Manila to Naga, via Kalayaan (approximately 340 km), which will be used for transmission of electricity generated by the power sources of the southern part of the island and geothermal power generated in Leyte Island.

The detailed design of the AC 500 kV transmission line is already finished.

3.3.3 Leyte-Samar power system

In the Leyte-Samar area there is so far only one major consumer of electricity, namely, the 138,000 t/y copper smelting plant located in the Isabel area which started its operation in 1983. The total power demand of the whole area is less than 1/100 compared with Luzon Island.

The power demand in the Isabel area is covered by the Tongonan 1, 2 and 3 power plants (112.5 MW) which entered in service in 1983.

There are plans to construct a 138 kV transmission line across the San Juanico strait between Leyte-Samar in 1984 to transmit abundant geothermal electricity of Tongonan to Samar Island in order to promote the rapid electrification of Samar Island together with Leyte Island, and the detailed design for the construction of the towers of the part of the transmission line crossing the strait was finished in late 1983.

In addition to the aforementioned facilities, there are plans for development of the geothermal energy resources of Leyte Island consisting of the Tongonan No.4 to Tongonan No.21 units (990 MW). The totality of the generated energy will be transmitted to Luzon Island and at the present time the HVDC power transmission system is undergoing detailed design.

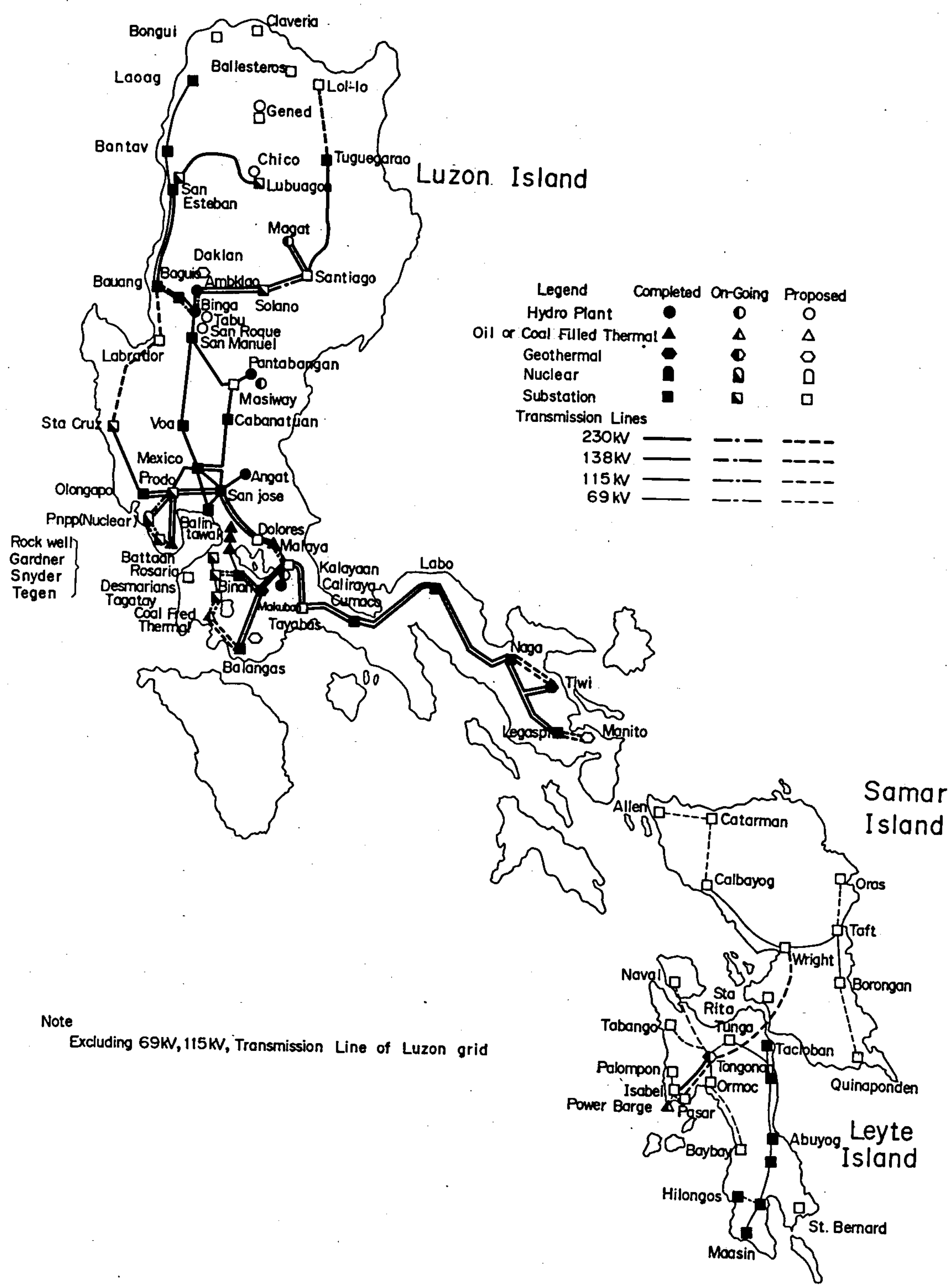
3.3.4 Power system of the Mindanao Island

The industrialization of Mindanao is being implemented principally in the north-western part of the island and the development of power sources and the construction and expansion of the 138 kV power transmission network is also progressing concurrently.

The power sources of Mindanao consist principally of Agus hydroelectric power stations and they are expected to play a leading part also in the future. However, the construction of the Bislig coal-fired thermal power plant is being planned in order to cope with the increase of power demand expected to occur after the second half of the '80s and in addition the interconnection with the Tongonan geothermal stations of the Leyte Island is being planned as well in order to upgrade the power supply reliability.

As for the improvement of the power transmission network, the 2 circuits between Tagoloan S/S (under construction), Kibawe and Kabacan consisting principally of 138 kV systems and one circuit between Butuan S/S-Bislig-Davao S/S (with future expansion to 2 circuits) are under construction at the present time and the Mindanao Grid is expected to be upgraded by a considerable extent after the completion of these transmission lines.

Fig. 3-2 Leyte, Samar, and Luzon Grid in 1982



Note
Excluding 69kV, 115kV, Transmission Line of Luzon grid

Fig. 3-3 Mindanao Grid in 1982

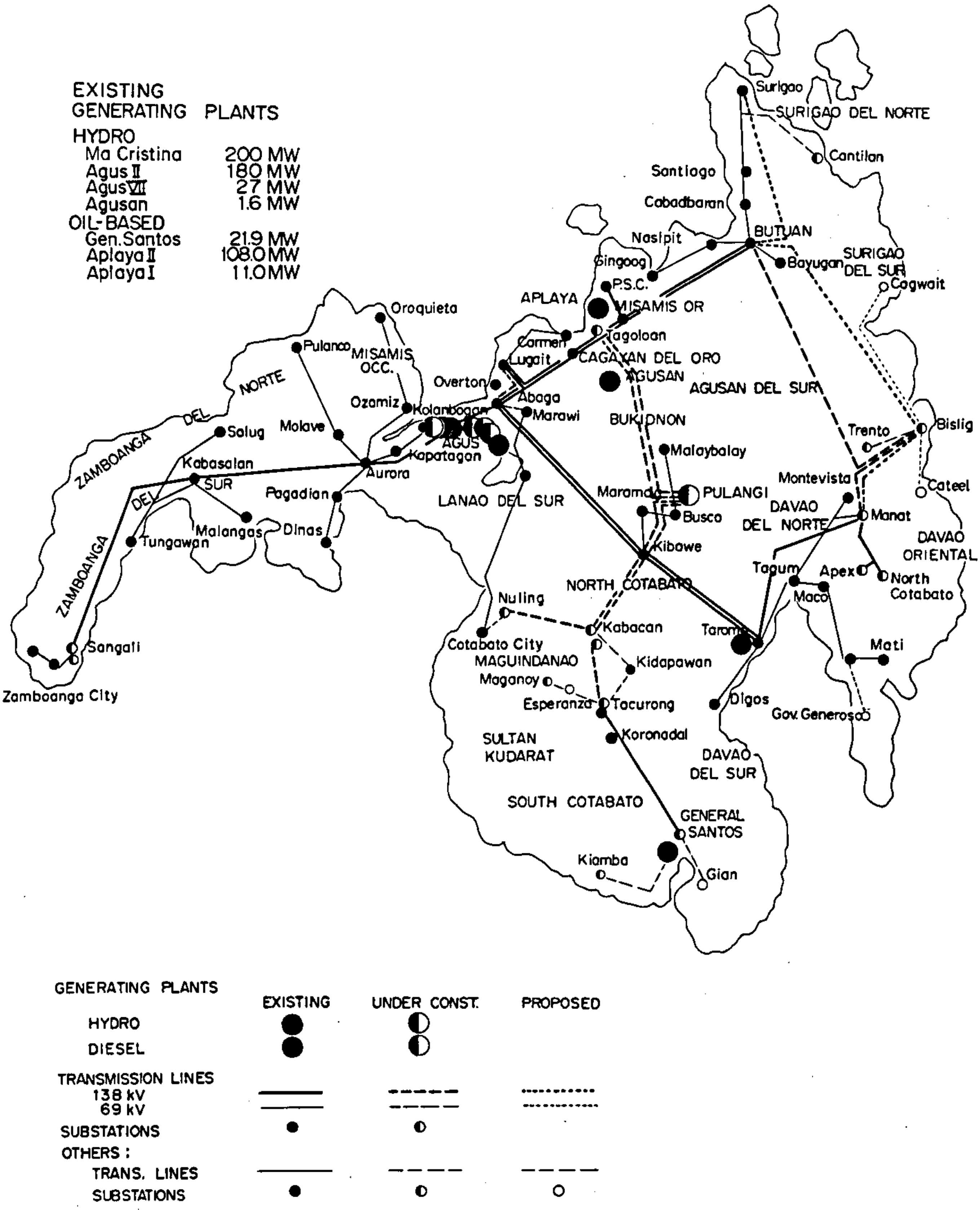


Table 3-7 Load Forecast of Luzon, Leyte - Samar and Mindanao Grids

Year	Luzon Grid		Leyte-Samar Grid		Mindanao Grid	
	Demand (MW)	Energy (GWh)	Demand (MW)	Energy (GWh)	Demand (MW)	Energy (GWh)
1982	2,263	14,481	21	45	357	2,101
1983	2,525	15,495	46	239	452	2,763
1984	2,705	16,580	76	355	554	3,512
1985	2,890	17,740	112	680	645	4,044
1986	3,100	18,980	128	848	779	4,844
1987	3,315	20,310	131	867	799	4,985
1988	3,545	21,730	134	938	863	5,466
1989	3,790	23,250	155	1,020	946	5,988
1990	4,060	24,880	169	1,101	1,004	6,340
1991	4,300	26,370	175	1,145	1,111	7,047
1992	4,560	27,955	184	1,196	1,197	7,587
1993	4,835	29,630	—	—	1,321	8,405
1994	5,125	31,410	—	—	1,441	9,163
1995	5,430	33,295	201	1,307	1,554	9,877
1996	—	—	—	—	1,673	10,648
1997	—	—	—	—	1,797	11,454
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2000	6,928	42,480	233	1,527	2,201	—

Table 3-8 Generation Expansion Plan of Luzon, Leyte - Samar and Mindanao Grids

(MW)

Year	Luzon Grid						Leyte-Samar Grid				Mindanao Grid				
	Hydro	Geo.	Coal therm.	Nucl.	Oil therm.	Total	Geo.	Power Barge	Diesel	Total	Hydro	Diesel	Coal therm.	Geo.	Total
1982	854	495	0	0	1,925	3,274	3	32	20	55	409	177	0	0	586
1985	1,214	660	300	620	1,925	4,719	115.5	64	25.7	205.2	976	235	0	0	1,211
1990	1,604	1,100	600	620	1,925	5,849	228.0	64	25.7	317.7	1,201	235	200	0	1,636
1995	1,754	1,650	1,200	620	1,925	7,149	—	—	—	—	1,673	235	400	110	2,418
1997	—	—	—	—	—	—	—	—	—	—	1,851	235	400	110	2,596

CHAPTER 4

POWER DEMAND FORECAST

CHAPTER 4 POWER DEMAND FORECAST

4.1 General

4.1.1 Objectives of power demand forecast in the present study

The objectives of power demand forecast in this study lie in the followings:

a) For Mindanao Grid:

To confirm the future power demand in Mindanao grid to determine the capacity of transmission line connecting Leyte-Samar grid and Mindanao grid.

b) For Leyte-Samar Grid:

To confirm the future power demand in Leyte-Samar grid to estimate the future surplus power to arise in this grid.

c) For Luzon Grid:

To confirm the future power demand in Luzon grid to estimate the requirement to be transmitted from Leyte-Samar grid to Luzon grid.

4.1.2 Methodology

(1) Mindanao Grid

For Mindanao power grid, the power demand forecast was carried out through projecting the GRDP (Gross Regional Domestic Product) elasticity of power demand which refers to the responsiveness of the power demand to changes in GRDP. The procedure is briefly described below.

a) First, the historical values of the GRDP elasticity of power demand were obtained based on the historical data of the GRDP growth and the power consumption growth (both in per capita basis).

b) The future per capita GRDP growth rates were estimated in two cases of high case and low case.

c) The growth rate of future power consumption in per capita basis was derived by applying the above elasticity to the estimated GRDP growth rates.

d) Future population growth rate was adopted from the projection of National Census and Statistics Office.

e) The peak demand was obtained based on the above estimated energy requirement taking into consideration such factors as the rate of energy loss and the load factor.

(2) Leyte-Samar Grid

The Leyte-Samar region is now still at the initial stage of social and economic development. In the past, the power demand in this region has been small and met by local supply sources such as privately operated utilities and cooperatives. However, since the geothermal potentials have been identified and exploited in the Leyte Island, industrial development of the region is now being started. Hence, a big hike in the power demand is expected in the region in the near future.

The situation being as such, the power demand forecast in the Leyte-Samar grid was made taking into considerations the potentials of economic development of the region and the Government's plan of the industrial development in this region.

(3) Luzon Grid

For Luzon grid, the power demand forecast was carried out by applying the same method as Mindanao grid described above.

4.2 Power Demand in Luzon Grid

4.2.1 Historical load increase in Luzon grid

In Luzon grid, from 1970 to 1981, the energy generation increased annually at the rate of 7.2% and the energy sales increased annually at the rate of 8.4%. The peak power demand nearly doubled from 1,111 MW in 1970 to 2,225 MW in 1981 with the annual increase rate of 6.5%.

The rate of system loss showed a prominent decrease from 18.2% in 1970 to 7.1% in 1981. The main reason of this low system loss is that many of the power plants are located near the Metro Manila area, the biggest load center in Luzon. However, this system loss covers only that of NAPOCOR and MECO and does not cover the distribution loss of cooperatives whose rate of loss is estimated to be bigger than the above figures.

The historical data on power generation, power sales, peak power demand, load factor and system loss in the Luzon power grid are shown in Table 4-1.

4.2.2 Power Demand Projection in Luzon

The methodology of power demand projection in Luzon grid was the same as was applied to the power demand projection for Mindanao grid in this Study. The said procedures applied for Mindanao grid are mentioned in detail in sub-section 4.4.3. The procedures applied for Luzon grid power demand projection are summarized below.

(1) The historical GRDP elasticity of power consumption in Luzon grid was derived based on the annual growth rates of per capita power consumption and per capita GRDP for the period from 1971 to 1981 (Table 4-2).

(2) The future GRDP elasticity of power consumption in Luzon grid was assumed at 1.2 for the period of 1982 — 1990 and 1.1 for 1991 — 2000.

(3) Growth of per capita GRDP was assumed in two cases of high case and low case. The target of 4.3% growth per annum indicated in the Philippines Development Plan 1983 — 87 was assumed as the growth rate in high case

and that in low case was set at 1.0% less than that of high case i.e. 3.3% per annum.

(4) Growth rate of per capita power consumption was derived by growth rate of per capita GRDP multiplied by GRDP elasticity of power consumption. Growth rate of power consumption was derived by the growth rate of per capita power consumption multiplied by the growth rate of population in Luzon. The growth rate of power consumption thus projected for the period of 1982 — 2000 was shown in Tables 4-4 and 4-5 for high and low cases respectively.

(5) Peak power demand in Luzon grid was projected based on the above projected growth rate of power consumption assuming system loss and load factor as shown in Table 4-6 and 4-7.

(6) The forecast of power generation and peak demand in Luzon grid prepared by NAPOCOR is shown in Table 4-8.

(7) The peak demand projected in this study of high and low cases are compared with that prepared by NAPOCOR in Table 4-9 and depicted in Fig. 4-1.

The NAPOCOR projection lies between the high case and low case projection made in this Study and was adopted as the basic demand projection based on which planning was carried out in this Study.

The NAPOCOR projection was prepared until the year of 1995 and was extrapolated until the year of 2000 by applying the annual growth rate of 6.0% which was determined based on the growth trend in the period from 1990 to 1995. The projected peak demand together with energy generation, energy sales, load factor and system loss is shown in Table 4-9. The peak demand in Luzon grid was projected to amount to 5,430 MW in 1995 and 6,928 MW in 2000.

4.3 Power Demand in Leyte-Samar Grid

4.3.1 Present socio-economy and power demand in Leyte-Samar region

The Leyte and Samar Islands are designated administratively as the Eastern Visayas Region (Region 8). This region has been one of the depressed regions in the Philippines. At present, however, the big scale industrial projects e.g. PASAR and PHILPHOS are being under way in the Leyte Island and the Region is at the initial stage of its socio-economic development.

(1) Population

In 1980, the population of the Eastern Visayas Region was 2,799 thousand (1,599 thousand in Leyte and 1,200 thousand in Samar). The average growth rate of the population of the region in the period from 1970 to 1980 was 1.6% per annum, which was far below that of the whole country of 2.8% per annum for the same period. The ratio of the population of the region to the whole Philippines showed a decreasing trend from 6.5% in 1970 to 5.8% in 1980 (Table 4-3). Approximately 80% of the population live in rural area and 20% in urban area. The employment in agriculture occupied 66% of the total labor force in 1980 and the remainder in other sectors. The unemployment rate of the region was 10.5% in 1980 while that of the whole country was 4.8%.

The population projection of the region was made by National Census and Statistics Office as shown in Table 4-10 (medium case projection). In projecting the future population of the region, it was assumed that the ratio of the population of the region to the whole Philippines population would decline until 2000 reaching 5.4% (3,754 thousand) following the past decreasing trend.

(2) Gross Regional Domestic Product (GRDP) of the Region

The Leyte-Samar Region is characterized to be an agricultural region. In 1981, the GRDP of primary sector including agriculture, forestry and fishery shared 55%, that of secondary sector including manufacturing, mining and quarrying, construction etc. shared 14% and that of services sector shared 31% each in the total GRDP (Table 4-11). During the period from 1979 to 1981, the share of primary sector showed a decreasing trend from 57% to 55%, while that of secondary sector showed an increasing trend from 13% to 14%; an industrialization is going on though slowly in the Region.

The annual growth rate of the GRDP in 1981 was 3.6%, which was below that of GDP of the whole Philippines of 4.8%. This low growth rate of GRDP was caused by the low growth rate of primary sector of 1.7%. The growth of secondary sector in the Region was as high as 6.5% in the same year.

Per capita GRDP in the Leyte-Samar Region in 1981 was ₱818 at 1972 constant price which corresponded to 42% of the per capita GDP of the whole Philippines of ₱1,942. Per capita GRDP in the Region decreased in 1981 & 1982 because population growth rate was higher than GRDP growth rate (Table 4-10).

Breakdown of industrial production by commodity in the Region is shown in Table 4-12. Centrifugal sugar and other sugar cane-based manufacturing products such as ribonucleic acid and molasses are on the tap of the list. In 1981, more than 90% of the total manufacturing products were produced by three manufacturers i.e. HIDECO and OSCO both of which are sugar mills located in Leyte Island and BIOPHIL which is a chemical factory located also in Leyte.

(3) Present power demand and supply

Electrification in the Leyte-Samar grid is at its initial stage. As mentioned in the preceeding section, the Leyte-Samar region has been characterized as an agricultural region and no big industries have been established in the Region. However, since the geothermal resources has been exploited in Tongonan, a rapid industrialization has been proceeding at Isabel industrial estate in northern Leyte.

Energization in the Leyte-Samar Region (Eastern Visayas Region) as of the end of 1981 is shown in Table 4-13. As for the house connection, about

71,500 households were provided with electric power within the total of 365,000 households situated in the area franchised by NEA in this Region. The ratio of power-connected household to the total household in the NEA franchised area in 1981 was about 20%, which was far below the average of the whole Philippines of 37%.

Since there exist no large scale industries in the Region at present, which is attributed to the region's characteristics to have been an agricultural region, the power demand in the region has been comparatively low in the past.

The historical peak demand was recorded at 4.0 MW at maximum for the period from 1968 to 1974 during which it increased with the average growth rate of 1.6% per annum. In 1975, the two cooperatives i.e. SAMELCO II and LEYECO II were newly established and the capacity of 1,300 kW and 5,670 kW (diesel generator) respectively were added to the power grid. Thereafter, the system peak demand increased at the average growth rate of 31% per annum reaching 17 MW in 1980.

The historical energy generation in the Leyte-Samar grid amounted to only 12.7 GWh in 1968 and it increased at a comparatively low growth rate of 2.6% per annum in the period from 1968 to 1974. Thereafter it increased at the average growth rate of 25% per annum reaching 56 GWh in 1980. The historical power generation and peak demand in the Leyte-Samar grid is shown in Table 4-14.

All the power demand in the region before 1977 has been met by the small scale diesel generators owned by private-run cooperatives. The supply capabilities of these cooperatives are as shown in Table 4-15.

In July 1977, the pilot plant (3 MW) of the Tongonan geothermal power station started commercial operation supplying power to Ormoc city. Having been reinforced by this geothermal power supply, the peak demand as well as energy generation in the grid has shown a big hike thereafter (Table 4-14).

4.3.2 Future development prospects in Leyte-Samar Region

In the on-going Five-year Philippine Development Plan (1983 - 1987), the development of Leyte-Samar region is expected to spur at the highest growth rate among the twelve regions in the whole country. According to the said plan, the per capita output of the region is planned to grow in the period from 1983 to 1987 at an average rate of 7.6% per annum, which is the highest among all twelve regions.

This accelerated growth is based on the fact that the region has substantial untapped resources such as arable lands, rich fishing grounds, forest resources and geothermal potentials. Especially, the geothermal power resources in the Leyte Island and the Biliran Island, as stated in the sub chapter 3.2, are expected to encourage industrialization of the region by supplying electric power to the industrial complex to be established in the Leyte Island.

The planned high growth of development is based on the industrial projects now under way at Isabel in northern Leyte: the copper smelter project and the phosphate fertilizer project. The outline of the two projects are described here-under.

Copper Smelter Project (PASAR Project)

The main features of the copper smelter project are:

Project site	:	Isabel, Northern Leyte	
Area (gross)	:	23 ha	
Construction	:	Started in April 1980; to be completed within 1983	
Test run	:	April - December 1983	
Commercial operation	:	Starting within 1984	
Refining capacity	:	138,000 (Cathode) MTPA	
By-products	:	Sulphuric acid, Gold, Silver, Selenium and Sulphuric Nickel	
Project cost	:	Capital cost:	US$306.2 $\times 10^6$
		Plant & equipment	213.1 $\times 10^6$
		Construction	57.5 $\times 10^6$
		Interest during construction	14.4 $\times 10^6$
		Infrastructure	21.1 $\times 10^6$
Implementing agency	:	Philippine Associated Smelting and Refining Corporation (PASAR)	
Employment	:	600 workers 200 staff members	

The construction works are now under way at Isabel in Northern Leyte. The electric power required for the construction is supplied through a power barge (8 MW × 4 = 32 MW) moored at the coast near Isabel. Tongonan generating power will be available to the project by the time when the test operation of the smelter will start.

The power demand of the smelter is estimated at 33 MW under full capacity operation and the annual energy requirement at 246 GWh.

Phosphate Fertilizer Project (PHILPHOS Project)

This project was initially programmed as one of the Five ASEAN Projects which aimed at benefitting commonly all the ASEAN countries. But the capacity planned presently is the enlarged one, which is shown below.

Project site	:	Isabel, Northern Leyte (immediately adjacent to PASAR Project Site)	
Area (gross)	:	180 ha	
Commissioning	:	expected within 1984	
Supply of phosphate rock	:	Morocco, Nauru, USA and Jordan	
Supply of sulphuric acid	:	440×10^3 MTPA from PASAR	
		917×10^3 MTPA from domestic pyrites	
Final products	:	Ammonium sulfate:	153×10^3 MTPA
		Granular NPK products:	
		15-15-15	72×10^3 MTPA
		14-14-14	55×10^3 MTPA
		16-20-0	126×10^3 MTPA
		Monoammonium phosphate	169×10^3 MTPA
		Diammonium phosphate	508×10^3 MTPA
Project cost	:	Capital cost	US$342 $\times 10^6$
		Plant & equipment	283.3×10^6
		Building & housing	8.9×10^6
		Other costs	21.2×10^6
		Financing costs (capitalized)	28.6×10^6
		Maintenance cost (annual cost under full operation)	8.59×10^6
		Working capital (under full operation in 1986)	38×10^6

Implementing agency	:	Philippine Phosphate Fertilizer Corporation (PHILPHOS)
Employment	:	650 workers 70 staff members

The power barge (32 MW) to be moored at the coast near Isabel will also supply the electric power for the construction of the PHILPHOS Project.

The power demand of the fertilizer plant is estimated at 30 MW under full capacity operation and the annual energy requirement at 236 GWh.

4.3.3 Power demand projection of Leyte-Samar Grid

The future power load of the Leyte-Samar grid is forecasted by NAPOCOR as shown in Table 4-16. The power load (at generation level) is forecasted to increase at as high growth rate as 75 % per annum from 21 MW in 1982 to 112 MW in 1985. This is due to the expectation that the industrial projects such as PASAR and PHILPHOS projects will start their operations in these years. Of the total power demand of 112 MW in 1985, the industrial power demand for these three big projects is projected to amount to 63 MW or 56 % of the total demand. The energy requirement (GWh) is projected to increase at as high growth rate as 147% per annum in the period from 1982 to 1985.

In the present study, the abovementioned NAPOCOR forecast for the period of 1982 - 1992 was adopted after having been reviewed based on the data and information obtained through field survey and on the socio-economic study on the Leyte-Samar region. The industrial demand forecast is compatible with the on-going construction schedule of the PASAR and PHILPHOS projects.

In the present study, the NAPOCOR forecast until 1992 was extrapolated until the year of 2000 at a growth rate of 3 % per annum. The load forecast of the Leyte-Samar grid until the year of 2000 is as presented in Table 4-16 and depicted in Fig. 4-2 and 4-3. The peak power demand in 2000 is projected to reach 233 MW. The energy requirement was also projected to amount to 1,527 GWh in 2000 by assuming the load factor of 74 % for the period of 1991 - 2000.

4.3.4 Surplus power expected in Leyte-Samar grid

According to the most up-to-date power development program prepared by NAPOCOR, the development of geothermal power in the Leyte Islands is scheduled as shown in the forgoing subsection 3.2.2 (2). In the present study, Tongonan geothermal station is assumed to be exploited by installing twenty two power units with the total installed capacity of 1,105 MW by 1993.

Based on this development program and the demand projection made in the foregoing sub-section 4.3.3, a bulk of surplus power exceeding the demand is expected to be produced in the Leyte-Samar grid. According to the long term power development plan prepared by NAPOCOR, the power demand in the Leyte-Samar grid will be met by the Tongonan geothermal units No. 1 through No. 6 and the energy generated by the Tongonan geothermal units No. 7 through No. 22 will be transmitted either to the Luzon grid or to the Mindanao grid.

In the present study, however, the surplus energy to be realized in Leyte-Samar grid is computed, based on the most efficient and realistic way of operation, by the total Tongonan geothermal energy deducted by the energy requirement in Leyte-Samar grid. The estimation of surplus energy together with its assumed volume of energy to be transmitted either to Luzon or to Mindanao grids is shown in Table 4-17.

4.4 Power Demand in Mindanao Grid

4.4.1 Present socio-economy and power demand in Mindanao

Mindanao is administratively divided into 4 regions: Western Mindanao (Region 9), Northern Mindanao (Region 10), Southern Mindanao (Region 11) and Central Mindanao (Region 12).

(1) Population

The population of Mindanao was 10,905 thousand in 1980 according to the population census. The average growth rate of the population of the region in the period from 1960 to 1980 was 3.6% per annum, which was higher than that of the whole country of 2.9% per annum for the same period. The ratio of the population of the region to that of the whole Philippines showed an increasing trend from 19.9% in 1960 to 22.7% in 1980.

Population growth rate of region 11 (4.7%) was much higher than that of region 12 (2.5%) because population have been moving from region 12 which has less opportunity of employment into the urban area centering around Davao in region 11.

(2) GRDP of Mindanao

The GRDP of Mindanao in 1980 amounted to P 16,870 million at 1972 price, which occupied 18.2% of the whole country.

The growth rate of GRDP in the region was 3.9% in 1981 which was almost the same as that of the whole country (3.8%).

Per capita GRDP of Region 11 (Southern Mindanao) was 1,870 pesos in 1980 nearly equal to the per capita GDP of the Philippines which was 1,918 pesos in the same period. However, per capita GRDP of other 3 regions in Mindanao was below the average of the Philippines. The average per capita GRDP of whole Mindanao was 1,538 pesos in 1980 which was 80% of the national average. The GRDP and per capita GRDP in Mindanao is shown in Tables 4-19 and 4-20.

(3) Present power demand and supply

The peak demand in Mindanao grid have increased from 68 MW in 1970 to 299 MW in 1981 with the growth rate of 14.4% per annum. In the same period, energy generation in Mindanao grid have increased from 362 GWh in 1970 to 1,819 GWh in 1980 with the growth rate of 15.8% per annum (Table 4-21).

In Mindanao grid, major supply source of electric power is hydropower. The three hydropower stations installed in the Agus river e.g. Agus VI established in 1953 and expanded in 1977 with the total installed capacity of 200 MW, Agus II in 1979 with 180 MW and Agus VII in 1983 with 54 MW occupy major portion of power supply. Another four power stations with the installed capacity of 510 MW in total are under construction in this Agus river. Besides hydropower, Aplaya diesel power plant has the installed capacity of 126 MW in total. Since there exist neither oil fired thermal nor coal fired thermal power plants in Mindanao, the power supply in Mindanao is vulnerable to drought; in 1983, Mindanao experienced a serious power shortage due to a record spell of drought.

4.4.2 Future development prospects in Mindanao

The area by administrative region in Mindanao is shown in Fig. 4-2.

(1) Region 9 (Western Mindanao)

In Western Mindanao, per capita GRDP in 1980 was P1,274 at 1972 prices, which was the lowest in 4 regions of Mindanao (Table 4-20). In the Five-Year Philippine Development Plan 1983 - 87, the main development objectives of this region are reducing unemployment and underemployment, attaining rice and corn self-sufficiencies and promoting some processing industries of traditional agribased products. In 1981 industrial development of this region was not so high due to the lack of sufficient and cheap power supply, which constrained entrepreneurs and capitalists to invest. Zamboanga City, which has been rapidly urbanizing, and some planned industrial area such as Zamboanga Industrial Estate, Export Processing Zone and Integrated Fisheries Project area will need power supply in the near future.

(2) Region 10 (Northern Mindanao)

Northern Mindanao is envisioned to develop into a major industrial center of the Mindanao Island. There are large potential for developments of cheap hydro-electric power, productive agricultural land, and abundant fishery and mineral resources.

The industrial development will be pursued by large-scale, agribased industries. Also there are expansion schedule of the Integrated Steel Mill in the PHIVIDEC compound near Cagayan de Oro.

The development of the Agusan and Cotabato river basins is important for agricultural development. In agriculture, the basic strategy for future growth is the expanded use of the region's rich arable lands for diversified and intensified agricultural cultivation and the introduction of modern agricultural practices.

For the infrastructure sector the main strategey is the improvement of existing road network, and expansion and improvement of existing water, power and communications facilities in all identified growth and service centers which are Cagayan de Oro, Butuan and Surigao.

(3) Region 11 (Southern Mindanao)

The overall development of Southern Mindanao is based on the modernization of agriculture. The industrial sector will still be complementation of agricultural activities by processing agriculture surplus, and regional economy is expected to remain basically agricultural until the late nineties. Until then, agriculture shall continue to provide the ever increasing requirements for job opportunities at higher levels of labour productivity. There is large potential areas for cultivation and also there is still a lot of room for increasing the current productivity of lands under cultivation. Major power demand center of this region is Davao city.

(4) Region 12 (Central Mindanao)

In Central Mindanao, economic development will be mainly agricultural base. There are many unemployed and underemployed in this region. There is a large potential for increasing the agricultural productivity with adequate farm inputs and appropriate technologies.

Industrial development will be pursued along the Iligan bay area where steel and related industries are presently located with use of cheap power generated in the Agus river.

4.4.3 Power demand projection of Mindanao grid

(1) GRDP elasticity of power consumption

The GRDP elasticity of power consumption can be derived by a proportionate change in the power consumption divided by that in the GRDP.

The Table 4-22 shows the historical GRDP elasticity of power consumption in per capita bases in Mindanao.

The average elasticity was 3.97 in the period from 1971 to 1981. In general, the GRDP elasticity of power consumption has a declining trend along with the economic development. Almost all developed countries and also Luzon region in the Philippines has 1 to 2 GDP or GRDP elasticity. Taking into consideration this general trend, the GRDP elasticity of power consumption of Mindanao grid is, in projecting the power demand, assumed to decline to 3.0 in average during the period of 1980 - 85 and then to 2.5 during 1985 - 90, 2.0 during 1990 - 95 and 1.5 during 1995 - 2000 (Table 4-23).

(2) Per capita GRDP growth

The historical growth rate of per capita GRDP (at 1972 constant prices) for the period of 1971 to 1981 showed 3.4% per annum, which was adopted as the future per capita GRDP growth for low case for the period of 1982 - 2000 in this study.

In high case of our projection, the growth rate of per capita GRDP was set at 1% more than that of low case i.e. 4.4% per annum.

(3) Per capita power consumption growth

The growth rate of per capita power consumption was derived by the growth rate of the per capita GRDP mentioned in (2) multiplied by the GRDP elasticity of power consumption (per capita basis) mentioned in (1) of this subsection. The growth rate of per capita power consumption was as shown in Tables 4-23 and 4-24 for both the high and low cases.

(4) Mindanao population growth

The population of Mindanao region was projected by National Census and Statistics Office (NCSO) from 1980 to 2000 in 3 cases i.e. high assumption, medium assumption and low assumption. In this study, the medium assumption was taken as future Mindanao population. The growth rate of population in this region was projected to decline from 2.6% (1980-85) to 1.6% (1995-2000) per annum.

(5) Power consumption growth

Based on the abovementioned assumptions on the GRDP elasticity of power consumption, the per capita GRDP growth and the Mindanao population growth, the power consumption growth was projected as shown in Tables 4-23 and 4-24. The annual growth rate of power consumption was estimated at 16.1% in 1982-85, 13.6% in 1986-90, 10.9% in 1991-95 and 8.3% in 1996-2000 in high case. In low case, the annual growth rates for the abovementioned periods were estimated at 13.1%, 11.0%, 8.8% and 6.8%.

(6) Projection of peak demand in Mindanao

The projection of the peak power demand in Mindanao was made as shown in Tables 4-25 and 4-26 for each case. The total system losses was assumed 5.0% for whole period for both the two cases. The load factor of 70.0% was also assumed.

The peak demand in Mindanao was projected by this Study to increase from 353 MW in 1982 to 2,613 MW in 2000 for the high case and 1,777 MW for the low case. The average annual growth rate in this 18 years was estimated at 11.8% and 9.6% in each case.

Meanwhile, in the NAPOCOR projection of the peak demand in Mindanao, the growth rate is estimated at 11.5% per annum reaching 1,797 MW in the year of 1997 (Table 4-27). This projection was extrapolated up to the year 2000 by assuming the growth rate of 7% per annum from 1997 to 2000, and from this extension, the peak demand of this region is estimated 2,227 MW in the year of 2000.

This brings a growth rate of 10.7%, which lies between the growth rates in high and low cases of our projection.

In this Study, this NAPOCOR projection was adopted for keeping the consistency required among the power demand projection, the future power development program and other related policies. The comparison of the NAPOCOR projection and our estimates are shown in Table 4-28 and Fig. 4-3.

Table 4-1 Historical Power Generation, Peak Demand and Power Supply in Luzon Grid

Year	Energy Generation (GWh)	Peak Demand (MW)	Load Factor (%)	Energy Sales (GWh)	System Loss (%)
1970	6,386	1,111	65.6	5,225	18.2
1971	7,048	1,205	66.8	6,141	12.9
1972	7,555	1,331	64.8	6,588	12.8
1973	8,212	1,335	70.2	7,210	12.2
1974	8,240	1,379	68.2	7,275	11.7
1975	9,014	1,513	68.0	8,032	10.9
1976	9,626	1,659	66.2	8,586	10.8
1977	10,380	1,709	69.3	9,812	5.5
1978	11,222	1,780	72.0	10,749	4.2
1979	12,504	1,926	74.1	11,645	6.9
1980	13,115	2,074	72.2	12,163	7.3
1981	13,666	2,225	70.1	12,690	7.1

Average annual growth rate (%)

	Energy Generation	Peak Demand	Energy Sales
1970 - 1975	7.1	6.4	9.0
1975 - 1980	7.8	6.5	8.7
1980 - 1981	4.2	7.3	4.3
1970 - 1981	7.2	6.5	8.4

Source: NAPOCOR, SPD-CORPLAN, March 19, 1981
NAPOCOR, 1982 ANNUAL REPORT

Table 4-2 GRDP Elasticity of Power Consumption in Luzon Grid (both in per capita bases)

Year	(1) Per Capita Power Consumption (kWh)	(2) Annual Growth Rate (%)		(3) Per Capita GRDP (Peso)	(4) Anual Growth Rate (%)		(5) GRDP Elasticity of Power Consumption (2)/(4)	
1970	265.4							
71	302.9	14.13		1,612				
72	315.6	4.19		1,628	0.99		4.23	
73	335.4	6.27		1,773	8.91		0.7	
74	328.7	-2.00		1,822	2.76		-0.72	
75	352.4	7.21	Average 4.60	1,916	5.16	Average 3.61	1.40	Average 1.27
76	366.7	4.06		2,003	4.54		0.89	
77	407.9	11.24		2,075	3.59		3.13	
78	435.0	6.64		2,134	2.84		2.34	
79	459.1	5.54		2,221	4.08		1.36	
80	466.4	1.59		2,268	2.12		0.75	
81	474.7	1.78		2,299	1.37		1.30	

Note: Historical GRDP at 1972 constant prices and population of the Luzon Region are presented in Table 4-3.

Table 4-3 Historical and Projected Population, GRDP and Per Capita GRDP in Luzon (At 1972 price)

Year	Population (10^3)	GRDP (P 10^6)	Per Capita GRDP (Peso)	
Historical				
1970	19,688/1			
71	20,273	32,686	1,612	Average Growth 3.61% p.a. (1971–81)
72	20,875	33,975	1,628	
73	21,495	38,110	1,773	
74	22,133	40,328	1,822	
75	22,790/1	43,656	1,916	
76	23,413	46,902	2,003	
77	24,054	49,913	2,075	
78	24,712	52,731	2,134	
79	25,387	56,393	2,221	
80/3	26,200	59,416	2,268	
81/3	26,883	61,795	2,299	
Projected				
1982/3	27,566	64,544	2,341	
83/3	28,249	67,965	2,406	
87/3	30,566	86,996	2,846	

		Per Capita GRDP		Growth of Per Cap. GRDP	
		High Case	Low Case	High Case	Low Case
1985	29,466/2	2,736	2,633	4.3% p.a.	3.3% p.a.
1990	32,658/2	3,377	3,097	4.3	3.3
1995	35,407/2	4,168	3,642	4.3	3.3
2000	38,028/2	5,145	4,284	4.3	3.3

Notes: /1. Population Census figures.

/2 Medium projection prepared by National Census and Statistics Office.

/3 Five Year Philippine Development Plan, 1983 - 1987.

Table 4-4 Projection of Growth Rate of Power Consumption in Luzon (High Case)

Year	(1) Per Capita GRDP Growth Rate (%)	(2) GRDP Elasticity of Power Consumption (Per Capita Bases)	(3) Per Capita Power Consumption Growth Rate (%)	(4) Luzon Population Growth Rate (%)	(5) Power Consumption Growth Rate (%)
1982	4.3	1.2	5.16	2.5	7.79
1983	4.3	1.2	5.16	2.5	7.79
1984	4.3	1.2	5.16	2.5	7.79
1985	4.3	1.2	5.16	2.5	7.79
1986	4.3	1.2	5.16	2.1	7.37
1987	4.3	1.2	5.16	2.1	7.37
1988	4.3	1.2	5.16	2.1	7.37
1989	4.3	1.2	5.16	2.1	7.37
1990	4.3	1.2	5.16	2.1	7.37
1991	4.3	1.1	4.73	1.6	6.41
1992	4.3	1.1	4.73	1.6	6.41
1993	4.3	1.1	4.73	1.6	6.41
1994	4.3	1.1	4.73	1.6	6.41
1995	4.3	1.1	4.73	1.6	6.41
1996	4.3	1.1	4.73	1.4	6.20
1997	4.3	1.1	4.73	1.4	6.20
1998	4.3	1.1	4.73	1.4	6.20
1999	4.3	1.1	4.73	1.4	6.20
2000	4.3	1.1	4.73	1.4	6.20

Note: (3) = (1) x (2)
(5) = (3) x (4)

Table 4-5 Projection of Growth Rate of Power Consumption in Luzon (Low Case)

Year	(1) Per Capita GRDP Growth Rate (%)	(2) GRDP Elasticity of Power Consumption (Pre Capita Bases)	(3) Per Capita Power Consumption Growth Rate (%)	(4) Luzon Population Growth Rate (%)	(5) Power Consumption Growth Rate (%)
1982	3.3	1.2	3.96	2.5	6.56
1983	3.3	1.2	3.96	2.5	6.56
1984	3.3	1.2	3.96	2.5	6.56
1985	3.3	1.2	3.96	2.5	6.56
1986	3.3	1.2	3.96	2.1	6.14
1987	3.3	1.2	3.96	2.1	6.14
1988	3.3	1.2	3.96	2.1	6.14
1989	3.3	1.2	3.96	2.1	6.14
1990	3.3	1.2	3.96	2.1	6.14
1991	3.3	1.1	3.63	1.6	5.29
1992	3.3	1.1	3.63	1.6	5.29
1993	3.3	1.1	3.63	1.6	5.29
1994	3.3	1.1	3.63	1.6	5.29
1995	3.3	1.1	3.63	1.6	5.29
1996	3.3	1.1	3.63	1.4	5.08
1997	3.3	1.1	3.63	1.4	5.08
1998	3.3	1.1	3.63	1.4	5.08
1999	3.3	1.1	3.63	1.4	5.08
2000	3.3	1.1	3.63	1.4	5.08

Note: (3) = (1) x (2)
(5) = (3) x (4)

Table 4-6 Projection of Energy Generation and Peak Power Demand in Luzon (High Case)

Year	Power Sales (GWh)	Total Loss (%)	Energy Generation (GWh)	Load Factor (%)	Peak Power Demand (MW)
1982	13,679	7.0	14,708	70.0	2,399
1983	14,744	7.0	15,854	70.0	2,585
1984	15,893	7.0	17,089	70.0	2,787
1985	17,131	7.0	18,420	70.0	3,004
1986	18,393	7.0	19,778	70.0	3,225
1987	19,749	7.0	21,235	70.0	3,463
1988	21,204	7.0	22,800	70.0	3,718
1989	22,767	7.0	24,481	70.0	3,992
1990	24,445	7.0	26,285	70.0	4,287
1991	26,012	6.5	27,820	70.0	4,537
1992	27,679	6.5	29,604	70.0	4,828
1993	29,457	6.5	31,501	70.0	5,137
1994	31,342	6.5	33,520	70.0	5,466
1995	33,351	6.5	35,669	70.0	5,817
1996	35,418	6.5	37,881	70.0	6,178
1997	37,614	6.5	40,229	70.0	6,561
1998	39,946	6.5	42,723	70.0	6,967
1999	42,423	6.5	45,372	70.0	7,399
2000	45,053	6.5	48,185	70.0	7,858

Table 4-7 Projection of Energy Generation and Peak Power Demand in Luzon (Low Case)

Year	Power Sales (GWh)	Total Loss (%)	Energy Generation (GWh)	Load Factor (%)	Peak Power Demand (MW)
1982	13,523	7.0	14,540	70.0	2,371
1983	14,410	7.0	15,494	70.0	2,527
1984	15,355	7.0	16,511	70.0	2,693
1985	16,362	7.0	17,594	70.0	2,869
1986	17,367	7.0	18,674	70.0	3,045
1987	18,433	7.0	19,821	70.0	3,232
1988	19,565	7.0	21,037	70.0	3,438
1989	20,766	7.0	22,329	70.0	3,641
1990	22,041	7.0	23,700	70.0	3,865
1991	23,207	6.5	24,820	70.0	4,048
1992	24,435	6.5	26,133	70.0	4,262
1993	25,727	6.5	27,516	70.0	4,487
1994	27,088	6.5	28,972	70.0	4,725
1995	28,521	6.5	30,504	70.0	4,975
1996	29,970	6.5	32,054	70.0	5,227
1997	31,493	6.5	33,682	70.0	5,493
1998	33,093	6.5	35,393	70.0	5,772
1999	34,774	6.5	37,191	70.0	6,065
2000	36,540	6.5	39,080	70.0	6,373

Table 4-8 Power Generation, Peak Demand - NAPOCOR Forecast in Luzon Grid

Year	Energy Generation (GWh)	Peak Demand (MW)	Load Factor (%)
1982	14,481	2,263	73.0
1983	15,495	2,525	70.0
1984	16,580	2,705	70.0
1985	17,740	2,890	70.0
1986	18,980	3,100	70.0
1987	20,310	3,315	70.0
1988	21,730	3,545	70.0
1989	23,250	3,790	70.0
1990	24,880	4,060	70.0
1991	26,370	4,300	70.0
1992	27,955	4,560	70.0
1993	29,630	4,835	70.0
1994	31,410	5,125	70.0
1995	33,295	5,430	70.0

Source: NAPOCOR, March, 1983

Table 4-9 Comparison of the Projection of Peak Demand in Luzon, 1982 - 2000

Year	NAPOCOR (MW)	High Case (MW)	Low Case (MW)
1982	2,263	2,399	2,371
1983	2,525	2,585	2,527
1984	2,705	2,787	2,693
1985	2,890	3,004	2,869
1986	3,100	3,225	3,045
1987	3,315	3,463	3,232
1988	3,545	3,718	3,431
1989	3,790	3,992	3,641
1990	4,060	4,287	3,865
1991	4,300	4,537	4,048
1992	4,560	4,828	4,262
1993	4,835	5,137	4,487
1994	5,125	5,466	4,725
1995	5,430	5,819	4,975
1996	/1 5,702	6,178	5,227
1997	/1 5,987	6,561	5,493
1998	/1 6,286	6,967	5,772
1999	/1 6,600	7,399	6,065
2000	/1 6,928	7,858	6,373
Average Annual Growth Rate (%)			
1982 - 1985	8.5	7.8	6.6
1985 - 1990	7.0	7.4	6.1
1990 - 1995	6.0	6.3	5.2
1995 - 2000	5.0	6.2	5.1
1982 - 2000	6.4	6.8	5.6

Note: /1 - Estimated with the assumption of the 5% annual growth rate.

Source: Project Development Department, NAPOCOR

Table 4-10 **Historical and Projected Population, GRDP and Per Capita GRDP in Leyte/Samar (Eastern Visayas) Region (At 1972 price)**

Year	Population (10^3)	Growth of Population (% p.a.)	GRDP (P 10^6)	Growth of GRDP (% p.a.)	Per Capita GRDP (Peso)	Growth of P.C. GRDP (% p.a.)
Historical						
1960	2,041/1					
70	2,381/1	1.6				
75	2,600/1	1.8	2,094		805	
80/3	2,806	1.5	2,318	2.1	826	0.5
81/3	2,863	2.0	2,341	1.0	818	-1.0
Projected						
1982/3	2,919	2.0	2,366	1.1	811	-0.9
83/3	2,975	1.9	2,404	1.6	808	-0.4
87/3	3,195	1.8	3,221	7.6	1,008	5.7
1985	3,077/2	1.7				
90	3,350/2	1.7				
95	3,587/2	1.4				
2000	3,754/2	0.9				

Notes: /1 Population Census Figures.

/2 Medium Projection prepared by National Census of Statistics Office.

/3 Five Year Philippine Development Plan, 1983 - 1987.

Table 4-11 Gross Regional Domestic Product (GRDP) by Industrial Origin in Leyte-Samar Region (1979 - 1981) (At 1972 price)

Unit: Million Pesos

Industry/Industry Group	1979/1	(%)	1980/1	(%)	1981/2	(%)	Annual Growth Rates (%) 1979-80	1980-81
Agriculture, Fishery and Forestry	1,245	(57)	1,264	(56)	1,285	(55)	1.5	1.7
Industry	293	(13)	309	(13)	329	(14)	5.5	6.5
Mining and Quarrying	21		16		16		-23.8	0
Manufacturing	63		65		68		3.2	4.6
Construction	194		211		226		8.8	7.1
Electricity, Gas & Water	15		17		19		13.3	11.8
Services	665	(30)	701	(31)	741	(31)	5.4	5.7
Transport, Communication and Storage	72		73		77		1.4	5.5
Commerce	351		368		386		4.8	4.9
Other Services	242		260		278		7.4	6.9
GRDP	2,203	(100)	2,274	(100)	2,355	(100)	3.2	3.6
GDP of Philippines	87,744		92,792		97,256/3		5.8	4.8

Notes: /1 National Account Staff, NEDA (Preliminary estimates as of February 2, 1982).

/2 NEDA, Region VIII estimates

/3 NEDA, Manila

Source: "Regional Development Report 1981 Eastern Visayas General Economy", NEDA Region VIII, July 1982

Table 4-12 Breakdown of Industrial Production by Commodity in Leyte-Samar Region (1979 - 1981) (At current price)

Unit: Million Pesos

Commodity	Amount 1979	1980	1981	Manufacturer
Centrifugal Sugar	123.8	123.0	134.9	OSCO, Ormoc city Leyte HIDECO, Kananga Leyte
Ribonucleci Acid	85.4	87.9	110.8	BIOPHIL, Ormoc city Leyte
Molasses	11.9	13.9	14.1	OSCO, HIDECO
Bentonite	1.7	2.6	5.6	FILMAG, Merida Leyte
Copper Concentrate	29.3	33.2	4.7	MMIC, Hinabangan Samar
Cassava Flour	n.a.	1.3	4.4	Equatorial Flour Mill, Kananga Leyte
Bagasse	n.a.	0.4	4.2	OSCO, HIDECO
Pyrite Concentrate	7.8	2.8	0.8	MMIC
Total	259.9	265.1	279.5	

Source: "Regional Development Report 1981 Eastern Visayas General Economy", NEDA Region VIII, July 1982.

Table 4-13 Status of Energization by Region as of December 31, 1981

Region	Municipalities		Villages		House Connection		
	Coverage	Total to Date	Coverage	Total to Date	Coverage (A)	Total to Date (B)	(B)/(A) (%)
Eastern Visayas (VIII)	112	81	3,210	885	365,000	71,511	19.6
Western Mindanao (IX)	70	53	1,737	444	268,000	65,558	24.5
Northern Mindanao (X)	98	93	1,927	1,048	325,000	116,495	35.8
Southern Mindanao (XI)	60	52	1,206	368	315,000	91,143	28.9
Central Mindanao (XII)	93	76	2,700	952	311,000	59,256	19.1
Total Philippine	1,233	1,060	31,055	13,694	4,816,000	1,769,817	36.7

Source: "Annual Report 1981, National Electrification Administration"

Table 4-14 Historical Power Generation and Peak Demand in Leyte-Samar Grid

Year	Power Generation (GWh)	Peak Demand (MW)	Load Factor (%)
1968	12.7	3.1	46.8
1969	15.8	3.7	48.7
1970	17.6	3.9	51.5
1971	18.1	4.0	51.7
1972	20.0	3.9	58.5
1973	13.9	3.2	49.6
1974	14.8	3.4	49.7
1975	23.9	5.8	47.0
1976	27.5	6.6	47.6
1977	28.9 (NAPOCOR)	6.9 (NAPOCOR)	47.8
1978	43.0 (6.0)	13.0 (2.0)	37.8
1979	49.0(12.0)	15.0 (4.0)	37.3
1980	56.0(19.0)	17.0 (6.0)	37.6
Average Annual Growth Rate (%)			
1968-74	2.6	1.6	
1974-80	24.8	31.0	

Source: NAPOCOR Power Expansion Program 1981-90.

Table 4-15 Supply Capabilities of Cooperatives (as of December, 1980)

Name of Cooperatives	Installed Capacity (kW)	Peak Load (kW)
1. DORELCO (LEYCO I)	11,300	5,900
2. LEYCO II	7,670	4,293
3. LEYCO IV	390	179
4. LEYCO V	1,000	1,600 /1
Sub-Total Leyte	20,360	
5. ESAMELCO	100	60
6. NORSAMELCO	100	70
7. SAMELCO I	1,100	716
8. SAMELCO II	6,306	1,950
9. SOLECO	1,065	700
Sub-Total Samar	8,671	
Total Leyte-Samar Grid	29,031	

Note: /1 Estimated to be tapped from other system(s)
Source: NAPOCOR, CORPLAN, Mar. 1981

Table 4-16 Projection of Peak Demand in Leyte-Samar Grid Prepared by NAPOCOR

Year	Energy Gen. (GWh)	Peak Demand (MW)	Growth of Peak Demand (% p.a.)	Load Factor (%)
1982	45	21		24.5
1983	239	46	119.0	59.3
1984	355	76	65.0	53.3
1985	680	112	47.0	69.3
1986	848	128	14.0	73.9
1987	867	131	2.3	75.6
1988	938	134	2.3	79.9
1989	1,020	155	15.7	75.1
1990	1,101	169	9.0	74.4
1991	1,145	175	3.6	74.7
1992	1,196	184	5.1	74.2
1995/1	1,307	201	3.0	74.2
2000/1	1,527	233	3.0	74.2

Note: /1 Extrapolated by a growth rate of 3% per annum.

Source: Project Development Department, NAPOCOR, Apr. 1983

Table 4-17 Estimated Surplus Energy Generated in Leyte - Samar Grid and Transmitted to Luzon and Mindanao Grids

Unit: GWh

Year	Tongonan Geothermal Energy generated by Plant #1-6	Plant #7-22	(A) Total	(B) Energy Requirement in L-S Grid/3	Surplus Energy (A)-(B)	Energy to be transmitted to Luzon Grid	Mindanao Grid
1986	1,307	-	1,307	848	459	-	-
1987	1,646	-	1,646	867	779	-	-
1988/1	1,646	794	2,440	938	1,502	1,502	-
1989	1,646	2,382	4,028	1,020	3,008	3,008	-
1990	1,646	2,382	4,028	1,101	2,927	2,927	-
1991	1,646	3,970	5,616	1,145	4,471	4,471	-
1992/2	1,646	5,558	7,204	1,196	6,008	5,395	613/4
1993	1,646	6,352	7,998	1,232	6,766	6,153	613
1994	1,646	6,352	7,998	1,269	6,729	6,116	613
1995	1,646	6,352	7,998	1,307	6,691	6,078	613
1996	1,646	6,352	7,998	1,346	6,652	6,039	613
1997	1,646	6,352	7,998	1,386	6,612	5,386	1,226/4
1998	1,646	6,352	7,998	1,428	6,570	5,344	1,226
1999	1,646	6,352	7,998	1,471	6,527	5,301	1,226
2000	1,646	6,352	7,998	1,527	6,471	5,245	1,226

Notes:
/1 Year of completion of Leyte-Luzon transmission line
/2 Year of completion of Leyte-Mindanao transmission line
/3 Energy requirement up to 1992 is that prepared by NAPOCOR, thereafter an annual growth of 3% was assumed.
/4 Equivalent to 100 MW and 200 MW respectively assuming a plant factor of 70%.

Table 4-18 Historical and Projected Population in Mindanao

Unit: 10^3

Year	Region 9	Region 10	Region 11	Region 12	Total Mindanao	Total Philippine	Ratio to Philippine (%)
Historical							
1960/1	1,351	1,297	1,353	1,383	5,384	27,088	19.9
70/1	1,869	1,953	2,201	1,941	7,964	36,684	21.7
71					8,188		
72					8,418		
73					8,654		
74					8,897		
75/1	2,048	2,314	2,715	2,070	9,147	42,071	21.7
76					9,474		
77					9,813		
78					10,165		
79					10,528		
80/3	2,546	2,775	3,370	2,278	10,969	48,317	22.7
81/3	2,601	2,859	3,478	2,322	11,260	49,526	22.7
Projected							
1982/3	2,657	2,944	3,588	2,366	11,555	50,740	22.8
83/3	2,713	3,030	3,701	2,409	11,853	51,956	22.8
87/3	2,943	3,384	4,167	2,572	13,066	56,761	23.0
1985/2					12,384		
1990/2					13,884		
1995/2					15,285		
2000					16,546		

Notes: /1 Population Census figures.

/2 Medium projection prepared by National Census of Statistics Office.

/3 Five.Year Philippine Development Plan, 1983 - 1987.

Table 4-19 **Historical and Projected GRDP and Per Capita GRDP in Mindanao (At 1972 price)**

Year	GRDP (P 10⁶)	Per Capita GRDP (Peso)	Growth of Per Cap. GRDP (% p.a.)	Per Capita GDP of Philippines (Peso)
Historical				
1971	9.180	1.121		
72	9,798	1,164	3.8	
73	10,115	1,169	0.4	
74	10.379	1,167	-0.2	
75	11,114	1,215	4.1	1,603
76	12,777	1,349	11.0	
77	13,509	1,377	2.1	
78	15,000	1,476	7.2	
79	16,048	1,524	3.3	1,874
80/1	16,870	1,538	1.5	1,918
81/1	17,522	1,556	1.2	1,942
Projected				
1982/1	18,276	1,582		1,975
83/1	19,227	1,622		2,026
87/1	25,502	1,952		2,403

	Per Capita GRDP		Growth of Per Cap. GRDP	
	High Case	Low Case	High Case	Low Case
1985	1,848	1,779	4.4% p.a.	3.4% p.a.
1990	2,293	2,102	4.4	3.4
1995	2,843	2,485	4.4	3.4
2000	3,526	2,937	4.4	3.4

Notes: /1 Five Year Philippine Development Plan, 1983 - 1987.

Table 4-20 Per Capita GRDP by Region (At 1972 price)

Unit: Peso

Region	Actual	Estimated		Projected		Growth Rates (% p.a.)		
	1980	1981	1982	1983	1987	80-81	81-82	83-87
Luzon (I - V)	2,268	2,299	2,341	2,406	2,846	1.4	1.8	4.3
Eastern-Visayas (VIII)	826	818	811	808	1,008	-1.0	-0.9	5.7
Mindanao	1,538	1,556	1,582	1,622	1,952	1.2	1.7	4.7
IX	1,274	1,300	1,331	1,377	1,688	2.0	2.4	5.2
X	1,537	1,565	1,602	1,659	1,968	1.8	2.4	4.4
XI	1,870	1,873	1,884	1,908	2,245	0.2	0.6	4.2
XII	1,343	1,358	1,379	1,411	1,757	1.1	1.5	5.6
Cf. Philippines	1,918	1,942	1,975	2,026	2,403	1.3	1.7	4.4

Source: Five Year Philippine Development Plan, 1983 - 1987.

Table 4-21 Historical Power Generation, Peak Demand and Power Supply in Mindanao Grid

Year Historical	Energy Generation (GWh)	Peak Demand (MW)	Load Factor (%)	Energy Sales (GWh)	System Loss (%)
1970	362	68	60.8	335	7.5
1971	372	74	57.4	364	2.2
1972	368	77	54.6	352	4.3
1973	483	88	62.7	462	4.3
1974	520	95	62.5	507	2.5
1975	574	120	54.6	560	2.4
1976	768	126	69.6	746	2.9
1977	1,009	162	71.1	873	13.5
1978	1,045	174	68.6	997	4.6
1979	1,146	194	67.4	1,105	3.6
1980	1,650	264	71.3	1,591	3.6
1981	1,819	299	69.5	1,772	2.7

Average annual growth rate (%)

	Energy Generation	Peak Demand	Energy Sales
1970-1975	9.7	12.0	10.8
1975-1980	23.5	17.1	23.0
1980-1981	10.2	13.3	12.4

Source: NAPOCOR, Power Expansion Program 1981-1990
NAPOCOR, 1982 Annual Report

Table 4-22 GRDP Elasticity of Power Consumption in Mindanao (both in per capita bases)

Year	(1) Per Capita Power Consumption (kWh)	(2) Annual Growth Rate (%)		(3) Per Capita GRDP (Peso)	(4) Annual Growth Rate (%)		(5) GRDP Elasticity of Power Consumption (2)/(4)	
1970	42.1							
71	44.5	5.7		1,121				
72	41.8	-6.1		1,164	3.8		-1.6	
73	53.4	27.8		1,169	0.4		69.5	
74	57.0	6.7	Average 13.5	1,167	-0.2	Average 3.4	-33.5	Average 3.97
75	61.2	7.4		1,215	4.1		1.8	
76	78.7	28.6		1,349	11.0		2.6	
77	89.0	13.1		1,377	2.1		6.2	
78	98.1	10.2		1,476	7.2		1.4	
79	105.0	7.0		1,524	3.3		2.1	
80	145.9	39.0		1,538	0.9		55.7	
81	158.4	8.5		1,556	1.2		7.1	

Note: Historical GRDP at 1972 constant prices and historical population of the Mindanao region are presented in Tables 4-18 and 4-19.

Table 4-23 Projection of Growth Rate of Power Consumption in Mindanao (High Case)

Year	(1) Per Capita GRDP Growth Rate (%)	(2) GRDP Elasticity of Power Consumption (Per Capita Basis)	(3) Per Capita Power Consumption Growth Rate (%)	(4) Mindanao Population Growth Rate (%)	(5) Power Consumption Growth Rate (%)
1982	4.4	3.0	13.2	2.6	16.1
1983	4.4	3.0	13.2	2.6	16.1
1984	4.4	3.0	13.2	2.6	16.1
1985	4.4	3.0	13.2	2.6	16.1
1986	4.4	2.5	11.0	2.3	13.6
1987	4.4	2.5	11.0	2.3	13.6
1988	4.4	2.5	11.0	2.3	13.6
1989	4.4	2.5	11.0	2.3	13.6
1990	4.4	2.5	11.0	2.3	13.6
1991	4.4	2.0	8.8	1.9	10.9
1992	4.4	2.0	8.8	1.9	10.9
1993	4.4	2.0	8.8	1.9	10.9
1994	4.4	2.0	8.8	1.9	10.9
1995	4.4	2.0	8.8	1.9	10.9
1996	4.4	1.5	6.6	1.6	8.3
1997	4.4	1.5	6.6	1.6	8.3
1998	4.4	1.5	6.6	1.6	8.3
1999	4.4	1.5	6.6	1.6	8.3
2000	4.4	1.5	6.6	1.6	8.3

Note: (3) = (1) x (2)
(5) = (3) x (4)

Table 4-24 Projection of Growth Rate of Power Consumption in Mindanao (Low Case)

Year	(1) Per Capita GRDP Growth Rate (%)	(2) GRDP Elasticity of Power Consumption (Per Capita Basis)	(3) Per Capita Power Consumption Growth Rate (%)	(4) Mindanao Population Growth Rate (%)	(5) Power Consumption Growth Rate (%)
1982	3.4	3.0	10.2	2.6	13.1
1983	3.4	3.0	10.2	2.6	13.1
1984	3.4	3.0	10.2	2.6	13.1
1985	3.4	3.0	10.2	2.6	13.1
1986	3.4	2.5	8.5	2.3	11.0
1987	3.4	2.5	8.5	2.3	11.0
1988	3.4	2.5	8.5	2.3	11.0
1989	3.4	2.5	8.5	2.3	11.0
1990	3.4	2.5	8.5	2.3	11.0
1991	3.4	2.0	6.8	1.9	8.8
1992	3.4	2.0	6.8	1.9	8.8
1993	3.4	2.0	6.8	1.9	8.8
1994	3.4	2.0	6.8	1.9	8.8
1995	3.4	2.0	6.8	1.9	8.8
1996	3.4	1.5	5.1	1.6	6.8
1997	3.4	1.5	5.1	1.6	6.8
1998	3.4	1.5	5.1	1.6	6.8
1999	3.4	1.5	5.1	1.6	6.8
2000	3.4	1.5	5.1	1.6	6.8

Note: (3) = (1) x (2)
(5) = (3) x (4)

Table 4-25 Projection of Energy Generation and Peak Power Demand in Mindanao (High Case)

Year	Power Sales (GWh)	Total Loss (%)	Energy Generation (GWh)	Load Factor (%)	Peak Power Demand (MW)
1982	2,057	5.0	2,166	70.0	353
1983	2,389	5.0	2,514	70.0	410
1984	2,773	5.0	2,919	70.0	476
1985	3,220	5.0	3,389	70.0	553
1986	3,657	5.0	3,850	70.0	628
1987	4,155	5.0	4,373	70.0	713
1988	4,720	5.0	4,968	70.0	810
1989	5,362	5.0	5,644	70.0	920
1990	6,091	5.0	6,412	70.0	1,046
1991	6,755	5.0	7,110	70.0	1,160
1992	7,491	5.0	7,885	70.0	1,286
1993	8,308	5.0	8,745	70.0	1,426
1994	9,213	5.0	9,698	70.0	1,582
1995	10,217	5.0	10,755	70.0	1,754
1996	11,066	5.0	11,648	70.0	1,900
1997	11,984	5.0	12,615	70.0	2,057
1998	12,979	5.0	13,662	70.0	2,228
1999	14,056	5.0	14,796	70.0	2,413
2000	15,222	5.0	16,024	70.0	2,613

Table 4-26 Projection of Energy Generation and Peak Power Demand in Mindanao (Low Case)

Year	Power Sales (GWh)	Total Loss (%)	Energy Generation (GWh)	Load Factor (%)	Peak Power Demand (MW)
1982	2,004	5.0	2,110	70.0	344
1983	2,267	5.0	2,386	70.0	389
1984	2,564	5.0	2,699	70.0	440
1985	2,899	5,0	3,052	70.0	498
1986	3,218	5.0	3,388	70.0	552
1987	3,572	5.0	3,760	70.0	613
1988	3,965	5.0	4,174	70.0	681
1989	4,402	5.0	4,633	70.0	756
1990	4,886	5.0	5,143	70.0	839
1991	5,316	5.0	5,595	70.0	912
1992	5,783	5.0	6,088	70.0	993
1993	6,292	5.0	6,624	70.0	1,080
1994	6,846	5.0	7,206	70.0	1,175
1995	7,449	5.0	7,841	70.0	1,279
1996	7,955	5.0	8,374	70.0	1,366
1997	8,496	5.0	8,943	70.0	1,458
1998	9,074	5.0	9,551	70.0	1,558
1999	9,691	5.0	10,201	70.0	1,664
2000	10,350	5.0	10,895	70.0	1,777

Table 4-27 Power Generation and Peak Demand in Mindanao Grid - NAPOCOR Forecast

Year	Energy Generation (GWh)	Peak Demand (MW)	Load Factor (%)
1982	2,101	357	67.2
1983	2,763	452	69.8
1984	3,512	554	72.4
1985	4,044	645	71.6
1986	4,844	779	71.0
1987	4,985	799	71.2
1988	5,466	863	72.3
1989	5,988	946	72.3
1990	6,340	1,004	72.1
1991	7,047	1,111	72.4
1992	7,587	1,197	72.4
1993	8,405	1,321	72.6
1994	9,163	1,441	72.6
1995	9,877	1,554	72.6
1996	10,648	1,673	72.7
1997	11,454	1,797	72.8

Source: NAPOCOR, March 1983

Table 4-28 Comparison of the Projection of Peak Demand in Mindanao, 1982 - 2000

Year	NAPOCOR Projection (MW)	High Case (MW)	Low Case (MW)
1982	357	353	344
1983	452	410	389
1984	554	476	440
1985	645	553	498
1986	779	628	552
1987	799	713	613
1988	863	810	681
1989	946	920	756
1990	1,004	1,046	839
1991	1,111	1,160	912
1992	1,197	1,286	993
1993	1,321	1,426	1,080
1994	1,441	1,582	1,175
1995	1,554	1,754	1,279
1996	1,673	1,900	1,366
1997	1,797	2,057	1,458
1998	/1 1,930	2,228	1,558
1999	/1 2,073	2,413	1,664
2000	/1 2,227	2,613	1,777
Average Annual Growth Rate (%)			
1982 - 1985	21.8	16.1	13.1
1985 - 1990	9.3	13.6	11.0
1990 - 1995	9.1	10.9	8.8
1995 - 2000	7.5	8.3	6.8
1982 - 2000	10.7	11.8	9.6

Note: /1 - Estimated assuming annual growth rate of 7%.

Source: Project Development Department, NAPOCOR.

Fig. 4-1 Projection of Peak Demand in Luzon Grid

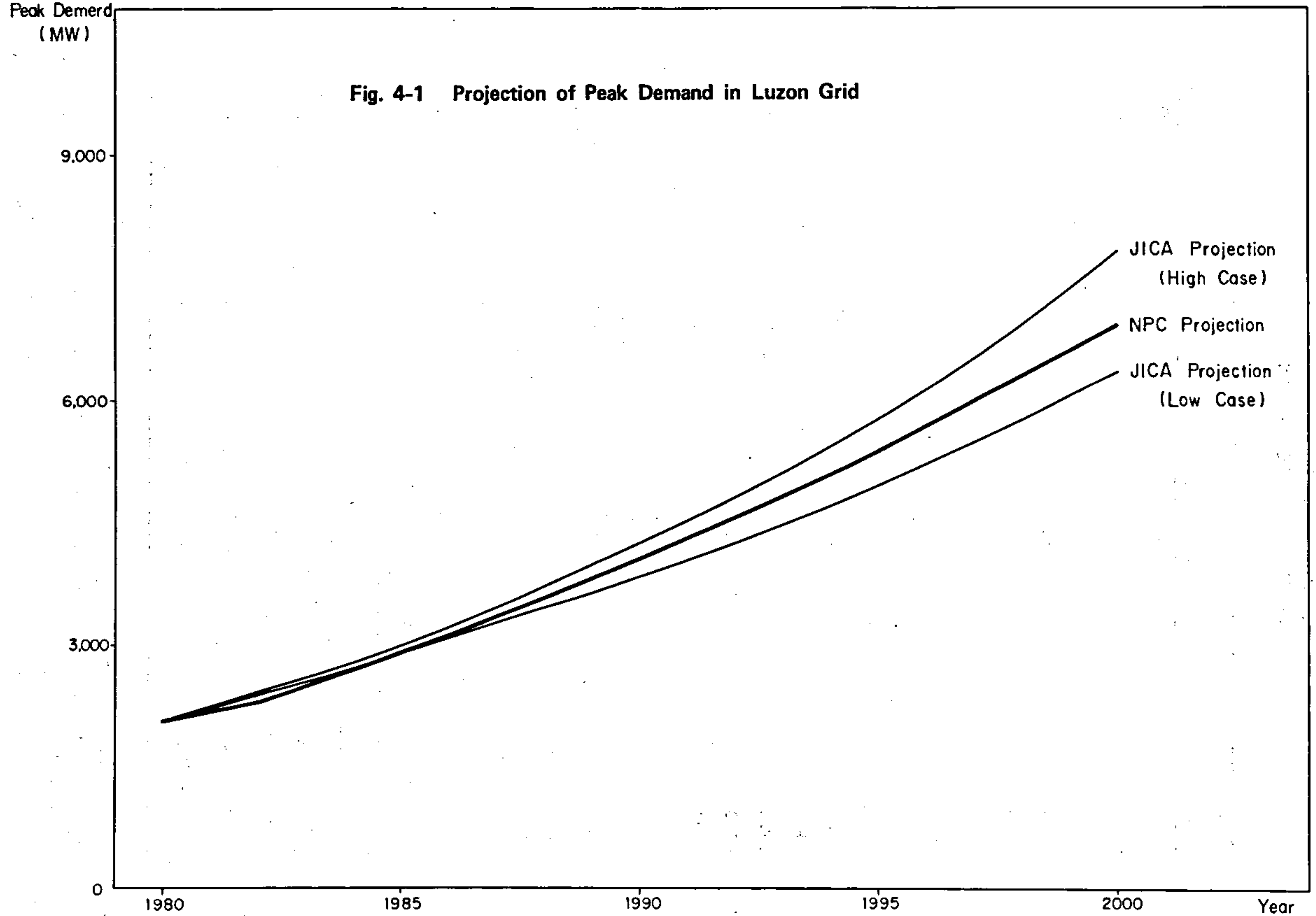
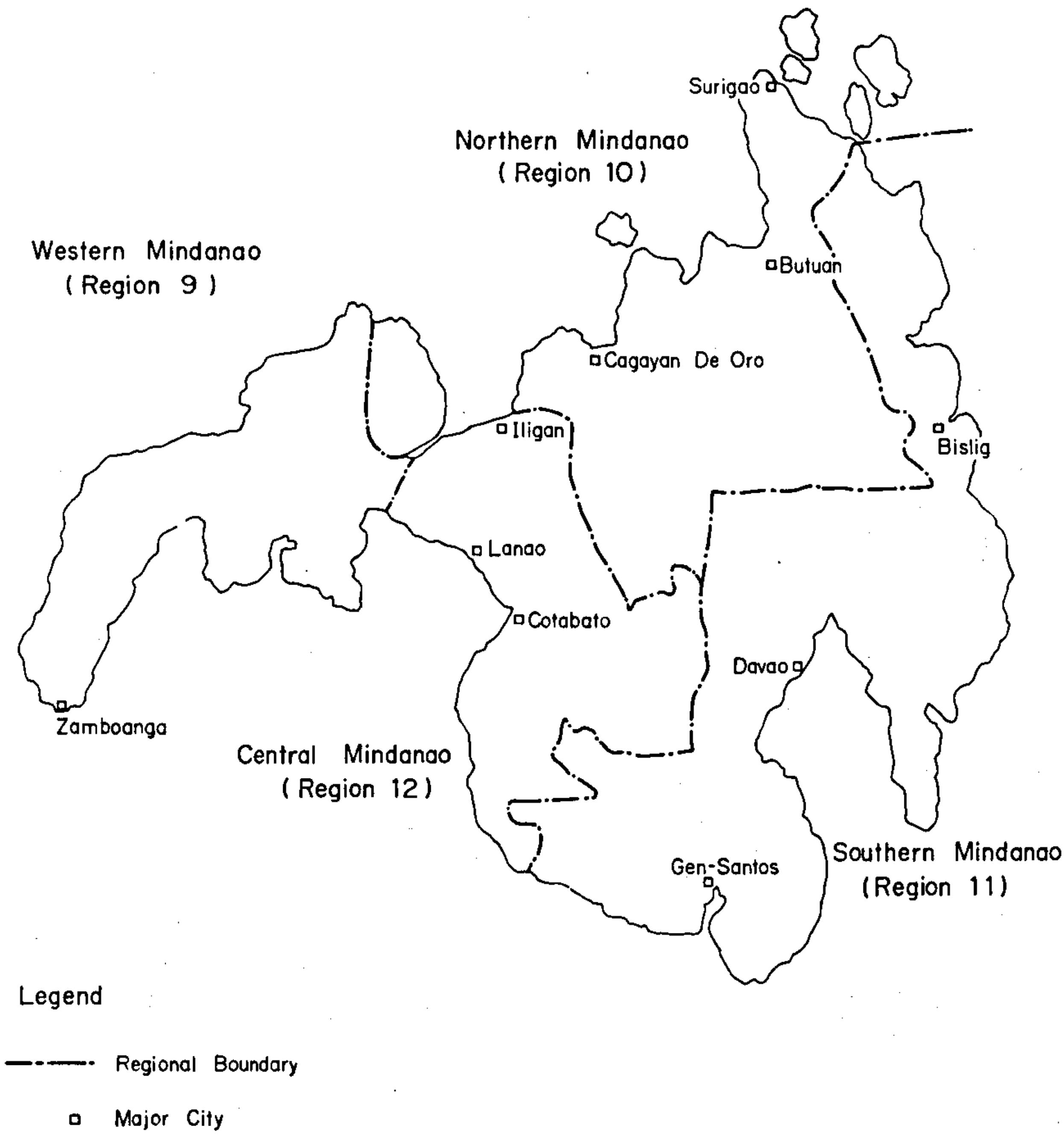


Fig. 4-2 Map of Mindanao by Regional Division



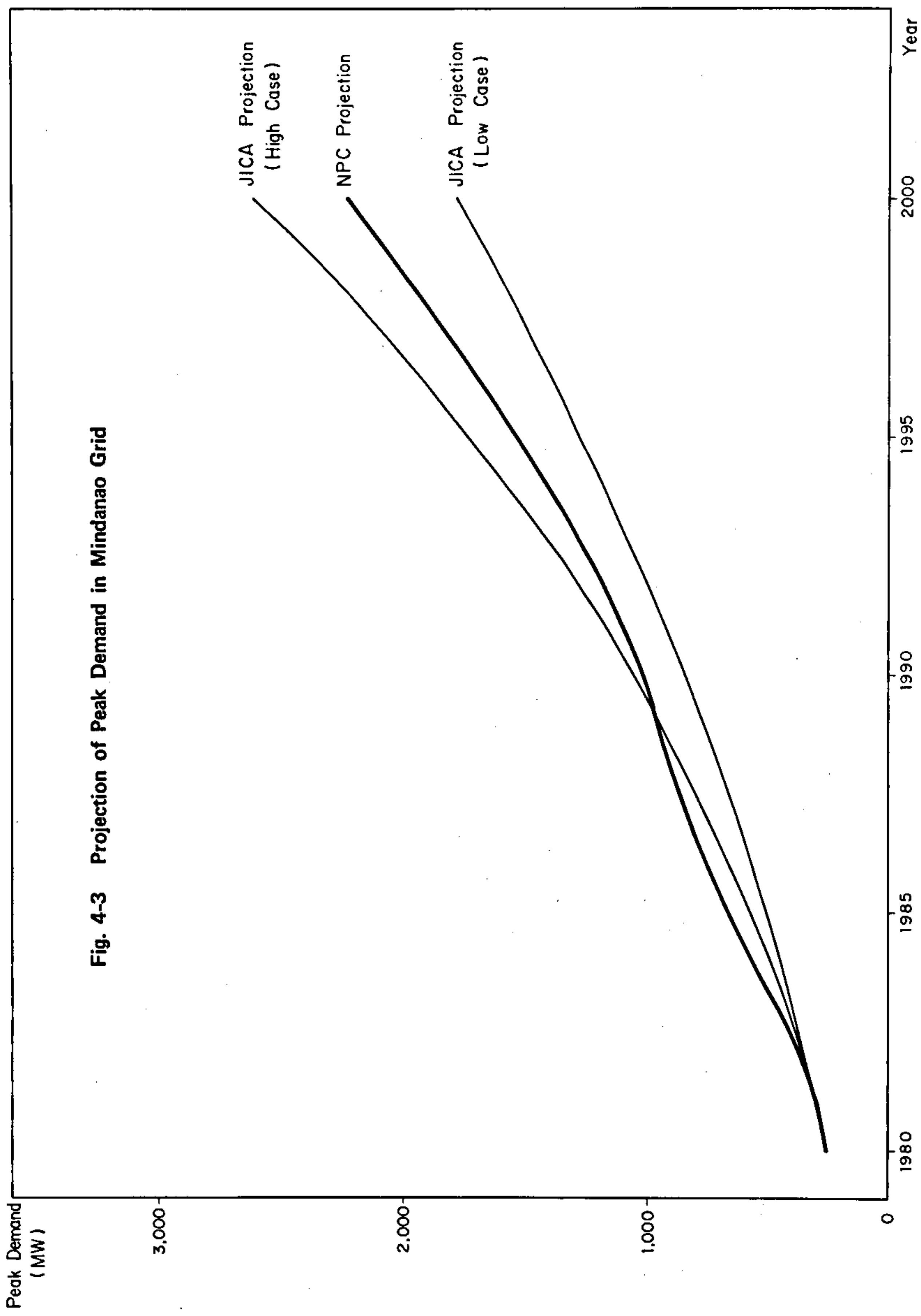


Fig. 4-3 Projection of Peak Demand in Mindanao Grid

CHAPTER 5

LEYTE-MINDANAO POWER TRANSMISSION PROJECT

CHAPTER 5 LEYTE-MINDANAO POWER TRANSMISSION PROJECT

5.1 Basic Consideration and Present Power Systems

In order to prove the feasibility of this Project, it is necessary to consider the future power demand and supply plan for the Luzon, Leyte-Samar and Mindanao grids, and clarify the state of usefulness of the Leyte-Mindanao transmission line under steady state and fault occurence conditions among the three grids.

The survey team clarifies the power demand and supply balance of each grid based on the power demand and the power development plan for the three grids established by the NAPOCOR at present, and also mentions the power flows of the interconnected transmission line between Leyte and Mindanao in this clause.

5.1.1 Power Demand and Supply Balance of Luzon Grid

The report of Leyte-Luzon power transmission project submitted by JICA to NAPOCOR in February, 1982 says that the Tiwi and Daklan geothermal development plans intended to supply a total of 440 MW up to 1990 which were later scrapped as a result of geothermal resource investigation. The expected peak power demand of 5,645 MW in 1995 was reduced to 5,430 MW as a result of power demand investigation in March, 1983.

Figs. 5-1 and 5-2 show the power demand and supply balance of Luzon grid. The scrapping of the Tiwi and Daklan geothermal development plans will force the existing oil fired thermal power plants into operation.

A total of 880 MW from unit No. 7 to unit No.22 of the Tongonan geothermal development plan in Leyte are incorporated in the power demand and supply balance of the Luzon grid.

Table 5-1 lists the power demand and supply balance of the Luzon grid.

5.1.2 Power Demand and Supply Balance of Leyte-Samar Grid

The NAPOCOR presumes that the rate of industrial power demand occupied in the power demand is large. The three projects, PASAR (33 MW), PHILPHOS (30 MW) and LSADA (6 MW), totals 69 MW, occupying 50% of the maximum power demand of 128 MW in 1986.

In the Tongonan area in Leyte, the geothermal development possible output is 1,000 MW. The geothermal energy confirmed is 448 MW. If Biliran and Burauen are involved, it seems that there is geothermal energy of 1,000 MW or greater. As listed in Table 5-2, the total installed capacity of up to unit No.6 in the Tongonan geothermal development plan is 228 MW including the pilot plant (3.0 MW). The supply capacity is large in comparison with the increase of power demand. Figs. 5-3 and 5-4 show the kW and kWh balances.

5.1.3 Power Demand and Supply Balance of Mindanao Grid

The main supply capacity of the Mindanao grid will be formed by hydro power up to 1987. After that, hydro and coal thermal power will be developed alternately. The maximum power demand in 1990 is 1,004 MW and the total installed capacity is 1,636 MW.

Table 5-3 lists the power demand and supply balance of the Mindanao grid. Figs. 5-5 and 5-6 show the kW and kWh balances. As shown in Fig. 5-5, the development of coal thermal power unit No.3 and No.4 will be postponed. Instead, electric power will be able to be received from the Luzon grid through the transmission line installed between Leyte and Mindanao.

5.1.4 Leyte Geothermal Development Plan

The Philippine's "Five-Year Energy Program 1981 - 1985" reports that its geothermal energy is one of the largest scales in the world. The Philippine government takes her energy circumstances into consideration and gives top priority to the development of geothermal energy.

This is shown in the construction plans of the geothermal power plants developed by the NAPOCOR. That is, the generated output of the geothermal power plants was 498 MW at the end of 1982 which will reach 1,328 MW in 1990. The Leyte geothermal power generation plan closely related to the Leyte-Mindanao Power Transmission Project is as follows:

Tongonan Geothermal Power Generation Plan in Leyte

	Year put in service	Unit installed capacity (MW)	No. of unit	Total installed capacity (MW)
May	1983	37.5	1	37.5
July	1983	37.5	1	75.0
Sep.	1983	37.5	1	112.5
Mar.	1986	37.5	1	150.0
Jun.	1986	37.5	1	187.5
Sep.	1986	37.5	1	225.0
	1988	55.0	2	335.0
	1989	55.0	4	555.0
	1991	55.0	4	775.0
	1992	55.0	4	995.0
	1993	55.0	2	1,105.0
	Total	—	22	1,105.0

The "Further Tongonan Geothermal Development, Leyte Prefeasibility Study Report by KRTA" prepared in November, 1979 estimates geothermal energy of at least 18,000 MWe-year in the Mahiao and Malitbog areas. Besides, it is reported that the reserved energy will approximate 25,000 MWe-year if the outside areas are included in the estimate.

The geothermal energy verified by drilling in November, 1979 was 11,200 MWe-year. If the geothermal energy is valuated by a generating equipment's service life of 25 years*, power facilities of 720 MW to 1,000 MW can be installed in the Tongonan area.

In addition to the Tongonan area, the Biliran and Burauen areas in Leyte have geothermal symptoms such as fumes over a wide range. Therefore, it is said that substantial development is possible. Three investigative wells are now being drilled by the PNOC in the Biliran area. It is presumed that there is geothermal energy of approximately 200 MW. In the Burauen area, drilling of investigative wells will be on-going since 1983.

The geothermal energy in Leyte is extremely abundant and expected to be developed. The Leyte-Luzon and Leyte-Mindanao transmission plans are closely related as a means to transmit the energy. Cooperative development planning between the transmission plans and geothermal energy development should be done adjusting the time of development of both projects.

5.1.5 Leyte-Mindanao Transmission Power

In planning the Leyte-Mindanao transmission project, it is necessary to forecast how the transmission line is utilized if the Luzon, Leyte-Samar and Mindanao grids are interconnected, based on the power development plans and the power demands for the three grids. The forecast mentioned above is made based on the power development plans and the power demand estimates for the three grids being planned at present. If the geothermal development plan in Leyte is developed up to about 1,000 MW as described later, it may be considered that the technical and economical feasibility of the Project is proved even though the power development plans for the Luzon and Mindanao grids are slightly changed in relation to power source configuration and time of development. The following two type standards for measuring the degree of usefulness of the transmission line in the Project are available: one is the reserve power interchange between the Luzon grid and the Mindanao grid, and the other is the economic energy interchange between both grids by replacing the construction of the coal fired thermal power station expected to be developed in the Mindanao grid by the oil fired thermal power station expected to be used as stand-by in the Luzon grid.

a) Reserve power interchange (Effects of reduction on power supply margin)

There are three advantages of reserve power interchange obtained by interconnecting two different grids excluding the economic energy interchange:

- Backup interchange power against outage generators
- Interchange power resulting from noncoincident of water flow between both grids
- Effective use of generating facility resulting from noncoincident power demand between both grids.

---

* In the economic and financial evaluations in Chapter 9, the service life of geothermal power facilities used is 20 years.

In addition, advantages of larger generator capacities scale up advantages, wide-ranging development, combined grid operation, improvement in system stability, reduction of ordinary frequency variation and mutual backup against abnormal conditions such as natural calamities may be included. However, these items are excluded as basis of evaluation because of difficulty in valuation. Therefore, evaluation will be made based on the above three items.

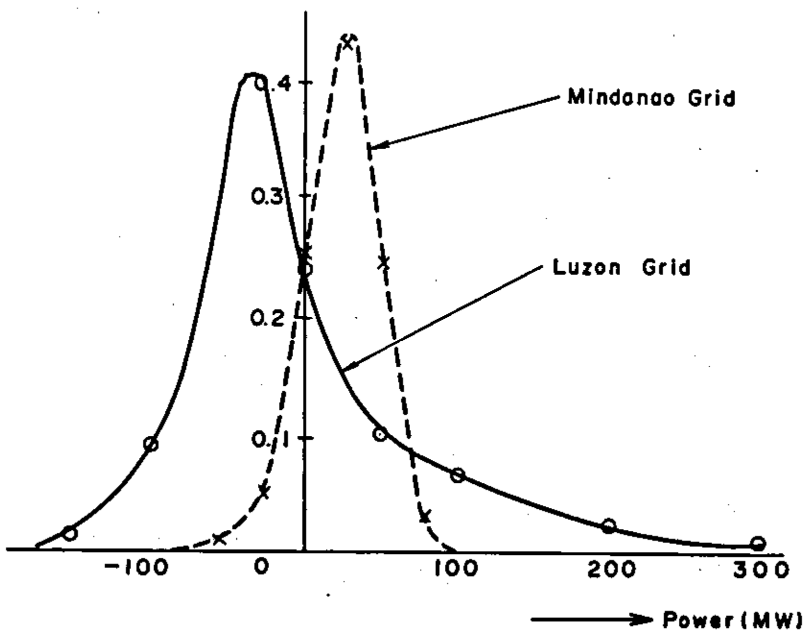
i) Backup interchange power against outage of generators

Generally, the power facilities in each grid have inherent forced outages of generators. The standard values used by the NAPOCOR on power demand and supply balance are as follows:

Categories	Forced outage by unit
Hydro	1.5%
Steam	
Oil-fired	3.0 - 8.0%
Coal-fired	7.0%
Geothermal	3.0%
Nuclear	14.0%

ii) Interchange power resulting from water flow noncoincident between both grids

The noncoincidence of rainfall in Luzon and Mindanao Islands is extremely remarkable. Luzon has the dry season from November through May. Contrary to this, Mindanao has the rainy season from October through April. Therefore, the reserve power interchange resulting from the noncoincidence of water flow is expected between both grids. The survey team obtained the probability distribution of hydropower supply merging between the Luzon grid and the Mindanao grid from the generation data of the existing hydro power plants of both grids for the month of May from 1971 through 1970. The result is as follows:

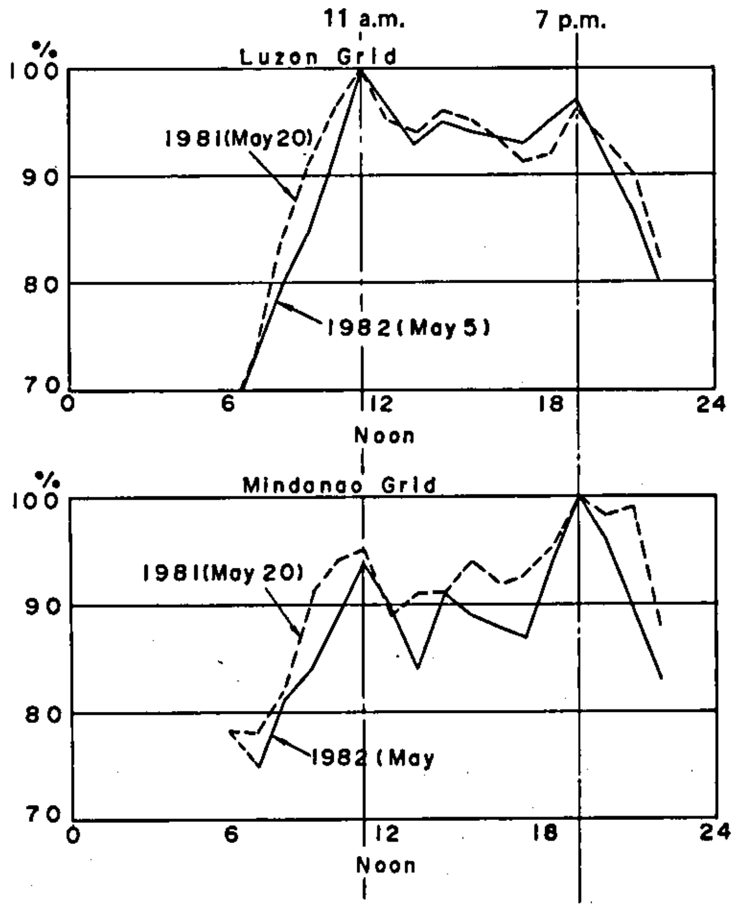


The hydropower supply margin in Luzon grid in every month of May when the maximum power demand of the Luzon grid emerges through the year will be probably negative. Contrary to this, that of the Mindanao grid will be probably positive.

iii) Effective use of generating facilities resulting from noncoincident of power demand between both grids

As shown in Fig. 5-7, the peak annual power demand of the Luzon grid is recorded at 11 a.m. in May. On the other hand, the peak power demand of the Mindanao grid comes at 7 p.m. when lighting peaks. Both grids have different peak time. This shows that the reserve power of both grids can be mutually utilized.

Fig. 5-7 Load Diversity



Peak coincident and non coincident lines

	Luzon	Mindanao
Luzon		5 %
Mindanao	3 %	

Regarding monthly daily load curves, please refer to Fig. 5-9.

For the three items, the values listed in Table 5-4 were obtained from the probability distribution of interchangeable reserve power between the Luzon grid and the Mindanao grid in the three years of 1990, 1995 and 2000 using the loss of load probability of both grids and the interconnection capacity of Leyte-Mindanao transmission line as parameters.

The estimation of 200 MW interconnection in the year 2000 shows that the utilization factor of the transmission line by the reserve power interchange is 2.46 % for transmission from the Mindanao grid to the Luzon grid and 10.74 % for reverse transmission. The Mindanao grid has benefits resulting from interconnection that are about 4 times as large as the Luzon grid.

Although the utilization factor of the transmission line by the reserve power interchange is low, the construction of the Leyte-Mindanao transmission line can still maintain the probability that both grids will receive 200 MW mutually. This means that the reserve power of both grids can be reduced up to 200 MW.

b) Economic energy interchange

As described previously, the introduction of coal fired thermal power plants will be started in 1988 in the Mindanao grid. If oil fired thermal power is compared with coal fired thermal power only in fuel cost per kWh, the fuel cost of coal fired thermal power is cheaper. However, if the oil fuel cost of the standby oil fired thermal plants in Luzon grid is compared with the power generation cost per kWh in constructing a coal fired thermal power plant, the oil fuel cost is cheaper. Table 5-5 lists the results of considering the economic energy interchange between the Luzon grid and the Mindanao grid based on such prerequisites. From this conclusion, it is clear that it is desirable to interconnect both grids to each other on and after the year 1992. Naturally, it is possible that the coal fired thermal power of the Mindanao grid is transmitted to the Luzon grid by 1991. Considering transmission loss, it would be proper to increase the oil fired thermal power of the Luzon grid.

The degree of usefulness of the Leyte-Mindanao transmission line is estimated based on the power plant projects and power demand of both grids. The relation between the transmission capacity of the transmission line and the utilization factor from 1992 is as follows:

Year		1992	1993	1994	1995	1996	1997	1998	1999
Transmission Power	(MW)	200	200	200	200	200	400	400	400
Utilization factor									
Reserve power interchange	(%)	4.9	4.5	4.2	3.7	3.4	7.1	6.6	6.4
Economic energy interchange	(%)	26.4	23.1	30.2	12.4	24.8	70.8	64.4	38.6
Total	(%)	31.3	27.6	34.4	16.1	28.2	77.9	71.0	45.0

5.1.6 Timing for implementation of Leyte-Mindanao power transmission project

As described in Item 5.1.5 (2), construction of the Leyte-Mindanao power transmission system should be completed after completion of the Luzon-Leyte power transmission system with ultimate installed capacity of 900 MW (2nd stage) and be divided into two stages.

Implementation stages (target year for the start of operation) for Luzon-Leyte • Samar-Mindanao interconnecting power transmission system are shown below:

Luzon-Leyte power transmission project

First stage (HVDC ±175 kV, 450 MW): early 1988

Second stage (HVDC ±350 kV, 900 MW): early 1991

Leyte-Mindanao power transmission project

First stage (HVDC +350 kV, 200 MW): early 1992

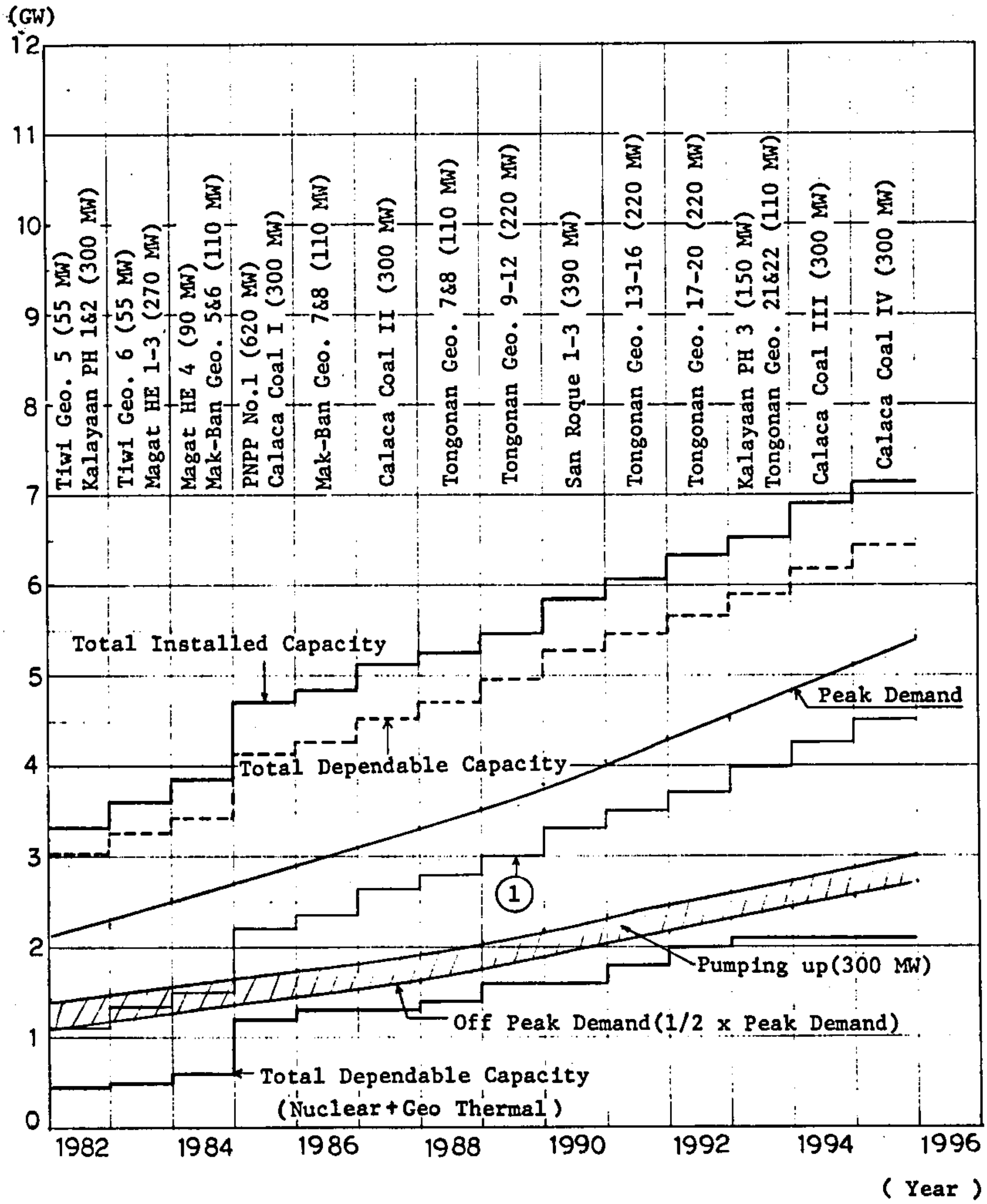
Second stage (HVDC ±350 kV, 400 MW): early 1997

Detailed design works and elaboration of tender documents including technical specifications should be started at the beginning of 1988.

Table 5-1 Luzon Grid Generation Expansion Program On-going, Firm and Probable Projects

Year of comm. (month)	Plant addition	Plant cap. (MW)	Installed capacity Hydro (MW)	Geo. (MW)	Coal therm. (MW)	Nucl. (MW)	Oil therm. (MW)	Total (MW)	Dep. cap. (MW)	Peak demand (MW)	Reserve capacity (MW)	(%)	Avail. energy (GWh)	Energy capability & requirement Hydro (GWh)	Geo. (GWh)	Coal therm. (GWh)	Nucl. (GWh)	Oil therm. (GWh)	Total (GWh)	Gen. level (GWh)	Surplus (def.) (GWh)
1982/ 1	Existing hydro	554	854	495	0	0	1,925	3,274	3,016	2,263	313	13	2,098	2,273	3,441	0	0	13,510	19,224	14,481	4,743
1	Existing geo.	440											3,110								
1	Existing thermal	1,925											13,510								
3	Tiwi geo. 5	55											397								
5	Kalayan PH2	150											150								
7	Kalayan PH1	150											150								
1983/ 1	Tiwi geo. 6	55	1,124	550	0	0	1,925	3,599	3,255	2,525	404	16	397	2,674	3,904	0	0	13,510	20,088	15,495	4,593
7	Magat HE-1	90											275								
9	Magat HE-2	90											276								
11	Magat HE-3	90											276								
1984/ 1	Magat HE-4	90	1,214	660	0	0	1,925	3,799	3,437	2,705	392	14	276	3,501	4,301	0	0	13,510	21,312	16,580	4,732
7	Mak-Ban Geo 5 & 6	110											794								
1985/ 1	PNPP No. 1	620	1,214	660	300	620	1,925	4,719	4,107	2,890	817	28	3,910	3,501	4,698	1,989	1,684	13,510	25,382	17,740	7,642
1	Calaca coal I	300																			
1986/ 1	Mak-Ban geo. 7 & 8	110	1,214	770	300	620	1,925	4,829	4,257	3,100	707	23	794	3,501	5,492	1,989	3,367	13,510	27,859	18,980	8,879
1987/ 1	Calaca coal II	300	1,214	770	600	620	1,925	5,129	4,577	3,315	762	23	1,989	3,501	5,492	3,978	3,639	13,510	30,120	20,310	9,810
1988/ 1	Tongonan geo. 7 & 8	110	1,214	880	600	620	1,925	5,239	4,727	3,545	632	18	794	3,501	6,286	3,978	3,856	13,510	31,131	21,730	9,401
1989/ 1	Tongonan geo. 9-12	220	1,214	1,100	600	620	1,925	5,459	4,967	3,790	587	15	1,588	3,501	7,874	3,978	3,910	13,510	32,773	23,250	9,523
1990/ 1	San Roque 1-3	390	1,604	1,100	600	620	1,925	5,849	5,255	4,060	605	15	1,153	4,654	7,874	3,978	3,910	13,510	33,926	24,880	9,046
1991/ 1	Tongonan geo. 13-16	220	1,604	1,320	600	620	1,925	6,069	5,455	4,300	565	13	1,588	4,654	9,462	3,978	3,910	13,510	35,514	26,370	9,144
1992/ 1	Tongonan geo. 17-20	220	1,604	1,540	600	620	1,925	6,289	5,655	4,560	505	11	1,588	4,654	11,844	3,978	3,910	13,510	37,102	27,955	9,147
1993/ 1	Kalayan PH3	150	1,754	1,650	600	620	1,925	6,549	5,905	4,835	480	10	150	4,804	11,844	3,978	3,910	13,510	38,046	29,630	8,416
1	Tongonan geo. 21 & 22	110											794								
1994/ 1	Calaca coal III	300	1,754	1,650	900	620	1,925	6,849	6,175	5,125	460	9	1,989	4,804	11,844	5,967	3,910	13,510	40,035	31,410	8,625
1995/ 1	Calaca coal IV	300	1,754	1,650	1,200	620	1,925	7,149	6,445	5,430	425	8	1,989	4,804	11,844	7,956	3,910	13,510	42,024	33,295	8,729
2000																					
	Annual increase	(%)	5.7	9.7	-	-	0	6.2	6.0	6.4	-	-	-	5.9	10.0	-	-	0	6.2	6.2	-

Fig. 5-1 Luzon Grid Power Balance (kW Balance)



(1) Total Dependable Capacity minus - Oil Thermal Capacity

Fig. 5-2 Luzon Grid Energy Balance (kWh Balance)

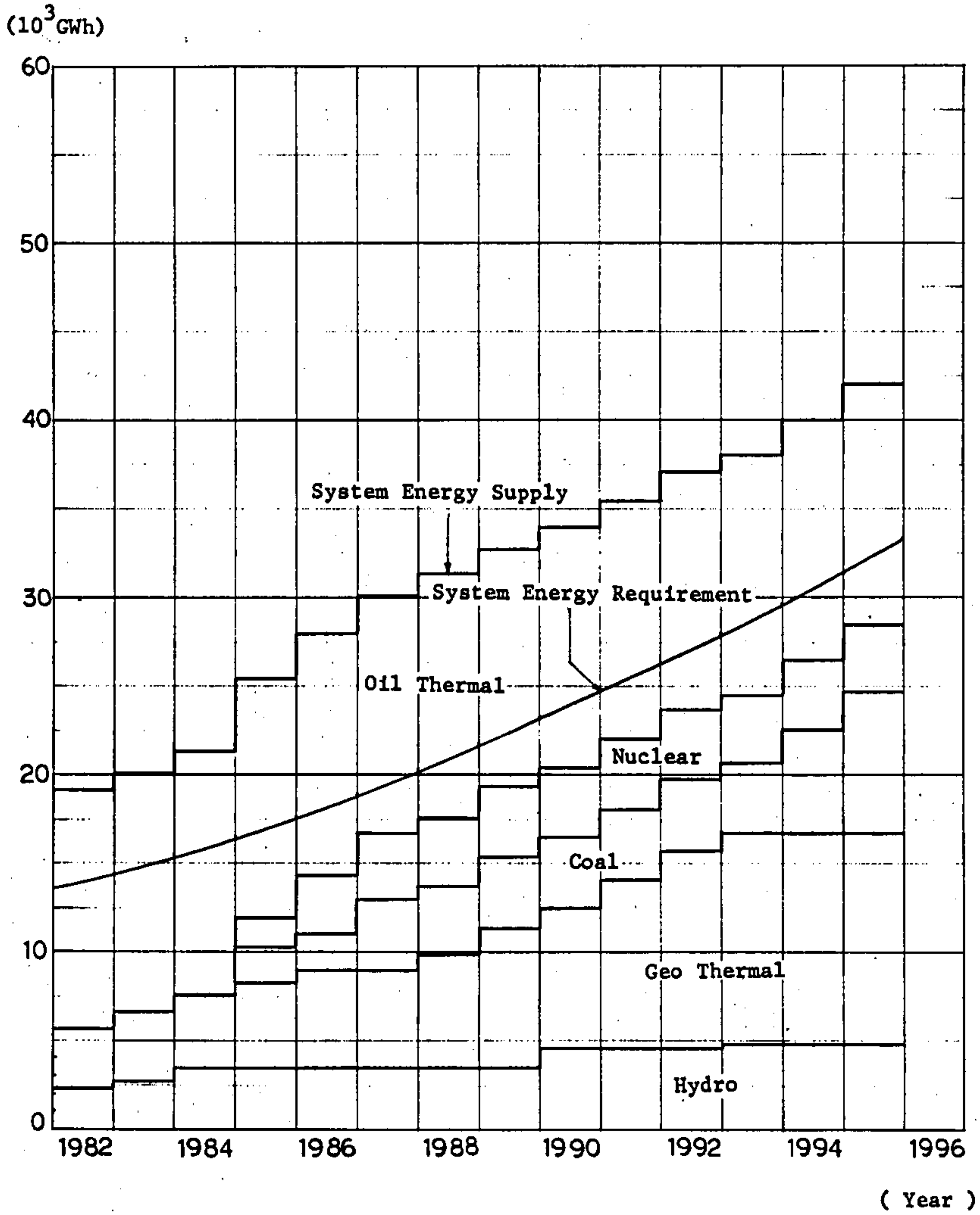


Table 5-2 Leyte-Samar Grid Generation Expansion Program On-going, Firm and Probable Projects

Year of comm. (month)	Plant addition	Plant cap.	Installed capacity: Hydro (MW)	Installed capacity: Geo. (MW)	Installed capacity: Power barge (MW)	Installed capacity: Diesel (MW)	Installed capacity: Total (MW)	Dep. cap. (MW)	Peak demand (MW)	Reserve capacity (MW)	Reserve capacity (%)	Avail. energy (GWh)	Energy capability & requirement: Hydro (GWh)	Geo (GWh)	Power barge (GWh)	Diesel (GWh)	Total (GWh)	Gen level (GWh)	Surplus (def.) (GWh)
1982/ 1	Tongonan geo.	3.0	0	3.0	32.0	20.0	55.0	44	21	16	70	20	0	20	131	83	234	45	189
1	Leyte Coop. D	20.0										83							
5	Power Barge No.1	32.0										196							
1983/ 5	Tongonan geo. 3	37.5	0	115.5	32.0	20.0	167.5	151	46	69	150	271	0	427	196	83	706	239	467
7	Tongonan geo. 2	37.5										271							
9	Tongonan geo. 1	37.5										271							
1984/ 1	Power Barge No.2	32.0	0	115.5	64.0	20.0	199.5	179	76	68	89	196	0	833	392	83	1,308	355	953
1985/ 7	SAMELCO No.1 & No.2	5.7	0	115.5	64.0	25.7	205.2	184	112	37	33	31	0	833	392	99	1,324	680	644
1986/ 3	Tongonan geo. 4	37.5	0	228.0	64.0	25.7	317.7	291	128	127	99	271	0	1,307	392	114	1,813	848	965
6	Tongonan geo. 5	37.5										271							
9	Tongonan geo. 6	37.5										271							
1987	-	0	0	228.0	64.0	25.7	317.7	291	131	125	95	0	0	1,646	392	114	2,152	867	1,285
1988	-	0	0	228.0	64.0	25.7	317.7	291	134	122	91	0	0	1,646	392	114	2,152	938	1,214
1989	-	0	0	228.0	64.0	25.7	317.7	291	155	101	65	0	0	1,646	392	114	2,152	1,020	1,132
1990	-	0	0	228.0	64.0	25.7	317.7	291	169	87	51	0	0	1,646	392	114	2,152	1,101	1,051
1991/ 1	Pull out barge No.1	32.0	0	228.0	32.0	25.7	285.7	263	175	53	30	196	0	1,646	196	114	1,956	1,145	811
1992	-	0	0	228.0	32.0	25.7	285.7	263	184	44	24	0	0	1,646	196	114	1,956	1,196	760
1995									201									1,307	
2000									233									1,527	
	Annual in crease	(%)	-	-	-	-	17.9	19.6	14.3	-	-	-	-	-	-	-	23.6	21.6	-

Fig. 5-3 Leyte-Samar Grid Power Balance (kW Balance)

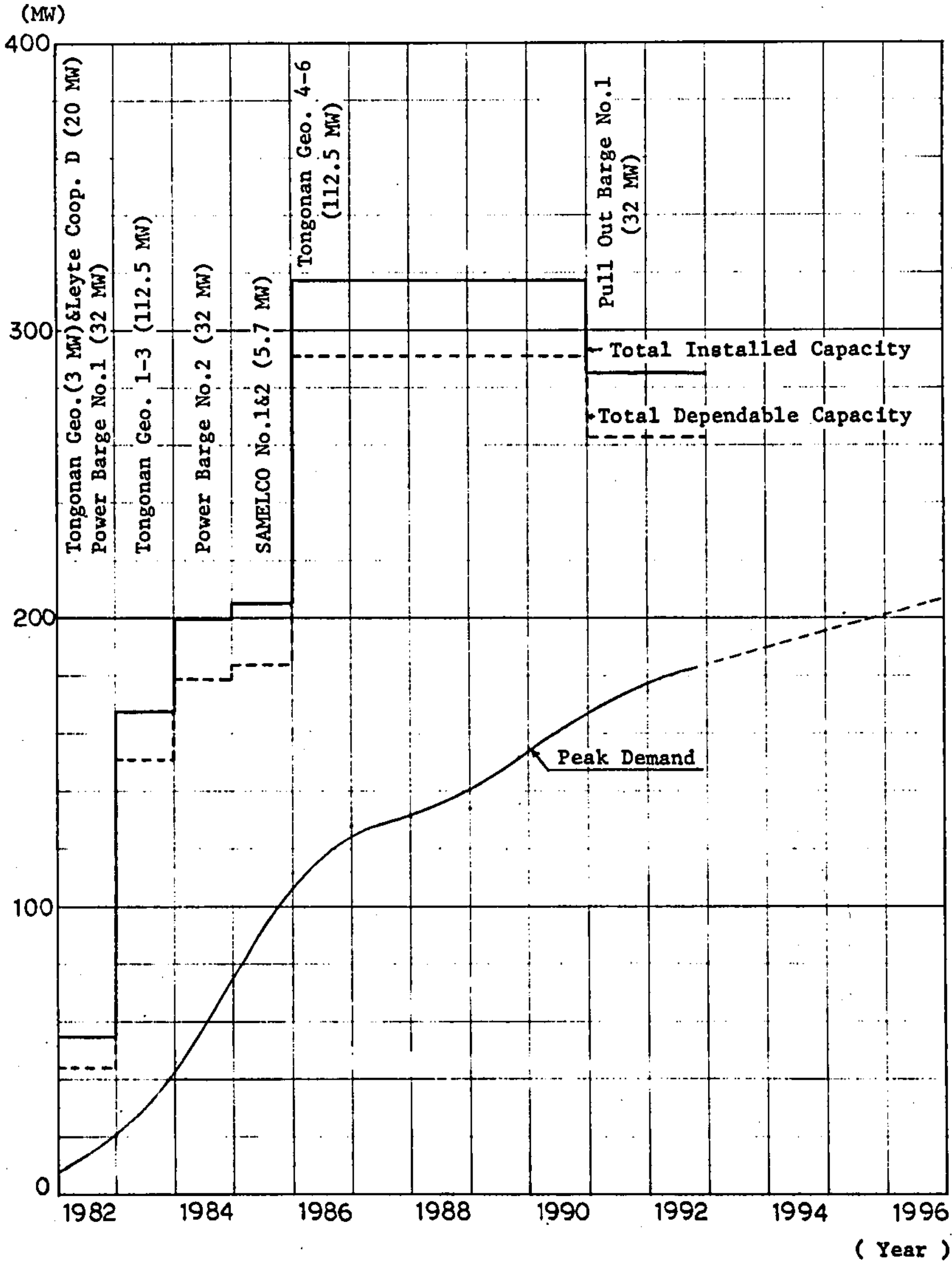


Fig. 5-4 Leyte-Samar Grid Energy Balance (kWh Balance)

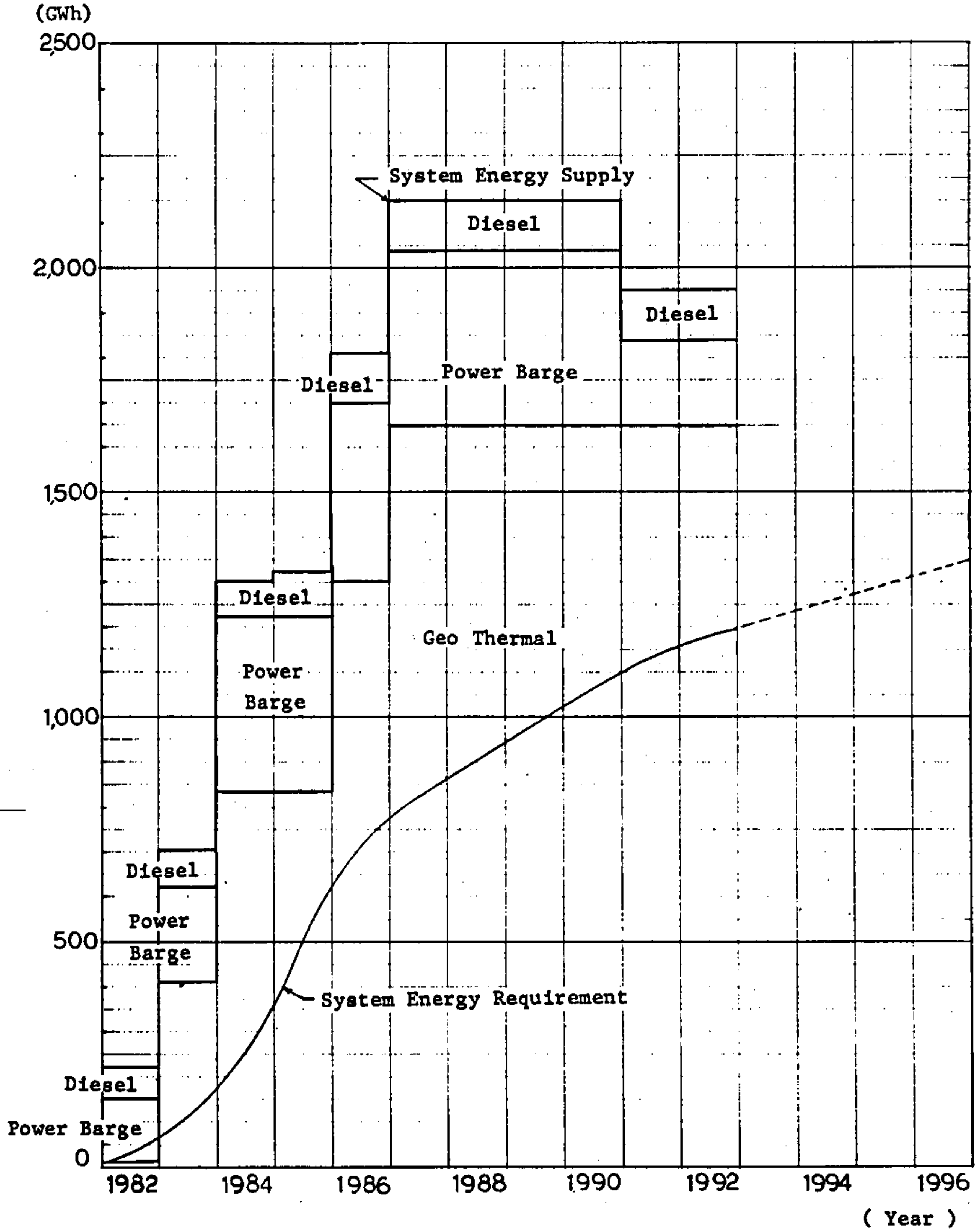


Table 5-3 Mindanao Grid Generation Expansion Program On-going, Firm and Probable Projects

Year of comm.	Month	Plant addition	Plant cap.	Installed capacity					Dep. cap.	Peak demand	Reserve cap		Energy capability & requirement						
				Hydro	Diesel	Coal Therm.	Geo.	Total					Hydro	Diesel	Coal therm.	Geo.	Total	Gen. level	Surplus (def.)
			(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(%)	(GWh)	(GWh)	(GWh)	(GWh)	(GWh)	(GWh)	(GWh)
1982	1	Existing hydro	382	409	177	0	0	586	480	357	123	35	1,952	1,164	0	0	3,116	2,101	1,015
		Existing diesel	177																
	11	Agus VII 2	27																
1983	1	Agus VII 1	27	436	199	0	0	635	506	452	54	12	2,132	1,236	0	0	3,368	2,763	605
	7	G. Santos D	21.9																
1984	1	Agus V 1	27.5	721	199	0	0	920	696	554	142	26	3,433	1,308	0	0	4,741	3,512	1,229
	2	Agus I 1	40																
	3	Agus I 2	40																
	3	Agus V 2	27.5																
	5	Agus IV 3	50																
	7	Agus IV 2	50																
	9	Agus IV 1	50																
1985	1	Zamboanga D	36	976	235	0	0	1,211	878	645	233	36	4,389	1,544	0	0	5,933	4,044	1,889
	3	Pulangi IV 1	85																
	5	Pulangi IV 2	85																
	7	Pulangi IV 3	85																
1986			0	976	235	0	0	1,211	927	779	148	19	4,717	1,544	0	0	6,261	4,844	1,417
1987			0	976	235	0	0	1,211	939	799	140	18	4,717	1,544	0	0	6,261	4,985	1,276
1988	1	Bislig 1	100	976	235	100	0	1,311	1,025	863	162	19	4,717	1,544	656	0	6,917	5,466	1,451
1989	1	Bislig 2	100	976	235	200	0	1,411	1,118	946	172	19	4,717	1,544	1,316	0	7,577	5,988	1,589
1990	1	Agus III	225	1,201	235	200	0	1,636	1,263	1,004	259	26	5,809	1,544	1,316	0	8,669	6,340	2,329
1991			0	1,201	235	200	0	1,636	1,274	1,111	163	15	5,809	1,544	1,316	0	8,669	7,047	1,622
1992	1	Bislig 3	100	1,201	235	300	0	1,736	1,380	1,197	183	15	5,809	1,544	1,972	0	9,325	7,587	1,738
1993	1	Bislig 4	100	1,423	235	400	0	2,058	1,576	1,321	255	19	6,685	1,544	2,628	0	10,857	8,405	2,452
	1	Bul Batang	222																
1994	1	Cagayan	160	1,583	235	400	0	2,218	1,684	1,441	243	17	7,318	1,544	2,628	0	11,490	9,163	2,327
1995	1	Pulangi III	90	1,673	235	400	110	2,418	1,887	1,554	333	21	7,623	1,544	2,628	720	12,515	9,877	2,638
	1	Geothermal	110																
1996	1	Tagoloan	178	1,851	235	400	110	2,596	1,980	1,673	307	18	8,177	1,544	2,628	720	13,069	10,648	2,421
1997	1		0	1,851	235	400	110	2,596	2,010	1,797	213	12	8,177	1,544	2,628	720	13,069	11,454	1,615
2000										2,201									
		Annual increase	(%)	10.6	1.9	-	-	10.4	10.0	12.9	-	-	10.0	1.9	-	-	10.0	12.0	-

Fig. 5-5 Mindanao Grid Power Balance (kW Balance)

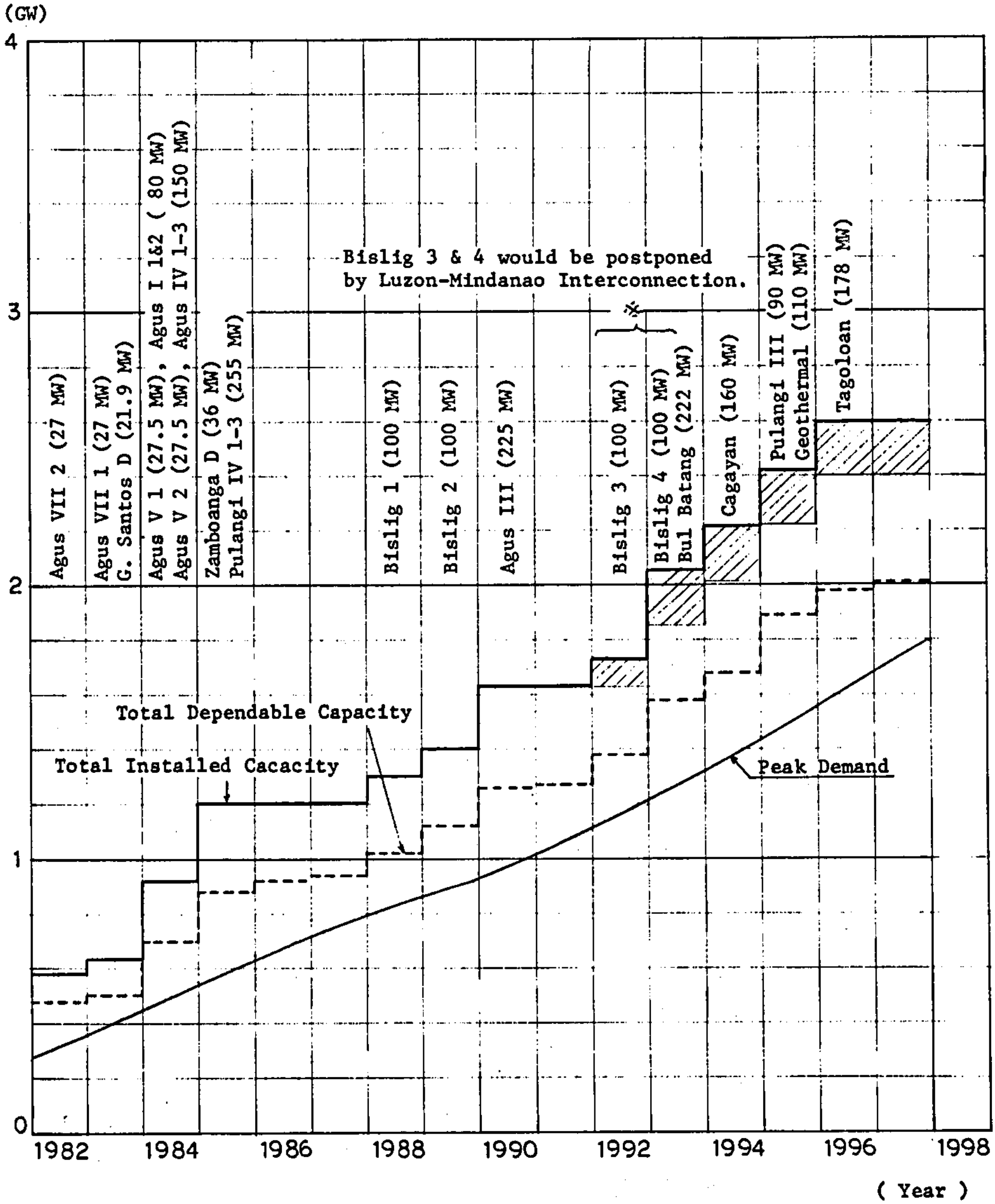


Fig. 5-6 Mindanao Grid Energy Balance (kWh Balance)

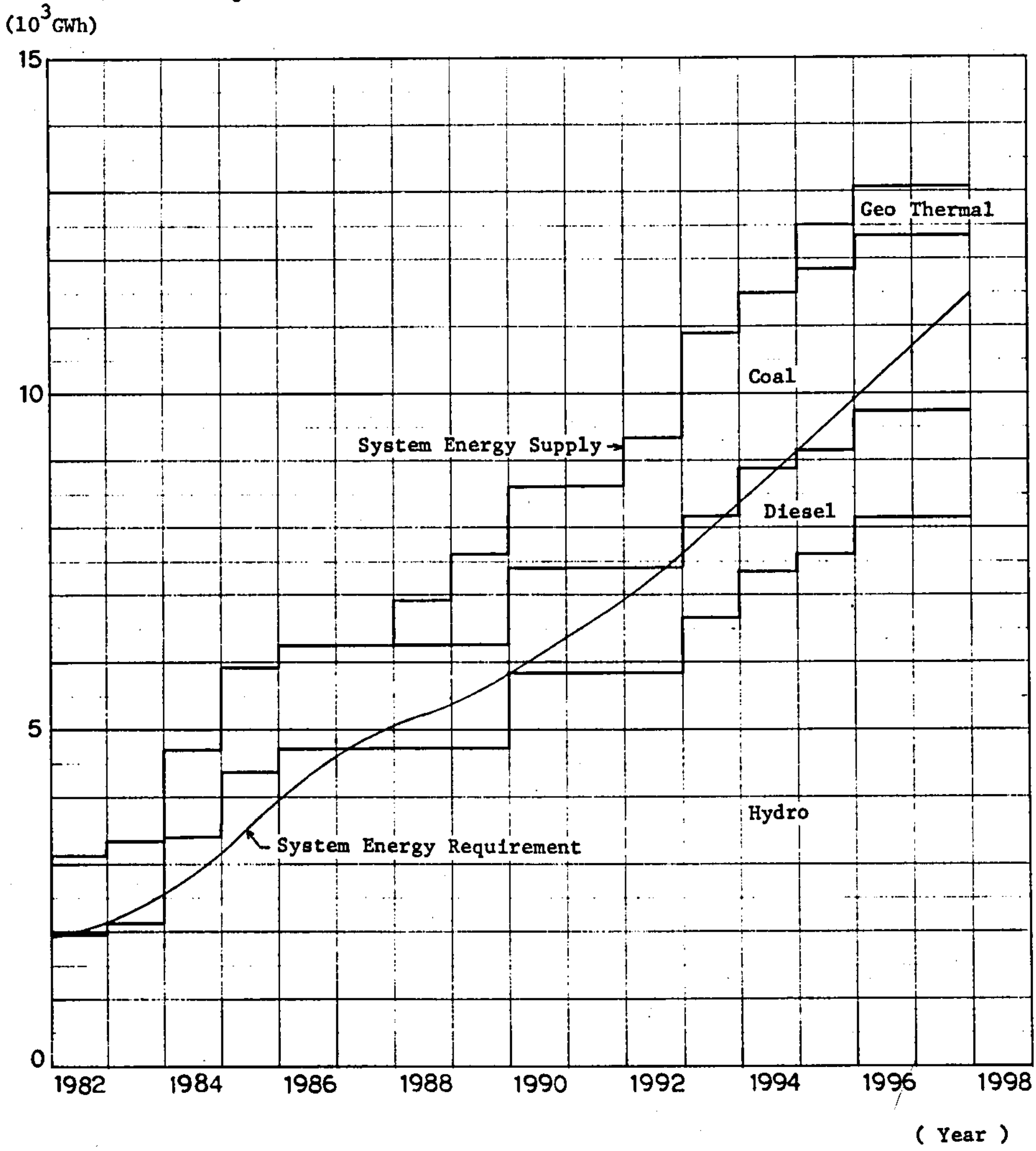


Table 5-4 Probability of Power Interchange between Luzon and Mindanao Power Grids

Year	1990		1995		2000	
	Mindanao to Luzon	Luzon to Mindanao	Mindanao to Luzon	Luzon to Mindanao	Mindanao to Luzon	Luzon to Mindanao
50 MW Interconnection						
Power flow range.						
0-0 MW	0.9828	0.9517	0.9826	0.9826	0.9821	0.9678
1-25 MW	0.0031	0.0254	0.0030	0.0030	0.0035	0.0128
26-50	0.0141	0.0229	0.0143	0.0143	0.0143	0.0194
100 MW Interconnection						
Power flow range						
0-0 MW	0.9825	0.8873	0.9796	0.9262	0.9786	0.9362
1-25 MW	0.0040	0.0503	0.0036	0.0289	0.0033	0.0236
26-50 MW	0.0029	0.0310	0.0032	0.0190	0.0031	0.0154
51-75 MW	0.0034	0.0173	0.0028	0.0121	0.0028	0.0108
76-100 MW	0.0073	0.0140	0.0107	0.0138	0.0122	0.0139
150 MW Interconnection						
Power flow range						
0-0 MW	0.9856	0.8046	0.9797	0.8812	0.9760	0.9076
1-25	0.0032	0.0783	0.0045	0.0425	0.0041	0.0312
26-50 MW	0.0035	0.0519	0.0027	0.0303	0.0034	0.0230
51-75 MW	0.0040	0.0317	0.0031	0.190	0.0035	0.0147
76-100 MW	0.0028	0.0184	0.0026	0.0127	0.0025	0.0102
101-125 MW	0.0006	0.0086	0.0024	0.0068	0.0026	0.0059
126-150 MW	0.0002	0.0066	0.0051	0.0075	0.0079	0.0074
200 WM Interconnection						
Power flow range						
0-0 MW	0.9859	0.7676	0.9826	0.8387	0.9754	0.8926
1-25 MW	0.0032	0.0906	0.0029	0.0550	0.0042	0.0354
26-50 MW	0.0023	0.0604	0.0033	0.0386	0.0034	0.0265
51-75 MW	0.0040	0.0380	0.0029	0.0273	0.0037	0.0170
76-100 MW	0.0027	0.0235	0.0027	0.0171	0.0025	0.0120
101-125 MW	0.0006	0.0112	0.0034	0.0111	0.0026	0.0072
126-150 MW	0.0002	0.0053	0.0013	0.0058	0.0022	0.0043
151-175 MW	-	0.0022	0.0008	0.0032	0.0023	0.0023
176-200 MW	-	0.0012	-	0.0031	0.0037	0.0026

Fig. 5-8 Required Reserve Capacity in 1990

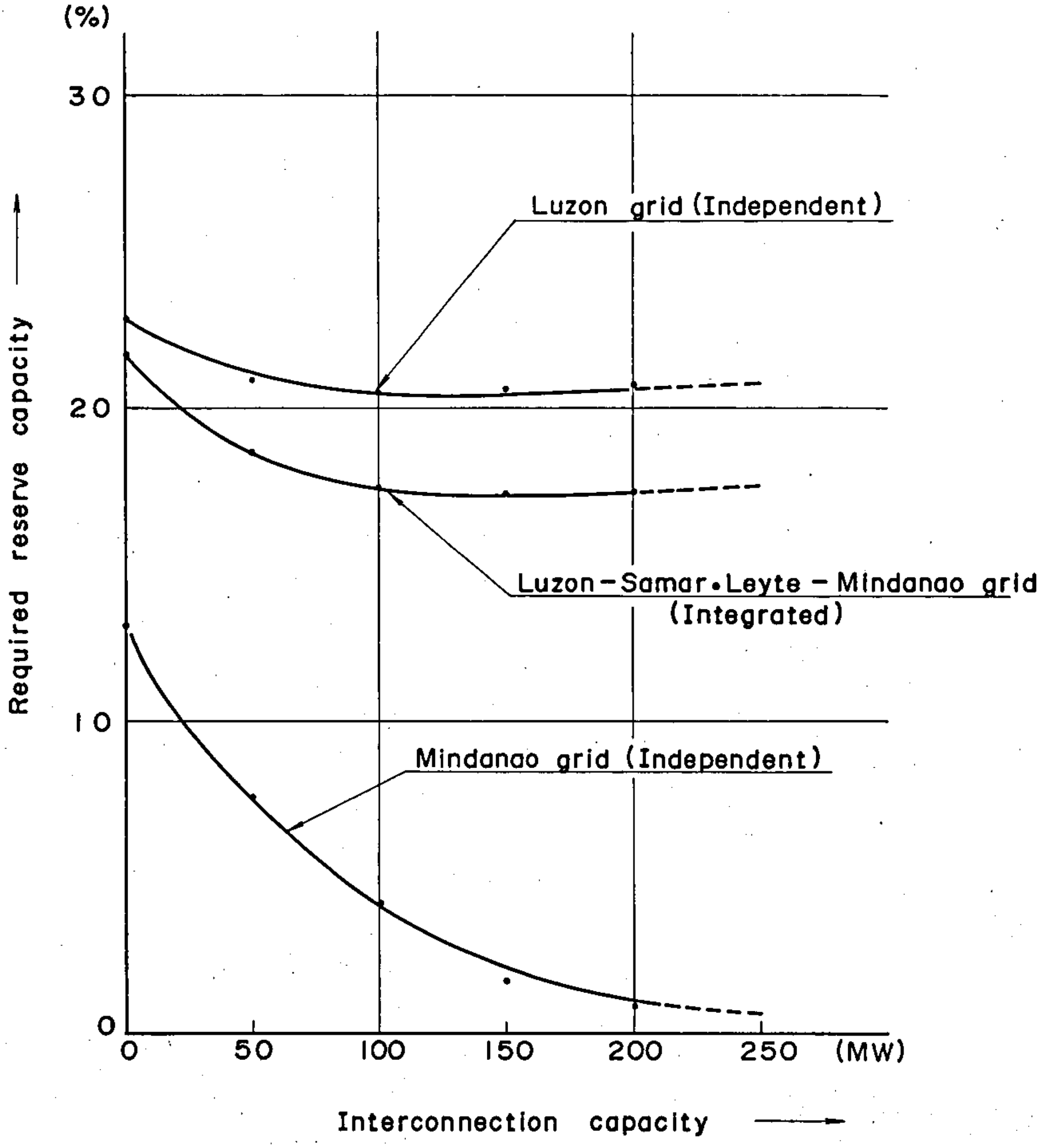


Table 5-5 Energy Exchange between Luzon and Mindanao Grids

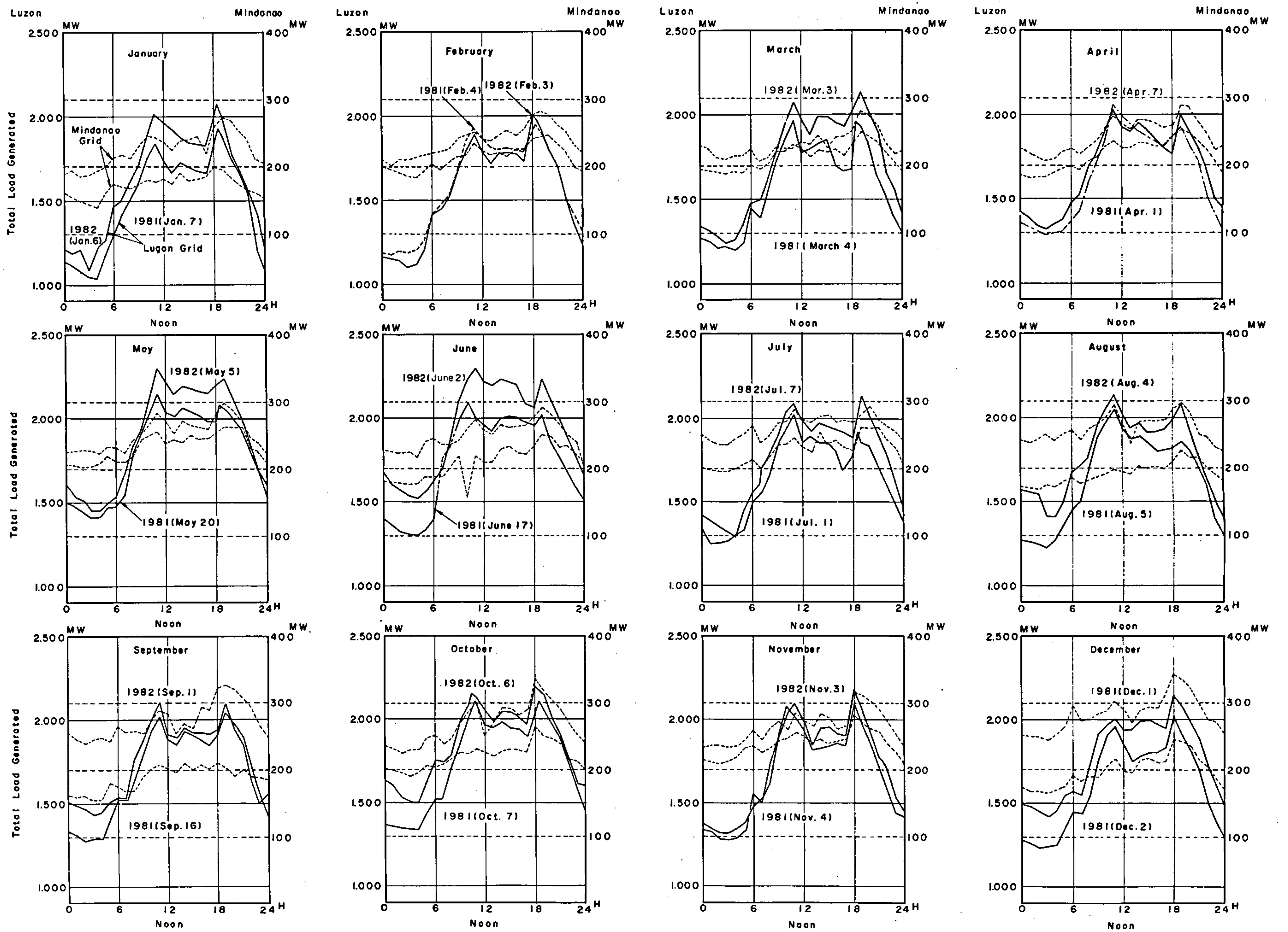
Unit : GWh

	1990			1991			1992			1993			1994		
	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total
(1) Energy demand	25,981	6,340	32,321	27,515	7,047	34,562	29,151	7,587	36,738	30,862	8,405	39,267	32,679	9,163	41,842
(2) Energy capability															
Hydro	4,654	5,809	10,463	4,654	5,809	10,463	4,654	5,809	10,463	4,804	6,685	11,489	4,804	7,318	12,122
Geo thermal	9,520	0	9,520	11,108	0	11,108	12,696	0	12,696	13,490	0	13,490	13,490	0	13,490
Coal	3,978	1,316	5,294	3,978	1,316	5,294	3,978	*1 1,316	5,294	3,978	*2 1,316	5,294	5,967	1,316	7,283
Nuclear	3,910	0	3,910	3,910	0	3,910	3,910	0	3,910	3,910	0	3,910	3,910	0	3,910
Sub-total	22,062	7,125	29,187	23,650	7,125	30,775	25,238	7,125	32,363	26,182	8,001	34,183	28,171	8,634	36,805
Diesel	506	1,544	2,050	310	1,544	1,854	310	1,544	1,854	310	1,544	1,854	310	1,544	1,854
Oil-fired thermal	13,510	0	13,510	13,510	0	13,510	13,510	0	13,510	13,510	0	13,510	13,510	0	13,510
Sub-total	14,016	1,544	15,560	13,820	1,544	15,364	13,820	1,544	15,364	13,820	1,544	15,364	13,820	1,544	15,364
Total	36,078	8,669	44,747	37,470	8,669	46,139	39,058	8,669	47,727	40,002	9,545	49,547	41,991	10,178	52,169
(3) Energy flow	(L)	← Coal 785	(M)	(L)	← Coal 78	(M)	(L)	Oil 462 →	(M)	(L)	Oil 404 →	(M)	(L)	Oil 529 →	(M)

	1995			1996			1997			1998			1999		
	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total	Luzon & Leyte	Mindanao	Total
(1) Energy demand	34,602	9,877	44,479	36,306	10,648	46,954	38,095	11,454	49,549	39,971	12,256	52,227	41,941	13,114	55,055
(2) Energy capability															
Hydro	4,804	7,623	12,427	6,281	8,177	14,458	7,434	8,177	15,611	7,964	9,091	17,055	8,768	10,401	19,169
Geothermal	13,490	720	14,210	13,490	720	14,210	13,490	720	14,210	13,490	720	14,210	13,490	720	14,210
Coal	7,956	1,316	9,272	7,956	1,316	9,272	7,956	1,316	9,272	7,956	1,316	9,272	7,956	1,316	9,272
Nuclear	3,910	0	3,910	3,910	0	3,910	3,910	0	3,910	3,910	0	3,910	3,910	0	3,910
Sub-total	30,160	9,659	39,819	31,637	10,213	41,850	32,790	10,213	43,003	33,320	11,127	44,447	34,124	12,437	46,561
Diesel	310	1,544	1,854	310	1,544	1,854	310	1,544	1,854	310	1,544	1,854	310	1,544	1,854
Oil-fired thermal	13,510	0	13,510	13,510	0	13,510	13,510	0	13,510	13,510	0	13,510	13,510	0	13,510
Sub-total	13,820	1,544	15,364	13,820	1,544	15,364	13,820	1,544	15,364	13,820	1,544	15,364	13,820	1,544	15,364
Total	43,980	11,203	55,183	45,457	11,757	57,214	46,610	11,757	58,367	47,140	12,671	59,811	47,944	13,981	61,925
(3) Energy flow	(L)	Oil 218 →	(M)	(L)	Oil 435 →	(M)	(L)	Oil 1,241 →	(M)	(L)	Oil 1,129 →	(M)	(L)	Oil 677 →	(M)

*1 *2 : Bislig 3 & 4 units would be postponed by Luzon-Mindanao interconnection.

Fig. 5-9 Daily Load Curve Weekdays 1981 & 1982 in Luzon & Mindanao Grids



electrodes will be constructed in the first stage. Only the additional converter facilities will be constructed in the second stage in order to compose the bipolar single circuit system.

The transmission loss of this pattern is twice as large as that one of the pattern 1 but electrode maintenance is required only in the Jaro and Naga HVDC substations of the Luzon-Leyte power transmission project. Therefore, the DC current passing through the electrodes can be reduced by controlling conveniently the transmitted power. As for the one circuit cable failure, the power transmission reliability can be made better than that one of the Pattern 1, through the temporary adoption of the sea return mode using a sound cable.

(3) Pattern 3

In this pattern the system will be constructed with bipolar single circuit configuration since the first stage, and the bipolar 200 MW converter facility will be installed in parallel with the existing one in the second stage.

This pattern has no problem with regard to the maintenance of the electrodes, including the Luzon-Leyte power transmission project, but on the other hand there are problems related to the balance of thyristor valve current, concurrently with the larger number of equipment and devices such as thyristor valves, etc. In addition, this pattern is not economical because the increase in cost of the converters in view of the higher transmission voltage compared with the capacity of the converter (100 MW for each converter).

(4) Pattern 4

In this pattern the bipolar 400 MW facility will be constructed in the first stage.

In spite of higher power transmission reliability this pattern requires larger initial investment and it can not be considered appropriate with regard to the development plan of this project.

The following conclusions are derived as a result of the aforestated comparative considerations on the 4 power transmission patterns taken into consideration in this study.

- Appropriateness with regard to the development plan

  Pattern 4 can not be regarded as appropriate, because it assumes the construction of all facilities in the first stage.

- Economy

  Pattern 1 is the most economical one, followed by the patterns 2, 3 and 4 in this order, but the difference between the patterns 1 and 2 is negligible if the stages 1 and 2 are examined as a whole. The converter equipment are rather expensive in the pattern 3.

- Ease of maintenance

  In the first stage pattern 2 has some problems with regard to the

5.2 Power Transmission Project

5.2.1 Possible DC and AC power transmission patterns

Three possible alternatives of power transmission systems are examined, by assuming a transmission capacity of 200 MW in the first stage of the project and 400 MW in the second stage. (Table 5-6.)

a) DC 3-terminal power transmission system (DC ±350 kV)

b) DC 2-terminal power transmission system (DC ±250 kV)

c) AC power transmission system

(1) DC 3-terminal power transmission system (DC ±350 kV)

The DC +350 kV monopolar metallic return single circuit transmission line will be constructed in the first stage. As for the HVDC substation required in the Leyte Island, this project will share the Jaro HVDC S/S of the Luzon-Leyte power transmission project and as for the HVDC substation of the Mindanao Grid, it will be constructed adjacent to the Butuan S/S and will be interconnected with the said substation by means of a 138 kV transmission line. The converter facilities corresponding to additional monopolar will be constructed in the second stage in the Butuan HVDC S/S in order to compose bipolar. Furthermore, appropriate quantities of synchronous rotary condenser will be installed as well, in order to assure the stability of the DC facilities.

- This alternative points out well the advantages of the DC power transmission system including two sections of submarine cables and is more economical compared with the other power transmission systems.

(2) DC 2-terminal power transmission system (DC ±250 kV)

The DC 250 kV monopolar single metallic return circuit transmission line will be constructed in the first stage. The HVDC substation of the Leyte Island will be constructed adjacent to the Jaro HVDC S/S of the Luzon-Leyte power transmission project and the interconnection with this project will be realized with AC 138 kV. The HVDC substation of the Mindanao Grid will be constructed adjacent to the Butuan S/S in the same way as in the case of the DC 3-terminal power transmission system and the interconnection with the Butuan S/S will be realized by means of AC 138 kV. The converter facilities corresponding to additional monopolar will be constructed in the Jaro and Butuan HVDC S/S in order to compose bipolar. Measures to stabilize the operation will be taken also in this case, in the same way as in the case of the DC 3-terminal power transmission system.

- Compared with the DC 3-terminal power transmission system this alternative becomes cheaper transmission line construction cost because it has lower voltage, but in reality the overall construction cost becomes more expensive because it requires the construction of a HVDC substation in Jaro.

(3) AC power transmission system

In the case of using this system, it is recommendable to adopt 230 kV, which is the standard voltage of NAPOCOR, in view of the power capacity. In the first stage this alternative will consist of one route with two 230 kV circuits between Jaro and Butuan and one single-circuit submarine cable route.

In the second stage this alternative will consist of 2 routes of double-circuit overhead transmission lines and 2 routes of single-circuit submarine cable.

- This alternative requires larger construction cost compared with other alternatives.

As can be seen from the aforestated considerations, the DC 3-terminal power transmission system is the most economical one, because it can use in common the Jaro HVDC S/S.

Should the operation of this project be started in 1992, it will be possible to adopt the DC 3-terminal power transmission system from the standpoint of schedule because the facilities of the Luzon-Leyte power transmission project are expected to become DC ±350 kV, 900 MW in 1991, the last stage of its execution.

Such being the case, the feasibility of the Leyte-Mindanao power transmission project will be examined by assuming the adoption of the DC 3-terminal alternative, which is the most economical one.

The DC 3-terminal power transmission system is perfectly feasible from the technical standpoint as well.

5.2.2 DC 3-terminal power transmission patterns

The various kinds of power transmission pattern of the aforementioned DC 3-terminal power transmission system are compared from the economic standpoint in the following (Table 5-7).

(1) Pattern 1

The first stage of the project will consist of monopolar 200 MW facilities with sea return mode. The converter facilities with 200 MW and transmission line of monopole will be constructed in the second stage in order to compose the bipolar single circuit system.

In this pattern there will be problem of maintenance of the electrodes, because there will be continuous passage of current through all electrodes of the 3-terminal system, including the Luzon-Leyte power transmission project. In addition, the power transmission reliability is lower compared with the other patterns, because the operation is stopped in the case of cable failure.

(2) Pattern 2

The metallic return mode will be adopted in this pattern, and the monopolar converter facilities and the totality of the transmission lines including the maintenance of electrodes at the Jaro and Naga HVDC substations of the Luzon-Leyte HVDC system, and pattern 1 has problems with regard to the maintenance of all electrodes of the system, including those ones of the Butuan HVDC S/S. However, in pattern 2 the DC current applied on the electrodes can be reduced by controlling adquately the transmitted power.

In patterns 3 and 4 there is no problem with regard to the maintenance of the electrodes because the bipolar configuration is adopted from the beginning, but in pattern 3 there are some maintenance problems concurrently with the increase of equipment and devices such as thyristor valves, etc., in the second stage.

- Power transmission reliability

  Patterns 3 and 4 have the highest power transmission reliability because the bipolar configuration is adopted from the beginning, and in pattern 2 the reliability can be improved with regard to cable failures that are accompanied with relatively prolonged stoppages.

  Pattern 1 has the lowest power transmission reliability.

In view of the aforestated considerations, pattern 2 is selected as objective of this study, from the standpoints of appropriateness with regard to the development plan, economy, ease of maintenance and reliability of power transmission.

5.2.3 Point of interconnection with the Mindanao Grid

Two points are proposed for the interconnection with the Mindanao Grid, i.e., the Tagoloan S/S (HVDC substation to be constructed in Kirahon) near by the power consumption centers represented by the industrial zones of Iligan and Cagayan de Oro, and the Butuan S/S (HVDC substation to be constructed adjacent to the substation) located in the circular transmission line of Mindanao and nearest to the Leyte Island.

The point of interconnection should be selected by taking into consideration the following conditions.

- No shortage of power transmission capacity should occur in the Mindanao Grid even when this system is interconnected with the Leyte-Mindanao interconnected power transmission facilities, or even in the case of any shortage, the costs of the required countermeasures should be minor.
- The short-circuit capacity of the place where the HVDC substation is installed should be approximately 3 times as large as the DC output.

The power flow, short-circuit capacity and other parameters of the Mindanao Grid are calculated for 1990 and 1995 in the case of independent systems, and as a result it is concluded that the transmission lines planned by NAPOCOR for 1990 have not over load sections.

In this connection, it is necessary to construct one additional circuit in the Butuan-Davao section to realize the two-circuit configuration therein, for the sake of stability of operation of the Bislig coal-fired thermal power station.

Furthermore, it is concluded that the transmission lines and substations of the Mindanao Grid have sufficient capacity to cope with the transmission of 200 MW from the Leyte-Mindanao power transmission project to the Butuan and Tagoloan substations in 1990 and 400 MW in 1995.

The yardsticks of the short-circuit capacities for stable operation of the converter facilities are 1,160 MVA and 1,940 MVA in Tagoloan and 641 MVA and 795 MVA in Butuan in 1990 and 1995, respectively. If the yardstick of the short-circuit capacity/converter facility capacity is assumed to be approximately 3 for the sake of stable operation, there will be considerable shortage of short-circuit capacity in the second stage of the Butuan interconnection.

However the comparison of Tagoloan and Butuan shows that the latter is more advantageous from the standpoint of construction cost in view of the shorter DC transmission line. The interconnection at Butuan will be cheaper even by taking into consideration the cost for installation of the synchronous rotary condenser to strengthen the short-circuit capacity. Therefore, Butuan is selected as point of interconnection with the Mindanao Grid in view of its economical advantages. (Table 5-8)

5.3 Outline of the Leyte-Mindanao Power Transmission Project

(1) Power transmission system (Fig. 5-10)

3-terminal power transmission system unified with the Luzon-Leyte HVDC system.

First stage: DC monopolar metallic return mode power transmission system

Second stage: DC bipolar transmission system

(2) Capacity of the facilities

First stage: 200 MW (DC +350 kV, 570 A)

Second stage: 400 MW (DC ±350 kV, 570 A)

(3) Interconnected sections

a) Overhead transmission line

Jaro HVDC S/S - Hinundayan	115 km
Balete Cove - Kantiasay	55 km
Lipata - Butuan HVDC S/S	123 km
Sub-total	293 km

b) Submarine cable

Hinundayan - Balete Cove	33 km
Kantiasay - Lipata	16 km
Sub-total	49 km
TOTAL	342 km

c) Electrode line

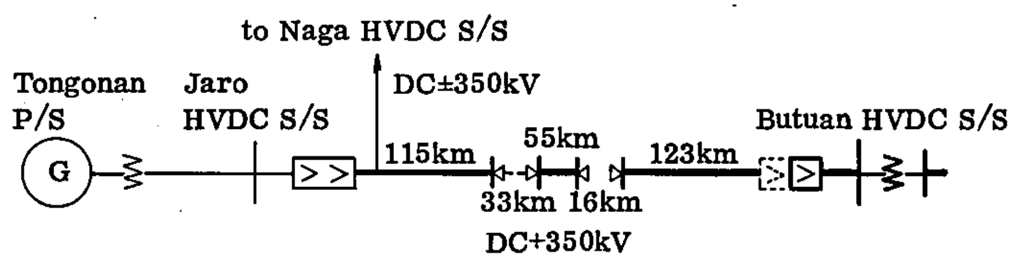
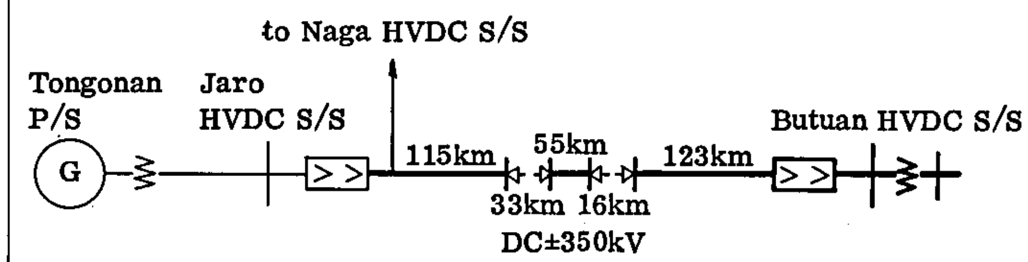
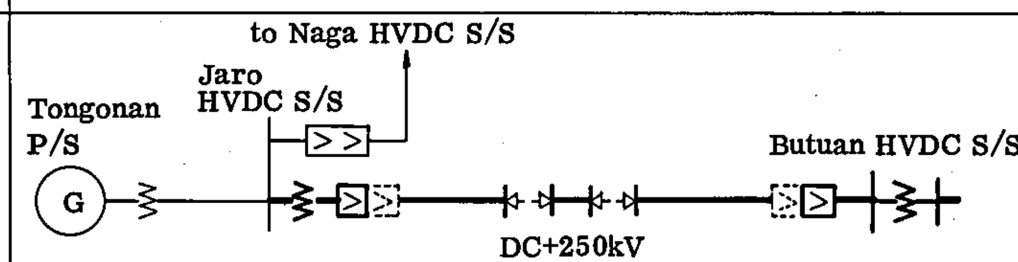
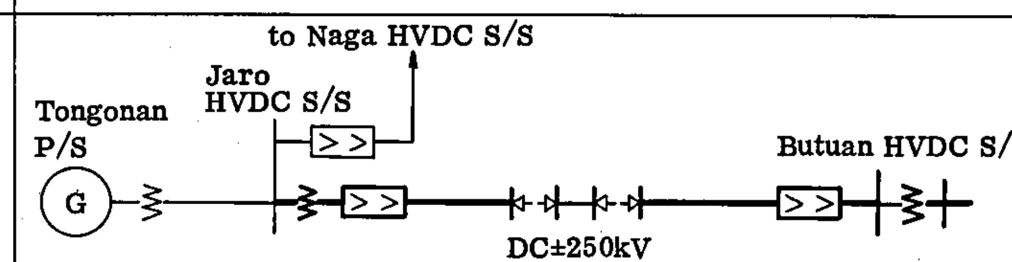
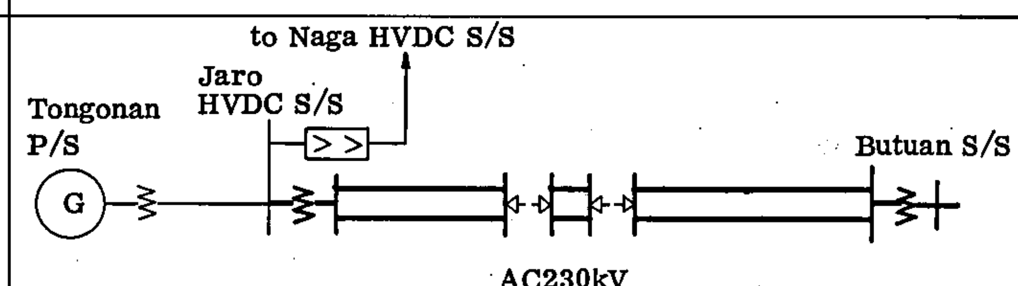
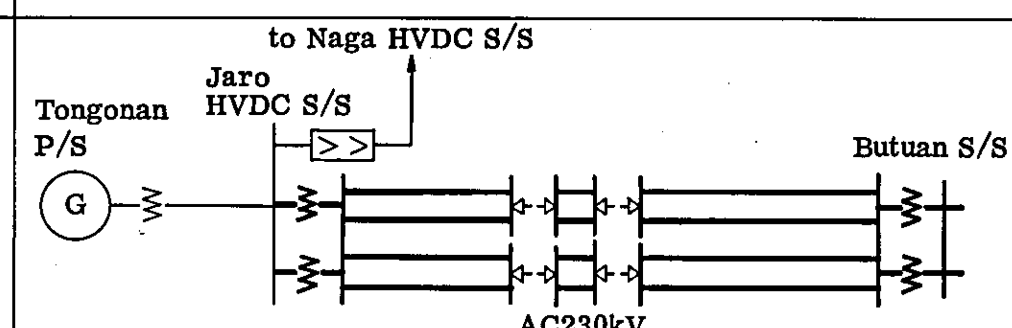
Jaro HVDC S/S - Managasnas	28 km
Butuan HVDC S/S - Carmen	30 km

(4) Selection of voltage and conductor size

The DC voltage rating will be same as that of the Luzon-Leyte power transmission project, i.e., DC ±350 kV, because the 3-terminal power transmission system is adopted in this project as well.

As for the size of the conductor, $610\,mm^2 \times 2$ is adopted in this project because this is the minimum size taking into consideration corona troubles.

Table 5-6 AC and DC System Cost Comparison (Direct Cost)

Plan	First Stage (1992)	Second Stage (1997)	Direct Construction Cost
DC±350kV 1st stage: 200 MW 2nd stage: 400 MW	 Construction Cost: 136,152×10³US$ Transmission line : 342 km Converter station : 200 MW Tele. facilities : 4 Micro R/S	 Construction Cost: 21,330×10³US$ Transmission line : 342 km Converter station : 400 MW Tele. facilities : 4 Micro R/S	157,482 ×10³US$ (100%)
DC±250kV 1st stage: 200 MW 2nd stage: 400 MW	 Construction Cost: 142,722×10³US$ Transmission line : 342 km Converter stations : 200 MW each Tele. facilities : 4 Micro R/S	 Construction Cost: 33,982×10³US$ Transmission line : 342 km Converter stations : 400 MW each Tele. facilities : 4 Micro R/S	176,704 ×10³US$ (112%)
AC230kV 1st stage: 200 MW 2nd stage: 400 MW	 Construction Cost: 138,504×10³US$ Transmission line : 342 km Substations : 300 MVA each Tele. facilities : 4 Micro R/S	 Construction Cost: 80,773×10³US$ Transmission line : 342 km Substations : 600 MVA each Tele. facilities : 4 Micro R/S	219,277 ×10³US$ (139%)

Note * : Cost discounted to the price in 1992 at discount rate 10% per year, No price escalation

Table 5-7. Comparison for HVDC Operating Alternative Plans

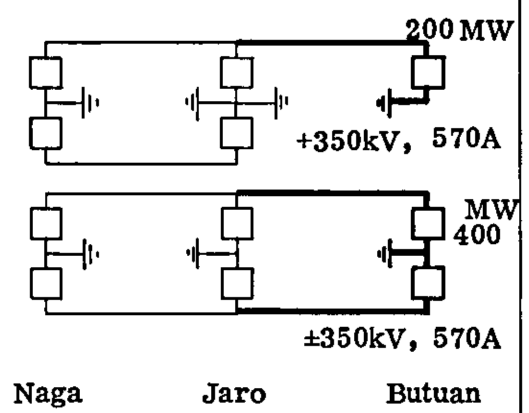
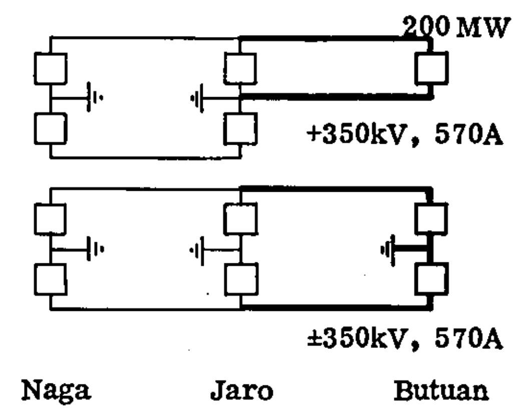
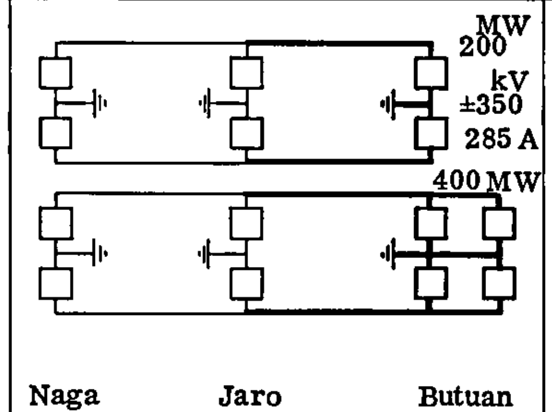
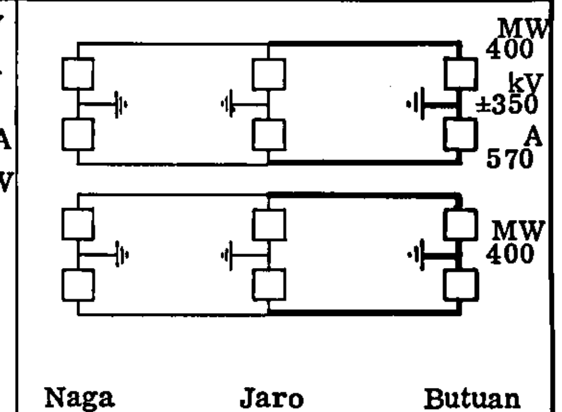
Item		Pattern 1 Monopolar sea return mode	Pattern 2 Monopolar metallic return mode	Pattern 3 Bipolar mode, parallel addition	Pattern 4 Bipolar mode, No addition
1st Stage Construction 2nd Stage Construction					
Evaluation	Technical Appropriateness	A	A	A	C
	Economic advantage	A	A'	B	C
	Maintenance advantage	C	B	C	A
	Power transmission reliability	C	B	A	A
Direct Construction Cost	1st Stage	102,948 × 10^3 US$	136,152 × 10^3 US$	144,161 × 10^3 US$	168,809 × 10^3 US$
	2nd Stage	48,295 × "	21,330 × "	24,761 × "	—
	Total	151,243 × "	157,482 × "	168,922 × "	168,809 × "

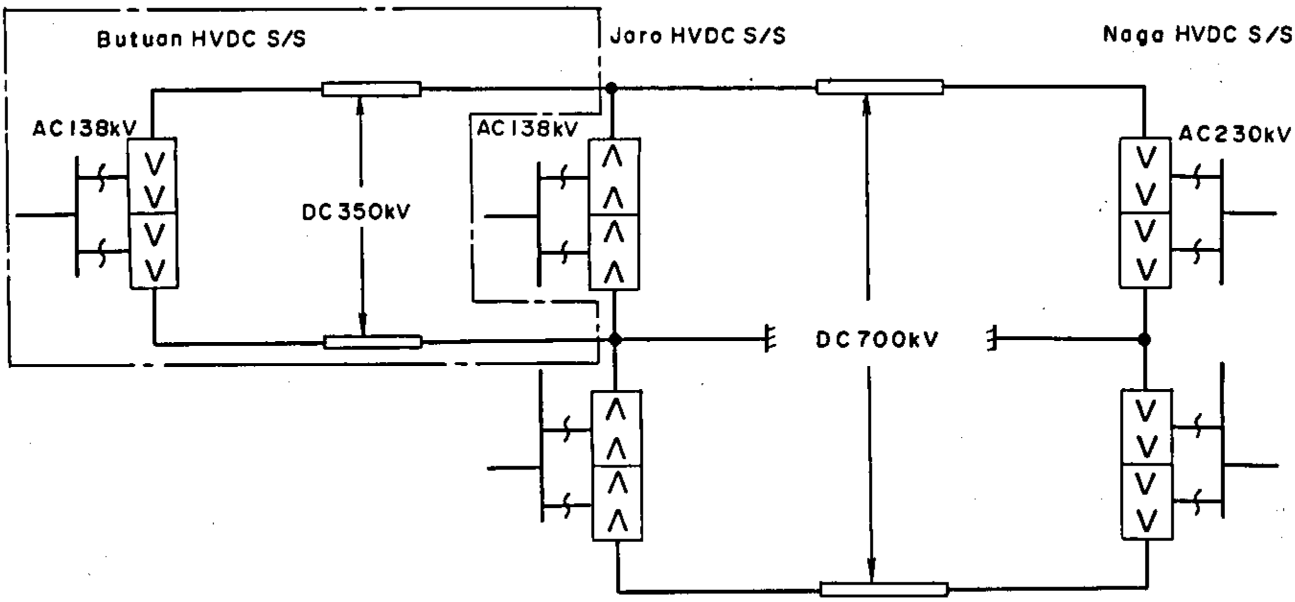
Table 5-8 Comparison of Direct Construction Cost

unit; $\times10^3$ US\$, ( ); Cost converted at 1992, 10% Discount rate

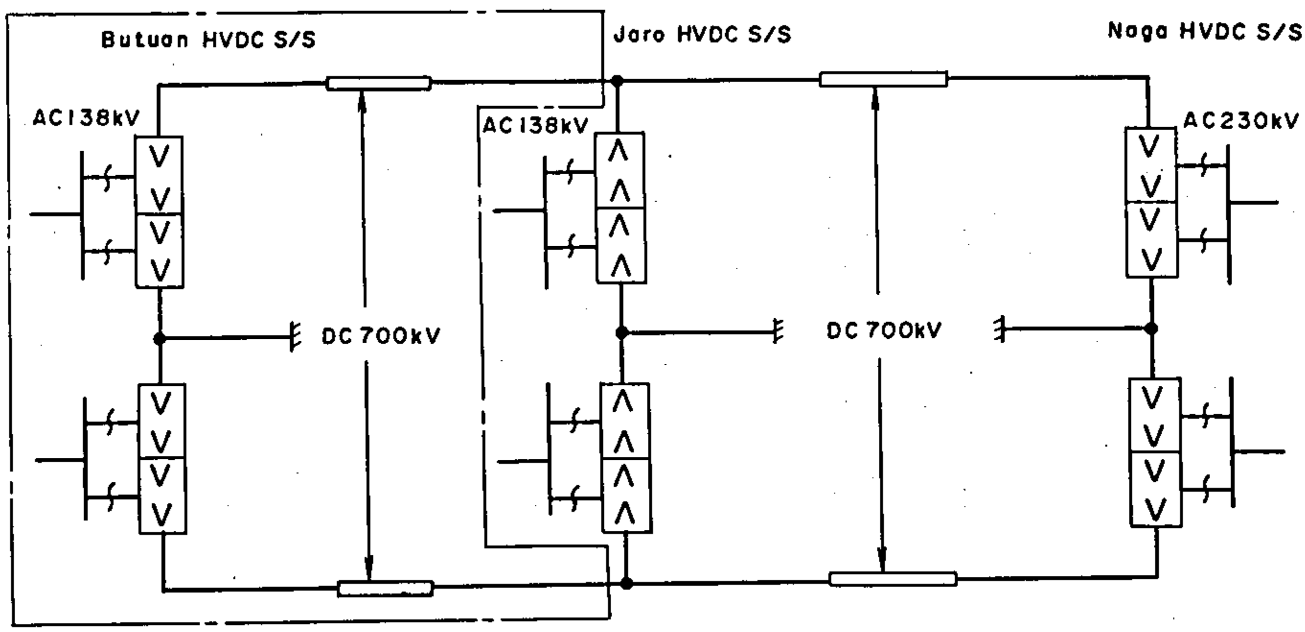
	Case of Butuan HVDC S/S Installation						Case of Kirahon HVDC S/S Installation					
	DC ± 350 kV Three Terminal		DC ± 250 kV Two Terminal		AC 230 kV Transmission System		DC ± 350 kV Three Terminal		DC ± 250 kV Two Terminal		AC 230 kV Transmission System	
	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage
Transmission Lines	101,460	—	85,713	—	113,157	113,157 (70,270)	115,091	—	96,557	—	130,504	130,504 (81,043)
HVDC S/S	29,996	34,348 (21,330)	52,313	54,721 (33,982)	20,652	16,913 (10,504)	30,148	26,500 (16,457)	52,465	46,874 (29,104)	20,652	16,913 (10,504)
Telecommu-nication Facilities	4,696	—	4,696	—	4,696	—	5,568	—	5,565	—	5,565	—
Sub-total	136,152	34,348 (21,330)	142,722	54,721 (33,982)	138,504	130,070 (80,773)	150,804	26,500 (16,457)	154,587	46,874 (29,104)	156,722	147,417 (91,548)
Total	170,500 (157,482)		197,443 (176,704)		268,574 (219,278)		177,304 (167,261)		201,461 (183,696)		304,139 (248,270)	
%	100 (100)		116 (112)		158 (139)		104 (106)		118 (117)		178 (158)	

Fig. 5-10 Main Circuit Diagram (Preliminary) (Three Terminal HVDC Transmission)

LEYTE-MINDANAO POWER TRANSMISSION PROJECT



(a) First Stage (200MW)



(b) Second Stage (400MW)

5.4 Communications Facilities

The Project calls for construction of a transmission line forming a DC 3-terminal system in combination with the Luzon-Leyte Project to connect the Luzon Grid - Leyte and the Samar Grid - Mindanao Grid. The line can be used to transmit the power generated in the Tongonan Geothermal Power Plants in the Leyte Island to the power consuming districts in Luzon and Mindanao via the HVDC system, and at the same time the advantages of HVDC interconnected transmission system can be utilized.

Since high reliability is the essential requirement of a HVDC system, a microwave circuit is structured on the line of Tongonan S/Y - Jaro HVDC S/S - Naga HVDC S/S in the Luzon-Leyte project for transmission of information needed to control and protect the HVDC system. In this project also, the survey team plans constructing an information transmission circuit by installing a microwave circuit of the same specifications between the Jaro HVDC S/S and Butuan HVDC S/S for high speed and reliable control and protection to ensure smooth operation of the HVDC 3-terminal system.

Installation of the microwave circuit of the Project completes a long distance microwave trunk circuit covering about 1,000 km from Manila to Butuan. This microwave trunk circulation can be extended to the major NAPOCOR's power facilities in Mindanao in the future, providing the function of highly reliable information exchange, and this will greatly contribute to the maintenance and operation of the power facilities.

5.4.1 Required telecommunication lines

Telecommunication lines needed between Jaro HVDC S/S and Butuan HVDC S/S will be obtained by mean of microwave circuit which consists of four repeater stations and two terminal stations. The telecommunication circuit between Jaro and Tongonan is not included in this Project because it will be constructed by the Luzon-Leyte project.

A stand-by circuit for emergency will be prepared by borrowing several channels from AFP (Armed Forces of the Philippines) Microwave Circuit.

Required telecommunication lines for this project are as follows.

(1) Between Jaro HVDC S/S and Butuan HVDC S/S

- a) High speed information transmission circuit for control and protection
- b) Low speed information transmission circuit for supervisory of the converter equipment
- c) Telephone circuit for maintenance use
- d) Telephone circuit for load dispatching use

(2) Between Butuan HVDC S/S and Butuan Sub-station

- a) A low speed information transmission circuit
- b) A telephone circuit for maintenance use
- c) A telephone circuit for load dispatching

Fig. 5-11 Microwave Radio Link Route

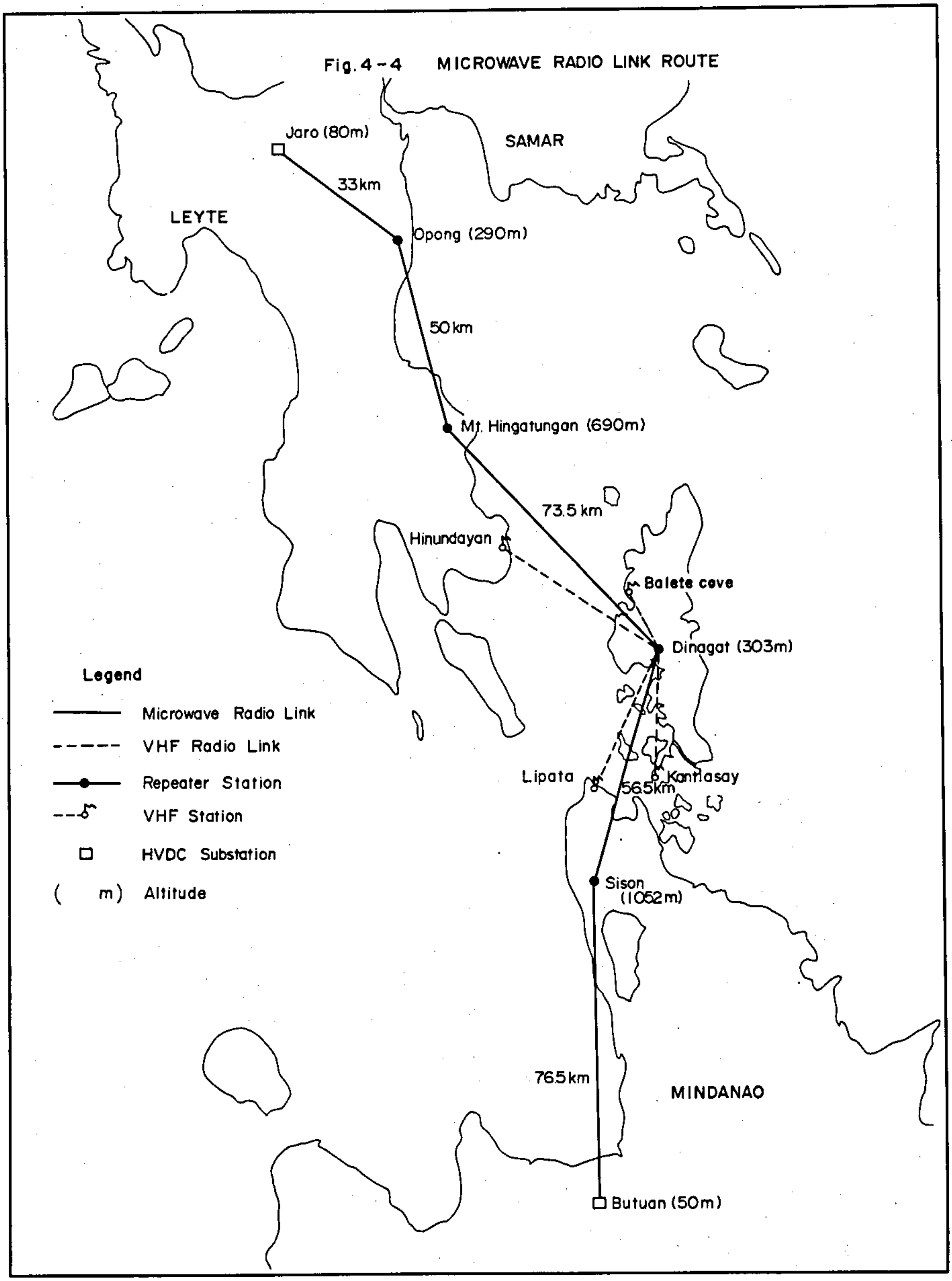
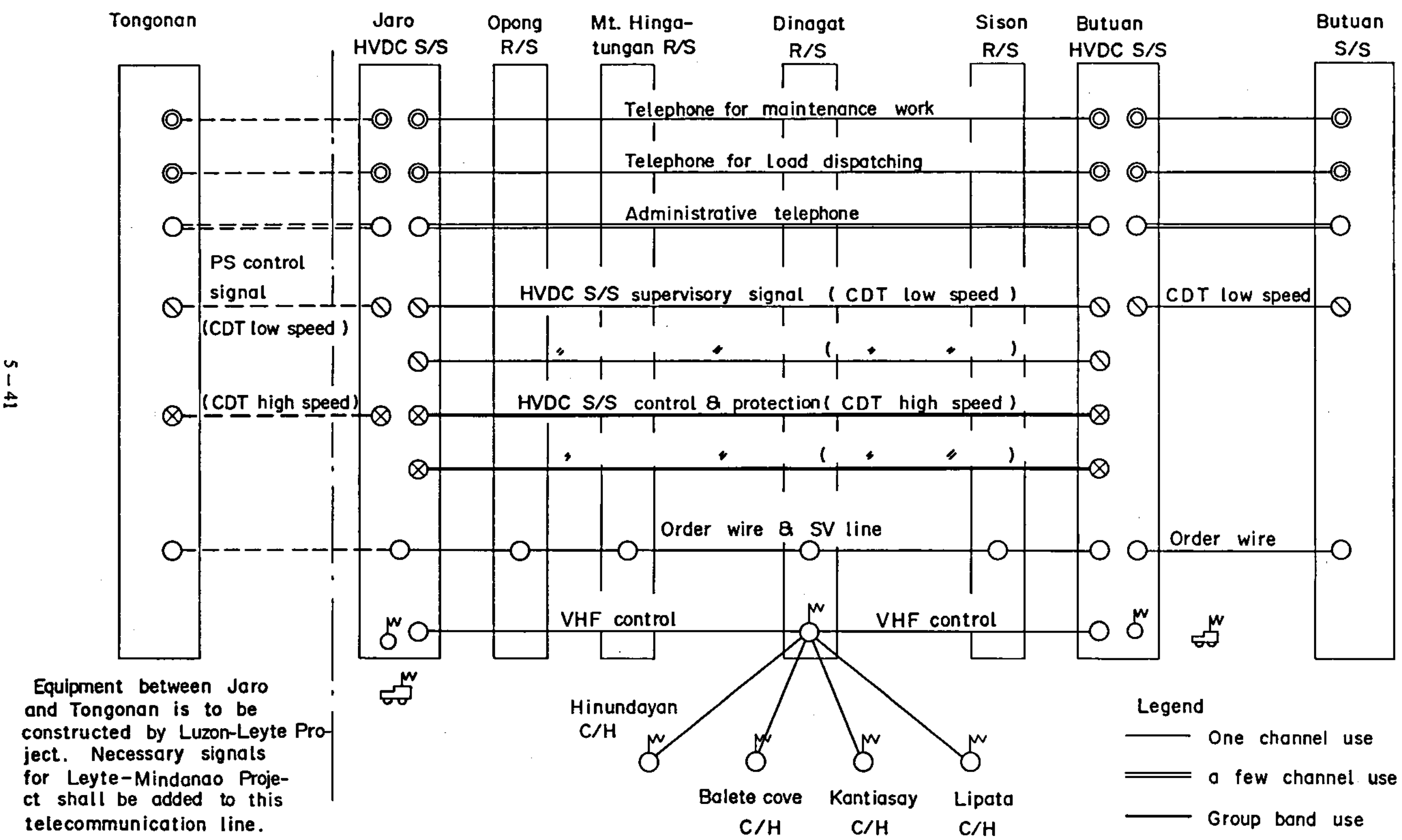


Fig. 5-12 Telecommunication Circuit



(3) Communication Circuit for cable head stations

Following Communication Circuit is required for the stations of four submarine cable terminals

a) Telephone circuit for maintenance use

b) Information transmission circuit for monitoring.

(4) Communication circuit for power transmission line

Communication circuit (mobile service) for HVDC transmission line is required.

(5) Stand-by circuit for emergency

At least several stand-by channels between both HVDC substations are required to reinforce the main microwave circuit.

5.4.2 Outline of the telecommunication equipment

(1) Microwave radio equipment

The microwave radio equipment between Jaro HVDC S/S and Butuan HVDC S/S consists of four repeater stations and two terminal stations, six stations in total. Multiplex terminal equipment is installed at both terminal stations and Dinagat repeater station which is a master station for VHF cable head stations. Order-wire and monitoring equipment for maintenance of the circuit is installed at each microwave station.

The 2 GHz microwave frequency band is considered to be suitable by taking into account related existing equipment and meteorological conditions of the area.

However, adoption of the frequency band will be finally decided as the same frequency band as that of the Luzon-Leyte project. Radio and multiplex equipment for small capacity microwave circuit will be installed at Butuan HVDC S/S in order to connect the AFP circuit.

Inter-connection between Jaro HVDC S/S and the AFP microwave station will be done making use of the circuit prepared by the Luzon-Leyte project.

(2) Information transmission equipment

a) Information transmission equipment for control and protection

Information transmission equipment will be installed at Jaro HVDC S/S and Butuan HVDC S/S respectively.

b) Information transmission equipment for supervisory

Low speed information transmission equipment for monitoring will be installed at both HVDC substations.

(3) Optical fiber communication circuit at Butuan

A small capacity digital communication circuit between Butuan HVDC S/S and Butuan S/S is to be provided by means of optical fiber line.

(4) Telecommunication equipment for maintenance and load dispatching use

Telephone equipment necessary for maintenance and load dispatching use will be installed at both HVDC substations and Butuan S/S.

(5) Telecommunication equipment for cable head stations

VHF radio equipment for maintenance and monitoring will be installed at each cable head station and Dinagat station. The telephone circuit and the monitoring circuit use a single VHF channel in common. Terminal equipment for the telephone and monitoring of the cable head stations will be installed at each HVDC S/S.

(6) Transmission line fault locator equipment

Fault locator equipment for HVDC transmission line will be installed at each HVDC S/S.

(7) Mobile service communication equipment

VHF equipment for mobile service will be installed at Butuan HVDC S/S. The base station at Jaro HVDC S/S will be utilized in common with that installed by the Luzon-Leyte project. As for the parts of HVDC lines where it is not able to talks with base station of both HVDC substations, existing NAPOCOR's base stations such as Mt. Kitanglad station will be utilized for them.

(8) Telephone exchange equipment

A telephone exchange equipment for maintenance and administrative use will be installed at Butuan HVDC S/S. At Jaro HVDC S/S, the telephone exchange equipment prepared by the Luzon-Leyte project will be used in common.

(9) Paging equipment

Paging equipment for communication within the yard will be installed at Butuan HVDC S/S. At Jaro HVDC S/S, the paging equipment prepared by the Luzon-Leyte project is extended for the use of the Leyte-Mindanao project.

(10) Power supply equipment

a) Power supply for converter station

Power supply equipment required for the telecommunication equipment at both HVDC substations is continuous power supply system consisting of a floating charger and a set of batteries.

b) Power supply for microwave repeater stations and cable head stations

Microwave repeater stations and cable head stations will be supplied by solar battery power supply equipment because cost of construction, maintenance and operation of public power supply system or diesel engine generator supply system will be more expensive.

However, the possibility to install a diesel engine generator which will automatically start during emergency should be studied at the definite study stage.

CHAPTER 6

SYSTEM ANALYSIS

CHAPTER 6 SYSTEM ANALYSIS

The following aspects related to the Mindanao Grid in 1990 and 1995 are examined based on the transmission schemes and transmission systems indicated in the Chapter 5.

- Steady-state power flow and voltage in the case of HVDC interconnected operation.
- Stable operation in the case of line fault of the AC system at the immediate vicinity of the HVDC substation.

As a result of the said analysis, it is concluded that both DC 2-terminal and 3-terminal systems have no problem at all in the case of 200 MW in 1992, and as for 400 MW in 1997, it is possible to cope with the situation by taking appropriate measures to reinforce the short-circuit capacity at the HVDC substation.

6.1 Premises

6.1.1 Conditions related to the power system

(1) Year of analysis

1990

1995

(2) Grids

The configuration of the Mindanao Grid is shown in the Fig.6-1.

As for the Leyte-Luzon Grid, the new projects up to the target years are added to the configuration of the grid taken into consideration in the Feasibility Study Report of the Luzon-Leyte power transmission project.

(3) Demand of load

The power demand of each substation taken into consideration in this study are shown in the Table 6-1.

The power factor of the load is assumed to be 95% and the load is simulated at the primary side of the transformer.

(4) Supply of power

This study assumes the following order of priority for the supply of power by the various kinds of generators.

(i) Hydroelectric power plant, (ii) Geothermal power plant, (iii) Nuclear power plant, (iv) Coal-fired thermal power plant, (v) Oil-fired thermal power plant and (vi) Diesel generator.

6.1.2 Conditions for calculation

(1) Constants of the transmission line

138 kV (795 MCM) single circuit

$Z = 0.045 + j0.256\,\%/km$
$Y/2 = -j0.0318\,\%/km$

(2) Permissible voltage fluctuation

The permissible limits of voltage fluctuation are 100 % ±5 % of the voltage rating at the extremity of the 138 kV and 69 kV bus bars.

The calculations are carried out by assuming that the prescribed power static condenser are installed in the principal substations and terminal substations where the aforementioned voltage conditions are not fulfilled. ("*" mark of Fig. 6-2 and 6-3)

(3) Short-circuit capacity

- The generator reactance is assumed to be the transient reactance (Xd').
- The back impedance of the AC system is assumed to be infinite.

(4) Conditions of protection against line fault

a) Line fault point of each grid

- Mindanao Grid

  One-circuit 3LG-0 at the vicinity of the Butuan end of the Butuan-Aplaya transmission line.

- Luzon Grid

  One-circuit 3LG-0 of the EHV 500 kV transmission line at vicinity of the Naga substation.

b) Line fault clearing time

0.1 sec (6 Hz).

c) Response of DC system

Stop-restart (No-voltage time 0.2 - 0.3 sec).

(5) Judgement conditions

- The swing curves of all generators should have attenuating tendency.
- No hunting should occur in the DC system.
- The voltage and frequency should not present major variation at the line fault clearing time.

6.2 Results of the Analysis

6.2.1 Results of the analysis of the independent Mindanao system

The power flow calculations and the stability calculations for 1990 and 1995 are carried out by taking into consideration the electric power development plans and transmission scheme drawn up by NAPOCOR for the Mindanao Grid as premises of the Leyte-Mindanao power transmission project, in order to examine the problems related to the reinforcement of the existing facilities of the Mindanao Grid and other relevant aspects.

The results of the calculations are shown in the Fig.6-2 and 6-8.

(1) It is necessary to construct 2 circuits of 138kV in the Butuan-Bislig-Davao section on the occasion of the start of operation of the Bislig coal-fired thermal power station because there are problems regarding stability even in the case of operating 2 generators in Bislig coal-fired thermal power station with one circuit cut. (Fig.6-6)

(2) It is indispensable to install ultra quick-response AVR equipped with PSS in the Bislig coal-fired thermal power plant (4 units) and in the geothermal unit (2 units), in order to assure stability of the system.

(3) The results of the power flow calculations of the Mindanao Grid carried out on the premise of 2 circuits of 138kV in the Butuan-Davao section indicate that there are no transmission lines with overload in 1990 and 1995.

Furthermore, the results of the power flow calculations with superposition of the interconnected power flow of 200MW in 1990 and 400MW in 1995 that are estimated to occur in the case of interconnection of the grids indicate that there is no over load section in the existing facilities (Fig.6-4 and 6-5).

This study assumes the following continuous power transmission capacity and short-time power transmission capacity.

138kV, 795MCM one-circuit

Continuous power transmission capacity: 187.3MW (825A)

Short-time power transmission capacity: 252MW (1,110A)

(4) The results of the calculation of the short-circuit capacity of the Mindanao Grid for 1990 and 1995 indicate that with regard to the interrupting capacity of 138kV circuit breakers they have sufficient interrupting capacity at the level of the IEC standard. (Fig.6-7 and 6-8)

6.2.2 Power system analysis in the case of interconnection of the Luzon-Mindanao grids

According to the power transmission project of Chapter 5, the timing and scale of interconnection will be as follows.

First stage plan	1992,	200MW
Second stage plan	1997,	400MW

In the analysis of the power system with interconnection of the grids the technical study is carried out by assuming 200 MW in 1990 and 400 MW in 1995 in order to have a rough outlook of the situation.

As for the method of interconnection, three distinct types, i.e., AC interconnection, DC 2-terminal interconnection and DC 3-terminal interconnection are taken into consideration in the study.

The point of interconnection is assumed to be Butuan in all cases.

(1) Results of analysis of the AC interconnection

The study is carried out by assuming the following specifications for the system with AC interconnection, in accordance with the power transmission project described in the Chapter 5.

- Constants of the circuit

230 kV, 2 cct, distance 285 km (100 MVA base)

$Z = 6.63 \times 10^{-3} + j\,0.069\,\%/km$
$Y/2 = -j\,0.116\,\%/km$

- Constants of the cable

OF cable 1,000 mm^2 distance 45 km

$Z = 3.4 \times 10^{-3} + j\,0.0356\,\%/km$
$Y/2 = -j\,6.58 \times 10^{-4}\,\%/km$

The scales of interconnection are 200 MW and 400 MW and the results of calculation of stability for 1990 and 1995 are shown in Fig.6-9 and 6-10.

a) Conditions of calculation

(i) Line fault point

- Butuan-Bislig section 1 cct 3LG-0 vicinity of Butuan S/S
- 230 kV interconnected system overhead transmission line section 1 cct 3LG-0 vicinity of Jaro HVDC S/S.

(ii) Power flow conditions

The study is carried out by assuming full operation of the interconnected system and the prescribed number of units of the Bislig coal-fired thermal power station of the Mindanao Grid is assumed to be stopped.

b) In the case of 200 MW interconnection (Fig.6-9)

- The system is stable in the case of line fault at vicinity of the Butuan S/S, but in the case of line fault in the 230 kV interconnection section, it is necessary to add 1 or 2 circuits more in order to maintain the system stability.
- In the Tongonan generator it is necessary to install ultra-quick response AVR equipped with PSS.

- The generators of the Luzon power system remain stable and suffer no influence at all in the case of line fault in the Mindanao Grid because it is interconnected from the Luzon Grid by means of HVDC transmission system.

c) In the case of 400 MW interconnection (Fig.6-10)

The study is carried out by assuming that the power flow of 400 MW is superposed to the base power flow of the Mindanao power system in the case of line fault. (4 units of the Bislig coal-fired thermal power station are assumed to be stopped.)

- The results of stability calculation indicate that particularly the Tongonan generator is in unstable situation from the standpoint of stability in the case of 230 kV interconnection with 4 cct. Therefore, it is necessary to consider the construction of one circuit more to reinforce the system or to upgrade 500 kV-class AC interconnection.

  However, in view of the results of the comparison of the alternatives of the project described in the Chapter 5, it may be safely said that the AC interconnection pattern is ranked at a lower position from the technical and economical standpoints.

(2) DC 2-terminal interconnection

a) In the case of 200 MW interconnection (Fig.6-11)

The study is carried out by assuming 3LG-0 at the immediate vicinity of the HVDC substation extremity of the Butuan-Aplaya transmission line which has the most severe power flow conditions in the case of line fault in the AC system of the Mindanao Grid with inverter operation in the Butuan HVDC S/S.

As a result of the said study, it is concluded that both AC system and DC system are stable even when the operation of the converter is resumed after stopping it once.

b) In the case of 400 MW interconnection (Fig.6-12)

The study is carried out by assuming line fault in the AC system, in the same way as in the case of the 200 MW interconnection.

In the case of inverter operation at Butuan HVDC S/S, it is possible to attain stable operation both in the AC system and in the DC system by taking measures to reinforce the short-circuit capacity at the point of interconnection.

(3) DC 3-terminal interconnection

a) In the case of 200 MW interconnection (Fig.6-13)

In this case only the operation of the Butuan HVDC substation is resumed after stopping it once at the point of line fault, likewise in the case of the 2-terminal interconnection. In this case, the output of the Tongonan generators is assumed to be constant.

Not only the 3 AC systems of Luzon, Leyte and Mindanao but also the DC system are stable even when the operation of the converter is resumed after stopping it once.

b) In the case of 400 MW interconnection (Fig.6-14, 6-15 and 6-16)

The following conclusions are arrived at as a result of the same analysis as the case of the DC 2-terminal interconnection.

- In the inverter operation both AC system and DC system can be operated with stability if adequate measures are taken to reinforce the short-circuit capacity. (Fig.6-14)

- It is possible to transmit a maximum of 200 MW in the case of power rectifier operation, and both AC system and DC system are stable even when the operation of the converter is stopped and resumed at the line fault occurrence. (Fig.6-15)

  In this case the hydroelectric power generators of the Mindanao Grid are practically in full operation and as a consequence there is considerable superposition of power flow between the Tagoloan S/S and Aplaya S/S, surpassing slightly the rated capacity of transmission lines according to the calculations carried out this time.

  Therefore, in the definite study it is necessary to carry out further detailed studies in a more realistic system.

- The system is analyzed by assuming inverter operation under the power flow conditions with transmission of 400 MW to Mindanao and 500 MW to Luzon and 3LG-0 line fault of one 500 kV transmission line circuit at vicinity of the Naga substation. Even in this case the system can be operated with stability in spite of some voltage fluctuations at the Jaro HVDC substation. (Fig.6-16)

As for the capacity of the synchronous rotary condenser to be installed in the Butuan HVDC substation at the second stage of this project as a measure to reinforce the short-circuit capacity, the problem is analyzed only for 1990 and 1995, the target years of the project. Therefore, further detailed analysis will be required to determine the final capacity in order to cope with more realistic power system.

6.3 Conclusion

(1) Mindanao Grid

a) In the Mindanao Grid it is indispensable to construct one 138 kV additional transmission line circuit in order to realize the 2-circuit configuration in the Butuan-Davao section to improve the stability of the system in the case of operation of 2 units in the Bislig coal-fired thermal power station, irrespective of the existence of the Luzon-Mindanao interconnection.

b) As for the thermal power stations to be constructed hereafter (Bislig and geothermal), it is indispensable to install ultra-quick response AVR equipped with PSS (Power System Stabilizer) in order to assure the stability of the system.

c) There is no over load section in the existing and proposed transmission lines both in the case of 200 MW interconnection and 400 MW interconnection.

d) There is no special problem with regard to the interrupting capacity of the existing circuit breakers, and they can be regarded as sufficient at the level of the IEC standard.

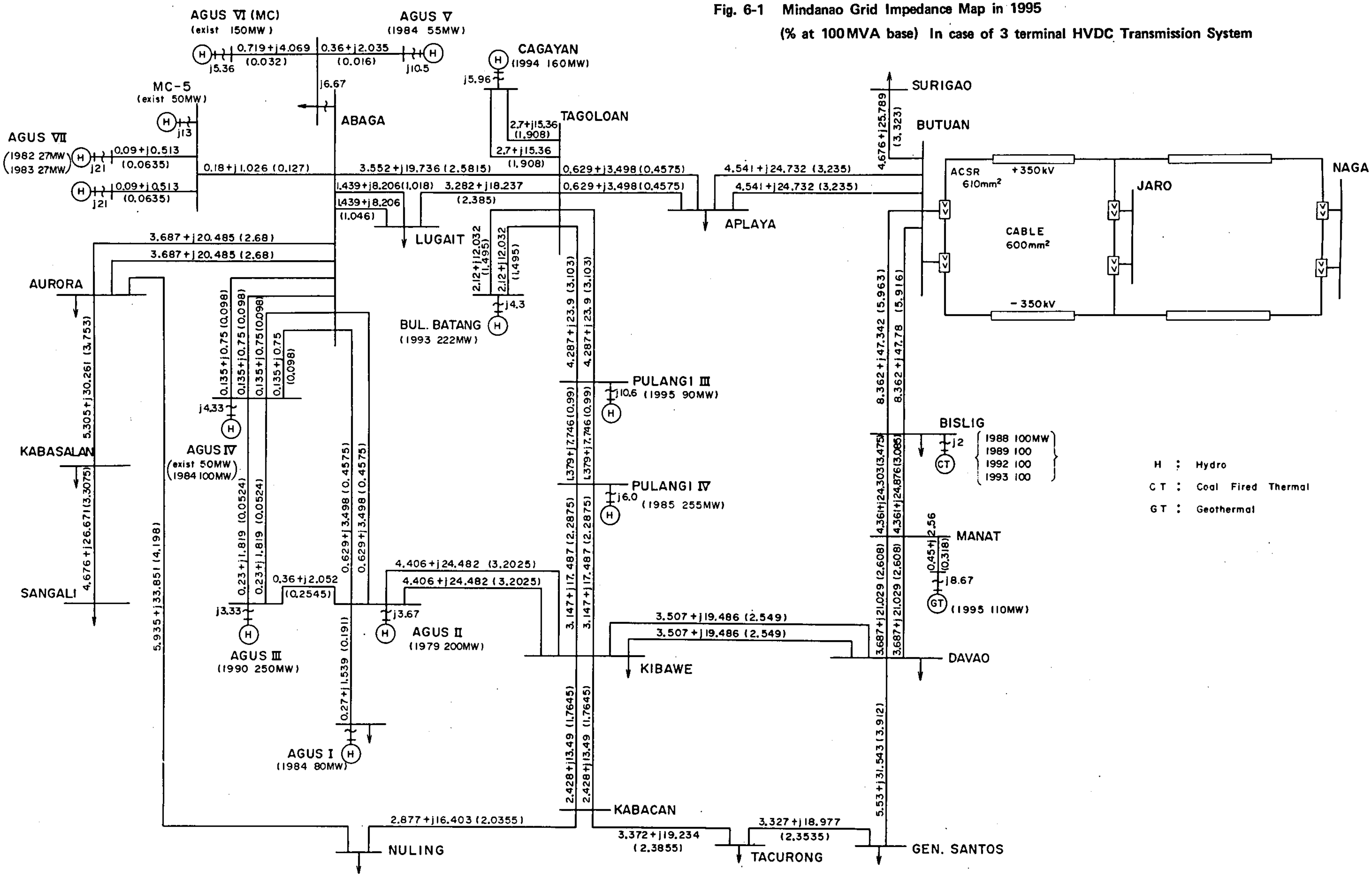
(2) In the case of Leyte-Mindanao interconnection

a) The AC interconnection (AC 230 kV) is not economical because it requires a larger number of circuits and other measures to assure the stability of the system.

b) In the DC interconnection it is necessary to install an adequate number of synchronous rotary condenser to reinforce the short-circuit capacity of the HVDC substations for the sake of stability of the system on the occasion of the completion of the second stage of the project.

c) There is no outstanding difference between the DC 2-terminal and 3-terminal systems, and the results of the analysis of the power system indicates that any one can be adopted with no problem at all.

Fig. 6-1 Mindanao Grid Impedance Map in 1995
(% at 100MVA base) In case of 3 terminal HVDC Transmission System



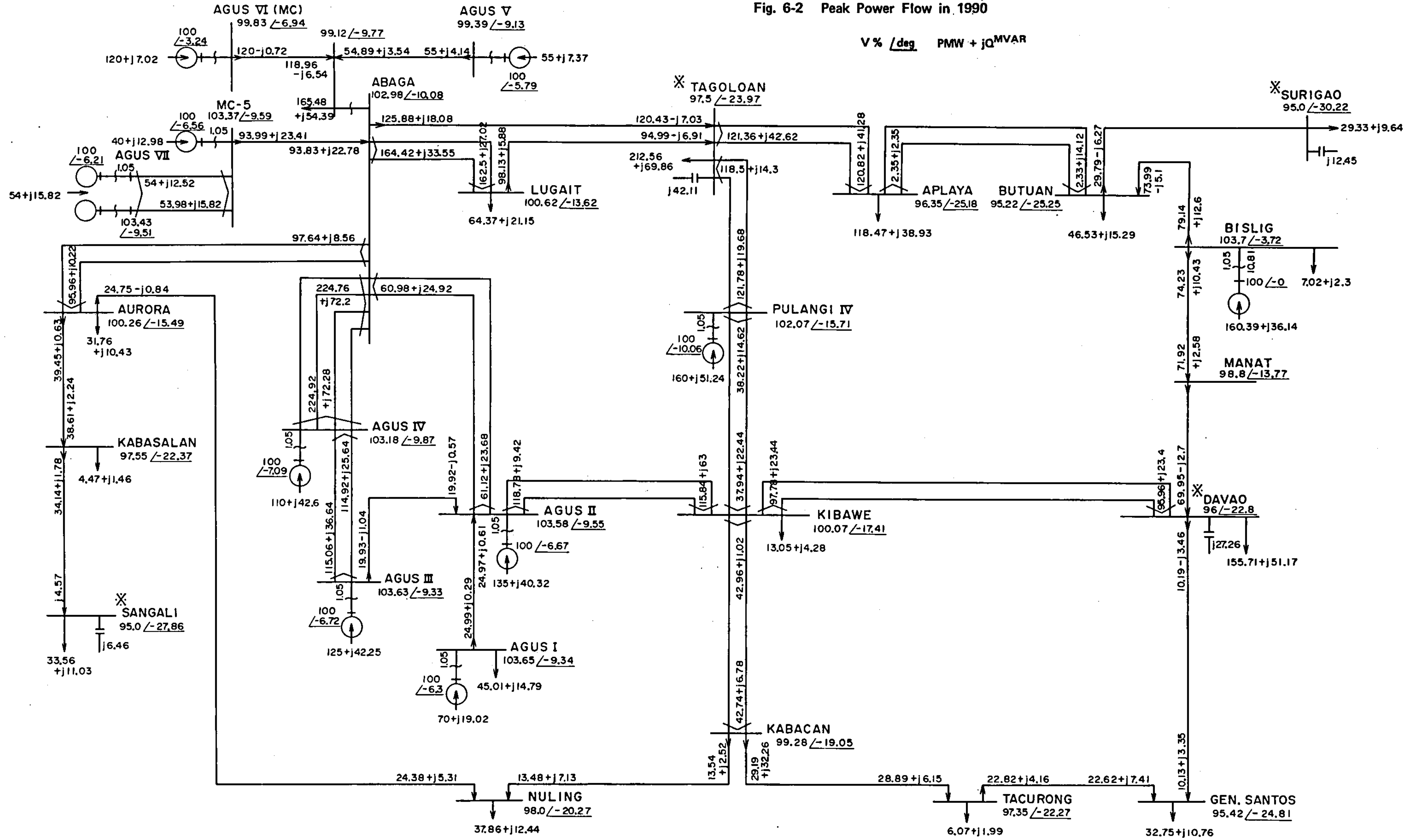


Fig. 6-2 Peak Power Flow in 1990

Fig. 6-3 Peak Power Flow in 1995

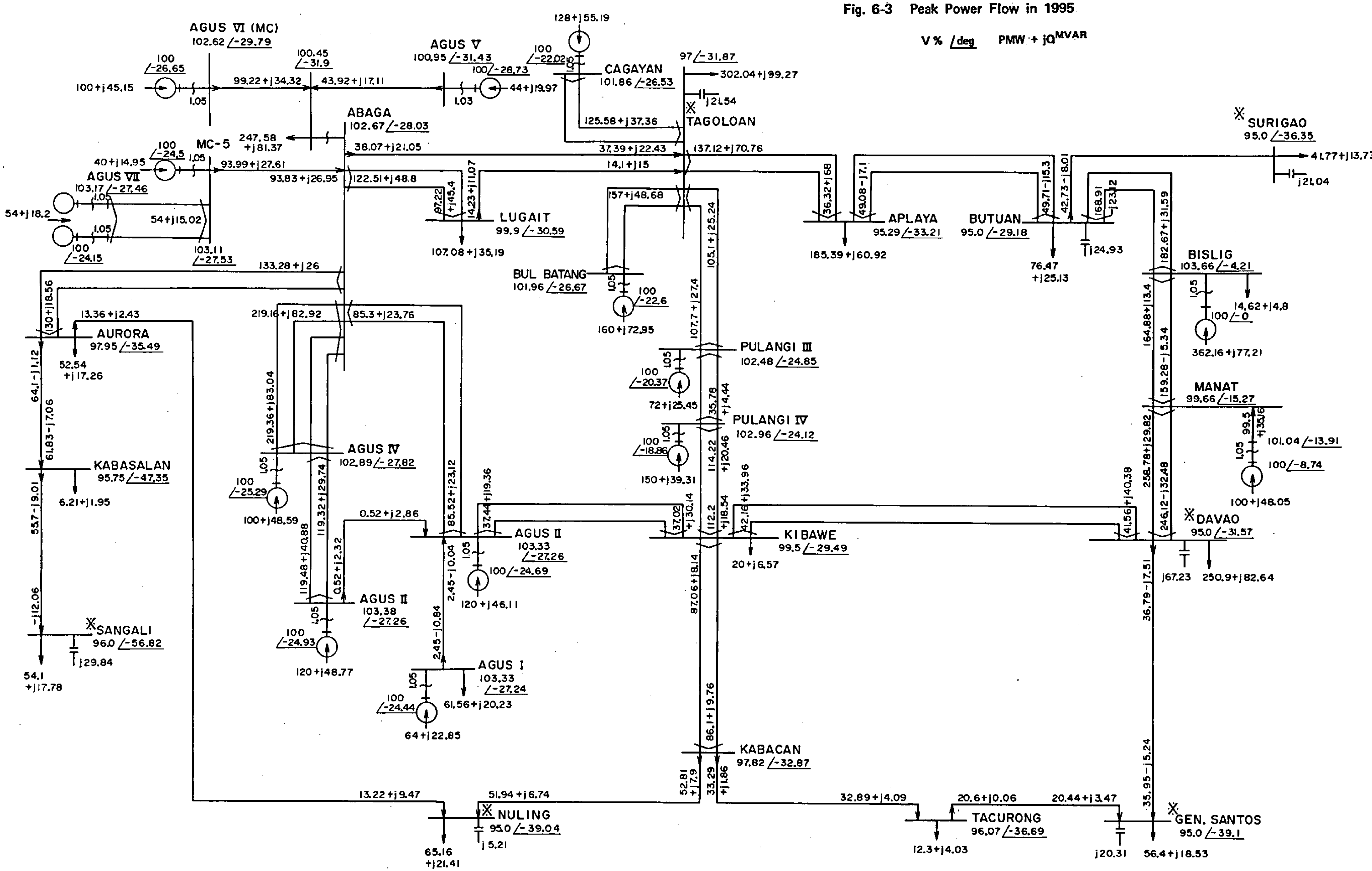


Fig. 6-4 Peak Power Flow in 1990
in the case of interconnection of 200 MW PMW + jQMVAR V% /deg

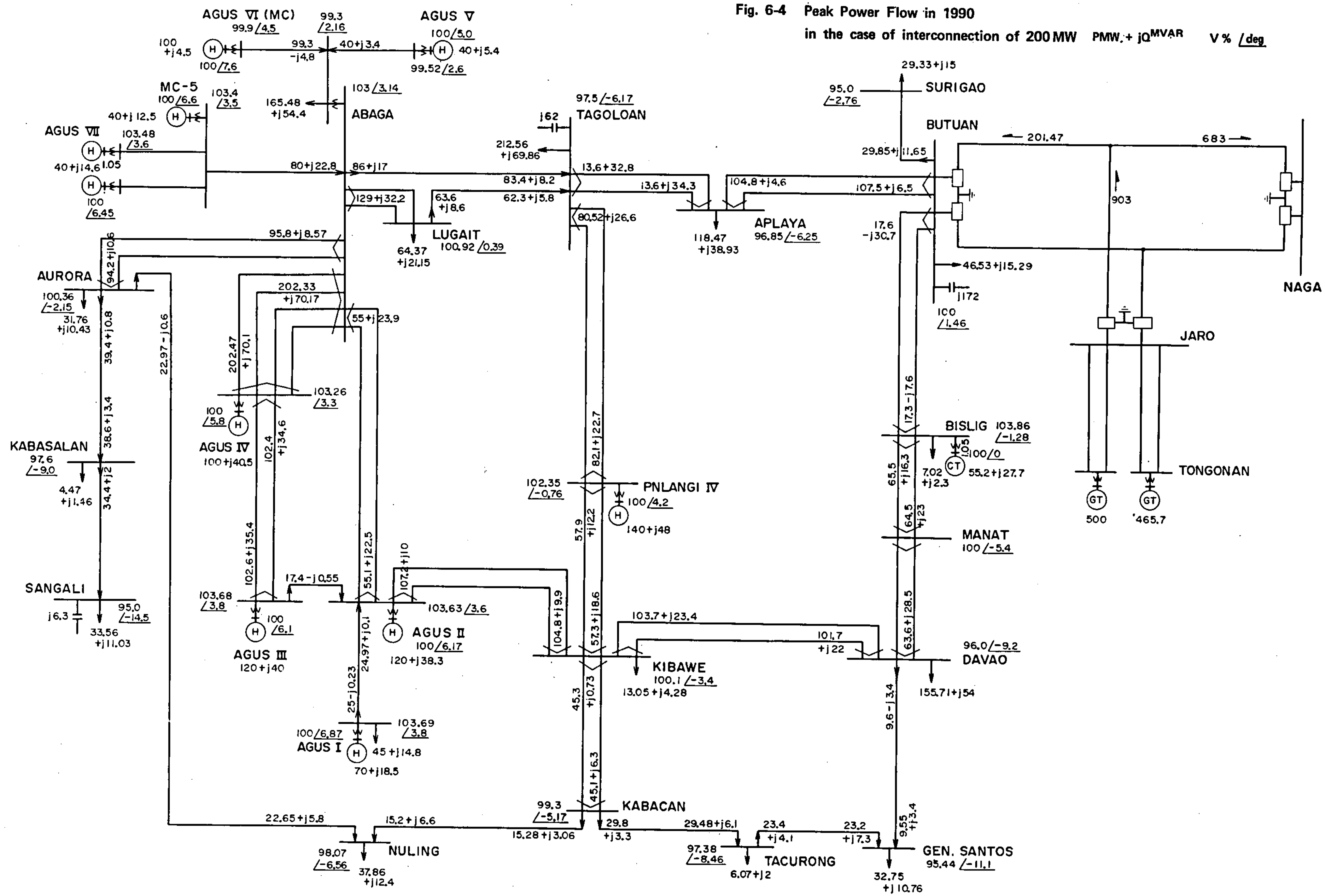


Fig. 6-5 Peak Power Flow in 1995
in the case of interconnection of 400 MW V % /deg PMW + jQ^MVAR

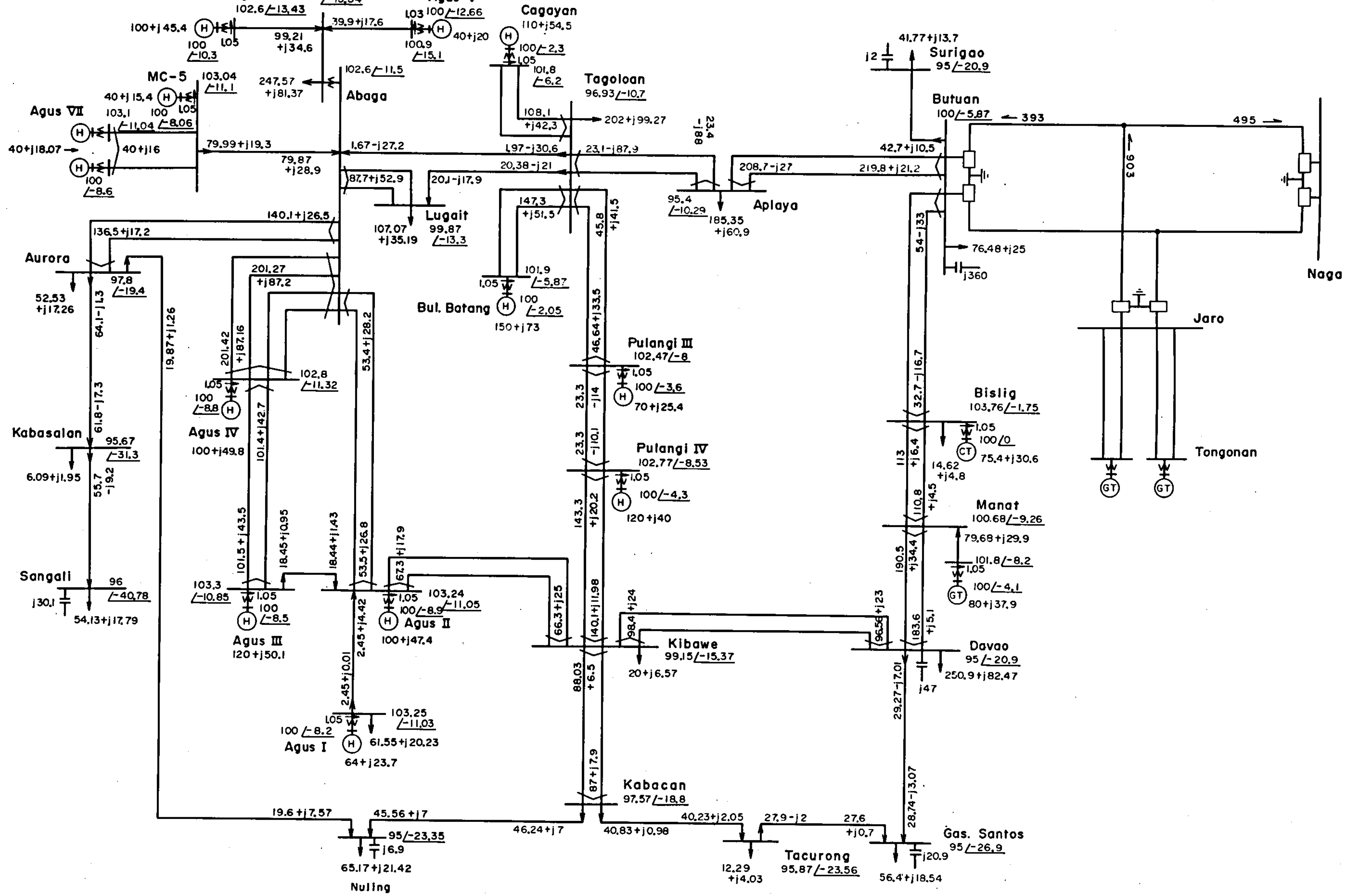
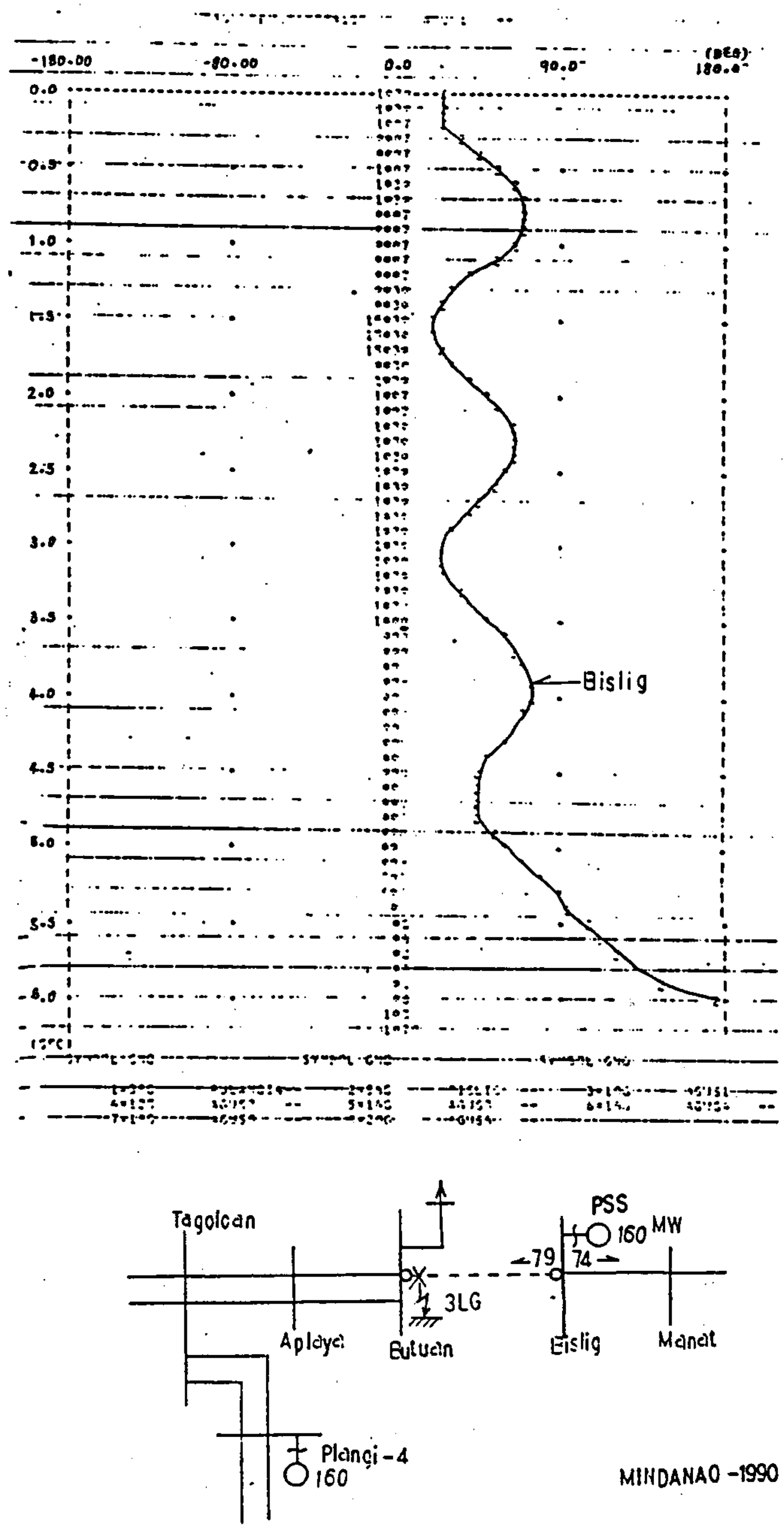
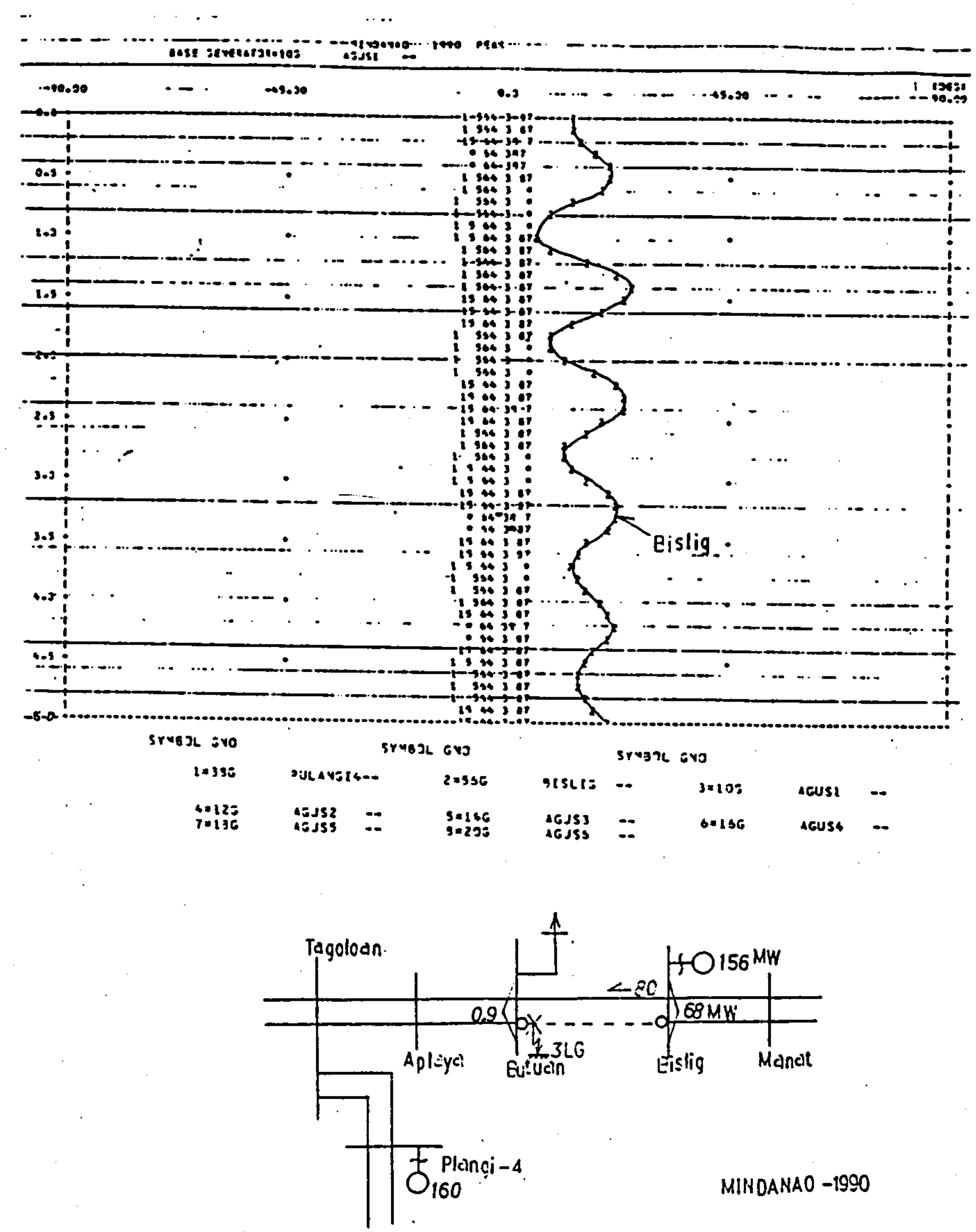


Fig. 6-6 Stability in 1990





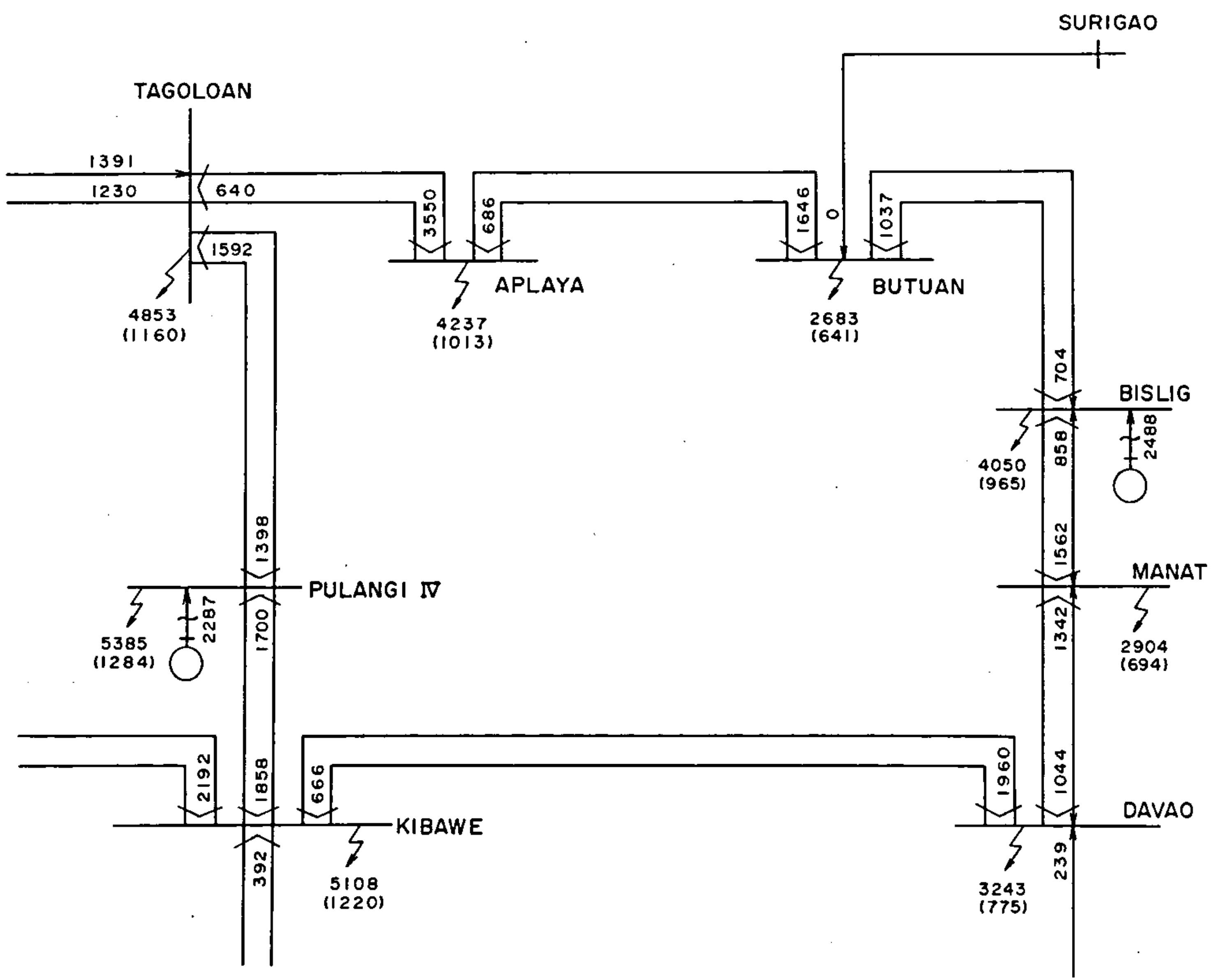


Fig. 6-7 Short Circuit Current and Capacity in 1995 A (MVA)

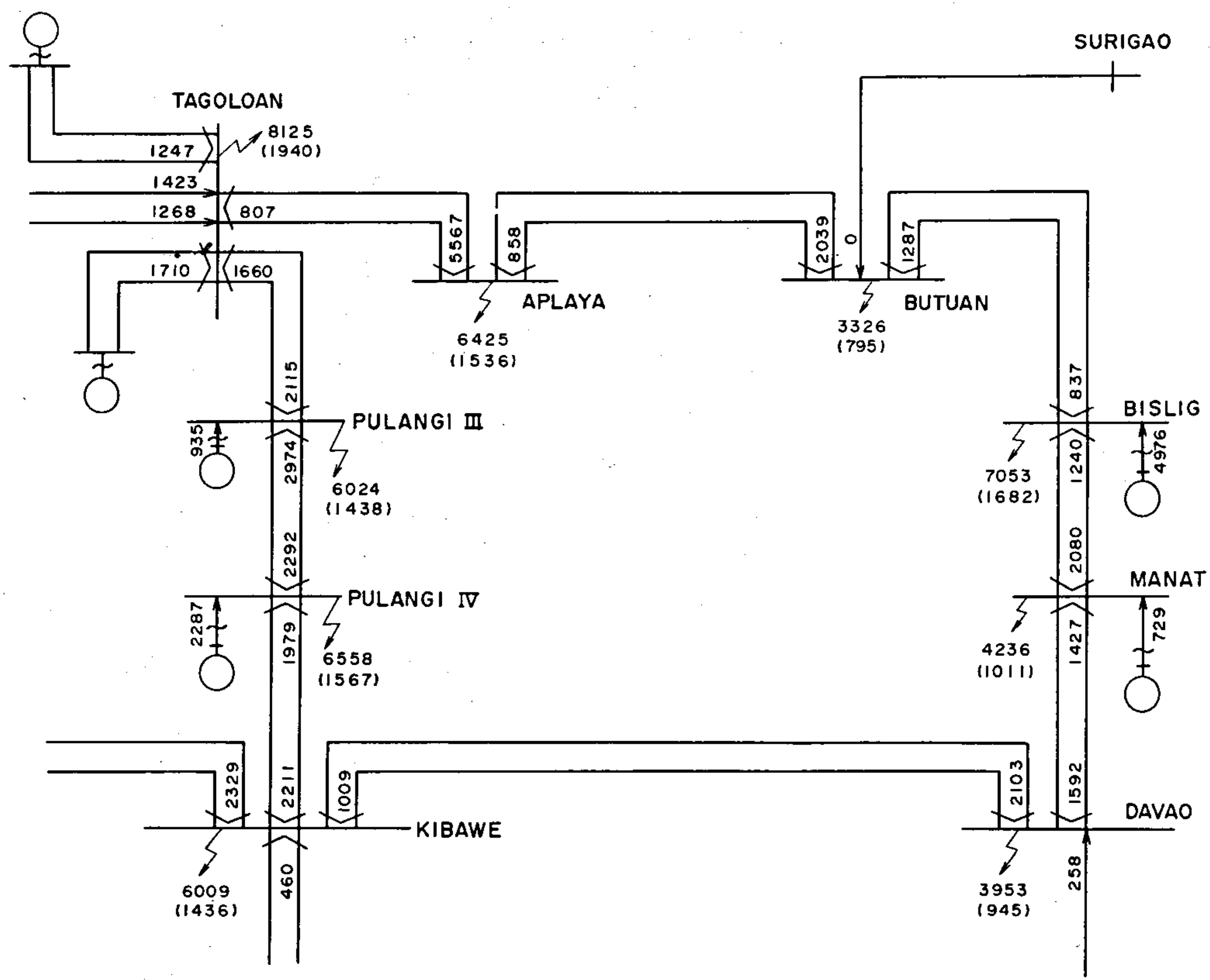
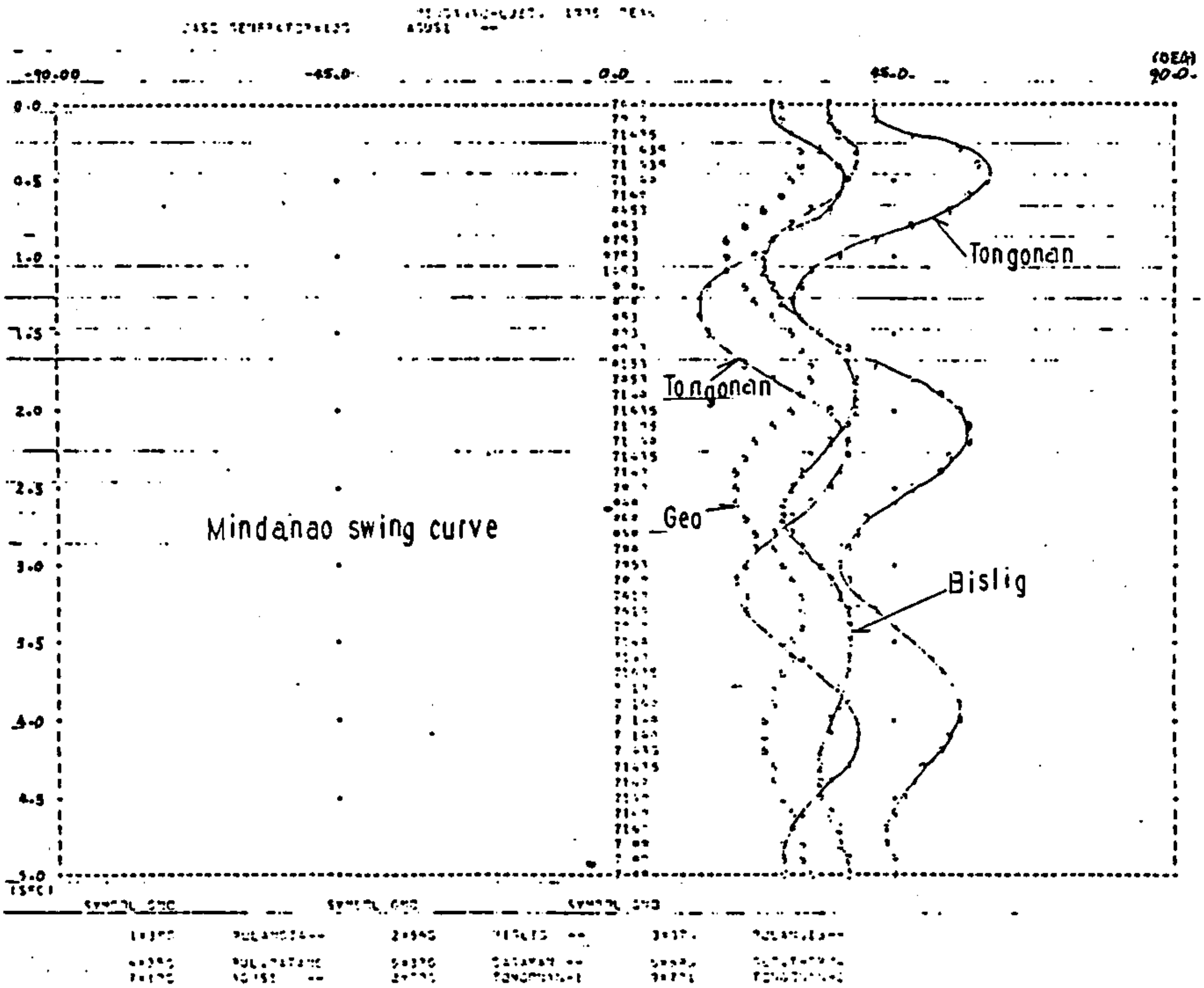
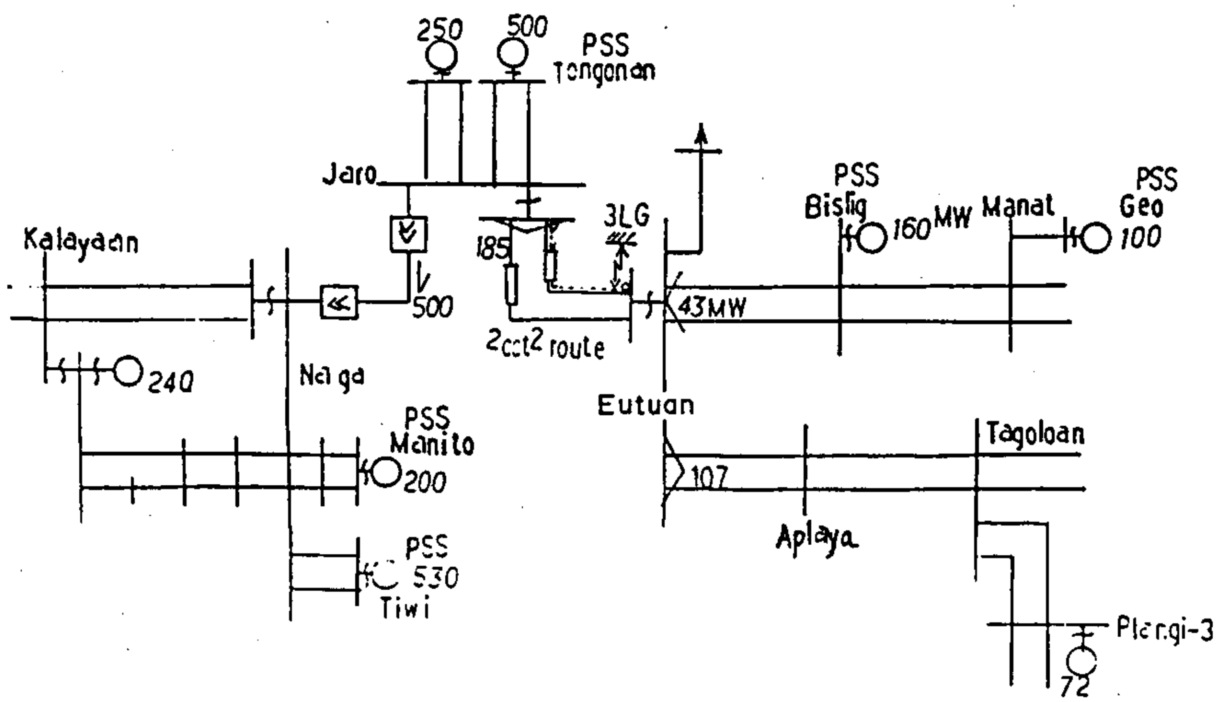


Fig. 6-8 Short Circuit Current and Capacity in 1990 A (MVA)

Fig. 6-9 Stability of AC 230 kV Transmission System Interconnection of 200 MW





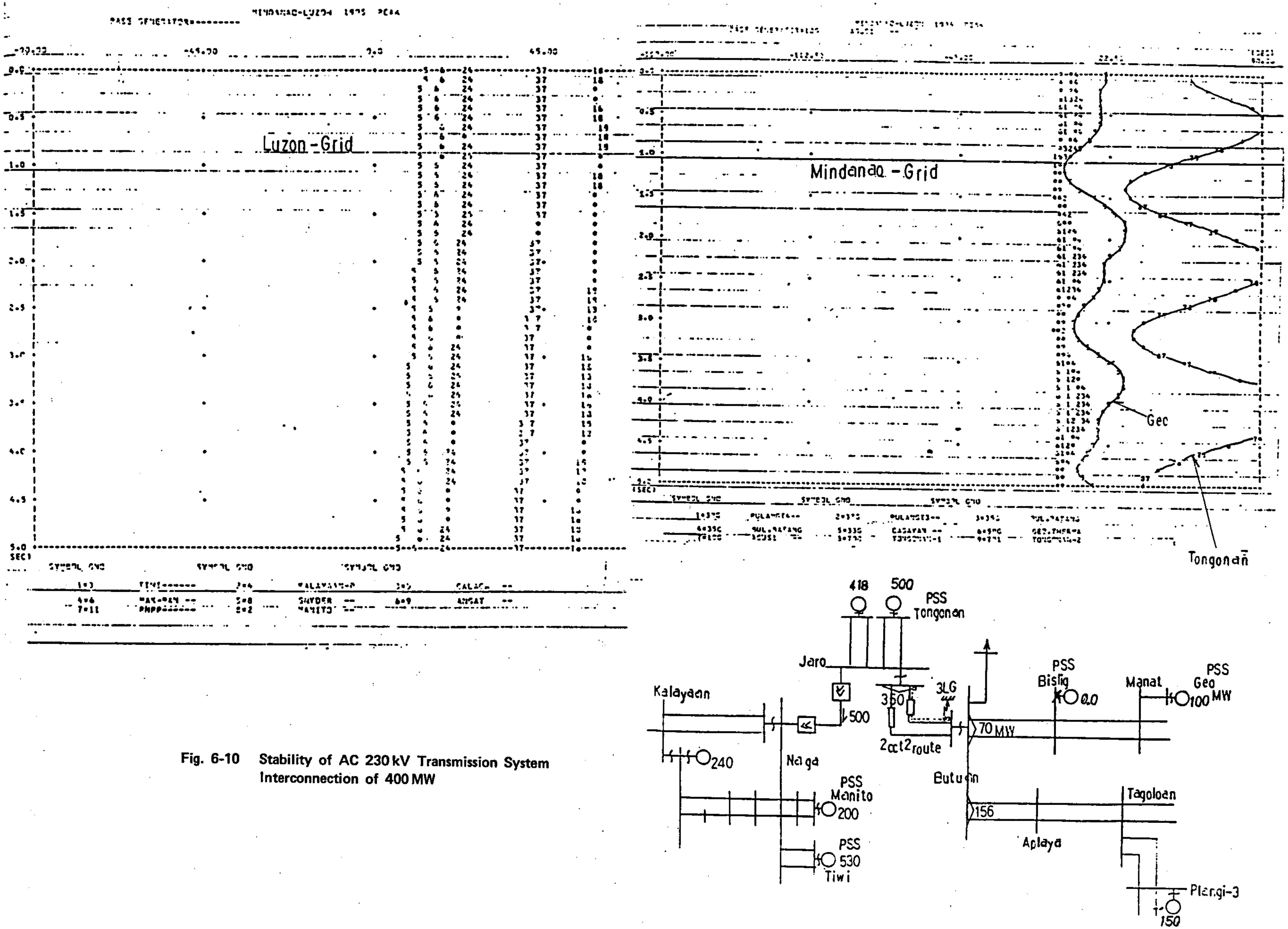
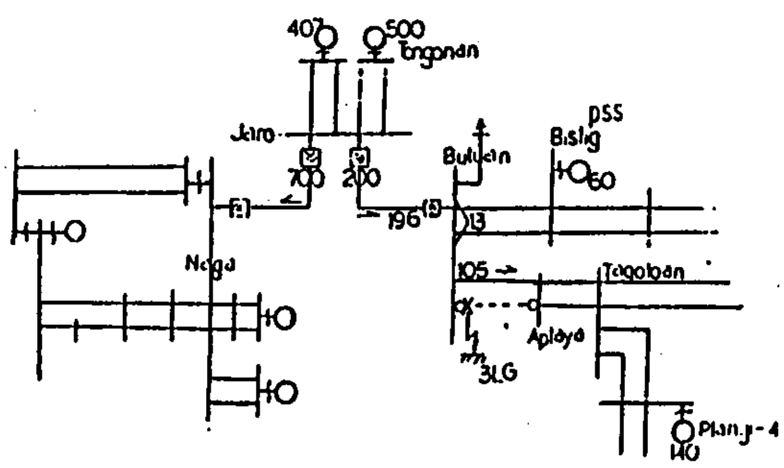
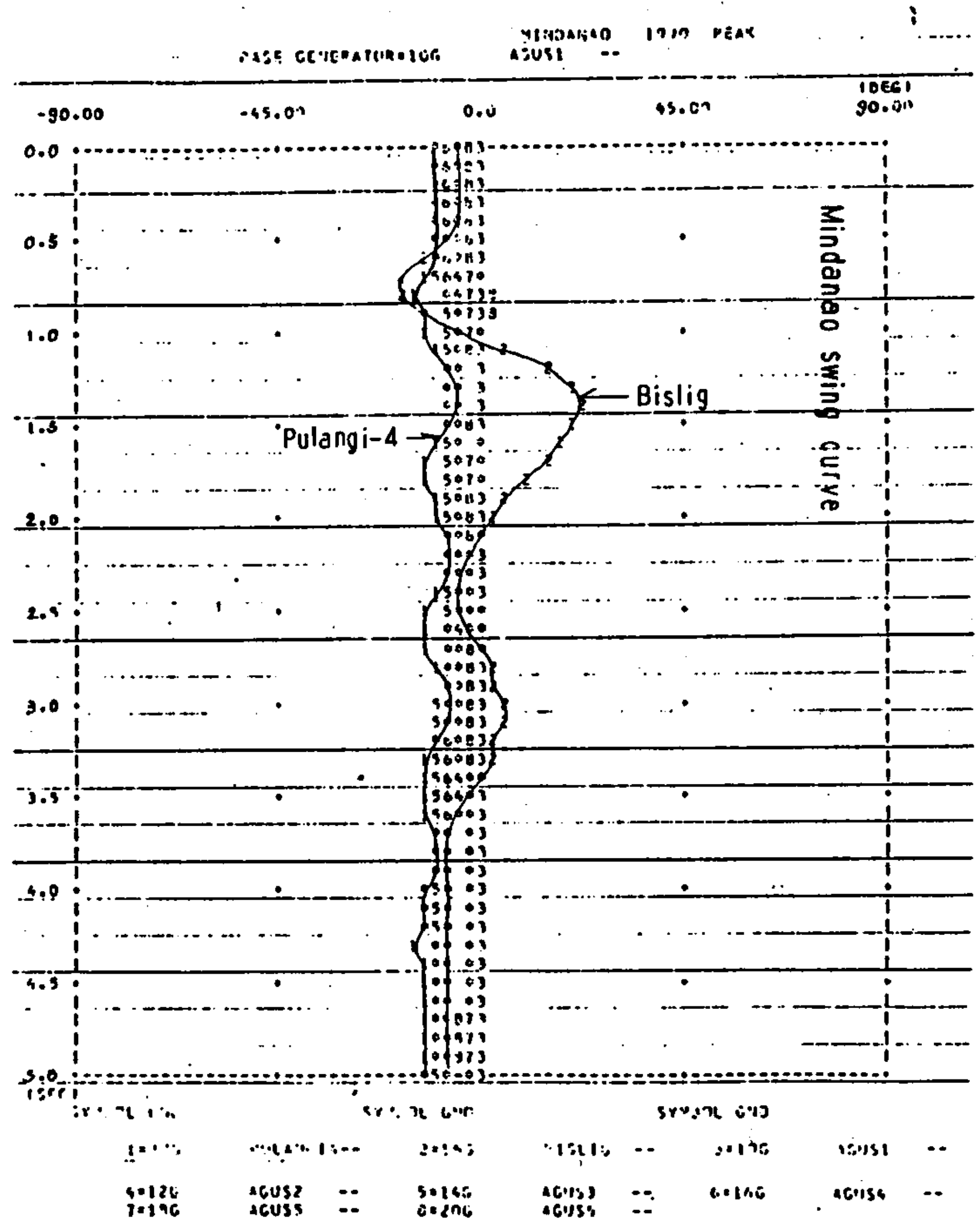


Fig. 6-10 **Stability of AC 230 kV Transmission System Interconnection of 400 MW**

Fig. 6-11 Stability in 1990
2 terminal HVDC Transmission System
3LG-O Line Fault on Mindanao AC Grid





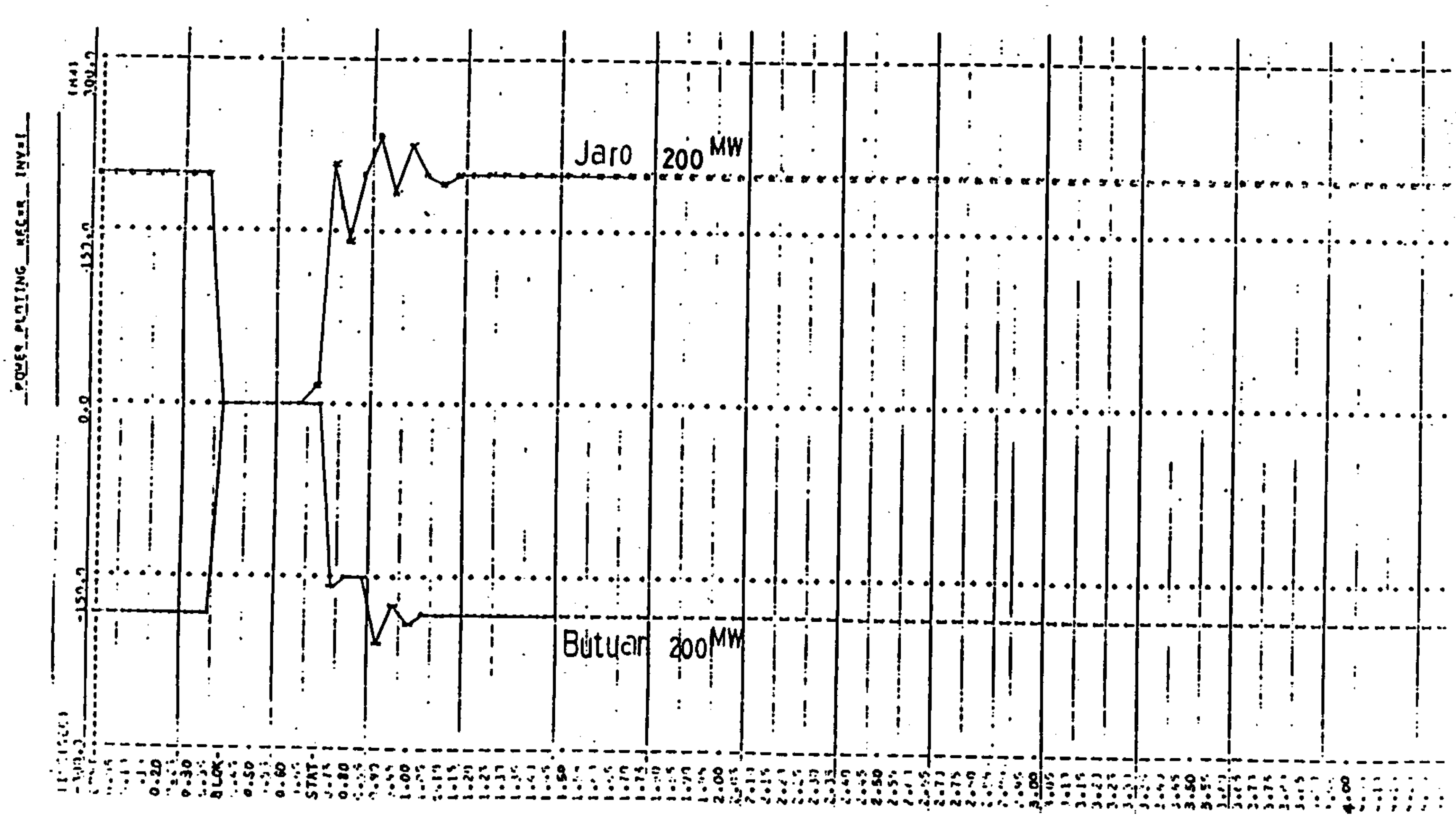
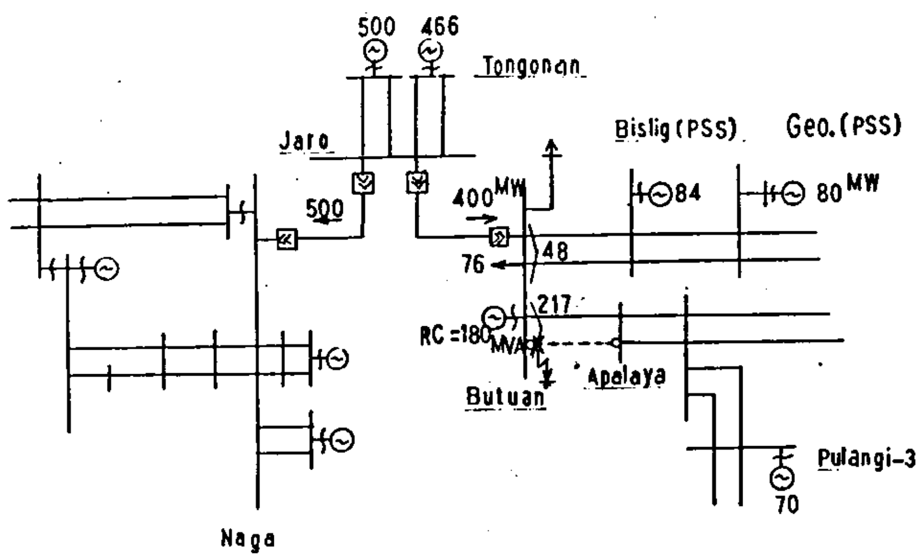
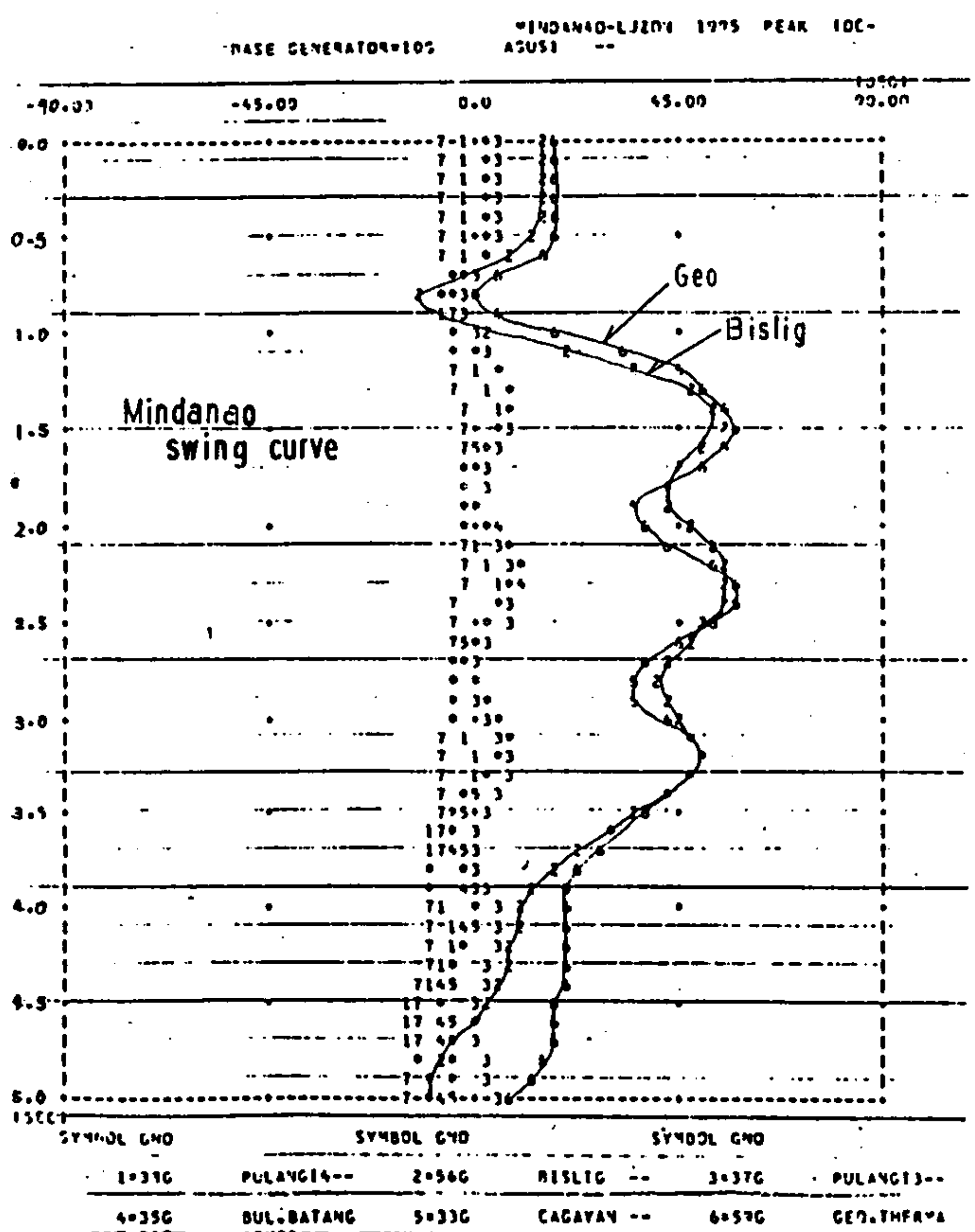


Fig. 6-12 Stability in 1995
2 Terminal HVDC Transmission System
3LG-O Line Fault on Mindanao AC Grid





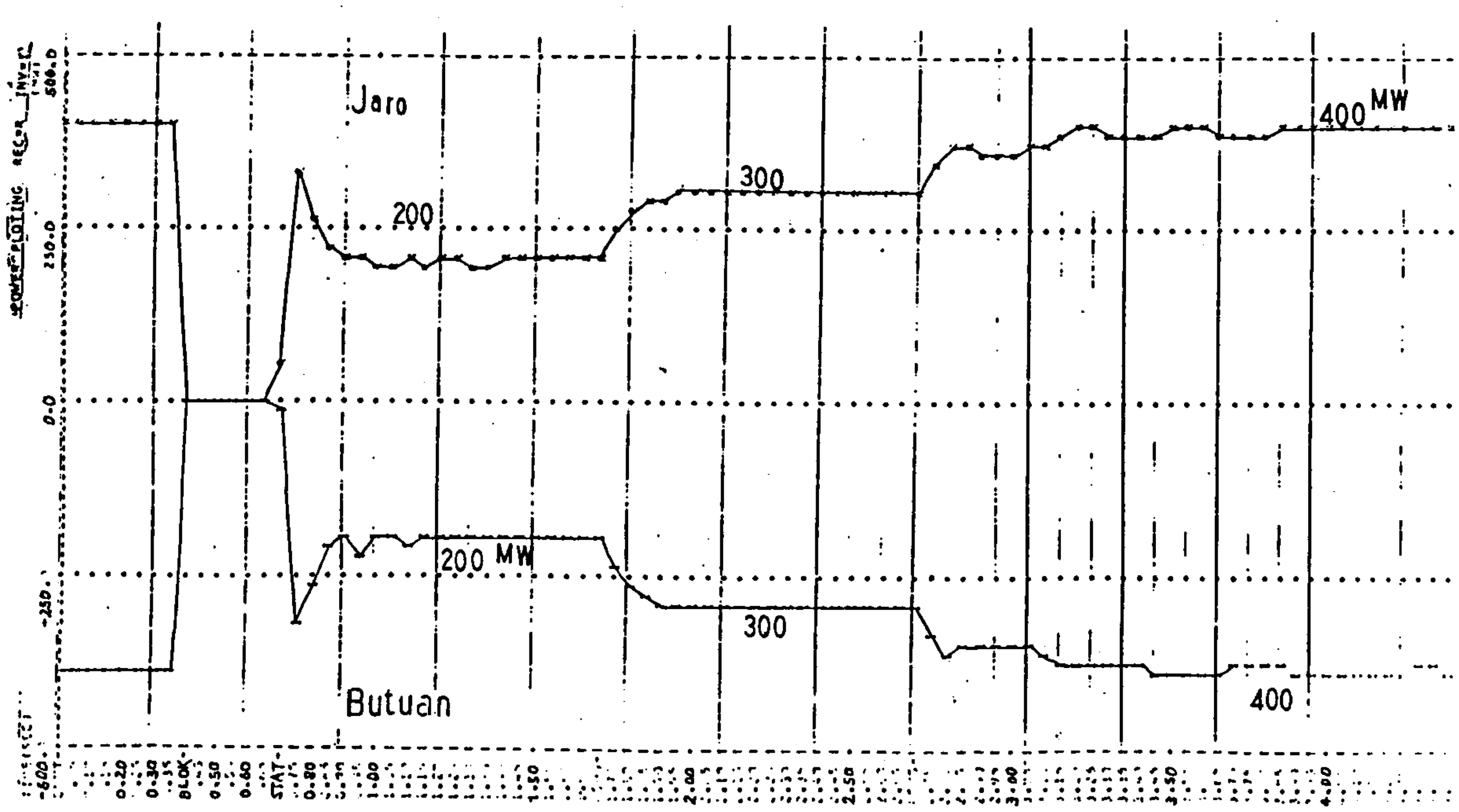
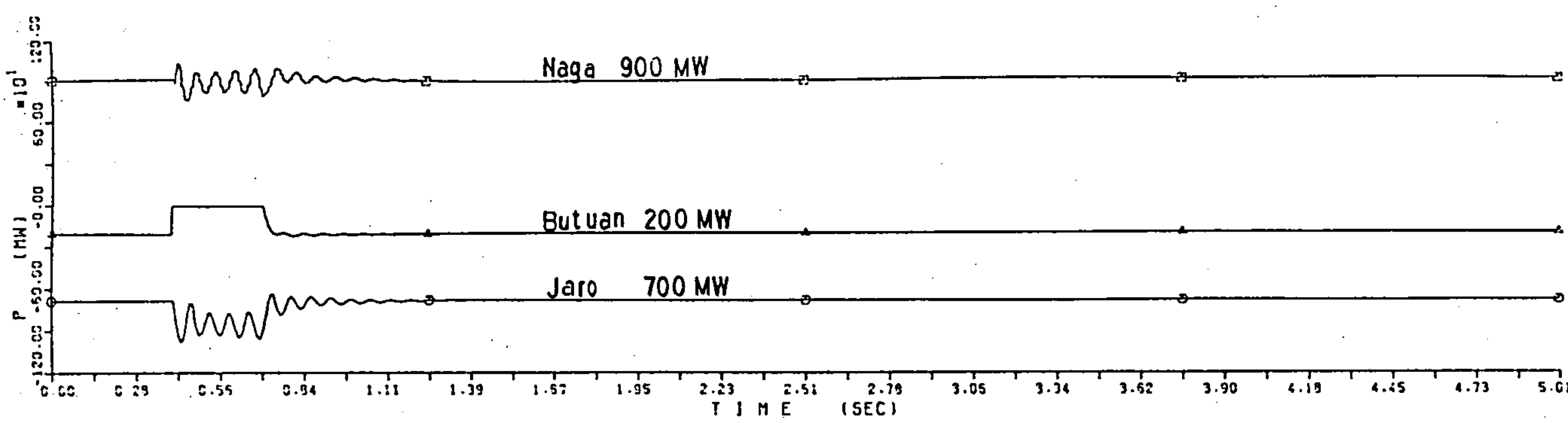


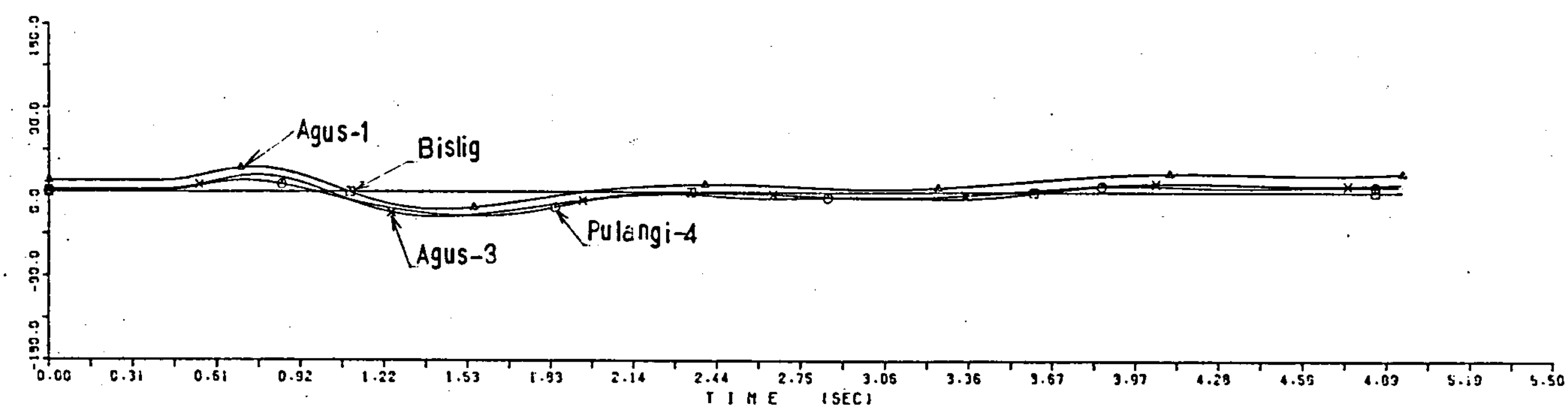
Fig. 6-13 Stability in 1990
3 Terminal HVDC Transmission System
3LG-O Line Fault on Mindanao AC Grid

	ND		MAX	MIN
⊙	27	INV	-631.5	-983.3
△	N520	INV	0.0	-216.0
⊡	77	REC	1022.9	747.9



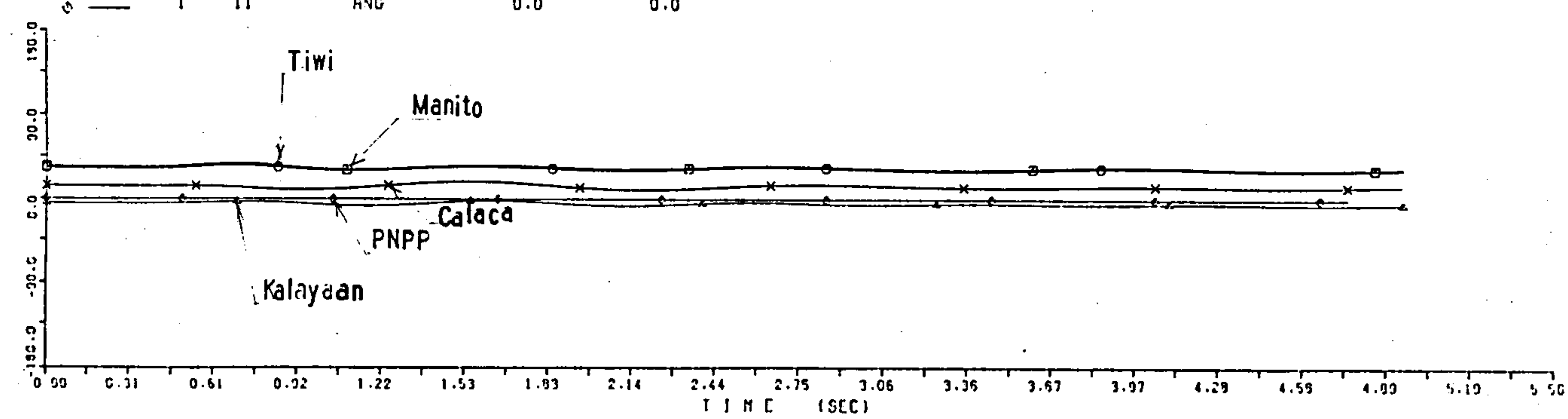
MINDANAO SWING CURVE
MINDANAO-LUZON. 1990 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	56G	ANG	0.0	0.0
⊙	1	38G	ANG	12.4	-25.5
△	1	10G	ANG	26.5	-18.7
×	1	14G	ANG	18.2	-26.2



LUZON SWING CURVE
MINDANAO-LUZON 1990 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	2	ANG	37.1	30.8
⊙	1	3	ANG	35.6	30.3
△	1	4	ANG	-1.8	-7.6
×	1	5	ANG	18.9	10.0
◇	1	11	ANG	0.0	0.0



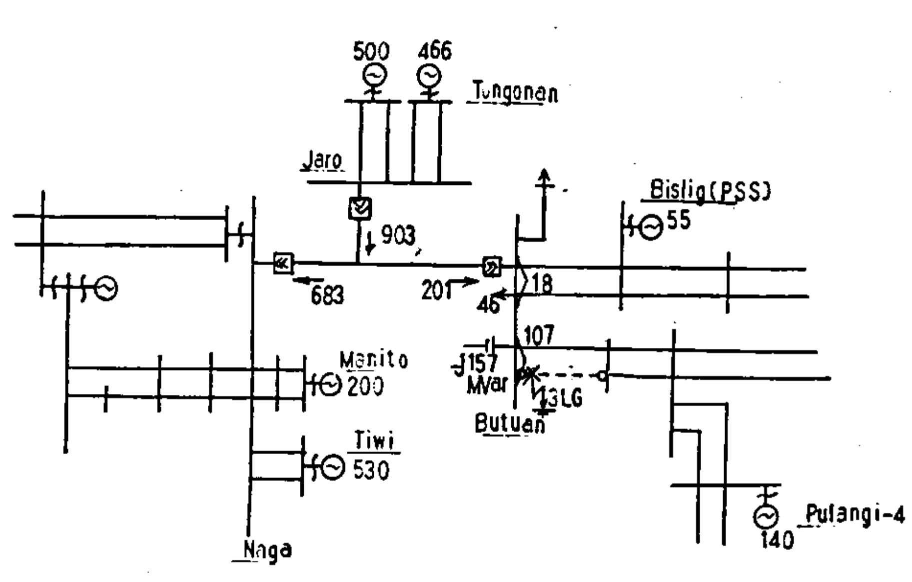
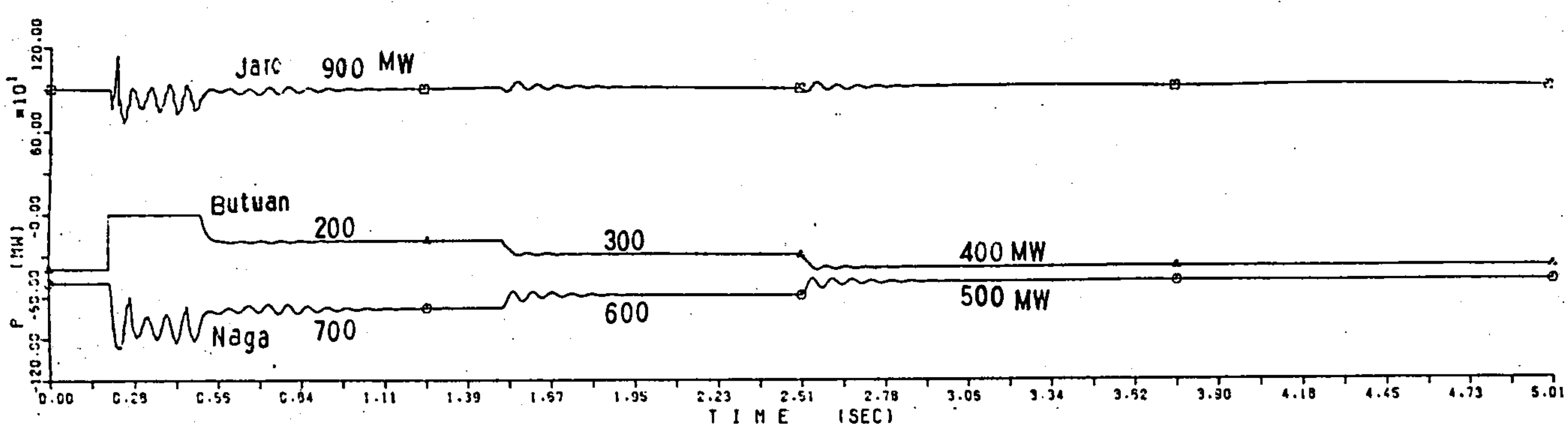


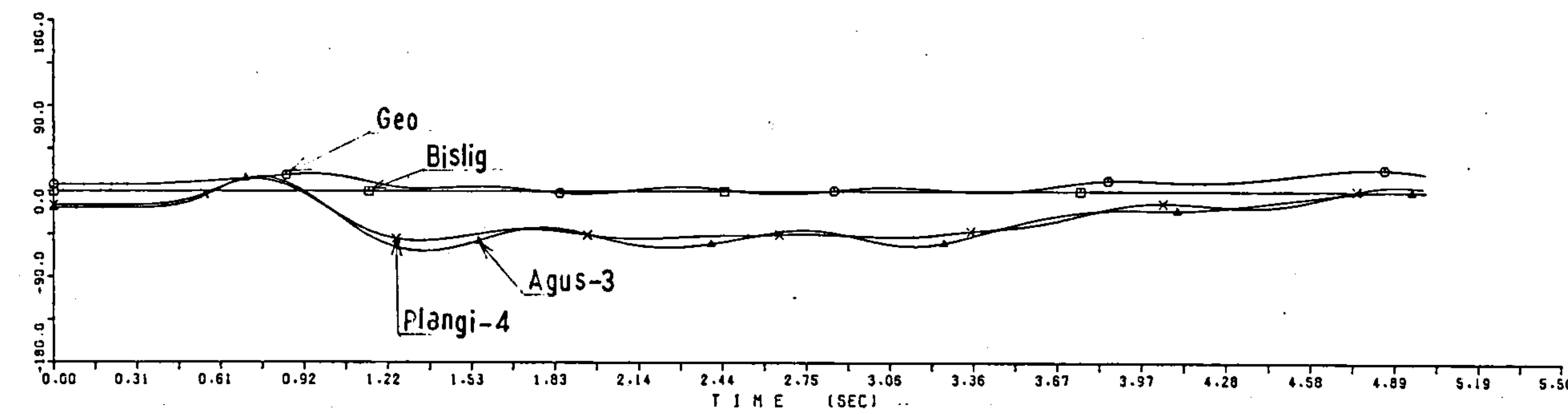
Fig. 6-14 Stability in 1995
3 Terminal HVDC Transmission System
3LG-O Line Fault on Mindanao AC Grid

	ND		MAX	MIN
⊙	27	INV	-467.8	-975.8
△	N520	INV	0.0	-406.7
⊡	77	REC	1147.3	670.4



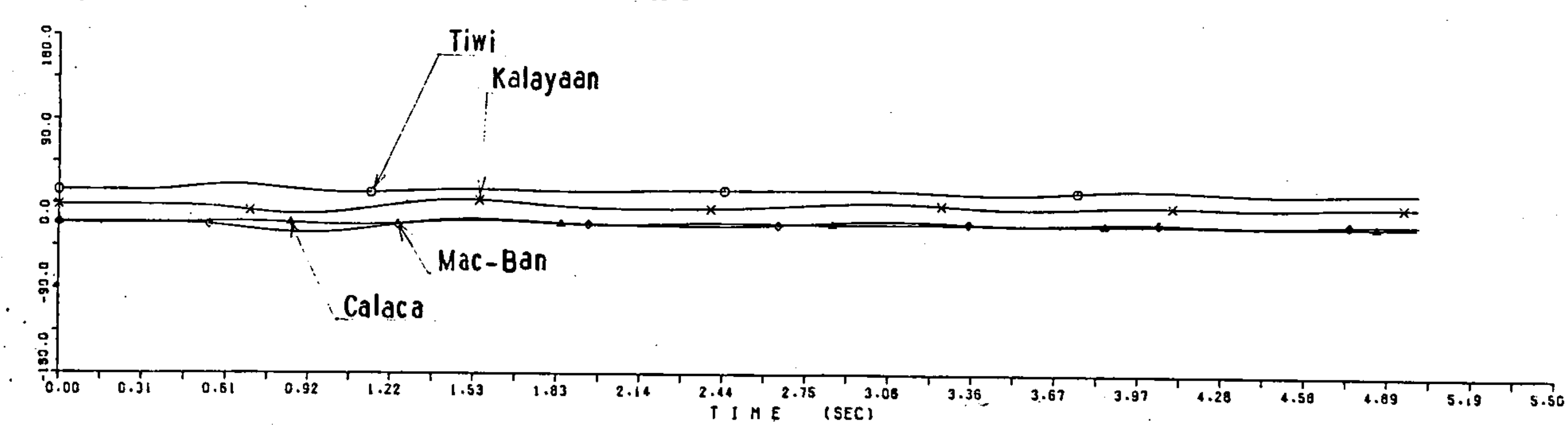
MINDANAO-GRID SWING CURVE
MINDANAO-LUZON 1995 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	56G	ANG	0.0	0.0
⊙	1	59G	ANG	23.7	-2.7
△	1	14G	ANG	15.7	-62.6
×	1	38G	ANG	13.4	-51.4



LUZON-GRID SWING CURVE
MINDANAO-LUZON 1995 PEAK (DC-

	CASE	NAME		MAX	MIN
⊙	1	3	ANG	20.9	11.6
△	1	4	ANG	-16.8	-22.1
×	1	5	ANG	4.7	-10.7
◇	1	6	ANG	-15.3	-30.8



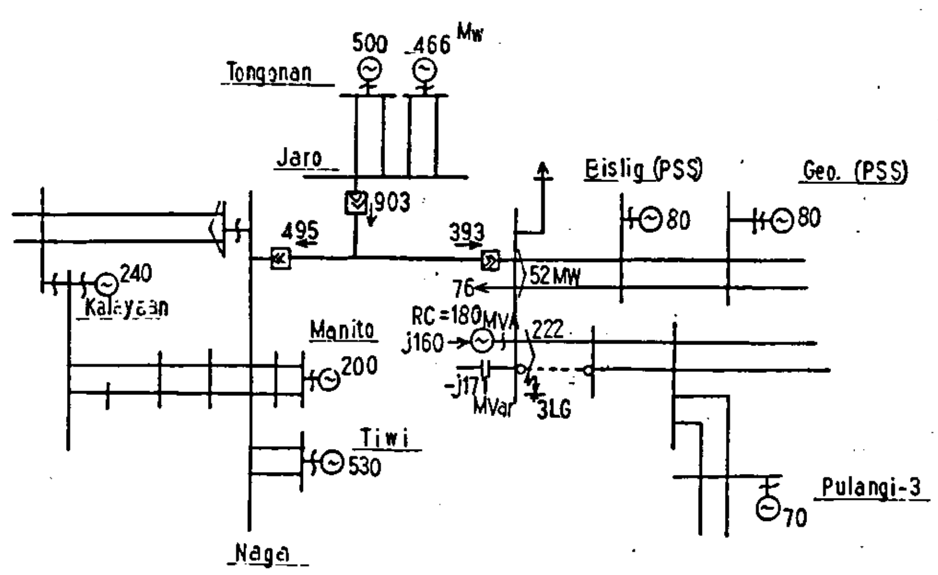
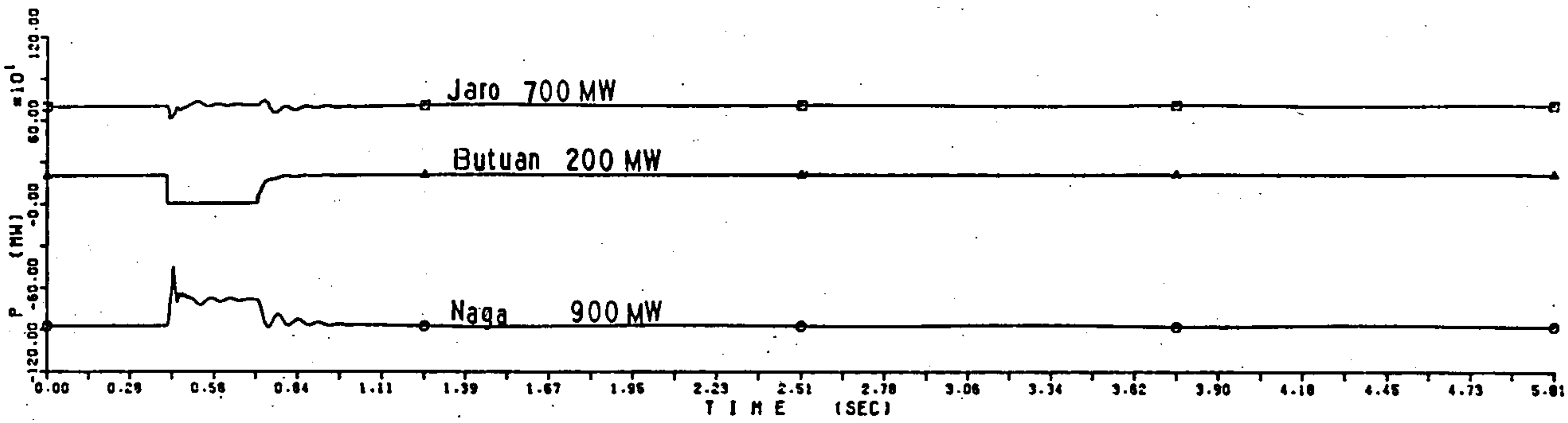


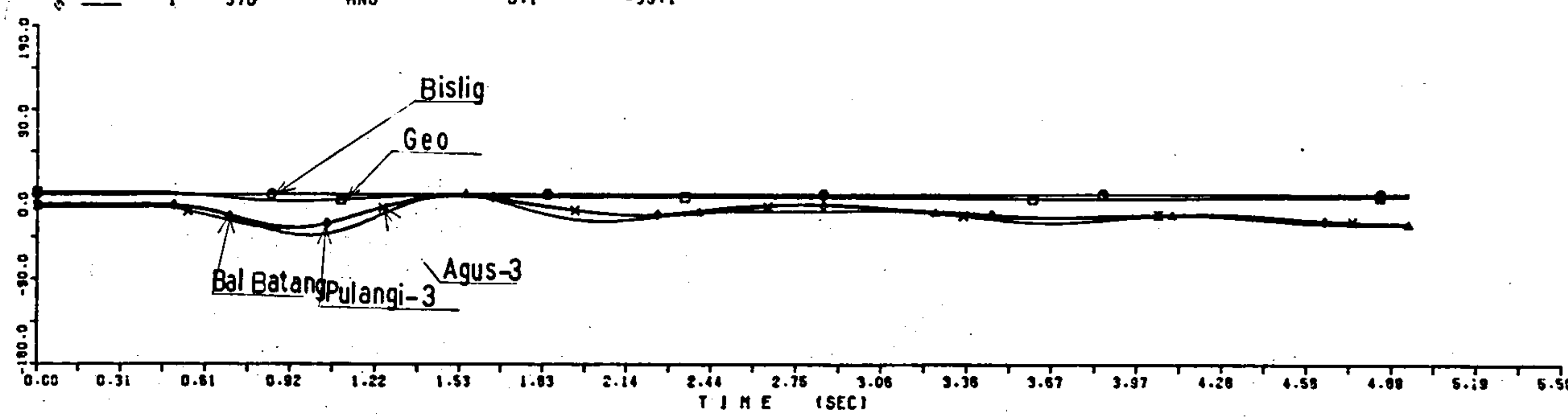
Fig. 6-15 Stability in 1995
3 Terminal HVDC Transmission System

	NO		MAX	MIN
⊙	27	INV	-452.9	-888.0
△	N520	REC	207.1	0.0
⊡	77	REC	736.8	610.0



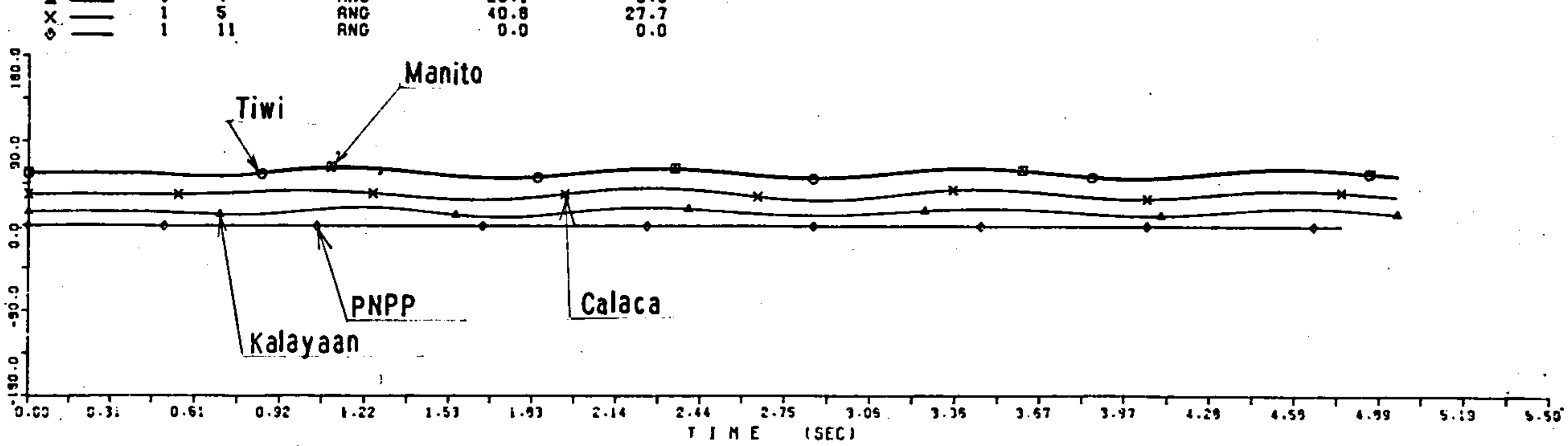
MINDANAO-LUZON 1995 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	59G	ANG	2.5	-7.5
⊙	1	56G	ANG	0.0	0.0
△	1	35G	ANG	-0.0	-43.5
×	1	14G	ANG	-2.2	-36.1
◇	1	37G	ANG	0.1	-35.1



LUZON SWING CURVE
MINDANAO-LUZON 1995 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	2	ANG	63.1	51.6
⊙	1	3	ANG	61.3	50.4
▲	1	4	ANG	20.1	9.5
×	1	5	ANG	40.8	27.7
◇	1	11	ANG	0.0	0.0



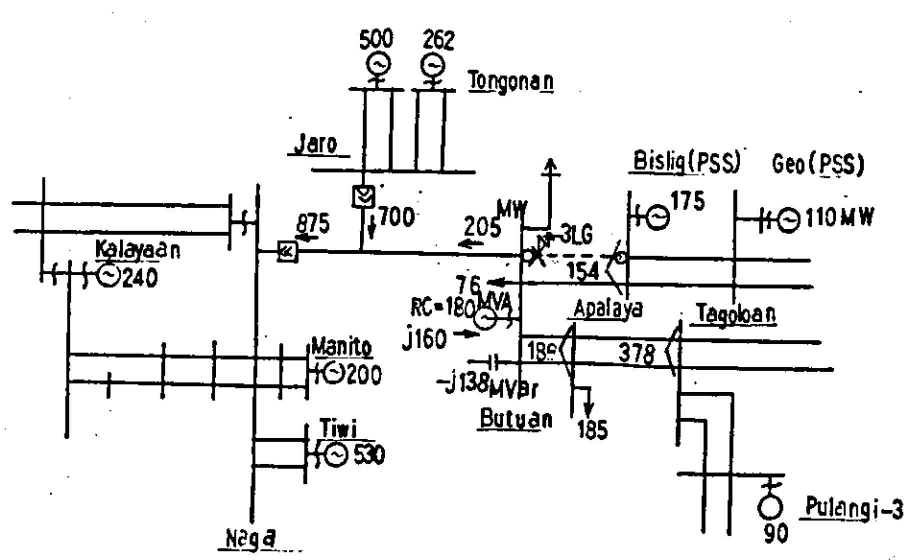
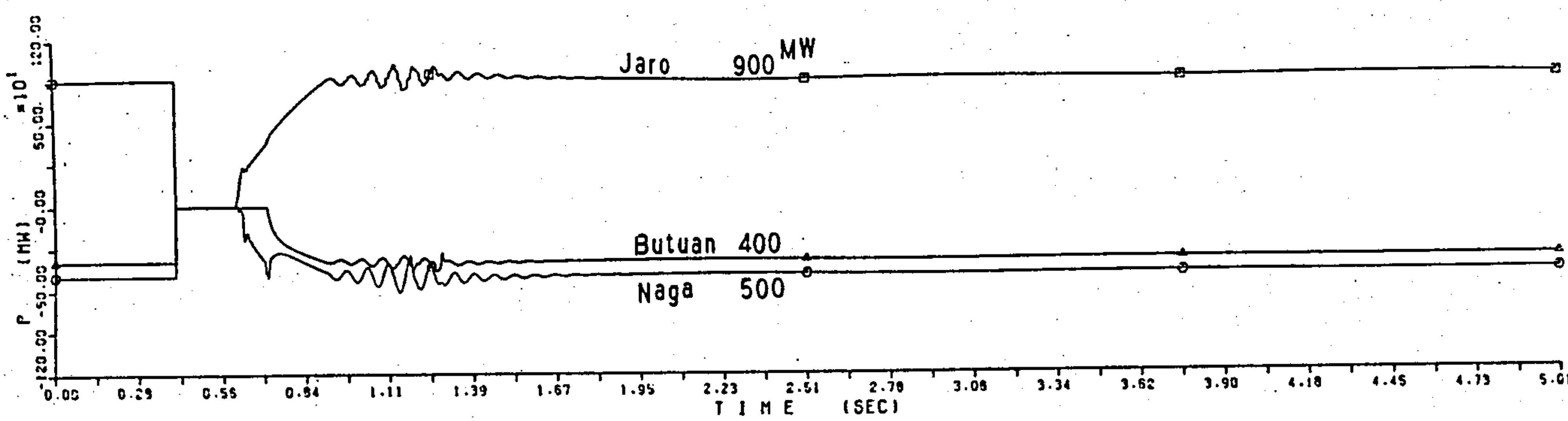


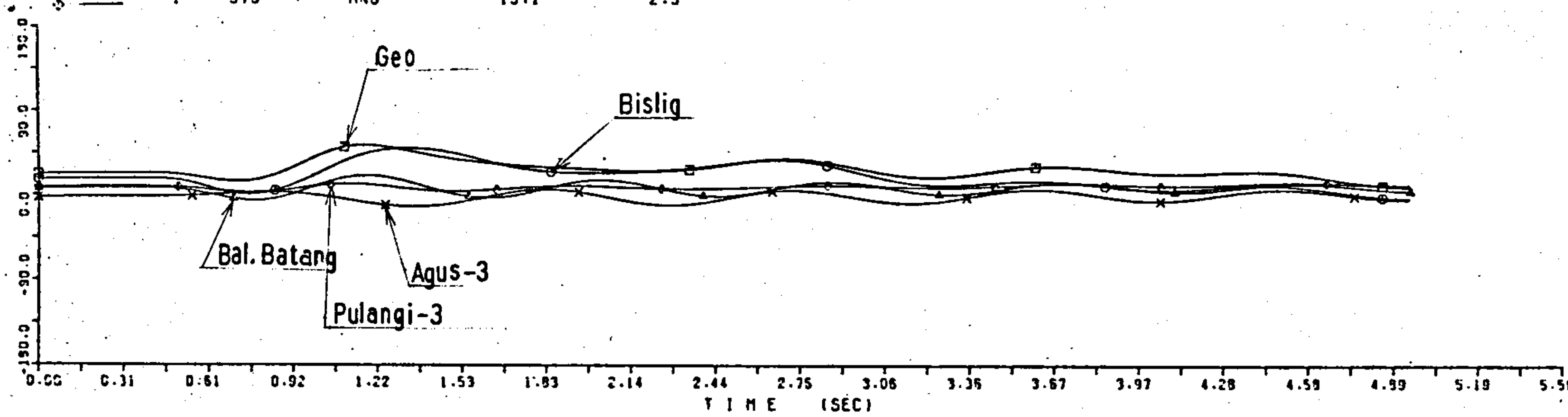
Fig. 6-16 Stability in 1995
3 Terminal HVDC Transmission System
3LG-O Line Fault on Luzon AC Grid

	NO		MAX	MIN
⊙	27	INV	0.0	-616.7
△	N520	INV	0.0	-462.6
⊡	77	REC	1017.3	0.0



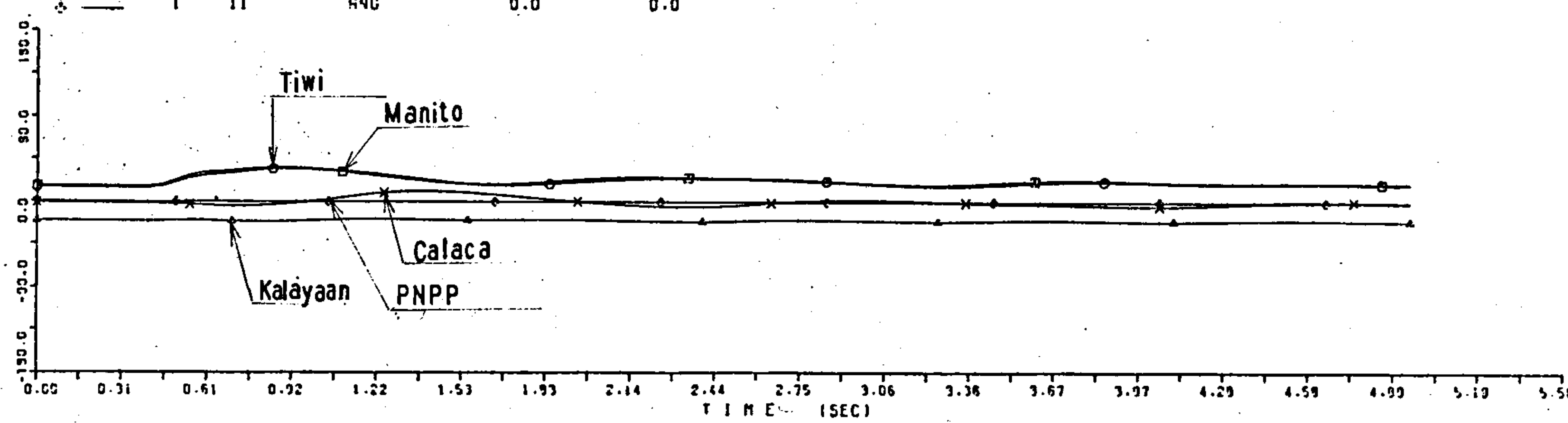
MINCANAO-LUZON 1995 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	59G	ANG	52.2	0.4
⊙	1	56G	ANG	49.1	-3.4
△	1	35G	ANG	20.6	-5.9
×	1	14G	ANG	5.9	-12.2
◇	1	37G	ANG	13.1	2.3



LUZON SWING CURVE
MINCANAO-LUZON 1995 PEAK (DC-

	CASE	NAME		MAX	MIN
⊡	1	2	ANG	35.2	15.2
⊙	1	3	ANG	34.4	14.2
△	1	4	ANG	-18.5	-21.6
×	1	5	ANG	10.8	-5.0
◇	1	11	ANG	0.0	0.0



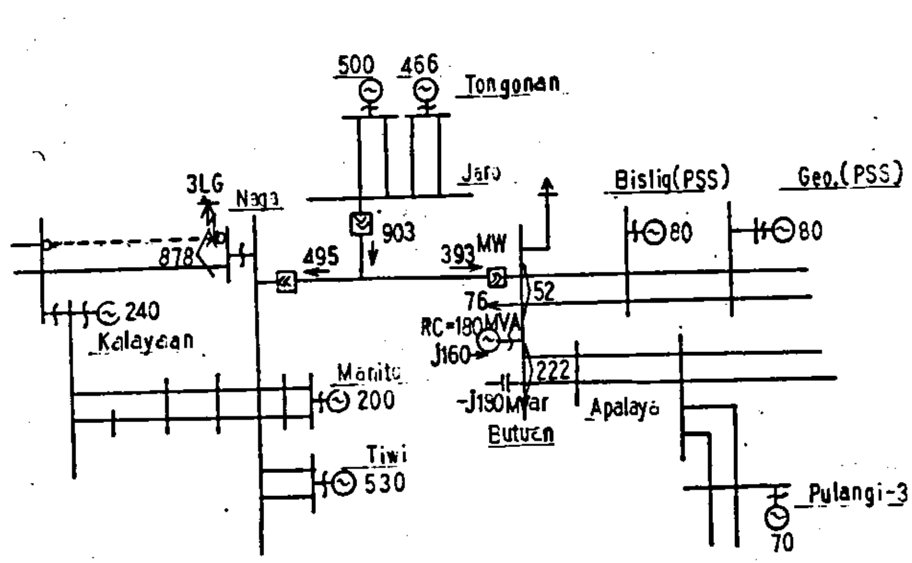


Table 6-1 Peak Load at Bulk Substations

Substations	1990 (MW)	1995 (MW)
Aurora	31.7	52.5
Kabasalan	4.4	6.0
Sangali	33.5	54.1
Lugait	64.3	107.0
Aplaya	118.4	185.3
Kibawe	13.0	20.0
Butuan	46.5	76.4
Davao	155.7	250.9
Abaga	165.4	247.5
Tagoloan	212.5	302.0
Bislig	7.0	14.6
Agus I	45.0	61.5
Surigao	29.3	41.7
Gen. Santos	32.7	56.4
Tacurong	6.0	12.2
Nuling	37.8	65.1
Total	1004.0	1554.0

CHAPTER 7

PRELIMINARY DESIGN

CHAPTER 7 PRELIMINARY DESIGN

Should the DC 3-terminal power transmission unified with the Luzon-Leyte power transmission project be adopted to the Leyte-Mindanao power transmission project studied in the present report, it will make possible the efficient and economical interconnection between Luzon and Mindanao, the part of the principal electric power systems of the Republic of the Philippines, as a consequence of the interconnection of approximately 800 km by means of a DC transmission line system.

7.1 Conception of the preliminary design

From the standpoint of system, the DC 3-terminal system taken into consideration in this study consists of two distinct 2-terminals systems that will be used in common with the Jaro HVDC substation of the Luzon-Leyte Power transmission project, i.e., the DC 2-terminal system between Luzon and Leyte and the DC 2-terminal system between Leyte and Mindanao.

As mentioned in the survey report of the Luzon-Leyte power transmission project published previously (JICA, March 1982), the 2-terminal power transmission system between Luzon and Leyte are utilized as a transmission line for power and energy supply to Luzon Grid and expected to be a reliable supply of power in the plan for extension of the system. On the other hand, the DC power transmission system between Leyte and Mindanao is expected its two function: one for an efficient interchange of reserve power between the Luzon and Mindanao Grids, other for energy transmission to Mindanao grid, in view of its scale of development.

As can be seen from the aforestated considerations, the plan for extension of the Leyte-Mindanao power transmission project is prepared by taking into consideration the reliability of the power supply with economy and ease of maintenance.

Therefore, the essential points of the power transmission project of Chapter 5 are summarized as follows.

- Economy

  The monopolar extension is more advantageous from the standpoint of cost.

- Ease of maintenance

  The metallic return mode is adopted with the purpose of reducing the maintenance of the electrodes and the 12-phase operation is adopted not only to facilitate the maintenance through the simplification of the control and protection system, but also to improve the reliability of the 3-terminal system.

- Reliability of power supply

  If all overhead transmission lines and submarine cables involved in the project are constructed in advance, including those facilities to be used in the future, the reliability of power supply can be upgraded because in the case of submarine cable fault involving prolonged operation stoppage, the transmission of power can be carried out through the other cable by sea return mode during the cable repair period, by using the facilities of the second stage.

7.1.1 Scope of execution of the first stage and second stage works

(1) DC overhead line, submarine cable, electrodes and electrode lines

All overhead lines and submarine cables will be constructed in the first stage, because the monopolar metallic return mode will be adopted in this stage.

Furthermore, the electrodes and electrode lines will be constructed in the first stage as well, in order to make possible the power transmission with sea return mode in the case of cable fault and other troubles.

(2) HVDC substation

a) First stage

The converter equipment (thyristor valve, converter transformer, DC reactor, DC & AC filter, control & protection equipment, etc.) required to realize the monopolar system, the switching equipment, etc., will be installed in the first stage.

b) Second stage

Converter equipment, synchronous rotary condenser, switching equipment, etc., similar to those of the first stage will be installed in the second stage.

(3) Communication equipment

The communication equipment will be installed in the first stage, by taking into consideration the requirements of the second stage.

7.1.2 Operation pattern of the HVDC system

The HVDC system of this project should be operated in accordance with operation able to assure high reliability for the totality of the 3-terminal system, with perfect coordination with the Luzon-Leyte HVDC system constructed before. The operation pattern of this project should be examined after comprehending perfectly the operation of the Luzon-Leyte HVDC system in its final stage.

7.1.3 HVDC system operation

(1) Direction of transmission of power

The Butuan HVDC substation of the Mindanao Grid is assumed to be able to function as rectifier (Mindanao → Luzon) and as inverter (Luzon → Mindanao) as well.

Polarity reversing switch should be installed at the DC side of the thyristor valves because in the case of 3-terminal operation the inversion of power flow in a converter station is carried out by inverting the valve current direction of the main circuit, unlike the case of the 2-terminal operation.

The thyristor valves with 2-group 12-phase are connected with the DC 350kV circuit because both groups are operated as rectifier and inverter as well. Therefore, the insulation level should be coordinated accordingly.

(2) DC output rating

The DC output rating is fixed on the basis of the line side of the DC reactor.

(3) Minimum DC continuous output

The target value of the minimum DC continuous output is 10% of the output rating.

(4) Basic control method

a) The basic control method of the Leyte-Mindanao HVDC system should be perfectly coordinated with the control method of the Luzon-Leyte project.

In the Luzon-Leyte power transmission project the voltage of the DC system is kept constant by means of the AVR (Constant Voltage Control) of the Naga HVDC substation which is the receiving end of the system. On the other hand the Jaro HVDC substation, which is the transmitting end, operates with the power set at a convenient value to keep constant the system frequency in order to attain the coordination with the generator output.

Generally speaking, the stable operation of a multi-terminal HVDC system is attained by keeping constant the voltage of the DC system by means of an AVR at one converter station and by keeping constant the current of each converter station by means of the ACR (Constant Current Control) of the other converter station. Therefore, the basic control at each converter station of this system should be as follows.

Jaro HVDC S/S ;	ACR (AFC)
Naga HVDC S/S ;	AVR
Butuan HVDC S/S ;	ACR (APR)

b) The power setting between the 3-terminals should be perfectly coordinated, and furthermore measures should be considered in order to prevent all converter stations from stopping even in the case of interruption of the communication circuit and instantaneous blocking of one converter station.

c) A global protection method including the use of DC circuit breakers to protect the 3-terminal system against failures of various types should be studied, by taking into consideration measures to set the reliability of the protection system free from excessive dependency on the communication circuit, the order of priority of protection, etc.

d) This 3-terminal system composes a decentralized-type 3-terminal system, with interconnection of the HVDC systems between Jaro and Naga and between Jaro and Butuan. Therefore, each one of these systems are equipped with operation and control functions such as start, stop, etc. However, it is more advantageous to operate the whole system by using the Jaro HVDC substation as main control center in the same way as in the case of the Luzon-Leyte power transmission project, because it makes possible a unified and efficient operation.

7.1.4 Requests to the Luzon-Leyte power transmission project

Some measures should be considered prior to the implementation of the Luzon-Leyte power transmission project, in order to shorten the term of works for construction and modification of the facilities of the Jaro and Naga HVDC substations required to interconnect the 3-terminals for future operation of the system with 3-terminals.

Concretely speaking, it is necessary to consider the following measures.

- To design and construct the control and protection equipment by taking into consideration the future 3-terminal operation.
- Reservation of space in the control room of the Jaro HVDC substation for installation of the operation & monitoring panel, line protection panel and information transmission equipment.
- Considerations about installation space and main circuit layout in order to cope with the installation of DC circuit breakers in the Jaro HVDC substation.

7.2 Overhead Transmission Line

7.2.1 Climate conditions

Since the Philippine Islands are located at a low latitude, the local climate is featured by a tropical weather pattern of very little temperature variation all the year round and much rainfall due to high temperature and moisture and seasonal wind blow. Typhoon hits the Philippine Islands very frequently, say about 20 times a year at average in close proximity to or within the influential area of the Philippines.

Meteorological study has been made from the observation data locally available on such specific items as wind velocity, temperature and number of thounder-storm days which should be incorporated into the transmission line design. Study result are outlined hereunder.

(1) Wind Velocity

The proposed transmission line route for this project will extend over a long distance of about 340 km, in which the overhead line is of 290 km, starting from Jaro HVDC S/S located at the northern part of Leyte Island and terminating at Butuan HVDC S/S after passing through the Dinagat Island. In the Leyte Island and in the northern part of Mindanao Island strong wind blows frequently and wind of high velocity is recorded.

Normally, in the case of the important transmission line which should require high reliability the design consideration must be given at least, on 50-year probability basis in the forecast of wind velocity. According to this normal design practice, therefore, the wind velocity has been estimated on the 50-year probability basis by due reference to the past recorded data on annual maximum wind velocity available from each local observation station near the proposed overhead transmission line route and the standard design criteria of NAPOCOR.

From the result of study, it is estimated that the extreme limit of wind velocity (gust) withstood by supporting towers of the overhead transmission line would be about 185 kPH.

(2) Temperature

Temperature in the Project Area is maximum at 37.2°C in Surigao and minimum at 17.8°C in Tacloban and average value is 27°C. With due consideration to the regional and altitudinal difference temperature may be 40°C as maximum and 10°C as minimum for project.

Since the design criteria of NAPOCOR provides maximum temperature at 48.9°C and minimum temperature at 7.2°C, the design for the transmission line of the Project has adopted the same figures at both maximum and minimum temperature degrees, or 48.9°C and 7.2°C.

(3) Number of Thunderstorm Days

Number of thunderstorm days is registered at 70 days in Tacloban City and 83 days in Surigao City. The design of the transmission line under this Project is based upon 80 days a year.

7.2.2 DC overhead transmission line

(1) Overhead transmission line route

The proposed route for the DC overhead transmission line of the Project extends over a distance of 340 km from Jaro HVDC S/S at the northern part of Leyte to Butuan HVDC S/S at the northern part of Mindanao by way of the Dinagat, Awasan and Nonoc Islands. The route of the transmission line is shown in Fig. 7-1. This transmission line between Jaro and Butuan HVDC S/S will cross Surigao Strait (Leyte - Dinagat) and Hinatuan Passage (Nonoc - Mindanao) and they may be divided into two different categories such as overhead line section on land and submarine cable section.

a) Route in Leyte Island

The route proposed for the section from Jaro HVDC S/S to the west of Abuyog passes flat terrain with coconut plantations and some intermediate paddy fields on the eastern foot of the main ridge.

From the west of Abuyog, the transmission line will run parallel with the Higasaan River along the gentle valley between eastern mountains to the Hinundayan cable terminal. Existing roads near the route can be utilized as access for construction and maintenance of the transmission line.

Another route running through the mountainous area along the National Highway to Sogod can be considered in the section between the west of Abuyog and Hinundayan. But this alternative route was not adopted in this study due to the facts that there were many steep mountains with the elevation of 700 m, that several land slips of small scale in north of Sogod were observed and that the length of the transmission line is longer than eastern route.

Judging from the geological maps there would exist fault line in the proposed route, therefore, it is very important to avoid such fault line in the proposed area for determination of tower location. The proposed route around the Hinundayan cable terminal is facing the sea.

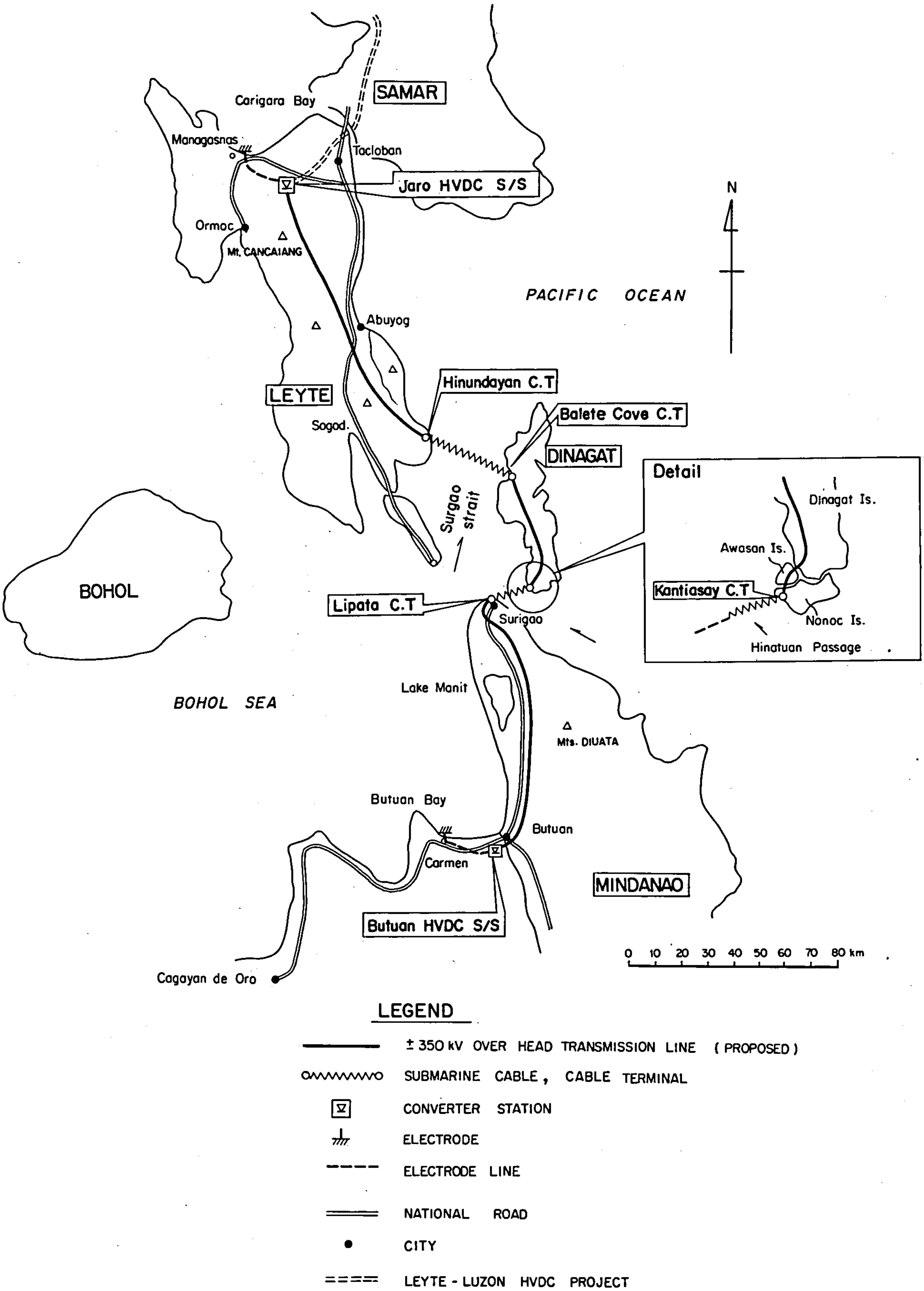
It is anticipated that insulator deterioration will be caused by salt contamination influenced by strong wind from the offshore. Since this problem must be considered most seriously in regard to electrical reliability of the transmission line, it will be necessary to carry out designing based on data obtained in the field.

Total length of the route in the section between Jaro HVDC S/S to Hinundayan cable terminal in Leyte Island is estimated to be about 115 km.

b) Route in Dinagat, Awasan and Nonoc Island

The route across Dinagat, Awasan and Nonoc Island from Balete cove cable terminal to Kantiasay cable terminal runs mainly in the uninhabited mountainous region with elevation of 200 m.

Fig. 7-1 Transmission Line Route



In those islands, there are several small ports which would facilitate the transportation of construction and maintenance for the transmission line. At the southern part of Dinagat Island, the route crosses two narrow channels lying between Dinagat-Awasan, and Awasan-Nonoc island by overhead line. The total length of the route in the section between Balete cove cable terminal to Kantiasay cable terminal is estimated to be about 55 km.

The proposed route in the Awasan and Nonoc Islands will encroach the mining area operated or planned by Marinduque Mining and Industrial Corporation (MMIC) covers on proposed area. Therefore, the final line route shall be selected after consultation with MMIC.

c) Route in Mindanao Island

The route proposed for the section from Lipata cable terminal in the west of Surigao to Butuan HVDC S/S will pass through coconut plantations and intermediate paddy fields on flat terrain or gentle hill, in parallel with the NAPOCOR's existing 66 kV and planed 138 kV transmission lines and along the existing National High Way No. 1. Therefore, the proposed route is easy for construction and maintenance. The length of the route in the section between Lipata cable terminal to Butuan HVDC S/S is estimated to be about 123 km.

(2) Outline of preliminary design

a) Voltage and conductor

Voltage and conductor are designed, as stated in 5.3 at DC ±350 kV and ACSR 610 mm^2, double conductors.

The stringing conditions of conductors will be less than 22 percent in tensile strength of breaking strength at normal condition (15°C, no wind) consider of mechanical stress and less than 40 percent at the worst condition in case of typhoon (7.2°C with wind (gust) velocity of 185 kPH, and a wind-pressure drop ratio of 0.6). It is recommended that the maximum horizontal tension should be designed at about 6,500 kg.

As a measure against conductor vibrations caused by light breezes, dampers and armor rods are to be provided at conductor supporting points.

b) Insulators

As stated earlier, the proposed route for the overhead transmission line is close to the coast in many sections. Since it is anticipated that the insulation ability may be affected by salt accumulation on insulators by tidal wind, required number of insulators must be determined with due consideration of such influence.

In the case of the DC transmission line, the quantity of contamination may be higher than in the case of the AC transmission line because of its dust collecting performance due to direct current charging. This is especially so in the less polluting inland area with few salt contamination.

In view of the fact that salt contamination to the insulator varies largely in its quantity depending upon the local climate condition and the point of measurement. Therefore, in determining the required number of insulators, the possibility of contamination must be investigated thoroughly along the proposed area of the Project.

According to rough estimation of probable salt quantity from a number of insulators in NAPOCOR's existing transmission line as well as from the local climate condition, the washable effect of insulators is higher in the project area due to frequent rain as evidenced by the recorded annual rainfall. It may be reasonable to assume that such salt deposit on insulators would be about 0.12 mg/cm^2 in the seaside area and about 0.03 mg/cm^2 in the general inland area.

On this basis, the required number of insulators to withstand normal working voltage of 350 kV would be estimated at 46 fog-type insulators of 250 mm (5.65 cm/kV in surface leakage distance) in the seaside zone and 29 fog-type insulators of same size (3.56 cm/kV in surface leakage distance) in off-seaside zone. This preliminary design is based upon the number of insulators thus estimated.

In the case of the DC transmission line, the insulator pin may be deformed by influence of electrolytic corrosion due to leaking current at plus direct current charging, thus probably affecting mechanical strength of the insulators.

Therefore, in order to preserve mechanical reliability of insulators for the transmission line under the project it is recommended that insulator pins with a zinc sleeve should be used for insulators.

c) Clearance

Clearance designing for the DC transmission line must be determined from required insulation strength against internal abnormal voltage, allowing for occurrence of lightning surge to a certain extent.

Required clearance has been reviewed on the following assumed conditions:

- Internal abnormal voltage would be 1.7 pu mainly from overvoltage in the sound pole at the time of one pole fault.
- No arcing horn would be provided for each string of insulators since grounding current would be much less than that in the AC transmission system and could be fully compensated by arc-resisting performance of insulators.
- Each string of insulators would be of considerable length to meet design requirement against possible salt contamination. Since it would have very high insulating strength in normal operation, any insulating coordination between air gap to the tower and the insulators' string would be difficult. For this reason, the design should allow for minimum flashover to the tower and the standard insula-

tion clearance would be determined from the lightning protection design.

Maximum allowable voltage for the transmission line is predetermined at 350 kV herein to determine required clearance with due consideration to all the foregoing conditions. Required insulation clearance would be 320 cm at standard and 185 cm at minimum.

d) Lightning protection design

Thunderstorm days a year amounts to 80 or so in the project area, and lightning strikes to the transmission line may probably occur 130 times a year per 100 km length of the line. Therefore, the lightning protection measures are to be provided.

As a step for this purpose, the conductor will be shielded by overhead ground-wire of 70 mm^2 GSC in two wires with the shielding angle designed to be less than 25° against the conductor.

In order to restrain possibility of causing back-flash over into the conductor to possible minimum, in case of lightning strike to either tower or overhead ground wire, the value for grounding resistance of the tower will be reduced toward the target value of 20 Ω .

Accordingly to estimating the lightning fault rate from the lightning protection design as specified above, it is expected that there will be 3.0 faults per 100 km annually.

e) In view of the fact that reliability at a high level should be required for the overhead transmission line as inter tie between Leyte and Mindanao islands and since the project area is subject to frequent typhoons, angle steel towers will be used as supports, the typical configuration which are shown in Fig. 7-2.

In view of the importance of high reliability, the tower foundation is designed for concrete base with normal slab. Tower foundation in the rice field or in swampy areas may require extra reinforcement by piles depending on the result of the geological investigation to be conducted.

Designed wind (gust) velocity for towers will conform to the value of 185 kPH (52 m/s) as described in the foregoing item 7.2.1.

(3) Outline of DC overhead transmission line

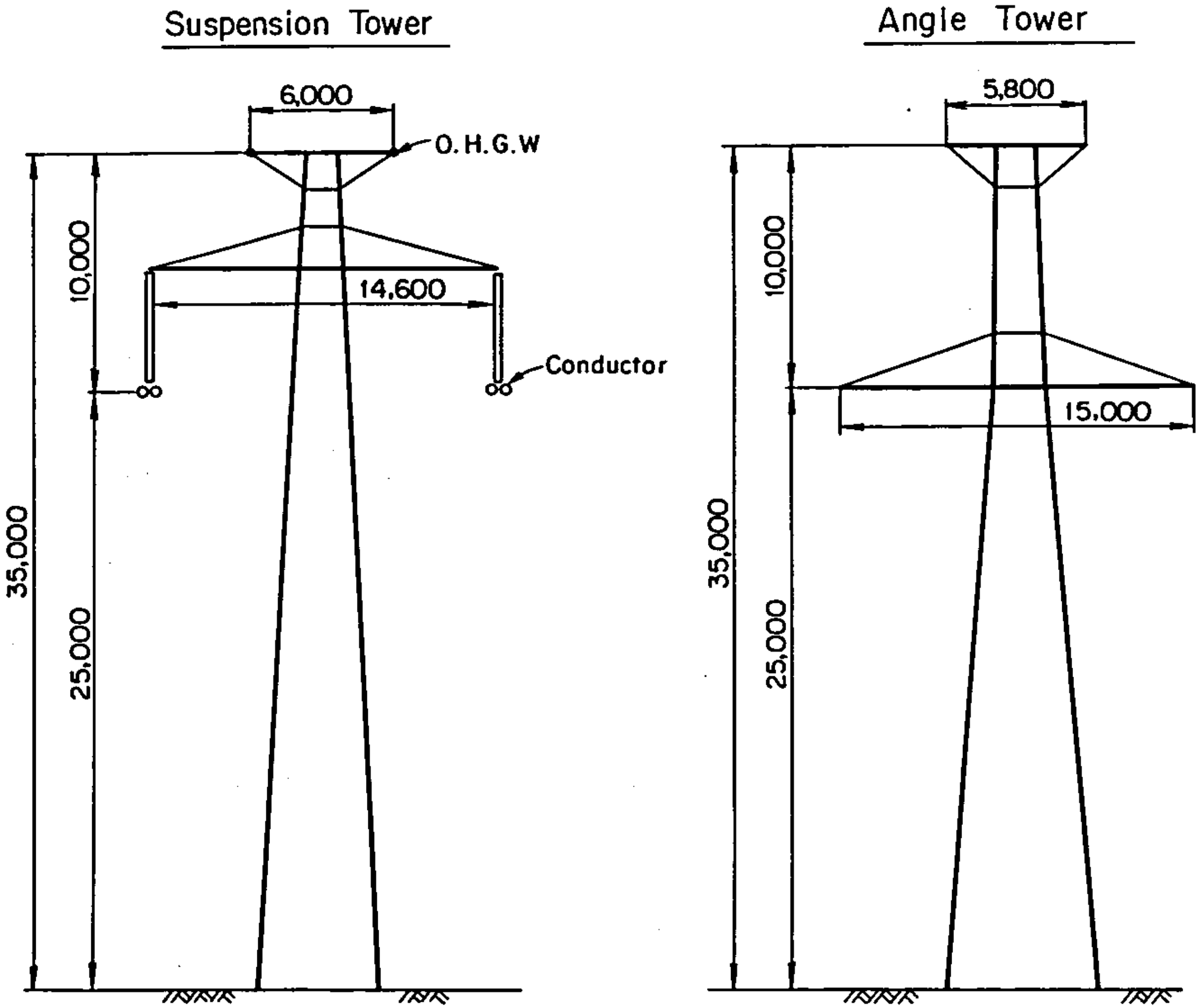
The following is the outline of preliminary design for the DC overhead transmission line.

Total length:	Leyte	115 km
	Dinagat, Awasan and Nonoc	55 km
	Mindanao	123 km
	Total	293 km

Voltage:	DC ±350 kV
Electrical system:	Bipolar transmission, grounding at both ends of neutral point
No. of circuit:	Single circuit
Conductor:	Double (2) conductors, each of 610 mm^2 ACSR
Overhead ground-wire:	70 mm^2 GSC, 2 wires
Insulator:	250 mm fog type suspension insulator with zinc sleeve, 29 and 46 units a string
Supporting structure:	Angle steel tower
Foundation:	Concrete slab foundation

Fig. 7-2 Conductor Configuration and Principal Dimension of Tower

(Unit : mm)



Note

1. Dimensions are shown for the standard design. (Not for costal area)
2. Conductor sag 14 m (at 60°C, no wind, span 400m)
3. Conductor height 11 m

7.2.3 AC 138 kV transmission line

The AC 138 kV side of Butuan Converter Station and the 138 kV outdoor switchyard of Butuan Substation are to be connected by an AC 138 kV transmission line, major features of which are as mentioned hereunder.

(1) Transmission line route

The route of the proposed line is on a hill forming a ridge between the converter station and substation. The land is generally flat and soil condition seems to be preferable for tower foundations. Total length of the line route is about 1,000 m. The line route is flat grass land near the access road to the converter station. Therefore, the tower sites will be easily accessible by car and there will be no difficulty in carrying out the construction work.

(2) Outline of preliminary design

a) Conductors

The maximum power flow on this transmission line is 400 MW which corresponds to the maximum capacity of the converter station. As this transmission line is a very important line for the Mindanao power system, the line is planned as a double circuit line capable of carrying the full load power under one circuit operation. The conductors are selected so as to have current capacity corresponding to the full sending power. Line current of the 138 kV line for transmitting power of 400 MW under power factor of 0.95 is 1,760 A. Duplex ACSR 610 mm^2, the same size conductors as those of the DC transmission line, is selected as the most appropriate size. The continuous current capacity of this conductor is 1,100 A and 2,200 A for the duplex conductors.

Conductor tension is normally decided taking into account the following conditions:

i) Tension at the normal operating condition (27.0°C, no wind) .... Within 22% of UTS

Note: UTS is ultimate tensile strength

ii) Tension at the worst condition (7.2°C, wind velocity of 185 KPH) .... Within 40% of UTS

The maximum conductor tension is usually selected at about 6,000 kg. However, the planned transmission line is very short and will consist of three to four towers. Therefore, the final tension should be decided during the detailed design after the selection of tower locations and span length.

b) Insulation design

As the project area is in the tropical zone with rare chance for occurrence of typhoon not accompanied by rain, salt contamination is considered not so serious.

As the transmission system will employ neutral direct grounding methods, switching surge voltage is normally within 2.8 times of the nominal voltage. The number of insulator units on the insulator string to withstand this voltage is seven. Even though one unit is added as a spare unit, an eight unit string will have enough insulation strength to withstand expected switching surges.

As the project area is in a region where frequency of lightening stroke is high (I.K.L. is around 80), it is preferable to insulate the transmission line higher than the minimum requirement. From such consideration the number of insulator discs on one string was selected at 10 pieces for a suspension string and 11 pieces for a tension string, which is the normally applied practice in the Philippines.

c) Protection against lightning stroke

The frequency of lightning stroke is high (I.K.L. is around 80) in the project area. Therefore, the transmission line must be well protected against lightning stroke. The following countermeasures are taken into account in insulation design of the transmission line:-

i) The number of insulator discs per string was increased from the minimum requirement of eight to ten discs for the suspension sets and eleven discs for the tension sets. With the rise of insulation strength, chance of flashover caused by a lightning stroke will decrease.

ii) Two overhead groundwires of 70 mm^2 zinc galvanized steel wire will be installed over the conductors with shielding angle of zero degree. Thus, direct hit of a lightning stroke to the conductors will be almost completely avoided.

iii) Grounding resistance of the towers will be lowered as far as applicable with a target value of 20 ohms by installation of grounding angles and/or counterpoise wires. Thus, voltage rise due to surge current on the towers will be minimized.

iv) The insulator sets except for jumper sets will be provided with arcing horns in order to avoid damage to insulator discs when a flashover fault occurs.

As the transmission line is around 1,000 m only in length, chance of fault due to a lightning fault, which is propotional to line length, will be very rare.

d) Supports

As this transmission line is an important line sending a maximum of 400 MW carrying duplex conductors of 610 mm^2 ACSR, supports are planned to be latticed steel towers.

The type of tower is a standard double circuit type with vertical conductor arrangement. The area is generally flat and hillside extension will not be required. Bearing capacity of subsoil at the tower sites seem to be preferable considering the surface soil conditions. Therefore, normal inverted-T type foundations will be applied for tower footings.

e) Outline of transmission line

Major conditions for the transmission line design will be as given below:

(a) Temperature

Annual average ambient temperature .... 27°C

Maximum ambient temperature .... 48.9°C

Minimum temperature .... 7.2°C

(b) Maximum wind velocity .... 185 KPH

(c) Annual number of days of thunderstorm (I.K.L.) .... 80 days/yr

Outline of the transmission line facilities is as given below:

(a)	Route length	About 1.0 km
(b)	Line voltage	AC 138 kV
(c)	Electric system	AC, 3-phase, 3-wire, 60 Hz
(d)	Conductors	Duplex ACSR 610 mm^2
(e)	Overhead groundwire	GSW 70 mm^2, 2 wires
(f)	Insulator sets	254 × 146 mm insulator disc
		Suspension string ... 10 pcs per string
		Tension string ...... 11 pcs per string
(g)	Supports	Double circuit latticed steel towers with vertical conductor arrangement

7.3 DC Submarine Cable

7.3.1 Selection of submarine cable routes and cable landing sites

(1) Principles of selection

Principal factors to be taken into account in selecting submarine cable routes and cable landing sites are the following two items:

(a) Project economy — The overall construction cost should be as low as possible.

(b) Safety in operation — There should be no possibility of serious damage during the economic life of the cables.

For selecting the submarine cable routes, the followings are to be taken into consideration:

(a) Length of the cable route should be as short as possible.

(b) There should be no anchoring or fishing which will cause serious damage to the cables to be laid on the seabed.

(c) Sea depth had better be within the proper range. Though the sea depth itself is not a decisive factor, cable laying becomes impossible in case that the sea depth exceeds a certain limit. The cable shall be buried in the shallow sea near the seashore. Therefore, burying cost becomes high in case that length of the shallow portion is long especially when the rocks are exposed on the seabed as widely seen in the Philippine seashores.

(d) The seabed shall be as flat as possible or without steep undulation. It is preferable to limit the maximum inclination of the undulation within 16 degrees.

(e) Sandy soil is most preferable as the seabed material. When buried into muddy soil, heat generated from the cables does not radiate well. Cable laying on hard materials such as rocks or corals shall be avoided as far as applicable; the cables on such hard materials may cause bridging and result in damage after short period of operation.

(f) It is preferable that tide current is slow especially on the rocky seabed.

For selecting the cable landing sites, the followings should be taken into consideration:

(g) There should be no difficulty in constructing the overhead transmission line to the site and in connecting with the cable ends. Transport of equipment and materials to the cable terminal station should also be possible.

(h) The cable landing site should not be affected by a big wave or repeated waves.

(i) Necessary land for construction of the cable terminal facilities and overhead transmission line should be available.

(j) The landing sites should be located far from a wharf, a break-water or any port facilities now existing or being planned so as not to cause any trouble.

(2) Seabed survey and selection of cable routes and cable landing sites

Before commencing the seabed survey, a few alternatives of the cable landing sites will be decided referring to the result of the reconnaissance survey of the overhead transmission line route and considering the factors as mentioned above. Some alternatives of cable alignment will also be selected referring to the marine charts. The seabed survey was carried out for a several kilometer width on both sides of the proposed alignment. Survey items were as given below:

- Cable length
- Seabed topography including shifting by drifting sand, etc.
- Seabed materials especially for rocky items, reefs, etc. and thermal conductivity especially for muddy layers
- Velocity of surface and seabed current
- Water temperature, water quality and microorganisms in the water
- Meteorological conditions such as ambient temperature, wind velocity, direction of wind, etc.
- Wave height, its frequency, time of occurrence, etc.
- Submerged items such as existing cables, sunken ships, fishing banks, etc.
- Actual status of large vessels passing the area and their anchorage
- Fishing methods and tackles used
- Cable landing sites and location of cable terminal facilities, topography, required land, soil conditions, distance from the seashore, contamination of insulator surface, assumed route of the overhead transmission line, distribution line for power supply

An echosounder was used for measuring the sea depth and for knowing seabed topography. An electronic distance meter (audistor) was used for identifying the points of the survey boat by measuring distance to two reference points on the ground. The composite materials on the seabed surface was collected by a cylindrical sampler. Where technical feasibility could not be confirmed by the above servey, supplemental survey was carried out using a side scan soner and apparatus for measuring the seabed tide current.

It is noted that the survey works carried out this time is a preliminary survey for feasibility study and detailed survey is required during the detailed design stage before setting to actual execution of the project.

Between Leyte and Dinagat

The initial seabed survey was carried out using an echosounder accross the Surigao Strait between the south of Hinundayan in Leyte and Balete Cove in Dinagat island with 6 km width; 3 km on both sides of the center line. Further the survey area was extended to the north and south during the supplemental survey, finally to more than 10 km near the seashore area and more than 20 km at the middle of the strait. In this area, the tectonic line is running from the north to the south in the same direction as the Surigao Strait. The seabed condition of the proposed cable route running from the west to the east is almost similar from the northern end to the southern end. General features are as mentioned below:

(a) Traffic of large vessels is rare; a few ships per day only. There is no port in the area and there will be no possibility for anchorage by a large vessel.

(b) Very primitive ways of fishing are prevailing in the area and modern large scale methods which will damage the submarine cables are not considered in the near future.

(c) For about 10 km from Hinundayan in Leyte, the seabed is generally flat though there are some undulations. The sea becomes deeper towards the center portion of the strait, the deepest sea is around 170 m in depth. Some steep slopes are found at the northern part of the strait and also near the southern end. This area shall be avoided in the selection of the route. The seabed materials are generally sandy containing a lot of sea shells and corals.

(d) In the center portion of the strait, where the sea is the deepest at around 200 m, there are rocky layers with rather rugged seabed, which extend from the northern end to the southern end along the supposed tectonic line with 3 to 5 km width. Some corals were found on the seabed. The seabed is generally undulated and there is much possibility to form bridging in laying the submarine cable. As the result of the supplemental survey, a suitable route was found about 5 km south of the initially selected route. Though the seabed is rocky, undulation is relatively small.

(e) There are step-like level difference with steep slope near the initially selected route at about 17 km from Hinundayan. The level difference is 10 to 40 m and maximum inclination is 10 to 40 degrees. By selecting the route toward south, inclination becomes gentle and there is no problem in cable laying along the finally selected route.

(f) From there to Dinagat, the seabed is generally flat with depth of around 100 m, which becomes shallow near the seashore. The seabed materials are sandy containing shells and corals and are preferable for cable laying. To the north of the area, there are some exposed rocky layers with step-like level differences. These areas shall be avoided in the selection of the cable route.

(g) The measured maximum speed of seabed tide current was observed as slightly exceeding 1.0 m/sec.

(h) The cable landing site on the Leyte island is located at the seashore at about 5000 m south of Hinundayan. The location of the cable terminating facilities is selected in a coconut plantation at about 200 m from the seashore.

A distribution line of 11 kV is running along the road to Sogod in parallel with the seashore. The power is sent from Tongonan Power Station through very long 66 kV and 11 kV lines. Judging from the line conditions, stability of power supply seems not so high.
On the Dinagat island, the cable landing site is selected at the southern side of Balete Cove and the cable terminal facilities will be located on a hill about 300 m from the seashore. The site is sheltered from the north and north-east strong wind which take place frequently by a northern ridge. There is no available power source near the cable terminal site.

The seabed topographic map prepared based on the result of echo sounding and the preliminarily selected cable route are given in Fig. 7-11. The total length of the cable route is about 33 km.

Between Nonoc and Surigao in Mindanao

The shortest route between the Nonoc Island and Surigao in the Mindanao island is the route connecting the south-western tip of Nonoc and North-eastern tip of Surigao. However, this portion is the narrowest part of the Hinatuan Passage and tide current is very fast flowing with large whirlpools. According to the result of the preliminary survey in 1979, the seabed is heavily undulated and is not suitable for cable laying.

The cable route selected as the result of preliminary reconnaissance was the route connecting the west coast of Hanigad and Bilan Bilan at the east of Surigao. The cable route is comparatively short and the overhead transmission line can be easily connected. However, in order to avoid the anchorage area of the Surigao Port, the cable route must be diverted toward east, where seabed condition is not preferable and sea is shallow and the cables must be buried for long distance.

As an alternative of this route, the route connecting the west coast of Nonoc and Lipata was selected. No suitable land for the cable terminal is available between the coast line of Lipata and Surigao City, because, the area is covered by the future city expansion and vast swamps. Length of this route is about 2 km longer compared with the route connecting Hanigad and Bilan Bilan.

Echo-sounding was conducted for 36 routes between Hanigad and Bilan Bilan and between Nonoc and Lipata. On the occasion of the supplemental seabed survey, the seabed condition was checked using the side scan soner in the center portion of the route where a lot of rocks are observed and speed of the seabed current was measured at where the tide current is fastest. Traffic of vessels was also investigated. The results are as mentioned below:

(a) Number of large vessels passing the area is only several per day. In the Surigao Port, normally 2 to 6 vessels are anchored. During the survey period, the survey team observed a large ore carrier anchoring far outside the designated anchorage area. In Lipata there was a newly constructed ferry terminal. It was told that no anchorage is considered around the ferry terminal area. However, from safety consideration, it will be preferable to keep away from this area in order to avoid possible damage to the cables.

(b) Fishing methods are very primitive and damage to submarine cables will not be considered.

(c) As for the route connecting Hanigad and Bilan Bilan, the seabed conditions are very rugged in the wide area at the offshore to the west of the southern Nonoc and also near Bilan Bilan. Sand wave area was observed in the middle of the route. Therefore, this route was judged to be not suitable as the cable route.

(d) Though seabed is generally rocky and rugged in the middle part of the Nonoc-Lipata route along the tectonic line from the Northwest to Southeast, comparatively flat route was found as the result of the echo-sounding covering wide areas. It was found that there is a narrow route connecting Kantiasay in Nonoc and Lipata, which is comparatively flat even on the rocky surface. Outline of this route are as mentioned below:

- The section up to 7 km from Lipata has flat seabed without much undulation. The seabed materials are sandy containing shells and corals. The maximum depth is around 70 m.

- In the 2 km width between 7 to 9 km from Lipata, the seabed consists of rocky bed covered with sand. The seabed in generally flat and there is not steep undulation. Such rocky seabed spreads from the northwest to the southeast along the tectonic line. Therefore, in case that Nonoc and Lipata is connected, passing through such rocky area is not avoidable. The areas other than the narrow selected route are not covered with sand presumably due to tide current in the area and seabed is rugged with a lot of undulation. The sea is the deepest in their cable route with depth of about 80 m. In laying the cables, care shall be taken to avoid bridging, and the laid conditions shall be checked afterward.

- The seabed from 9 km from Lipata to Kantiasay is generally flat and the seabed materials consist of sand containing shells and corals.

(e) In the southern side of the selected route, the offshore of the southern Nonoc, the seabed conditions are very rough and those on the northern side near Hikdop are also very rough. Then any route other than the selected one seems not preferable for cable laying.

(f) The maximum tide current was observed at the mouth of the strait between Hanigad and Hikdop. The maximum surface speed measured in this area was 1.3 m/sec. However, according to the marine chart, the fastest current is 3 to 4 knots. The measured seabed current was 0.9 m/sec, which will not be troublesome for the laid cable. In the middle of the passage to the offshore of Surigao, the maximum surface current was within 1.0 m/sec.

(g) The cable landing site on Nonoc was selected on the sand beach south of Kantiasay and the site of the cable landing facilities on a ridge about 100 m from the seashore. For access to the site, about 1 km of access road is to be constructed from the existing road in Nonoc. At present, there is no available power source.

At the Lipata site on the Surigao side, a coconut processing plant is occupying the most preferable site for cable landing. Therefore, the northern or southern side of the plant shall be selected. The northern side is too near to the ferry terminal, therefore the southern side was selected as the cable landing site. The shallow sea portion of the southern side is longer than that of the northern side. However, seabed is sandy not containing rocks and no difficulty is expected for burying. There is a village at the cable landing site along the seashore. In this area a few houses are to be relocated. The cable terminal facilities will be installed on a hill about 140 m away from the seashore. There is no problem in constructing the overhead transmission line from the site. The site is accessible by car and a distribution line of 11 kV forming a part of the Surigao power system is running nearby.

The result of the echo-sounding which is depicted as a topographical map and the proposed cable route are shown in Fig. 7-12. The total length of the cable route is about 16 km.

7.3.2 Submarine cable

(1) Outline of preliminary design

a) Selection of cable type

Solid cables and OF cables were examined for selection of cable type to be used for the submarine cable line.

Solid cable involves the problem of extraction of oil from the insulation layer and its reliability is inferior compared to OF cable. However, because of the fact that no oil feeding equipment is required, it is frequently used for voltages of DC ±300 kV class or less in general. Solid cable is affected by the external pressure of the seawater in a deep sea and such consideration in design to employ oval structure for conductors.

OF cable is of the highest reliability, as insulation characteristics are improved by feeding oil under pressure. However, OF cable require oil feeding equipment and this equipment requires maintenance.

The length of the submarine cable for crossing Surigao Strait is about 33 km and the maximum depth is about 200 m. Therefore, there are no large problems in the aspect of oil feed design. In addition, it is considered possible to use stationary type oil feeding equipment, and therefore, maintenance is not so great.

GF cable, XLPE cable and so forth are available besides the above as power cables. Although GF cable is inferior to OF cable in the aspect of reliability, GF cable is superior to solid cable. However, the number of actual use is small in the world because of special manufacturing technology. As for XLPE cable, it may be considered no data which corroborate its use for DC has yet been obtained. Its accomplishments as existing DC cables is also none.

The transmission lines of the project are large capacity lines and the economical loss is great if service is interrupted due to a trouble with the submarine cable. Accordingly, it is necessary to maintain high reliability for the cable itself.

As the cable type largely affects the reliability of the HVDC system of this project, it was determined to adopt OF cable which is the most superior in the aspect of reliability taking into account the above consideration.

b) Cable size and number of cables to be laid

It is necessary to prepare the onshore cable between the seashore and the cable terminal which is installed inland 200 m far from sea line.

The current capacity of a cable is affected by the thermal conductivity of the surrounding soil in the condition where the cable is laid.

As the cable size to match the power to be transmitted of 400 MW (final stage), 600 mm^2 may be used if the specific thermal resistivity of the soil is 100°C cm/W or less. However, because the specific thermal resistivity of the field is not yet known, final selection of the cable size should be made after the value of the specific resistivity is found through detailed survey. As bipolar single circuit, both neutral points grounding system is adopted as the main circuit composition of the HVDC system, so, it is possible to transmit half of the transmission capacity by one pole even on occurrence of a trouble to the other pole of the HVDC transmission lines. Accordingly, the number of cables to be laid is only two.

c) Insulation design

The composition of the insulator is designed based on the maximum temperature of conductor, the potential and electric field distribution generated in the insulator when operating at rated voltage, the phenomenon of changing the polarity and abnormal voltage applied to the insulator. With DC cables, distribution of potential gradient is determined by insulation resistance. As this insulation resistance changes in accordance with temperature and by potential gradient itself, distribution of potential gradient changes in complexity in accordance with load conditions.

Improvement of insulation characteristics can be expected with DC cable as it is possible to use insulation paper of high density because the problem of dielectric loss tangent does not exist in DC cables.

With OF cables, the maximum allowable potential gradient of insulation paper is 35 kV/mm from records of existing cables.

The thickness of the insulation paper is designed based on the above indicated value with allowance in production and laying taken into account.

The insulation thickness was determined as 22.0 mm with the rated voltage of the submarine cable of the project assumed as DC 350 kV and BIL assumed as 1,050 kV and with the experience with DC cables taken into account.

As locations of cable terminals are close to the seashore, insulation deterioration of pot head for cable end box due to salt will have to be considered. Therefore, it is necessary to consider contamination proof design for pot head and to consider cleaning of pot head in dry seasons.

On the other hand, taking into account the fact that the project area is frequently hit by lightning, lightning arresters will be set up at cable terminals for protection of cables from lightning surges.

d) Oil feed design and oil feeding equipment

As the inside of OF cables is filled with insulation oil, it is necessary to compensate changes of oil level and oil pressure caused by changes of temperature accompanying ON and OFF of loads, etc. so that the oil pressure is always kept at a certain positive value.

The oil pressure and the feeding capacity for the insulation oil should be designed considering the diameter of oil duct and oil viscosity.

e) Method for steel armoring and protection of cables

The cables will be armored with a layer of steel wire for preventing damage caused by anchors and also for mechanical reinforcement against the laying tension.

The construction of OF submarine cable is shown in Table 7-1 and Fig. 7-3.

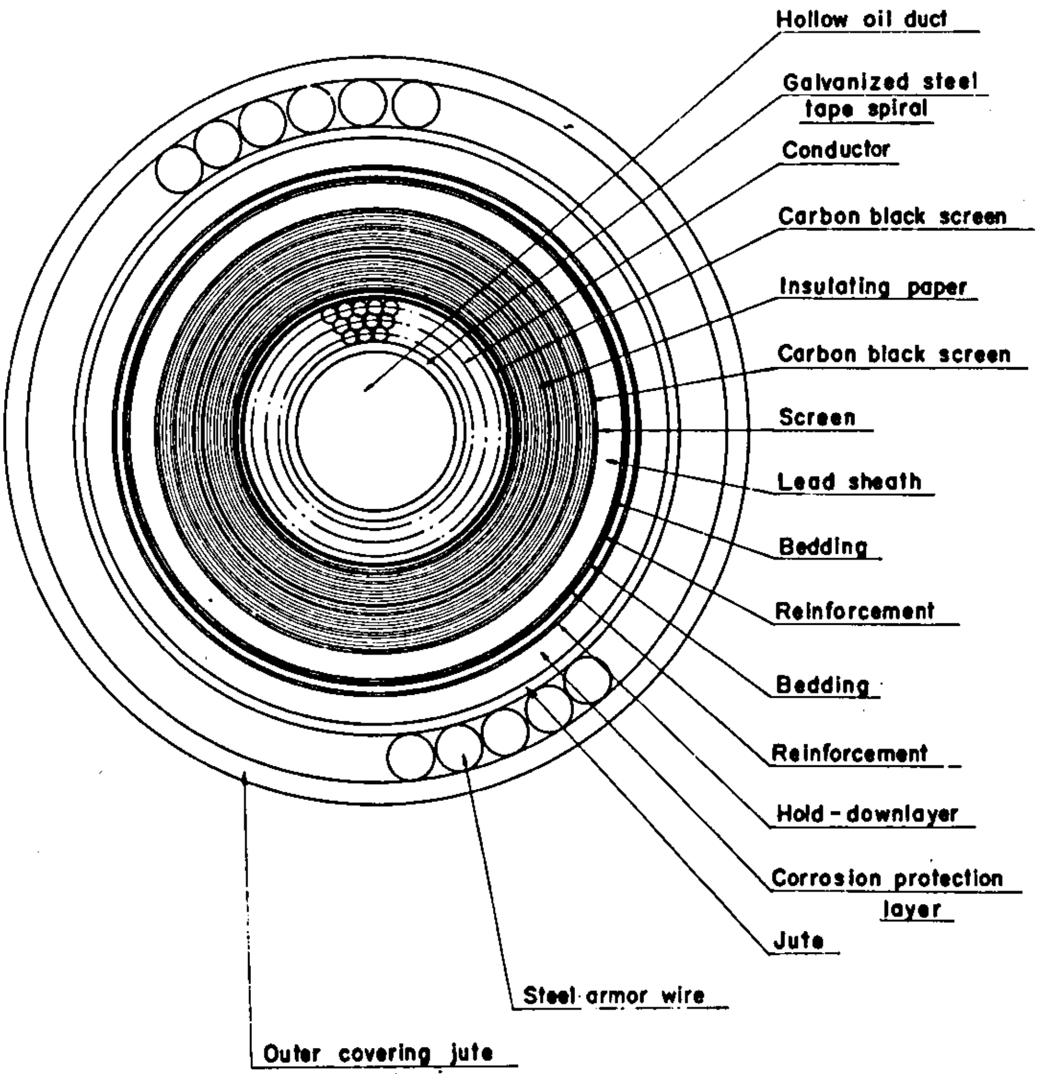
The purpose of protection of a submarine cable is to prevent damage to cable due to fishing net, anchoring and waves. Therefore, concrete method of protection will be determined based on the result of detailed investigation of the sea bottom conditions, but the following is assumed in the report.

The cables in the water depth to about 50 m from the sea level will be buried under the sea bottom mainly by jet burying process. Of this section at each end of the cables, protective tubes made of cast iron will be attached to the cables to the section of water depth up to about 20 m from the sea level. As the shallow sections near both islands have developed coral reefs, trenches will be excavated in advance by using a machine, cables will be laid in these trenches and then cables will be covered up by using sand bags or concrete.

Table 7-1 Construction of OF Submarine Cable

Conductor	Nominal cross-sectional area	mm^2	600
	Outer diameter	mm	42.4
Hollow oil duct	Inner diameter	mm	25
	Steel tape thickness	mm	1.5
Inner-carbon black screen layer		mm	0.3
Insulation layer		mm	22.0
Outer-carbon black screen layer		mm	0.15
Lead sheath thickness		mm	4.5
Reinforcement layer		mm	1.0
Corrosion protection layer		mm	4.5
Outer-bedding layer		mm	1.5
Steel armor wire		mm	8.0
Outer covering jute		mm	4.75
Finished outer diameter		mm	142
Approximate weight		kg/m	57

Fig. 7-3 Cross Section of Submarine Cable
Leyte-Mindanao Power Transmission Project



f) Cable terminals

A cable end box and its stand, oil feeding equipment and a tower for outgoing overhead transmission lines will be installed at each cable terminal. In addition, a lightning arrester for protection of cables will also be installed. Telecommunication lines are also required, and solar cells and storage batteries will be installed, and distribution lines will put up for supplying power.

A proposed layout of a cable terminal is shown in Fig. 7-4.

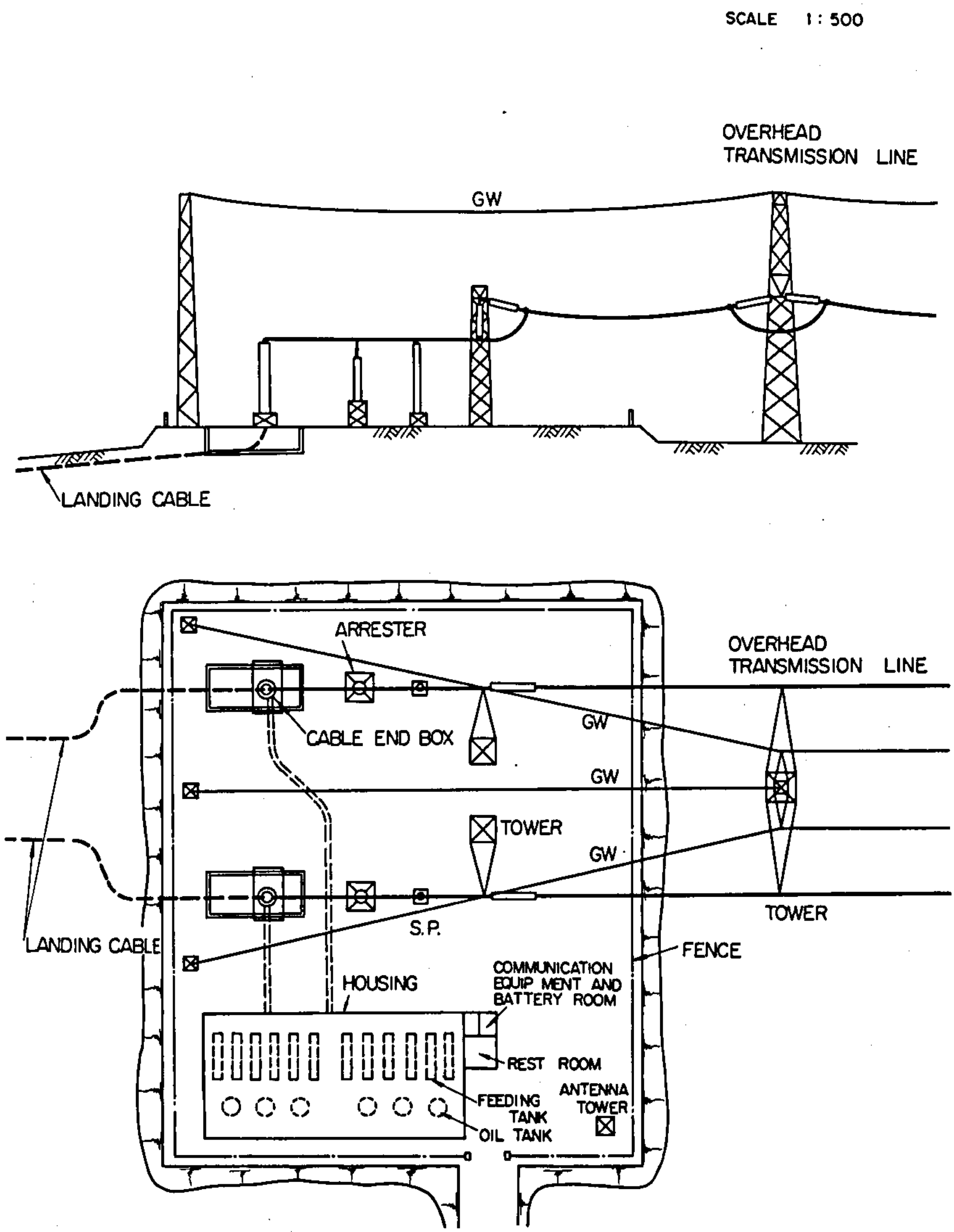
g) Cable laying work

It is desirable that laying of submarine cables is executed in April - June in which oceanic conditions are most stable. According to the time schedule for the project, the laying work will be executed in April - June in which oceanic conditions are likewise relatively stable, and preparatory civil works and works for cable terminal will be executed in advance for several months. After completion of cable laying work, cable protection work and other related activities will be executed in the succeeding months.

(2) Outline of facilities of submarine cables

Length and max. depth	Surigao strait	33 km, 200 m
	Hinatuan Passage	16 km, 70 m
Voltage	DC ±350 kV	
Submarine cables	$600\ mm^2$ single core OF cable (lead sheathed/ 8 mm dia. steel wire single layer armored)	
Number of cables to be laid	2 cables	
Protection	Burial under sea bottom, mounting of protection tube	
Cable terminals	Cable end boxes, its stands, steel towers for outgoing transmission line, lightning arresters	

Fig. 7-4 Cable Terminal Arrangement



7.4 Grounding Electrodes and Electrode Lines

7.4.1 Influence by earth return circuit operation

The DC power transmission lines of this project constitute the inter tie of large capacity power transmission. From the standpoint of reliability, therefore, it was decided to employ bipolar single circuit power transmission and neutral point both ends grounding system, as already described in 5.2.2.

This system is such that grounding is made by electrodes installed near the HVDC substations located at both ends of power transmission lines, and normally, only unbalance current of a few percent or less flows to the earth because of unbalance of impedance of converter transformers on plus and minus polarity and also control angle.

On occurrence of a fault with one pole, it is possible to transmit half electric power through the earth return circuit by making use of the other pole. In this case, however, it is necessary to thoroughly examine electrolytic corrosion to buried metal articles, and the influence over magnetic ompass, telecommunication lines and so forth due to current that flows to the earth or seawater.

Electrolytic corrosion to buried metal articles, and influence over telecommunication circuits and so forth is what should be thoroughly considered in the stage of selection of points for grounding electrodes.

The influence over magnetic compass is a phenomenon making compass error on the ships which use magnetic compass for navigation.

The influence over the magnetic compass depends on whether the ship is provided with magnetic compass or not, magnitude of DC current, depth of cables in the water, cable laying direction and cable laying interval.

The magnetic compass error caused by DC current (590 A) of submarine cables to be laid across the Surigao strait and Hinatuan passage are accordingly a rough estimate, about 1 degree on the sea surface during bipolar or single pole earth return circuit operation in the case where cable laying interval is 100 m, depth of cables in the water is 100 m. Though it's estimate value seems to be neglegible for ship navigation, thorough care should be taken in the selection of the submarine cable route and in the decision of laying interval. In addition, it is necessary to investigate the situation of use of magnetic compasses by ships, adjustment with relevant governmental organizations and so forth.

7.4.2 Grounding electrodes and electrode lines

(1) Selection of sites of installation of grounding electrodes and of route of electrode lines

a) Principle for selection

Grounding electrodes may be installed on the land, at the beach or in the sea, but places of installation should be determined upon synthetic examination of economy, ease of execution of installation work, management and maintenance of equipment and so forth. If a grounding electrode is installed at the beach or in the sea, influence exerted over other facilities and equipment is minor and it is possible to install it compactly in a small space. In the case of a HVDC substation located near the sea, therefore, the grounding electrode is usually installed at the beach or in the sea.

The main items to be investigated are earth resistivity, moisture content of soil, buried metal articles, possibility of access of men and animals, distance to HVDC substation and transportation of material.

b) Selection of sites of installation of grounding electrodes and of routes of grounding electrode lines

The places of installation of grounding electrodes were at first roughly determined through topographical maps and marine charts and then proposed sites were investigated through exploration and observation from helicopter.

As both of Jaro and Butuan at which construction of HVDC substations is planned in this project are relatively close to the sea, investigations were made with the point laid on the beach because of the reasons stated above. Points at which investigations were made in Carigara Bay and Butuan Bay are shown in Fig. 7-5.

i) Managasnas electrodes (Jaro HVDC S/S side)

Managasnas area located along the west coast of Cariga Bay was selected as the proposed site for the installation of grounding electrodes. As this place is shallow and the coastline is used as a passage for local residents, which are situations unsuitable for a place for installation of grounding electrodes, it is necessary to design the electrode with these situations taken into account.

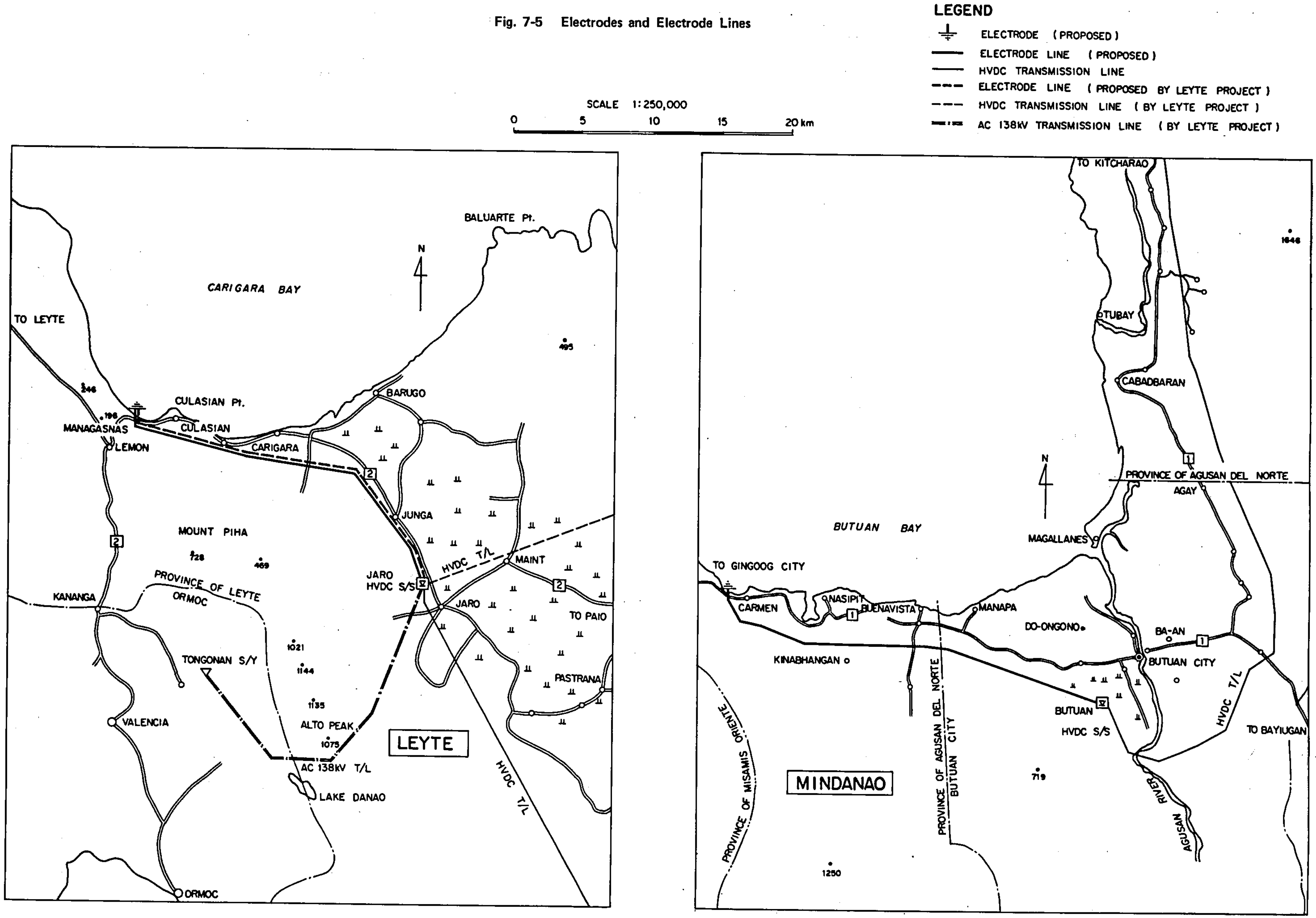
ii) Carmen electrodes (Butuan HVDC S/S side)

A place that is located in a distance of about 20 km on the west side of Butuan was selected as proposed sites for installation of the grounding electrodes on Butuan HVDC substation side.

As this place is also shallow, it is necessary to design the electrode with this situation taken into account.

The routes of electrode lines should be between these places of installation of grounding electrodes and HVDC substations along the road as much as possible. Although the places stated above were selected in the present stage for installation of grounding electrodes, detailed investigations regarding earth resistivity, coastline topography and so forth should be done and then places of installation of grounding electrodes should be decided finally.

Fig. 7-5 Electrodes and Electrode Lines



(2) Preliminary design of grounding electrodes and grounding electrode lines

a) Grounding electrodes

For grounding electrodes installed at the beach or in the sea, corrosion resistance of the electrode itself, relative ease of maintenance and replacement, influence over fishing are important items.

Although various materials are available for electrodes, graphite which is of relatively good corrosion resistance and is of relatively low cost was selected. Configuration of the electrode will be of bar structure of about 10 cm (diameter) × about 2 m (length) with the surface current density taken into account. It is assumed that a current of 50 A is fed to each electrode, and 12 electrodes (load current 590 A) will be used at one place. The configuration of these electrodes is shown in Fig. 7-6.

In case of both electrodes, the shoreline of those site are used as the passageway for traffic of local residents and it is of shoaling topography as already described, electrodes will be installed at a place of the water depth of about 4 m that is located off the waterfront by about 300 m.

Cases made of concrete and containing several electrodes will be arranged in a circular form so that the current distribution will become uniform. Connection between these electrodes and the electrode line terminal on the land will be made by means of submarine cables.

These concrete cases will be buried by using concrete block and/or tetra pods to avoid damage due to the strong wave. But it is necessary that they are of a structure that makes free entry of seawater. Fences will be installed around the entire area in which electrodes are installed, for protection of men and fishes.

b) Outline of preliminary design of grounding electrode line

ACSR 240 mm^2, 2-conductors will be used for matching DC current of 590 A and with power loss taken into account.

The number of insulators will be two 250 mm fog-type insulators (with zinc sleeve) for voltage drop due to grounding current.

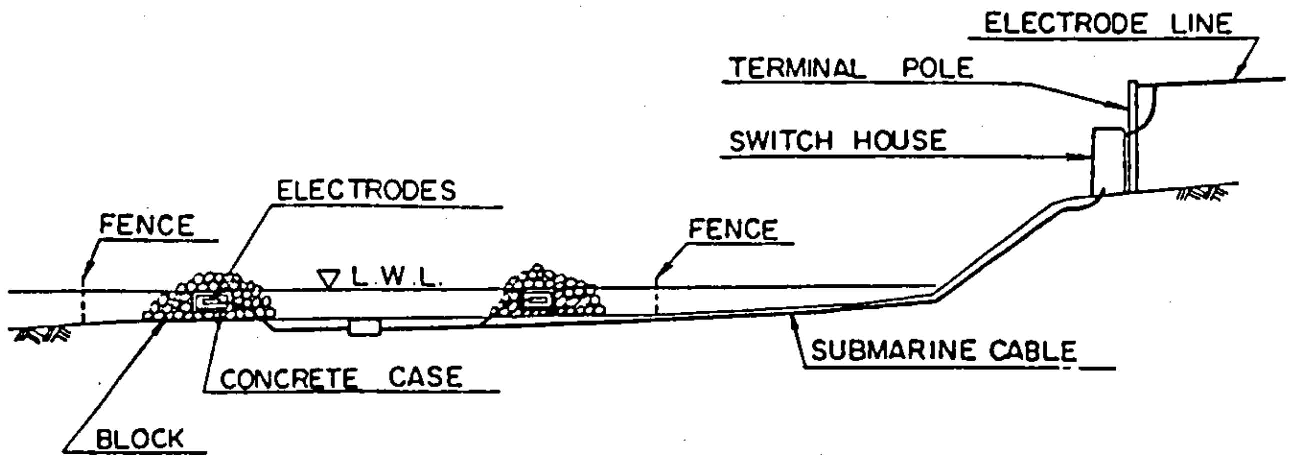
The supports are steel post and wooden pole. Wooden pole will be used from the standpoint of electrolytic corrosion in the section of several kilometers from grounding electrodes.

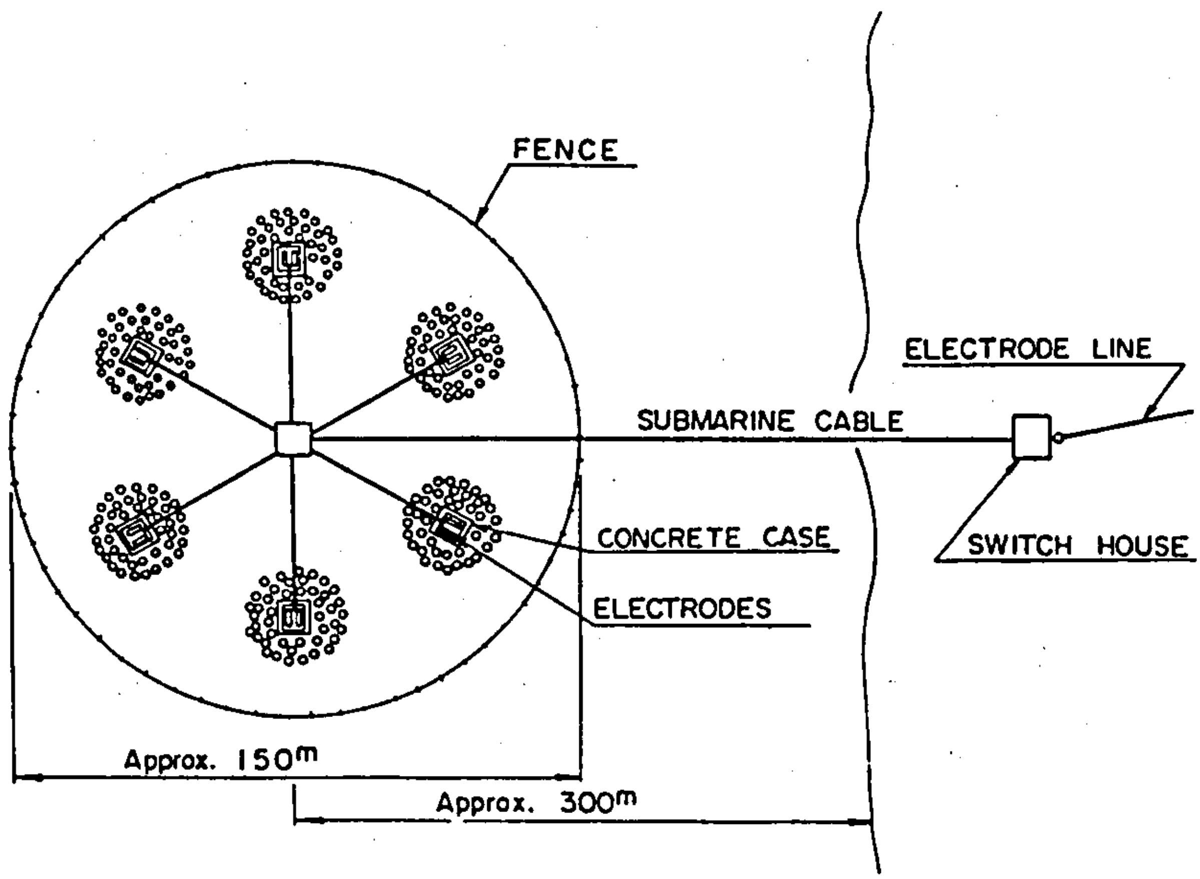
c) Outline of facilities of grounding electrodes and grounding electrode lines

Site of grounding electrodes

Jaro HVDC S/S:	Managasnas (Carigara Bay)
Butuan HVDC S/S:	Carmen (Butuan Bay)

Fig. 7-6 Electrode Arrangement





Length

Jaro HVDC S/S - Managasnas electrode: 28 km

Butuan HVDC S/S - Carmen electrode: 30 km

Conductor

240 mm^2 ACSR, 2 conductors

Insulators

250 mm fog-type insulator (with zinc sleeve)
two pieces

Supports

Steel pole and wooden pole

7.5 HVDC Substation

7.5.1 Applicable standards

AC equipment; ANSI

DC equipment (Thyristor valves); IEC

7.5.2 Meteorological conditions

		Butuan	Jaro
(1)	Altitude	Less than 1000 m	Less than 1000 m
(2)	Maximum temperature	40°C	40°C
(3)	Maximum wind velocity	40 m/sec	40 m/sec
(4)	Maximum air cleanliness	Clean	Clean
(5)	Pollution	0.03 mg/cm^2	0.01 mg/cm^2
(6)	Earthquake (acceleration)	0.3 G	0.2 G

(Dynamic design to be applied to thyristor valve)

7.5.3 Target value of availabity

The target value of availabity should be set on the basis of the Luzon-Leyte HVDC power transmission project.

7.5.4 Conditions for AC interconnection of the systems (Butuan and Jaro HVDC substations)

(1) Fluctuation of frequency (target value)

60 Hz ±0.3 Hz continuous

- 1.5 Hz during one minute

(2) Fluctuation of voltage at the HVDC substations (target value)

138 kV ±5%

7.5.5 Preliminary design of the HVDC substation

The preliminary single line diagram of the Luzon-Leyte-Mindanao DC 3-terminal system (Butuan HVDC substation only) is shown in Fig. 7-7.

(1) Rating of the facilities

First stage

DC +350 kV, 570 A (200 MW)

Monopolar configuration, metallic return mode

Second stage

DC ±350 kV, 570 A (400 MW)

Bipolar configuration

(2) Thyristor valve operation

The system will undergo 12-phase operation, with possibility of both rectifier and inverter operation modes. Therefore, the thyristor valves will be equipped with polarity reversing switch at the DC side of the thyristor valves.

(3) Basic control method

Constant-current control (with constant power compensation) will be used both in the inverter and rectifier operations.

(4) Principal facilities

a) Thyristor valve

Principal equipment for AC/DC conversion

- Two groups for each pole
- The insulation level should be determined by taking into consideration the connection of both valve groups with the DC 350 kV circuit because they will undergo both inverter and rectifier operations.
- The indoor-type air insulation and air-cooling system are recommended for the valves.

b) Converter transformer

This transformer has two function, i.e., to transform the primary AC voltage into the secondary voltage required for the thyristor valve to generate the rated DC voltage and to make the insulation between the AC and DC sides.

- These transformers per pole have 2-group composition in the same way as the thyristor valves, and the secondary winding have star and delta connections, respectively. This configuration makes possible a phase difference of 30 degrees, which reduces the generation of harmonics with 12-phase operation.
- Maximum insulation level is required at the secondary winding of both groups.
- As for the rated secondary winding voltage, the value prevailing in the case of inverter operation is adopted, unlike in the case of the 2-terminal power transmission.

In other words, constant-current control is carried out in the case of inverter operation of the Butuan HVDC S/S, but the control angle is selected in such a way to prevent commutation failure caused by fluctuations of AC voltage at steady state and fluctuations of DC & AC voltage during transient operation. This angle is of the order of 25°

to 30° or further larger in some cases. Therefore, in the case of generating DC voltage close to the rated one, it is necessary to set the rated secondary winding voltage at a value higher than that one of the rectifier operation.

The secondary winding voltage rating exerts influence not only on the transformer capacity rating, but also on the design of the valve insulation, filter and reactive power supply equipment. Therefore, the secondary winding voltage should be determined with particular care.

c) DC reactor

DC reactors are installed to decrease the ripple of DC current and to limit the fault current.

- The value of the DC reactor is determined by taking into consideration the minimum continuous operation current of the DC system, the resonance at the vicinity of the basic frequency, the limit of the commutation failure current, etc.

d) AC & DC filter

The AC & DC filters are installed to absorb the harmonic voltage and current generated concurrently with the AC/DC conversion.

- HP filter is installed at the DC side and 11, 13, HP filter is installed at the AC side, because the system is operated with 12 phases.

- The AC filter becomes a condensive reactive power source for the fundamental wave.

e) Reactive power supply equipment

The static condenser equipment is installed with the purpose of supplying inductive reactive power consumed during the operation.

- In the first stage this reactive power is supplied by the static condenser and AC filter and in the second stage it is supplied by the filter and by the synchronous rotary condenser installed to stabilize the operation of the system.

7.5.6 Layout of the HVDC substation

The layout of the Butuan HVDC substation is shown in the Fig. 7-8.

The site required to construct including the second stage (last stage) is 180 m ± 195 m = 35,100 m^2, but this area can be obtained by making some embankment at the planned site.

Fig. 7-7 Single Line Diagram (Preliminary)
(Three Terminal HVDC Transmission)

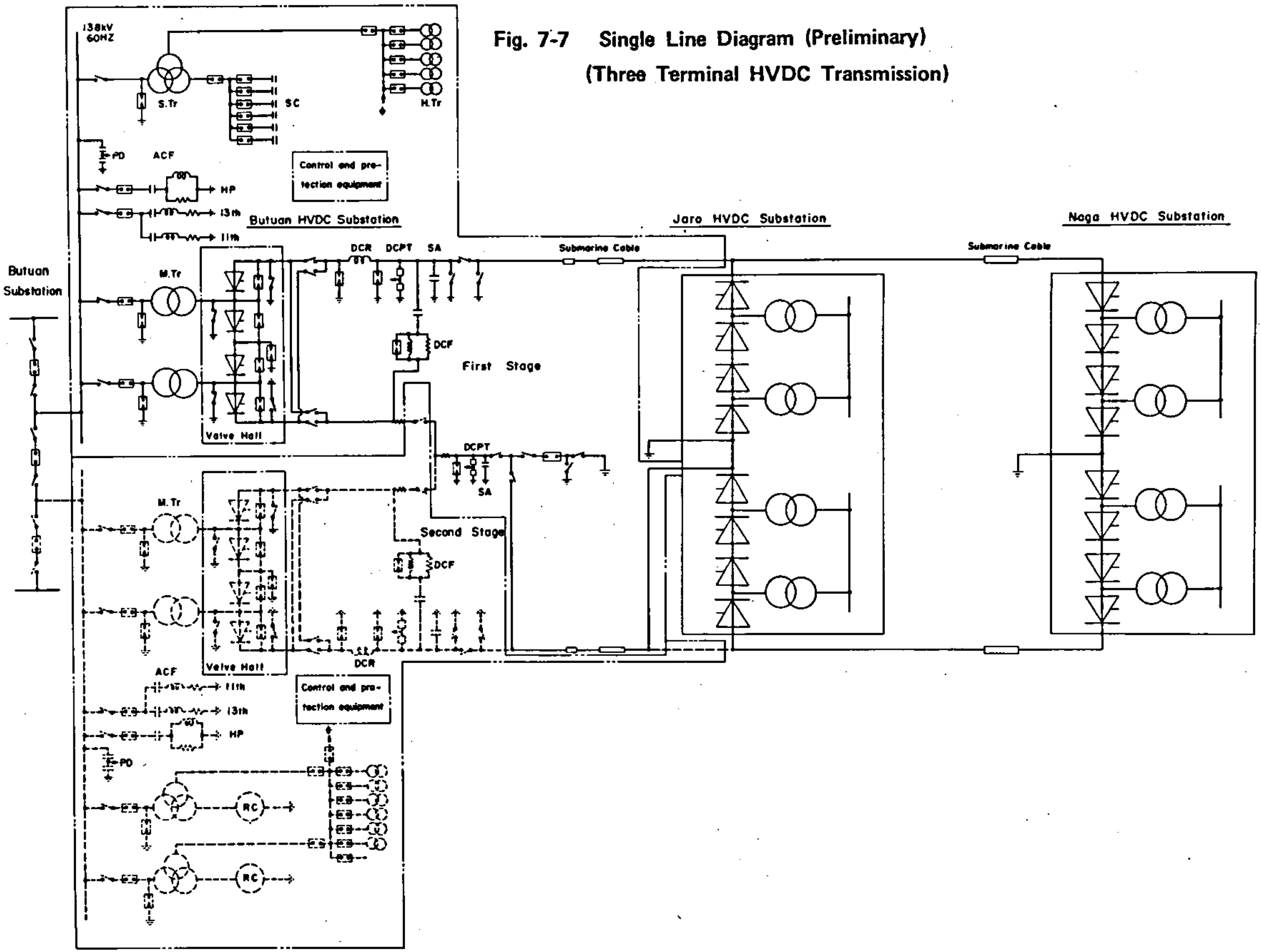


Fig. 7-8 Layout of Butuan HVDC Substation (Preliminary)

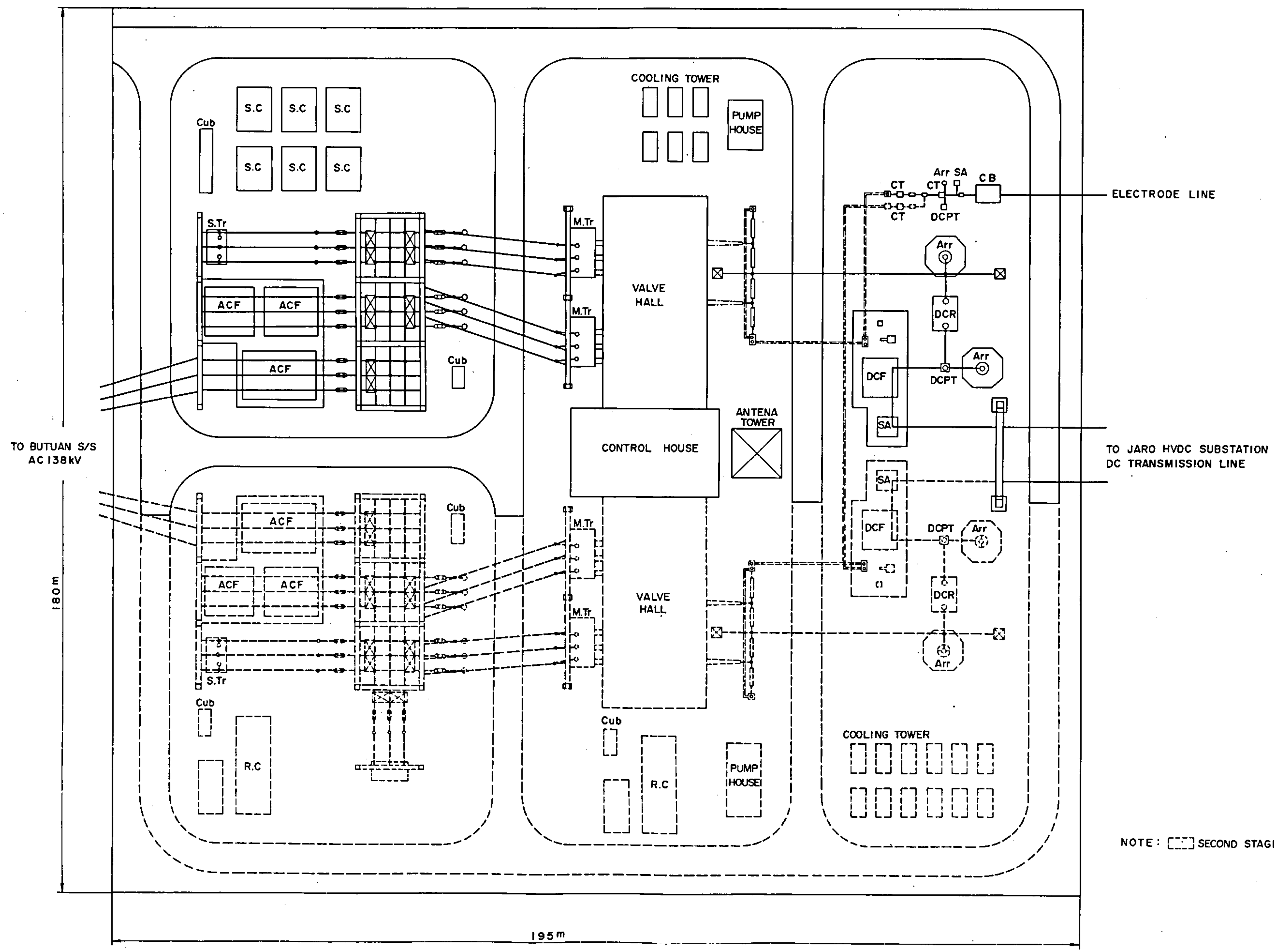
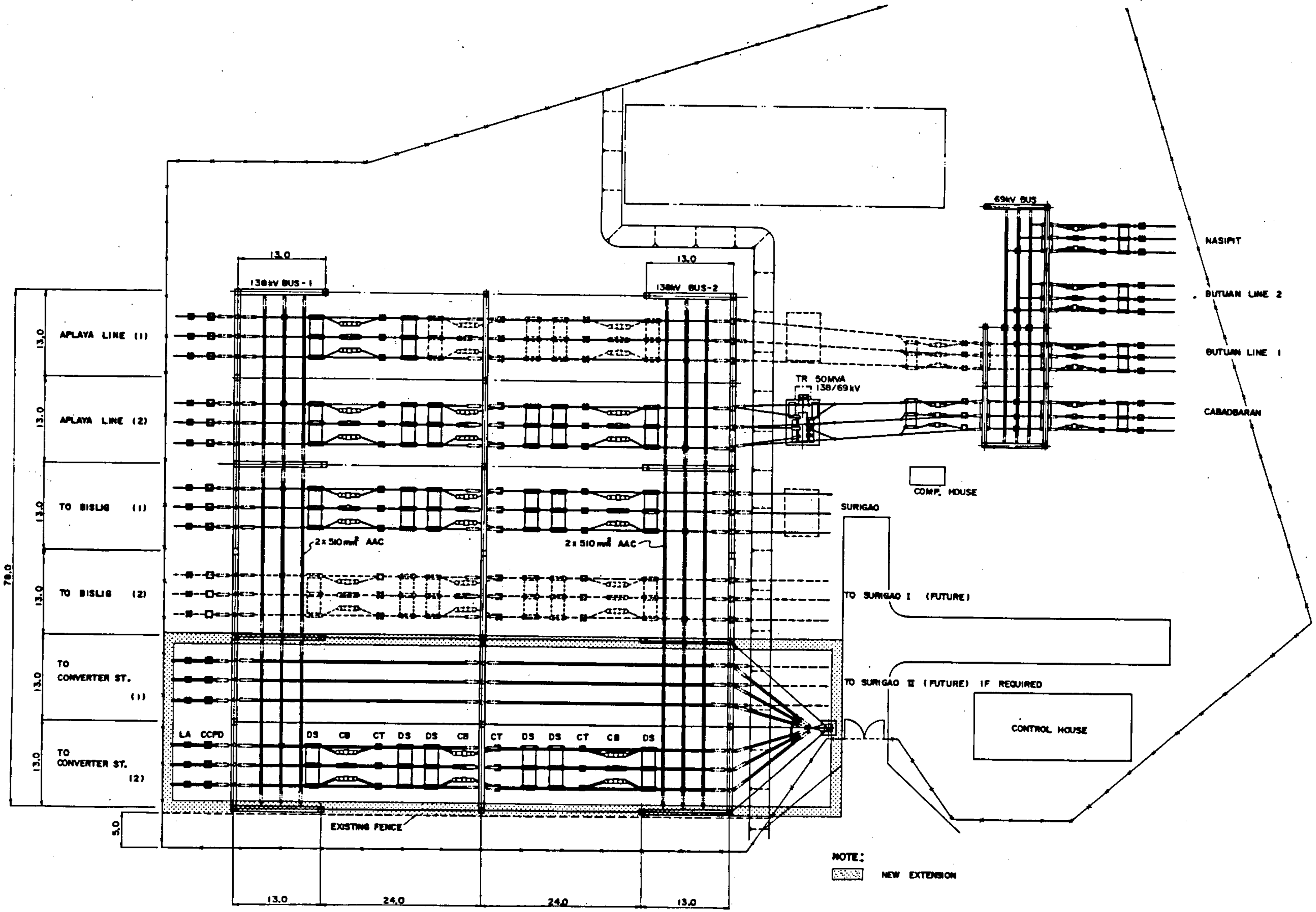


FIGURE 7-9 LAYOUT OF BUTUAN SUBSTATION (TENTATIVE)



7.6 Related Substation

The 400 MW power from Tongonan in Leyte received at the converter station at Butuan will be transformed from DC ±350 kV to AC 138 kV and connected to the bus of the existing Butuan substation. For this purpose, two bays of the 138 kV busses are to be extended toward the east in the direction to the access road to the substation. The existing concrete boundary wall is to be shifted by at least 5 m toward the road and the drain ditch is also to be shifted.

The rated current rating of the related switchgear is selected at 2,000 A taking into account the transmission of full 400 MW power. The existing bus conductors are duplex AAC 795 MCM, but these conductors are to be replaced with duplex conductors of duplex AAC 510 mm^2 considering the required current capacity. The rated current rating of the existing facilities is assumed to become insufficient in the future. This is to be reviewed in the detailed design stage.

By the time when the Leyte power is transmitted, the transmission line between Butuan and Davao via Bislig is to be double-circuited. However, this idea have already been planned by NAPOCOR.

Layout of the extended portion of Butuan Substation is as shown in Fig. 7-9.

7.7 Telecommunication System

The construction of the HVDC transmission system will be executed as devided into the first stage and the second stage, and the most part of telecommunication equipment will be in common use for the HVDC system consisting of two stages. Therefore the principal telecommunication equipment should be entirely completed at the first stage construction.

7.7.1 Design conditions

Telecommunication equipment of this project is designed under the following conditions:

(1) Microwave radio equipment

a) Frequency band used

As for the frequency band, 2 GHz band is adopted in this study by taking into consideration related existing equipment, meteorological conditions etc., but the frequency band should be selected at finally so as to be in accord with that of the Luzon-Leyte project.

b) Circuit reliability

Circuit unavailability assigned to the microwave circuit should be less than 5×10^{-5} as a target value.

c) Diversity reception system

Diversity reception systems will be provided for the propagation paths where required path reliabilities are not obtainable.

d) Transmission quality

As the microwave circuit is to consist of a part of a long distance microwave trunk line, the recommendation of the International Consultative Committee for Radio (Organized under the auspices of ITV, International Telecommunications Union), CCIR Rec. 395-2 should be applied as a quality objective.

e) Transmission capacity

Taking account of future extension, transmission capacity of 300 CH is required.

f) Selection for the sites of repeater stations

In this study the sites of repeater stations were selected on the map by means of desk plan based on the rough field surveys. For final selection of sites, however, it is necessary to carry out more detailed field surveys regarding topology, road conditions, path profile and so forth.

(2) Information transmission equipment for control and protection

a) Transmission speed

Transmission speed of 42 kb/s is selected, because high speed transmission is required for control and protection signals.

b) Redundant system

A dual system is to be provided for transmission between both HVDC substations, because particularly high reliability is required.

(3) Information transmission equipment for supervision

Although high transmission speed of signals is not particularly required, high reliability is required between both HVDC substations. Therefore, a dual system of transmission speed of 1,200 bit/s will be installed, at each HVDC S/S.

For the information transmission system between Butuan HVDC S/S and Butuan Substation, single system for low speed of 200 bit/s will be provided.

(4) Optical communication equipment
(For Butuan HVDC S/S and Butuan Substation)

Optical communication equipment of which, bit error rate of transmission circuit is less than 1×10^{-7}, transmission capacity is six channels, transmission speed of digital carrier is 386 kb/s will be provided at both HVDC stations.

(5) Telecommunication equipment for cable head stations

A VHF circuit for maintenance telephone and monitoring at each cable head station is provided by means of simple radio system because this system can be supplied by solar energy system which is the most economical system. The frequency band is possibly 70 MHz and speech system is simplex (press-talk) system. Monitoring method from the master station (Dinagat Station) to four cable head stations is polling system with the speed of 50 Band.

(6) Transmission line fault locator

Pulse rader fault locator is adopted for the section of overhead transmission line. Fault locator is not installed for the overhead transmission line on Dinagat Island.

(7) Power supply facilities for communication equipment

a) DC un-interruptible power supply system at HVDC converter stations

DC 24 V UPS equipment for radio equipment, data transmission equipment etc., and DC 48 V UPS equipment for automatic telephone exchange and paging facilities are to be installed at both HVDC substations. Battery reserve time in case of power failure should be more than five hours.

b) Solar battery power supply equipment for repeater stations.

The solar battery system is so designed as to maintain furnishing enough energy even in the worst solar radiation condition.

Battery reserve time should be more than 20 days.

7.7.2 Required equipment and specifications

Telecommunication equipment required for this project is shown in Fig. 7-10 and Table 7-2. Major specifications for these equipment are as follows:

(1) Microwave radio equipment

a) Frequency band: 2 GHz band

b) Transmitting power: 0.1 W or 0.5 W

c) Transmission capacity: 300 CH

d) Transmission system: SSB-FM

e) Redundancy system: Twin pass system

f) Type of antenna: Parabolic antenna

(2) Information transmission equipment for control and protection

a) Transmission speed: 42 kb/s

b) Signalling system: 4-phase PSK

c) Number of words

Jaro HVDC S/S to Butuan HVDC S/S : 11 Words

Butuan HVDC S/S to Jaro HVDC S/S : 11 Words

(3) Information transmission equipment for supervision

a) Transmission speed: 1,200 b/s

b) Signalling system: FS

c) Number of words

Jaro HVDC S/S to Butuan HVDC S/S : 31 Words

Butuan HVDC S/S to Jaro HVDC S/S : 31 Words

Butuan HVDC S/S to Butuan S/S : 6 Words

(4) Optical communication equipment at Butuan

a) Transmission system: Digital (PCM) system

b) Transmission speed: 386 kb/s

c) Transmission capacity: 6 CH

d) Optical fiber: quartz glass

(5) Telephone equipment

a) Telephone circuit for maintenance use

Telephone circuit among Jaro HVDC S/S, Butuan HVDC S/S and Butuan substation is provided by means of a party line telephone system.

b) Telephone circuit for load dispatching use

Telephone circuit between Jaro HVDC S/S and Butuan HVDC S/S will be provided by means of a common battery system. However, the final schem will be decided at the definite study stage.

c) Telephone circuit for administrative use

Telephone exchange equipment with capacity of 100 lines is installed at Butuan HVDC S/S.

(6) Radio equipment at cable head stations

a) Frequency band: 70 MHz band

b) Transmitting power: 1 W or 3 W

c) Speech system: simplex (press talk) system

d) Transmission capacity: 1 CH (both for telephone and monitoring)

e) Monitoring system: Polling system

(7) Transmission line fault locator

a) Type of locating: pulse rader system

b) Locating span: From Jaro to Hinundayan and from Butuan to Lipata

(8) Power supply facilities at HVDC S/S

a) 24 V power supply equipment

Battery charger: 24 V 100 A

Battery: 24 V 700 AH

b) 48 V power supply equipment

Battery charger: 48 V 30 A

Battery: 48 V 210 AH

(9) Solar battery power supply equipment

a) Solar battery: mono-crystal or poly-crystal cell

b) Output

Microwave repeater stations: 400 W

Cable head station: 50 W

c) Battery: Lead-acid battery or alkaline battery

d) Voltage and capacity of the battery

Microwave repeater station: 24 V 1000 AH

Cable head station: 12 V 300 AH

(10) Mobile service radio for maintenance of transmission line

a) Frequency band used: 150 MHz band

b) Transmitting power

Base station: 10 W

Mobile station (Vehicle): 10 W

Portable station: 1 W

(11) Paging equipment

a) Type: Wired system

b) Output power: 200 W

Fig. 7-10 Telecommunication System Diagram

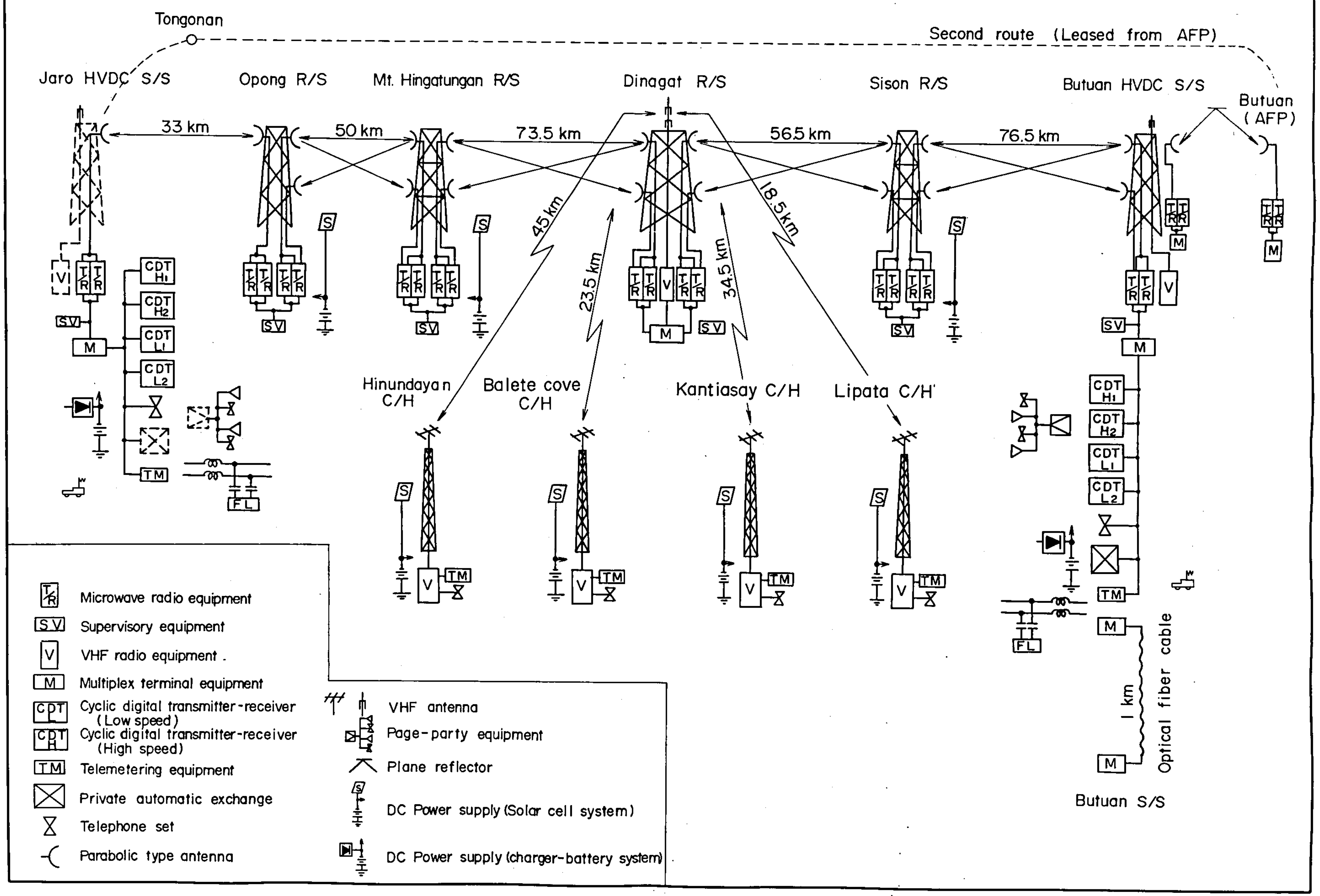


Table 7-2 Telecommunications Equipment List

Telecommunications Equipment \ Name of stations	Jaro HVDC S/S	Opong R/S	Mt. Hinga-Tungan R/S	Dinagat R/S	Hinunda-yan C/H	Balete Cove C/H	Lipata C/H	Kanti-asay C/H	Sison R/S	Butuan HVDC S/S	Butuan (AFP) R/S
Microwave radio equipment (2 T/R)	1	2	2	2					2	2	1
Multiplex terminal equipment	1			1						2	1
VHF radio equipment (Fixed station type)				1	1	1	1	1			
(Base station type)										1	
(Portable type)	10									10	
Supervisory equipment	1	1	1	1					1	1	1
Cyclid digital transmitter-receiver (High speed type)	2									2	
(Low speed type)	2									2	
Fault locator (Pulse radar type)	1									1	
Parabolic antenna (3mø)	1	2	2	2					2	2	1
(4mø)		1	2	2					2	1	
Antenna tower (20 m)					1	1	1	1			
(40 m)		1	1	1					1	1	
Repeater station building (4m × 4m)					1	1	1	1			
(4m × 6m)		1	1	1					1		
Passive reflector (6m × 8m)										1	
Automatic telephone exchange (100L)										1	
Line trap (500μH)	2									2	
Coupling capacitor (0.002μF)	2									2	
Page-party equipment Hand set 30 Loud-speaker 30										1	
Telephone set for operation work	1									1	
Charger (DC48V, 200A)	1									1	
Battery (1000AH)	1	1	1	1					1	1	
(500AH)					1	1	1	1			
Solar battery (400W)		1	1	1					1		
(50W)					1	1	1	1			
Power distribution board	1									1	
Optical fiber terminal equipment										2	
Optical fiber cable										1000m	

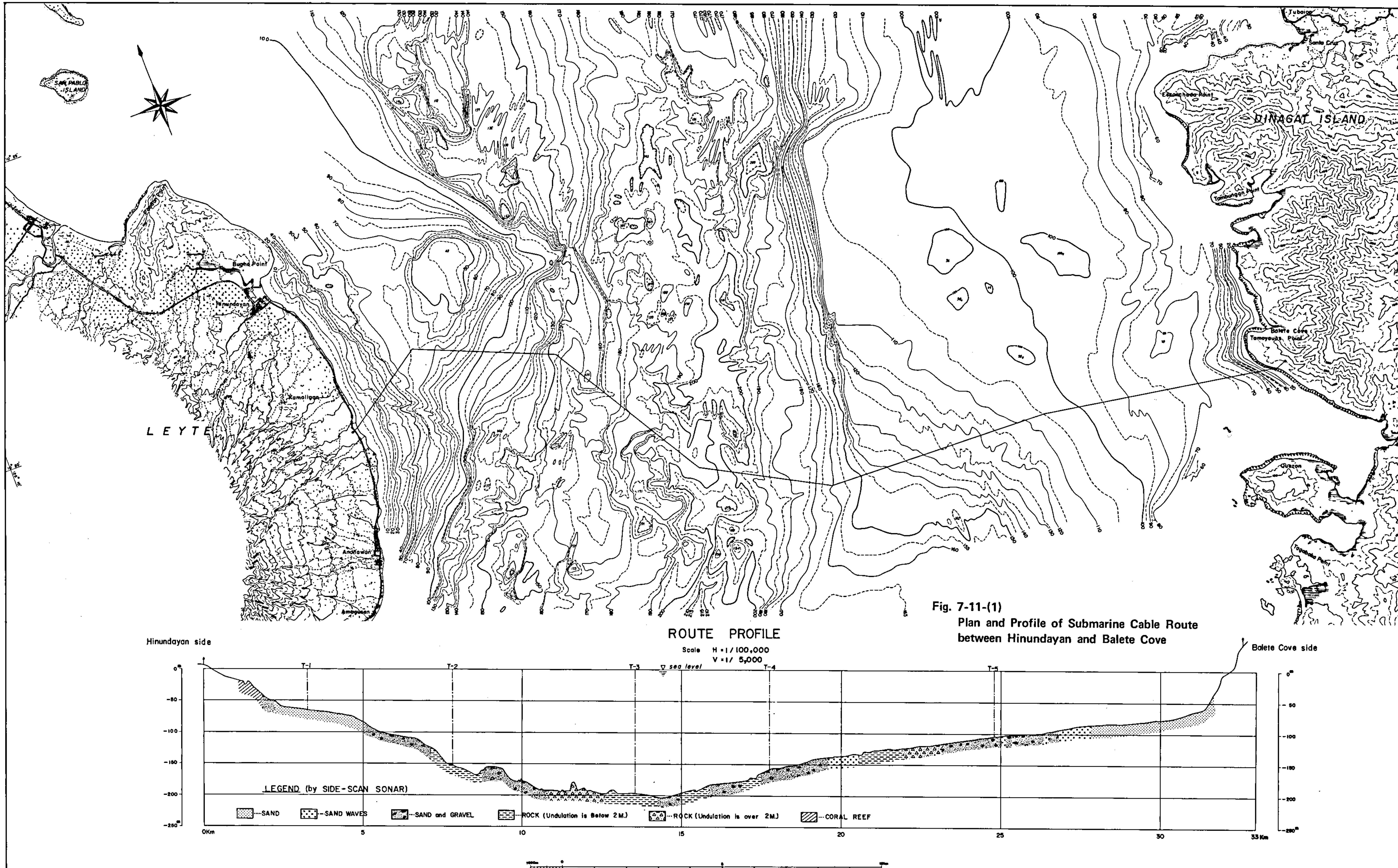


Fig. 7-11-(1)
Plan and Profile of Submarine Cable Route between Hinundayan and Balete Cove

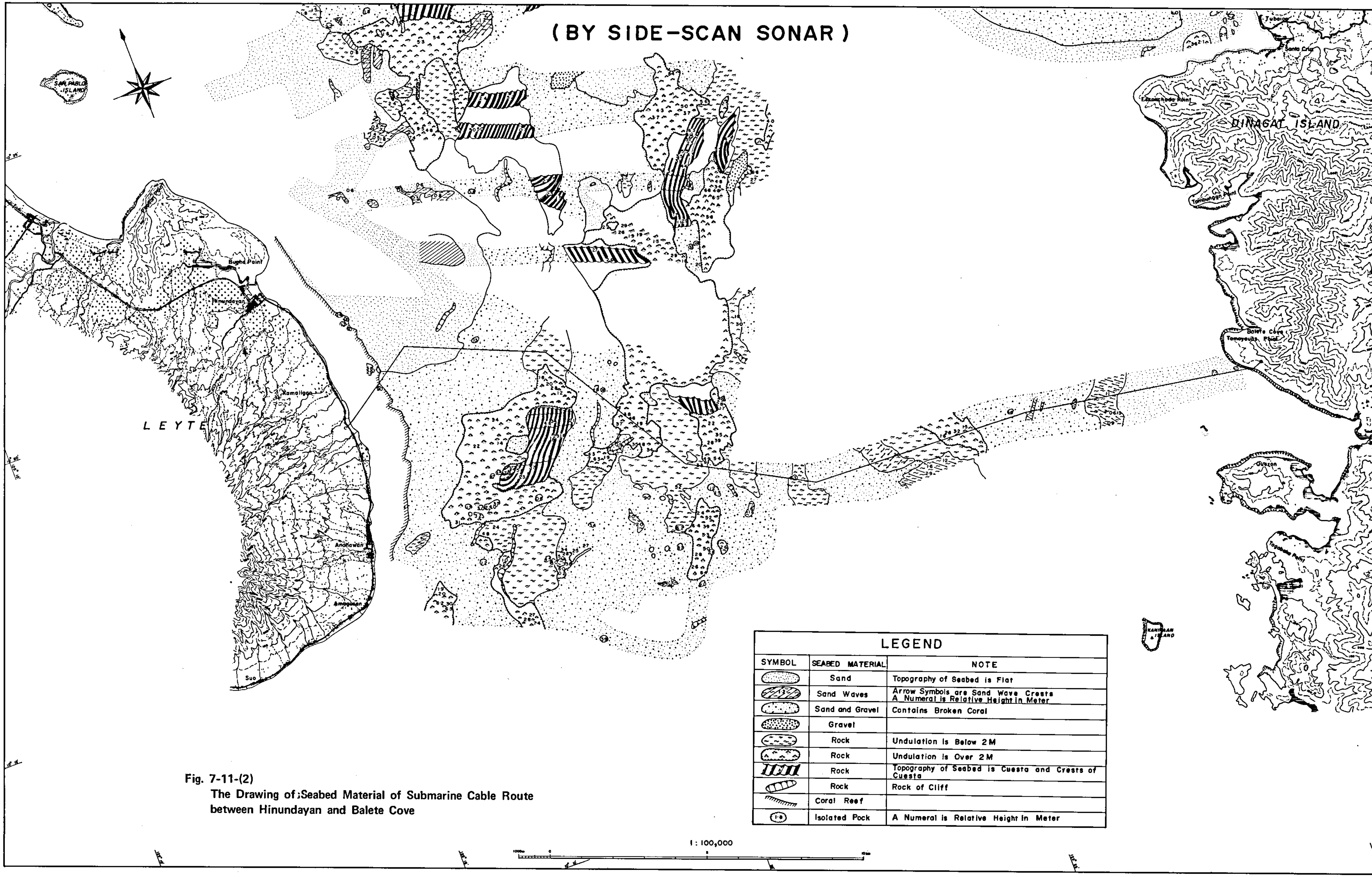


Fig. 7-11-(2)
The Drawing of ;Seabed Material of Submarine Cable Route between Hinundayan and Balete Cove

LEGEND

SYMBOL	SEABED MATERIAL	NOTE
	Sand	Topography of Seabed is Flat
	Sand Waves	Arrow Symbols are Sand Wave Crests A Numeral is Relative Height in Meter
	Sand and Gravel	Contains Broken Coral
	Gravel	
	Rock	Undulation is Below 2M
	Rock	Undulation is Over 2M
	Rock	Topography of Seabed is Cuesta and Crests of Cuesta
	Rock	Rock of Cliff
	Coral Reef	
1·0	Isolated Pock	A Numeral is Relative Height in Meter

Fig. 7-11-(3)
Plan of Cable Landing Points and Cable Terminal Points at Hinundayan and Balete Cove

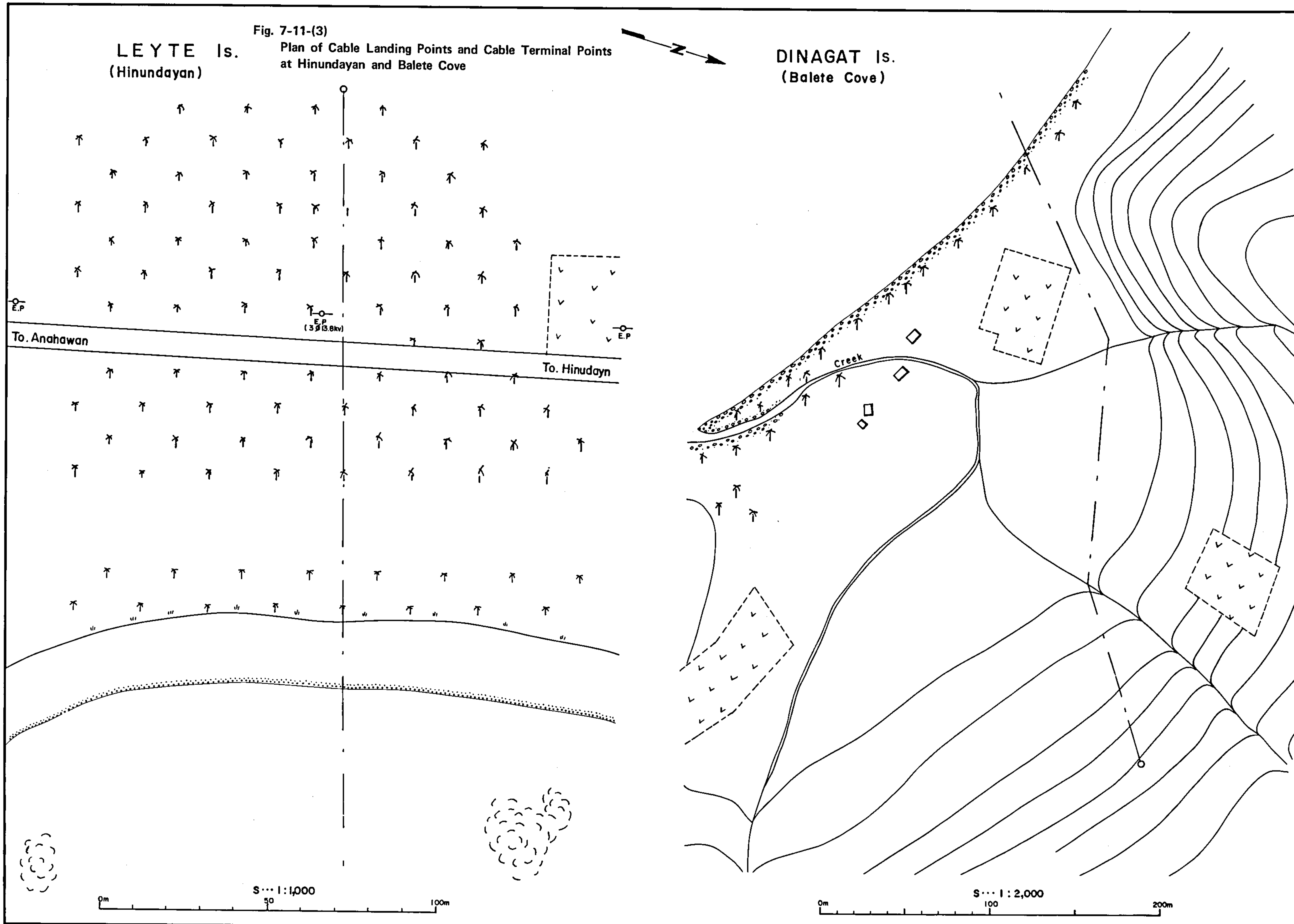


Fig. 7-12-(1)
Plan and Profile of Submarine Cable Route between Kantiasay and Lipata

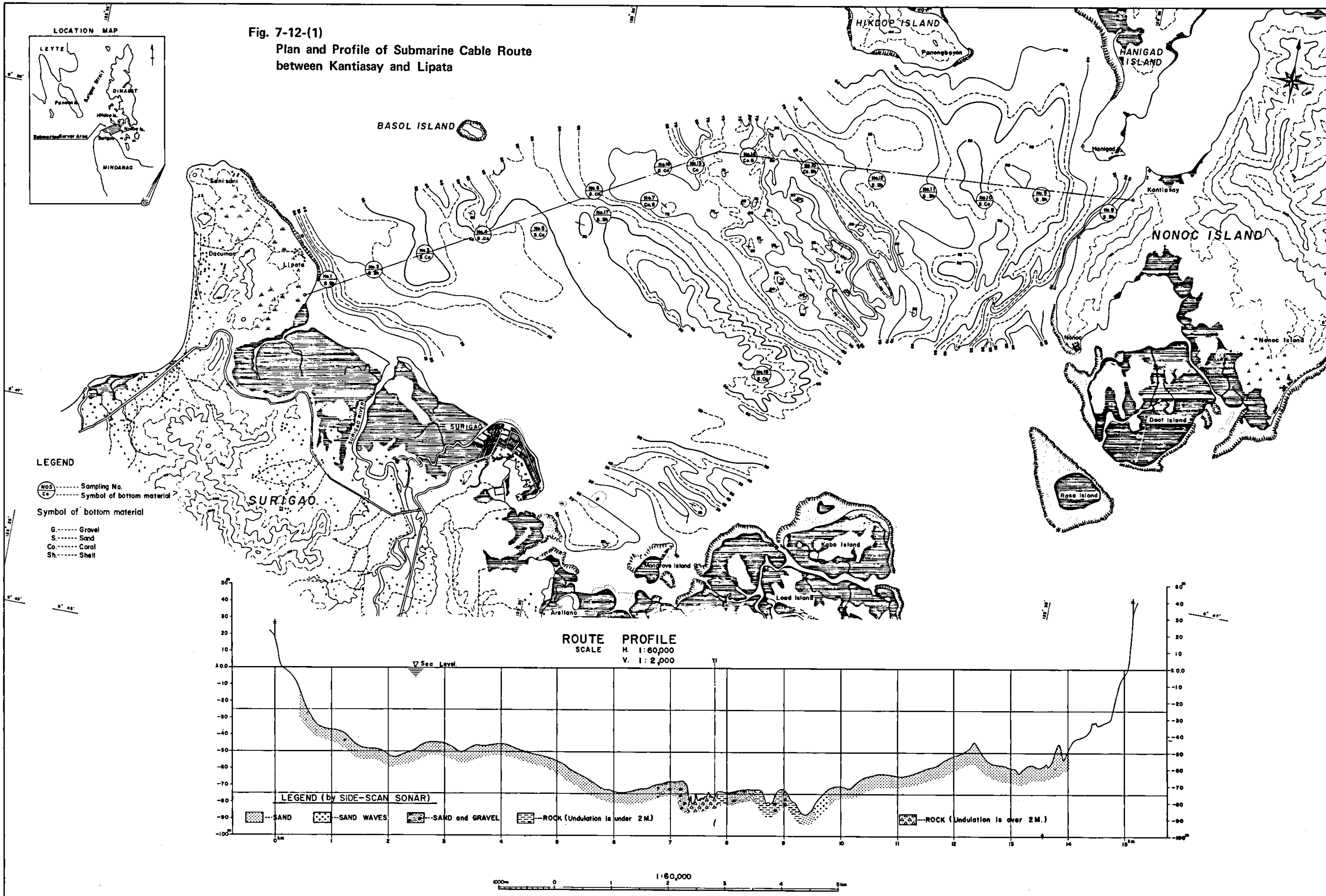
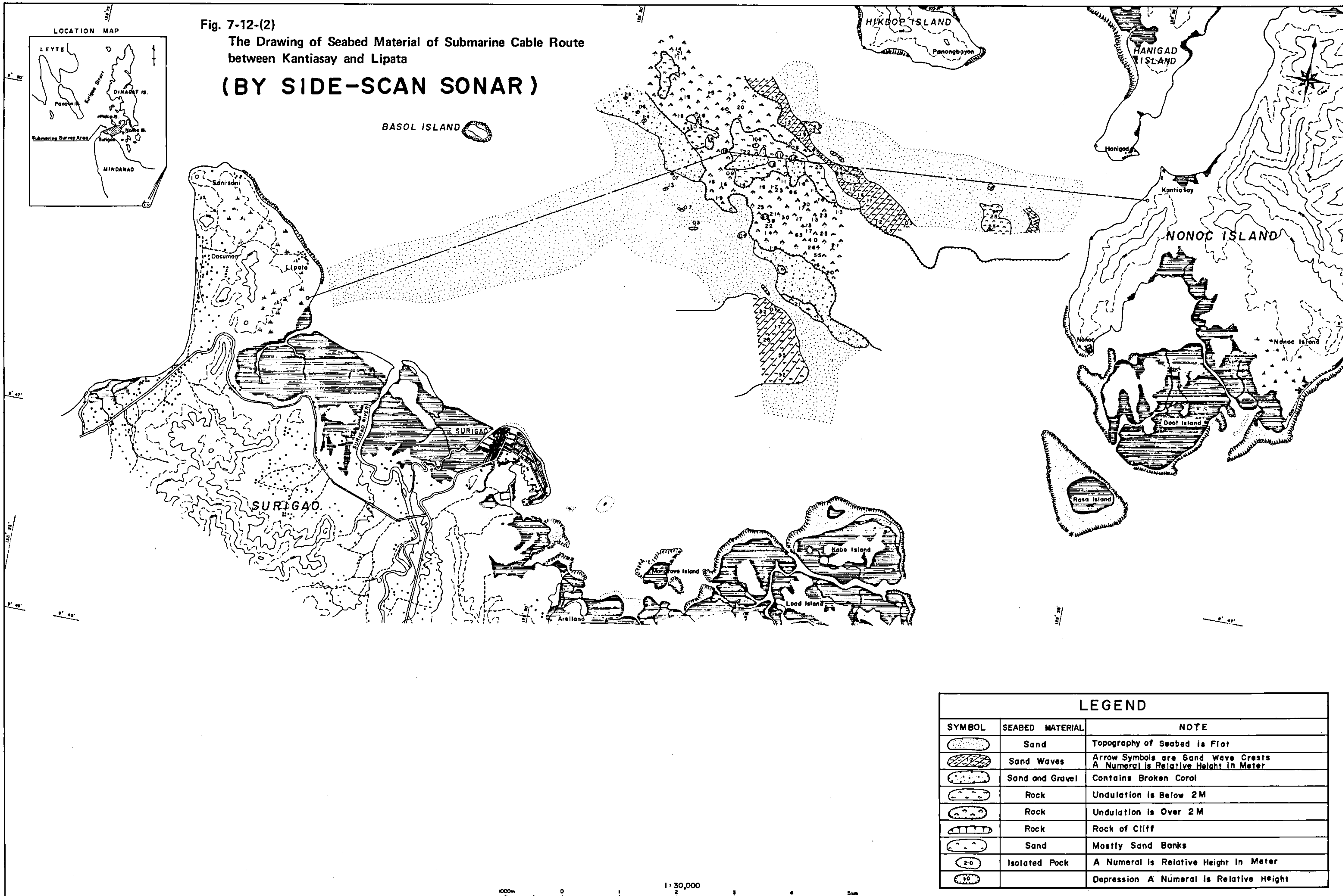


Fig. 7-12-(2)
The Drawing of Seabed Material of Submarine Cable Route between Kantiasay and Lipata

(BY SIDE-SCAN SONAR)



SYMBOL	SEABED MATERIAL	NOTE
	Sand	Topography of Seabed is Flat
	Sand Waves	Arrow Symbols are Sand Wave Crests A Numeral is Relative Height In Meter
	Sand and Gravel	Contains Broken Coral
	Rock	Undulation is Below 2M
	Rock	Undulation is Over 2M
	Rock	Rock of Cliff
	Sand	Mostly Sand Banks
2·0	Isolated Pock	A Numeral is Relative Height In Meter
1·0		Depression A Numeral is Relative Height

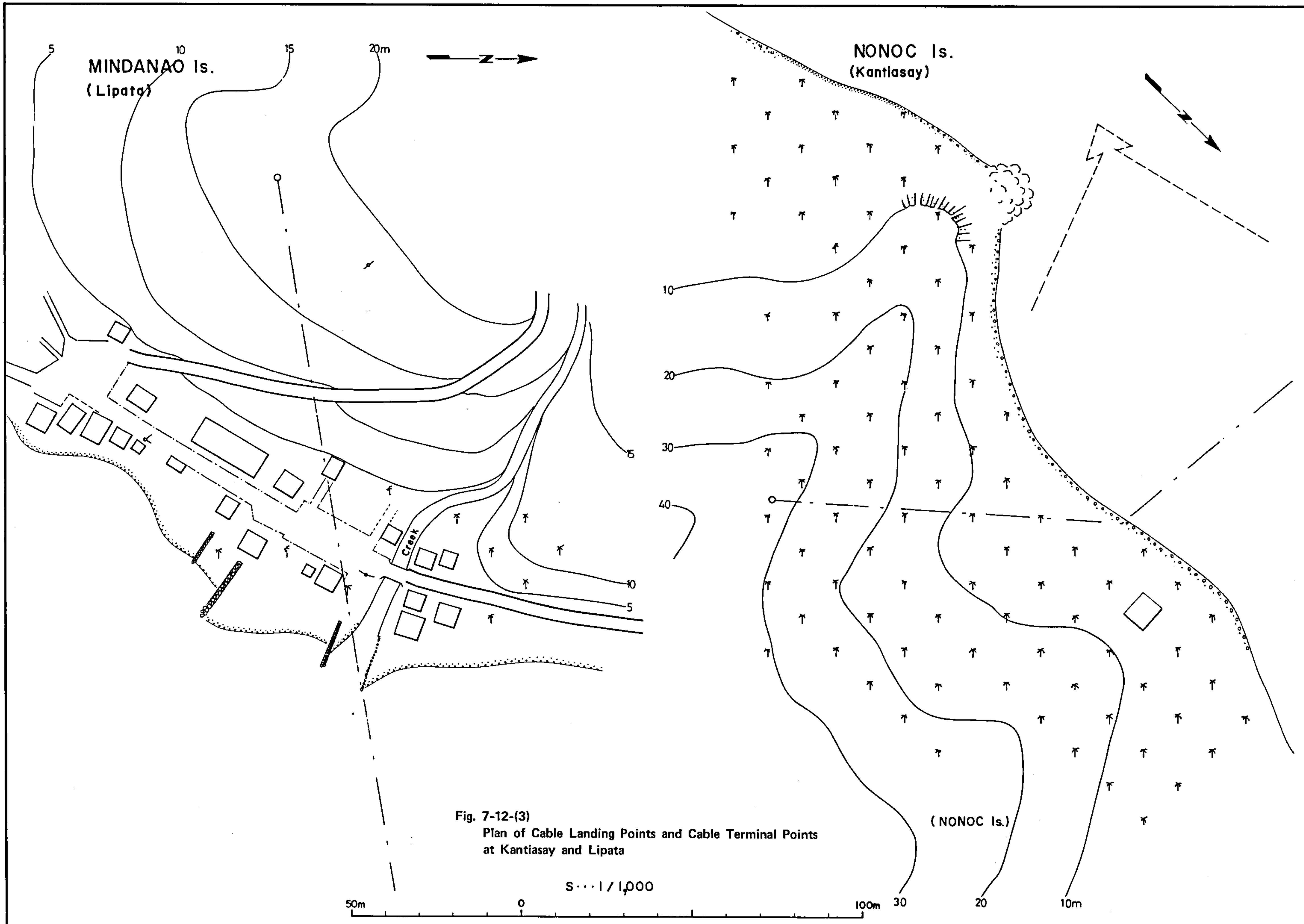


Fig. 7-12-(3)
Plan of Cable Landing Points and Cable Terminal Points at Kantiasay and Lipata

CHAPTER 8

CONSTRUCTION COST AND CONSTRUCTION SCHEDULE

CHAPTER 8 CONSTRUCTION COST AND CONSTRUCTION SCHEDULE

8.1 Construction Cost

(1) Basic premises

The construction cost is calculated on the basis of the prices prevailing in March 1983, by taking into consideration the topography, meteorology, transportation, environment, etc., related to the overhead transmission lines, submarine cables, cable terminals, HVDC S/S construction site, electrode construction sites, electrode lines, microwave repeater stations, etc.

The costs of all items that can be supplied in the Philippines are summed up in terms of domestic currency and the costs of all other items are summed up in terms of foreign currency for the sake of calculation of the cost of this project. However, the transfer costs such as taxes and charges are not included in the costs of the project.

(2) Scope of calculation of the construction cost

The scope of estimation of the construction cost is as follows. The construction cost consists of two components, i.e., the direct cost taking into consideration the work by contractors and the indirect required to execute this project. This project will be implemented by dividing it in two distinct stages and therefore the construction cost is divided accordingly.

a) Scope of estimation of the construction cost

	First stage	Second stage
DC ±350 kV overhead transmission line	293 km	—
DC ±350 kV submarine cable	49 km	—
HVDC S/S	Jaro HVDC S/S lead-out facilities Butuan HVDC S/S	Butuan HVDC S/S
AC 138 kV overhead transmission line and Butuan S/S lead-in work	1 km	1 km
Electrodes	Managasnas electrode	—
	Carmen electrode	—
Electrode line		
Managasnas	28 km	—
Carmen	30 km	—

	First stage	Second stage
Communication facilities		
Microwave base stations	2 stations	—
Microwave repeater stations	4 stations	—
VHF stations	4 stations	—

b) Cost of electric equipment, materials of transmission lines, etc.

The equipment of the HVDC substation, such as thyristor valves, transformers, filters, switches, etc., as well as the communication equipment and the materials for construction of transmission lines, such as steel towers, conductors, insulators, submarine cables, electrodes, etc., are assumed to be manufactured overseas. The CIF price costs of these imported materials and equipment are summed up in terms of foreign currency, and the costs for unloading and land transportation of these items, costs of items supplied in the local market and the installation and erection costs are summed up in terms of domestic currency. The submarine cables, HVDC S/S equipment, electrodes, communication equipment, etc., are assumed to be submitted to adjustments after their installation and the costs of technical personnel of foreign manufacturers required for this purpose as well as the costs of special materials for construction of special buildings (valve hall, control room) are calculated in terms of foreign currency. On the other hand, costs related to land formation, foundations, ordinary buildings, etc., are calculated in terms of domestic currency.

c) Costs of temporary facilities

The costs of temporary buildings, stock yards, etc., required for execution and supervision of construction work of this project are calculated in terms of domestic currency.

d) Engineering cost and administrative cost

The costs related to the detailed design (D/S) and supervision (S/V) of the consultant required to execute this project are calculated in terms of foreign currency, and the costs involved in the management of the construction work by NAPOCOR are calculated in terms of domestic currency.

e) Training cost

The costs involved in the training of NAPOCOR engineers for operation and maintenance of the HVDC system are calculated in terms of foreign currency.

f) Contingency

Contingency corresponding to 5 % of the foreign currency and 15 % of the domestic currency are included in the costs of the DC ± 350 kV overhead transmission line, submarine cable, HVDC S/S, electrodes, electrode lines, communication facilities, AC 138 kV overhead transmission lines and Butuan S/S lead-in facilities of this project.

h) Escalation of the construction cost

The time schedule for construction of this project extends over two distinct periods of time, i.e., 1988 - 1991 in the first stage and 1994 - 1996 in the second stage. The earliest construction work will be started 5 years hence and the latest construction work will be started nothing less than 13 years hence. It is extremely difficult to make an accurate forecast of the escalation of this remote future in view of the economic situation of the world and of the Philippines as things now stand. However, it was decided to adopt the following values for the sake of financial analysis of this project.

Unit: % p.a.

	1983	1984	1985	1986	1987-96
Local currency portion	14.0	24.0	18.0	12.0	8.0
Foreign currency portion	4.0	3.75	3.5	3.0	3.0

(3) Total construction and annual construction cost

The construction costs in terms of prices prevailing in 1983, calculated by taking into consideration the construction schedule of the first and second stages and the premises for estimation of the construction cost, is as follows.

Unit: US$1,000

	Foreign currency	Domestic currency	Total
First stage	122,637	33,498	156,135
Second stage	32,677	7,636	40,313
Total	155,314	41,134	196,448

The period of construction of this project is 4 years in the first stage and 3 years in the second stage and the requirement of capital by year is indicated in the Tables 8-1 and 8-2.

The foreign currency portion and the domestic currency portion are allotted in the aforementioned total construction cost by assuming the following conditions of payment.

Foreign currency	Contract	FOB	Arrival	Completion
Materials of overhead transmission lines and electrode lines	10%	60%	30%	—
Submarine cables, electrodes	10%	60%	—	30%
HVDC S/S equipment and communication equipment	10%	80%	—	10%
Domestic currency				
Materials & labour cost	Reimbursement system			

The indirect costs consisting of contingency, engineering cost, administrative cost and training cost sum up US$19,437,000 in the first stage and US$5,879,000 in the second stage, totaling US$25,316,000 which corresponds to 12.9% of the direct construction cost.

8.2 Construction Schedule

The construction schedules of the first stage and second stage are shown in the Fig. 8-1 and 8-2, respectively. The timing of completion of the first stage of this project is assumed to be 1991 and the second stage 1996, by taking into consideration the development project of the Mindanao Grid and the forecast of demand and supply of power.

The term of works of the first stage is assumed to be 48 months consisting of 12 months for detailed design and preparation of the specifications, 6 months for bidding and 30 months from the signature of the contract to the completion of the construction work. It is assumed that the totality of the DC overhead transmission lines, submarine cables, electrodes, electrode lines and communication facilities will be constructed in the first stage. The construction of these facilities including the HVDC substation will require 27 months from the signature of the contract to the completion, in addition to 4 months more for tests.

The time schedule is determined by taking into consideration the following stages of work.

(1) Overhead transmission line construction stage

The construction of the DC ±350 kV overhead transmission line (293 km) and AC 138 kV overhead transmission line (1.0 km) will be constructed in the first stage.

a) Quantity of the construction work

The sections of work and the quantity of work for construction of the overhead transmission line are as follows.

	Section of work	Quantity of work
DC ±350 kV overhead transmission line (Leyte Island):	1 section	115 km
DC ±350 kV overhead transmission line (Dinagat, Awasan & Nonoc Islands):	1 section	55 km
DC ±350 kV overhead transmission line (Mindanao Island):	2 section	123 km
AC 138 kV overhead transmission line (Butuan HVDC S/S - Butuan S/S)	—	1 km

There are no roads along part of the overhead transmission line route in the Leyte Island and in the Dinagat Island and the transportation of materials requires longer time. However, it is presumed that there are no serious problems because these routes are located in hilly districts with relatively mild undulations and altitude not exceeding 300 m.

Most of the overhead transmission line route of the Mindanao Island is located in areas with flat topography, including rice paddies. The transmission lines of the Mindanao Island, including the AC 138kV one, will be constructed by dividing them in 2 distinct work zones by taking into consideration the coordination with the cultivation of rice, difficulties related to the construction of the foundations of the towers during the wet season and the longer distance of this section of the transmission line.

b) Period of transportation of the materials

Materials and equipment necessary for the project except for the cement and reinforcing bars required to construct the foundations of the towers of the transmission line will be imported, their marine and land transportation will require 2 months.

c) Tower manufacturing capacity

Approximately 3 months are required from the signature of the contract to the start of manufacture of the towers. The stages of work to be carried out in the meanwhile include the design, purchase of materials, test of model, etc. It is estimated that approximately 9,000 t of steel materials will be required in this project. Approximately 9 months are required to manufacture the total steel towers required in this project if they are manufactured at a monthly rate of approximately 1,000 t. The total period required to manufacture the towers will be 12 months, by taking into consideration the period for procurement of materials.

(2) Submarine cable laying stage

This project comprises two submarine cable sections. Details about the submarine cable, such as laying route, schedule of the laying work, location of the cable terminal, type of cable to be used, etc., should be decided in advance in the detailed survey stage.

a) Field survey and final design

It is recommendable to contract all of the submarine cable laying works on full-turnkey basis. The contractor should carry out subsidiary survey on the designated cable route and cable terminal site after the signature of the relevant contract. The final design of the cable laying work should be carried out based on the results of the said subsidiary survey.

b) Cable manufactureing stage

Approximately 3 months will be required after the signature of the contract for execution of the design, purchase of the material, sample test, etc. The cables will be constructed in units of 2,000 m which will be spliced in accordance to the distance of the cable laying section. Approximately 15 months will be required to manufacture and splice the cables.

c) Cable laying work

Prior to the execution of the cable laying work, the preparatory works of the cable landing site, cable burying route at the land section of the submarine cable and cable terminal site will require approximately 6 months. The cable laying work will be carried out during months with favourable meteorological conditions and marine meteorology conditions. The months of April to June are preferable for the submarine cable laying because oceantic conditions are most stable. The cables for the first laying section will be loaded on the cable laying ship in March, then the ship will be cruised from the loading harbour to the laying section site.

The laying work of the submarine cables will be excuted in April selecting preferable marine meteorology condition days.

After laying the cables of the first section, the ship will be returned to the loading harbour for the cables loading of the remain section, then the ship will be crused to the laying section site after loading the cables. One (1) month will be needed for the round trip sailing and the cable loading. The cable for the remaining section will be layed in June. Three (3) months are needed for the cable terminal installation work and the others. Therefore, twelve (12) months are estimated for total period required for submarine cable laying work including preparation work and six (6) months for cable laying work.

(3) Construction of electrodes and electrode lines

The electrode site should be determined in advance through detailed survey. The work related to the construction of the electrodes and electrode lines should be concluded concurrently with the work of the transmission line.

(4) Construction of HVDC S/S

The work for construction of the HVDC S/S will consists of civil engineering works for the grading work, foundation work and the architectural work and electrical work for installation and tests of electrical equipment. The topography of the site for construction of the Butuan HVDC S/S consists of ravines at both sides and part of the dale of the said ravines reach the construction site. Therefore, it is necessary to cut part of the foot of the nearby mountain to fill these dales and the grading work will require 5 months. The foundations of the outdoor equipment and the buildings the valve hall hand control house to contain the equipment such as the thyristor valves and switch-boards should be finished prior to the arrival of the equipment to the construction site. The work of the Jaro HVDC S/S consist of the installation of the DC lead-out equipment and control equipment for transmission of power to Mindanao and will not include the thyristor valves and the equipment of the AC side. The installation of these equipment will be finished concurrently with the work of the Butuan HVDC S/S.

The periods of design, manufacturing, transportation, installation and test of the HVDC S/S equipment are approximately as follows.

a) Design

The thyristor valves, transformers and filters will require 4 months after the signature of the contract while the control and protection equipment will require 10 months.

b) Manufacturing

The various kinds of equipment of the HVDC S/S will require the following manufacturing periods.

- Thyristor valves:	12 months
- Converter transformers, DC reactors, etc.:	8 to 10 months
- Switchgears and switchboard:	8 to 12 months.

c) Transportation and installation

Each one of the equipment should be ordered at appropriate timing in order to prevent any delay in the installation schedule. It is recommendable to carry out the transportation of the equipment to the Butuan HVDC S/S in a planned way, by carrying out in advance the survey about the unloading harbour and roads and bridges from the unloading harbour to the construction site. The ocean and land transportation are required to require 2 to 3 months and the installation work is expected to require 3 to 5 months.

d) Field test

Field tests of various kinds for the equipment will be conducted after their installation. After the individual tests of each equipment in the HVDC S/S, the totality of the DC power transmission facilities will be tested in order to make the adjustment and setting of the 3-terminal operation of the Naga, Jaro and Butuan HVDC S/S and to confirm their performance. It is estimated that these adjustments and tests will require approximately 4 months.

(5) Construction of telecommunication equipment

Designing, manufacturing, installation works and tests of the telecommunication equipment will be conducted during the first stage of the construction of HVDC systems and will be finished in 1991.

License procedure for radio equipment in the Philippines and leasing procedure of a part of AFP microwave channels as a stand-by circuit will be carried out on schedule under the responsibility of NAPOCOR.

Further surveys will be needed for the exact location of the sites of repeater stations and check of the path obstacle in between repeater stations. Detailed survey of conditions of reflecting point,possibility of building station and antenna towers will also be needed.

Difficulties about transportation of construction materials and worker's access to the three radio station sites on Dinagat Island are foreseen, so enough period of 14 months for telecommunication installation works is estimated on the construction schedule.

(6) Time schedule of the work of the second stage

The DC power transmission facilities corresponding to the additional monopolar of the system will be constructed in the second stage of the project, which will be concluded in 1996, realizing as a result the system with final capacity of DC ±350 kV, 400 MW. The lead-in facilities of the AC 138 kV Butuan substation and the transmission line for interconnection with this substation will be constructed concurrently with the facilities of the second stage.

Table 8-1 Construction Cost at First Stage

Unit: US$$10^3$

Item	1988			1989			1990			1991			Construction cost		
	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total
A. HVDC Substation															
Butuan station															
DC equipment	—	—	—	1,722	0	1,722	13,774	0	13,774	1,722	0	1,722	17,218	0	17,218
AC equipment	—	—	—	271	0	271	2,171	0	2,171	271	0	271	2,713	0	2,713
Civil works & building	—	—	—	93	1,100	1,193	684	2,421	3,105	0	880	880	777	4,401	5,178
Installation & others	—	—	—	19	19	38	1,149	893	2,042	747	364	1,111	1,915	1,276	3,191
Jaro station															
DC equipment	—	—	—	70	0	70	560	0	560	70	0	70	700	0	700
Civil works	—	—	—	0	0	0	2	13	15	1	6	7	3	19	22
Installation & others	—	—	—	0	0	0	108	46	154	163	70	233	271	116	387
Butuan Substation expansion															
Switchyard equipment				39	0	39	274	18	292	78	26	104	391	44	435
Sub-total				2,214	1,119	3,333	18,722	3,391	22,113	3,052	1,346	4,398	23,988	5,856	29,844
B. Transmission lines															
DC line															
DC 350 kV overhead line															
Materials	—	—	—	4,877	0	4,877	17,068	0	17,068	2,438	0	2,438	24,383	0	24,383
Installation	—	—	—	282	1,624	1,906	989	11,371	12,360	141	3,249	3,390	1,412	16,244	17,656
DC 350 kV submarine cable															
Materials	—	—	—	4,780	0	4,780	28,684	0	28,684	14,343	0	14,343	47,807	0	47,807
Installation	—	—	—	624	219	843	2,810	988	3,798	2,809	987	3,796	6,243	2,194	8,437
AC 138 kV line	—	—	—	0	0	0	67	41	108	17	27	44	84	68	152
Electrode & electrode lines	—	—	—	356	0	356	1,246	909	2,155	178	489	667	1,780	1,398	3,178
Sub-total				10,919	1,843	12,762	50,864	13,309	64,173	19,926	4,752	24,678	81,709	19,904	101,613
C. Telecommunication facility	—	—	—	666	25	691	2,666	102	2,768	1,111	126	1,237	4,443	253	4,696
D. Temporary facility & others	—	—	—	0	190	190	0	190	190	0	165	165	0	545	545
Direct cost (A+B+C+D)	—	—	—	13,799	3,177	16,976	72,252	16,992	89,244	24,089	6,389	30,478	110,140	26,558	136,698
E. Contingency	—	—	—	690	477	1,167	3,613	2,549	6,162	1,204	958	2,162	5,507	3,984	9,491
F. Engineering & adm. cost	2,050	100	2,150	1,340	952	2,292	1,722	952	2,674	1,722	952	2,674	6,834	2,956	9,790
G. NPC's engineer educational cost	—	—	—	—	—	—	78	0	78	78	0	78	156	0	156
Sub-total (E+F+G)	2,050	100	2,150	2,030	1,429	3,459	5,413	3,501	8,914	3,004	1,910	4,914	12,497	6,940	19,437
Total	2,050	100	2,150	15,829	4,606	20,435	77,665	20,493	98,158	27,093	8,299	35,392	122,637	33,498	156,135

Table 8-2 Construction Cost at Second Stage

Unit: US$$10^3$

Item	1994			1995			1996			Construction Cost			Total (1st & 2nd)		
	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total
A. HVDC Substation															
Butuan station															
DC equipment	1,641	0	1,641	13,131	0	13,131	1,641	0	1,641	16,413	0	16,413	33,631	0	33,631
AC equipment	976	0	976	7,805	0	7,805	976	0	976	9,757	0	9,757	12,470	0	12,470
Civil works & building	18	67	85	855	2,020	2,875	0	157	157	873	2,244	3,117	1,650	6,645	8,295
Installation & others	45	80	125	534	2,003	2,537	311	588	899	890	2,671	3,561	2,805	3,947	6,752
Jaro station															
DC equipment	64	0	64	511	0	511	64	0	64	639	0	639	1,339	0	1,339
Civil works	0	1	1	0	12	12	0	0	0	0	13	13	3	32	35
Installation & others	5	7	12	63	182	245	37	54	91	105	243	348	376	359	735
Butuan substation expansion															
Switchyard equipment	39	0	39	274	18	292	78	26	104	391	44	435	782	88	870
Sub-total	2,788	155	2,943	23,173	4,235	27,408	3,107	825	3,932	29,068	5,215	34,283	53,056	11,071	64,127
B. Transmission lines															
DC line															
DC 350 kV overhead line															
Materials	–	–	–	–	–	–	–	–	–	–	–	–	24,383	0	24,383
Installation	–	–	–	–	–	–	–	–	–	–	–	–	1,412	16,244	17,656
DC 350 kV submarine cable															
Materials	–	–	–	–	–	–	–	–	–	–	–	–	47,807	0	47,807
Installation	–	–	–	–	–	–	–	–	–	–	–	–	6,243	2,194	8,437
AC 138 kV line	–	–	–	6	0	6	49	10	59	55	10	65	139	78	217
Electrode & electrode lines	–	–	–	–	–	–	–	–	–	–	–	–	1,780	1,398	3,178
Sub-total	0	0	0	6	0	6	49	10	59	55	10	65	81,764	19,914	101,678
C. Telecommunication facility	–	–	–	–	–	–	–	–	–	–	–	–	4,443	253	4,696
D. Temporary facility & others	–	–	–	0	43	43	0	43	43	0	86	86	0	631	631
Direct cost (+B+C+D)	2,788	155	2,943	23,179	4,278	27,457	3,156	878	4,034	29,123	5,311	34,434	139,263	31,869	171,132
E. Contingency	139	23	162	1,159	642	1,801	158	132	290	1,456	797	2,253	6,963	4,781	11,744
F. Engineering & adm. cost	721	576	1,297	729	476	1,205	596	476	1,072	2,046	1,528	3,574	8,880	4,484	13,364
G. NPC's engineer educational cost	–	–	–	26	0	26	26	0	26	52	0	52	208	0	208
Sub-total (E+F+G)	860	599	1,459	1,914	1,118	3,032	780	608	1,388	3,554	2,325	5,879	16,051	9,265	25,316
Total	3,648	754	4,402	25,093	5,396	30,489	3,936	1,486	5,422	32,677	7,636	40,313	155,314	41,134	196,448

Fig. 8-1 Construction Schedule of Leyte-Mindanao Power Transmission Project (First Stage)

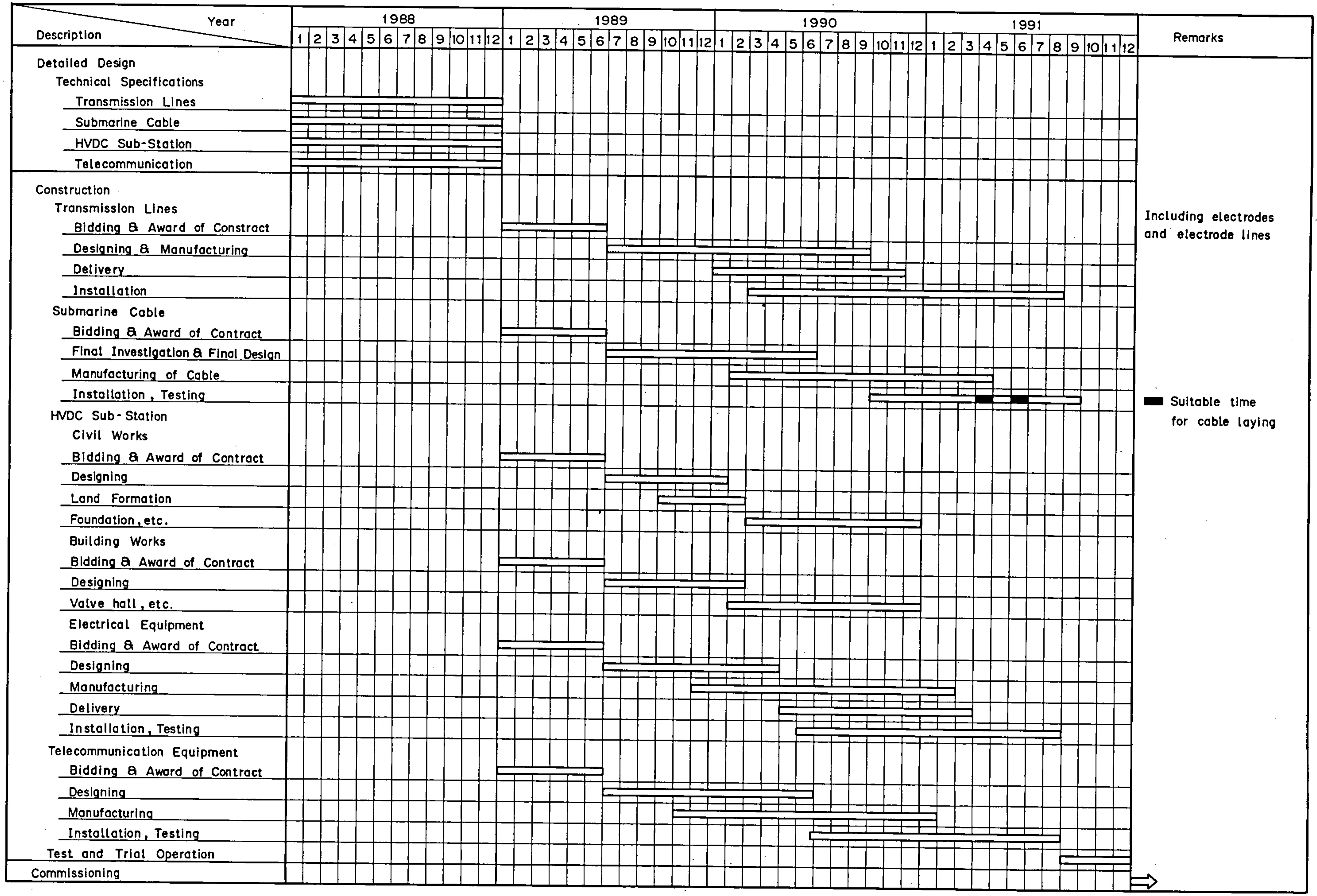
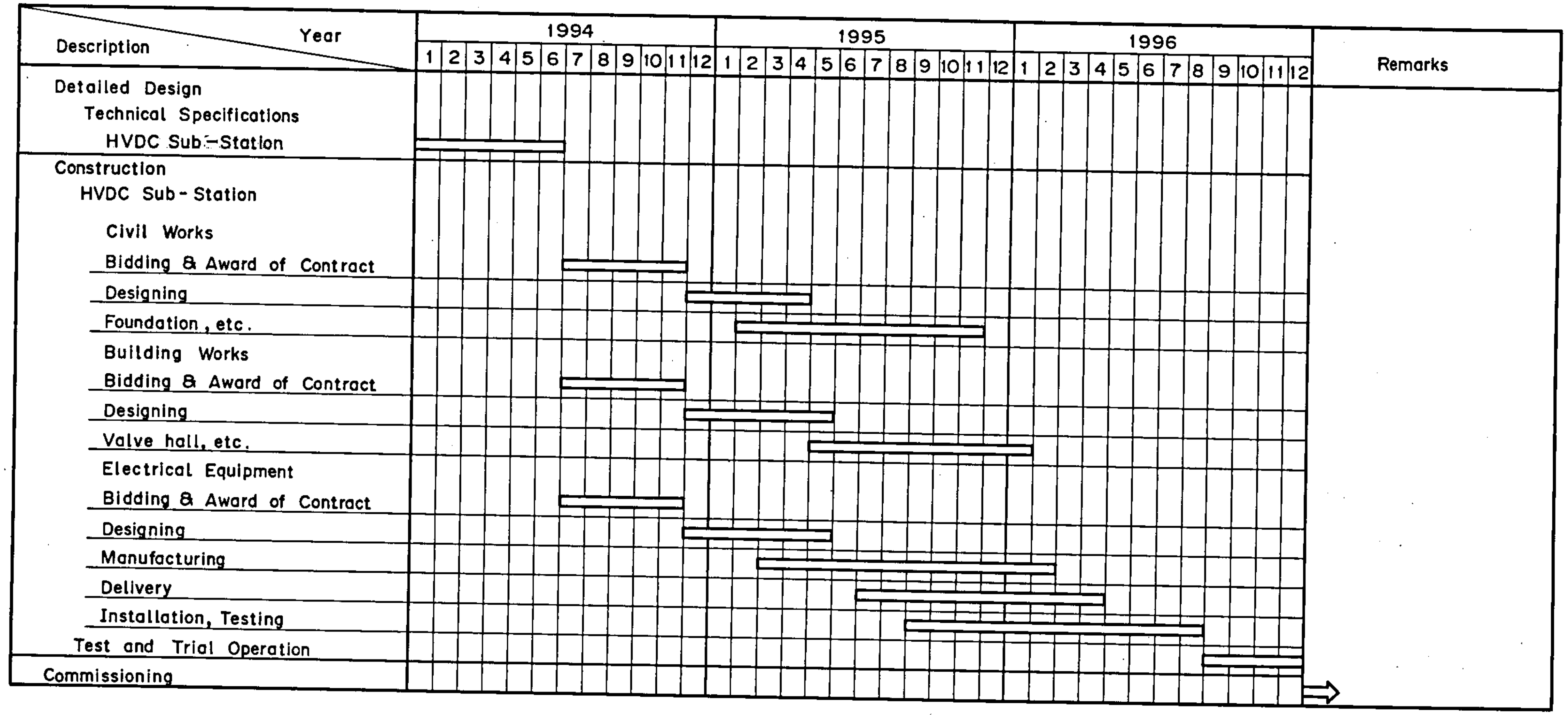


Fig. 8-2 Construction Schedule of Leyte-Mindanao Power Transmission Project (Second Stage)



CHAPTER 9

ECONMIC EVALUATION AND FINANCIAL ANALYSIS

CHAPTER 9 ECONOMIC EVALUATION AND FINANCIAL ANALYSIS

This project will be interconnected with the Luzon-Leyte power transmission project being planned by NAPOCOR at the present time. After the realization of this project the Luzon, Samar, Leyte and Mindanao Islands will be interconnected by means of transmission lines and as a consequence it will be possible to carry out the integrated operation of all electric power systems of the Philippines, except part of the Visayas Islands.

Therefore, the economic evaluation and financial analysis of this project should be carried out taking into consideration not only the independent project but also the totality of the DC ±350 kV transmission line and substation facilities with total distance of 769 km, extending from Naga HVDC S/S to Butuan HVDC S/S via Jaro HVDC S/S that compose the interconnected power transmission facilities.

It is possible to make the economic evaluation of a project by examining if the project in question is able to utilize the capital in a more effective way compared with other alternatives. In this study however, the project is evaluated from the economic standpoint by evaluating its effects on the Luzon Grid and Mindanao Grid in the form of benefit, in view of the intrinsic characteristics of the project. The selection of the best alternative is carried out by comparing the costs of the various alternatives in the first step and by evaluating the effects of the project on the two aforementioned grids in the second step.

On the other hand, from the purely economic standpoint, it is clear that this power transmission project individually generates no benefit at all in relation to the capital invested, because it is merely a transmission facility. Therefore, the economic evaluation is made in terms of the comparison between the cost and the revenue resulting from the sale of electricity generated by the Tongonan geothermal power plant to the centers of demand located in Luzon Island and Mindanao Island, with the cost including the investments for construction of the DC ±350 kV power transmission facilities making the Luzon-Mindanao interconnection and the Tongonan geothermal power plant as well.

9.1 Economic Evaluation

As mentioned in the subsection 5.2 of the Chapter 5, the DC ±350 kV 3-terminal system is adopted in this project, as a result of the cost comparison with the other alternatives, namely the DC ±250 kV 2-terminal system and the AC 230 kV power transmission system.

9.1.1 Basic considerations for economic comparison

This project will be interconnected with the Luzon-Leyte power transmission project which is being planned at the present time by NAPOCOR. Therefore, particular attention is paid to make a clear distinction between the benefits of the Luzon-Leyte power transmission project whose feasibility has been already confirmed and the benefits of this project, in order to prevent them from being summed up twice. Furthermore, the study is carried out by assuming two distinct cases, i.e., this project evaluated individually and evaluated in combination with other subsidiary projects (including the totality of the DC-interconnected power transmission and HVDC substation facilities extending from Naga HVDC S/S to Butuan HVDC S/S).

The economic costs (excluding direct taxes such as custom charges, etc.) are used to calculate the cost (C) and benefit (B) of this project but the shadow prices such as labour, foreign currency, goods, etc., are not used in view of the state of things of the economy of the Philippines as things now stand.

According to the World Bank (IBRD), the internal rate of return regarded as acceptable for projects to be implemented in the Philippines is 14%/year. It is presumed that the aforesaid rate is calculated from the standpoint of the opportunity cost of the capital, by taking into consideration the state of the economy of the Philippines as things now stand. Therefore, survey team carried out the economic evaluation of the project by paying attention to the following aspects.

With regard to the cost of petroleum and coal, which are the indeterminate factors for the sake of economic evaluation of this project, the study is carried out by assuming US$29.0/Barrel, the OPEC standard price. As for the discount rate, the evaluation is carried out by assuming $i = 14$%/year and by using these evaluation coefficients as parameters.

(1) Independent evaluation

a) The economic feasibility of the Luzon-Leyte power transmission project has been proved by assuming that the totality of the energy generated by the Tongonan geothermal power plant will be transmitted to the Luzon Grid. In other words, it has been proved that the cost obtained by summing the geothermal power generation cost with the power transmission cost results to be more advantageous than the fuel cost of the existing oil-fired thermal power plants of the Luzon Grid. Therefore, the most of the existing oil-fired thermal power generating facilities with total installed capacity of 1,925 MW will be used as standby capacity after the completion of the Leyte-Luzon power transmission project. On the other hand, in the electric power development plan of the Mindanao Grid there are plans for construction of the No.3 and No.4 coal-fired thermal power generator units with 100 MW each in Bislig in 1992 and 1993, respectively, on the premise of no interconnection between the Luzon Grid and the Mindanao Grid. Therefore, should the fuel cost of the oil-fired thermal power plants of the Luzon Grid be cheaper than the power generation cost of the aforesaid coal-fired thermal plants after the realization of the Leyte-Mindanao interconnected power transmission project, it will be possible to take into consideration the benefits resulting from the postponement of the development of these coal-fired thermal power plants.

b) Should any failure occur either in the Luzon Grid or in the Mindanao Grid after the interconnection of the two grids by the Leyte-Mindanao power transmission project, it will be possible to interchange power by using the standby capacity of the sound grid.

In other words, the realization of this project will make possible to reduce the standby capacity required to maintain the power supply reliability of the two grids.

c) The increase of consumption of fuel in the oil-fired thermal power plants of the Luzon Grid to replace the Bisling No.3 (100 MW) and No.4 (100 MW) coal-fired thermal generator units means that 200 MW of power generated by the Tongonan geothermal power plant and transmitted to the Luzon Grid is diverted to the Mindanao Grid, which in other words brings about the reduction of the transmission loss of the Luzon-Leyte power transmission project.

(2) Integrated evaluation

a) This project is part of an integrated project aimed at making the interconnection between the Luzon Grid and the Mindanao Grid. The principal characteristic of this project is its role as interconnection transmission line, and it should be regarded as an extension of the Luzon-Leyte power transmission project. Therefore, the evaluation of this project is made in the global form as a part of the Luzon-Leyte-Mindanao power transmission project.

b) In making the integrated evaluation, the part to be played by the transmission line is limited exclusively to the transmission of power generated by the Tongonan geothermal power station to the Luzon Grid and to the Mindanao Grid, and its effects to reduce the reserve power between the two grids which was taken into consideration in the independent evaluation is excluded in this case.

9.1.2 Conclusion of the economic evaluation

(1) Basic premises of the economic evaluation

a) All costs and benefits are expressed in terms of prices prevailing in March 1983.

b) The exchange rates are the following values prevailing in March 1983.

1US$ = 9.6056 Pesos

1US$ = ¥230

c) Fuel cost of oil-fired thermal plants and coal-fired thermal plants.

Price of petroleum	Fuel cost per kWH (US mills/kWH)	
	Oil-fired thermal	Coal-fired thermal
US$25.0/barrel	41.2	24.7
US$29.0/barrel	*47.8	28.7
US$34.0/barrel	56.0	33.6

(NOTE: * is the actual fuel cost of NAPOCOR. In this connection NAPOCOR assumes that the fuel cost of coal-fired thermal plants is 65% of the fuel cost of oil-fired thermal plants, but the results of the studies carried out by the survey team indicate that 60% is a more realistic value).

d) Construction cost per kW and unit steam cost of the Tongonan geothermal power station

The following values are used in the evaluation of the Tongonan geothermal power generation project for second stage carried out by NAPOCOR.

Construction cost: US$745/kW

Cost of steam purchased from PNOC:

- Financial cost: 25.1 US mill/kWH (0.241 Peso/kWH)
- Economic cost: 15.3 US mill/kWH (0.147 Peso/kWH)

e) Construction cost of the alternative coal-fired thermal plant: US$1,087/kW

f) Life time

(i) Life time of this project: 50 years

(ii) Life time of the geothermal and alternative coal-fired thermal power stations: 20 years

(NOTE: The potential of the Tongonan geothermal energy resource is said to be 1,000 MW at 25 years).

g) The following costs per kW are used to evaluate the merits of the reduction of the reserve power.

- Evaluation of Diesel generators: US$89.1/kW
- Evaluation of coal-fired thermal plants: US$163.1/kW (for reference)

h) The evaluation is carried out through discounting the cash flow of the cost and benefits, and the period of evaluation is assumed to be 30 years.

(3) Conclusion

The results of the independent evaluation of this project are as follows.

Benefit (B):	$230,501 \times 10^3$ US$
Cost (C):	$219,348 \times 10^3$ US$
B/C:	1.05
B - C:	$11,153 \times 10^3$ US$
EIRR:	21.3%

The economic internal rate of return (EIRR) obtained as a result of the combination of this project with the Luzon-Leyte power transmission project is 14.4%.

From the aforestated considerations, it is concluded that this project is economically feasible both in the independent evaluation and in the integrated evaluation.

Fig. 9-1 Leyte-Mindanao Power Transmission Project

(Economic evaluation)

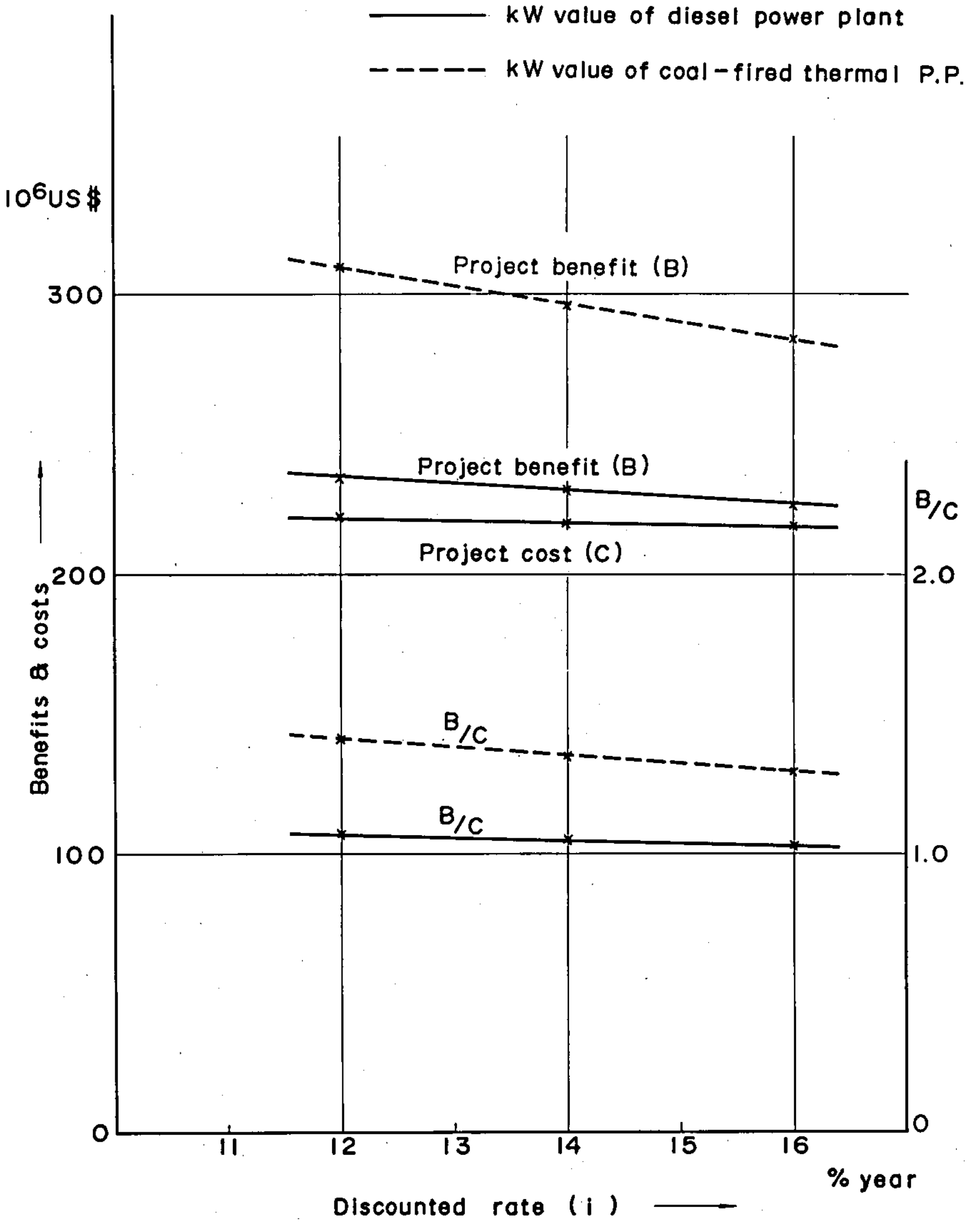


Fig. 9-2 Leyte-Mindanao Power Transmission Project

(Economic evaluation at discounted rate $i = 14\%$)

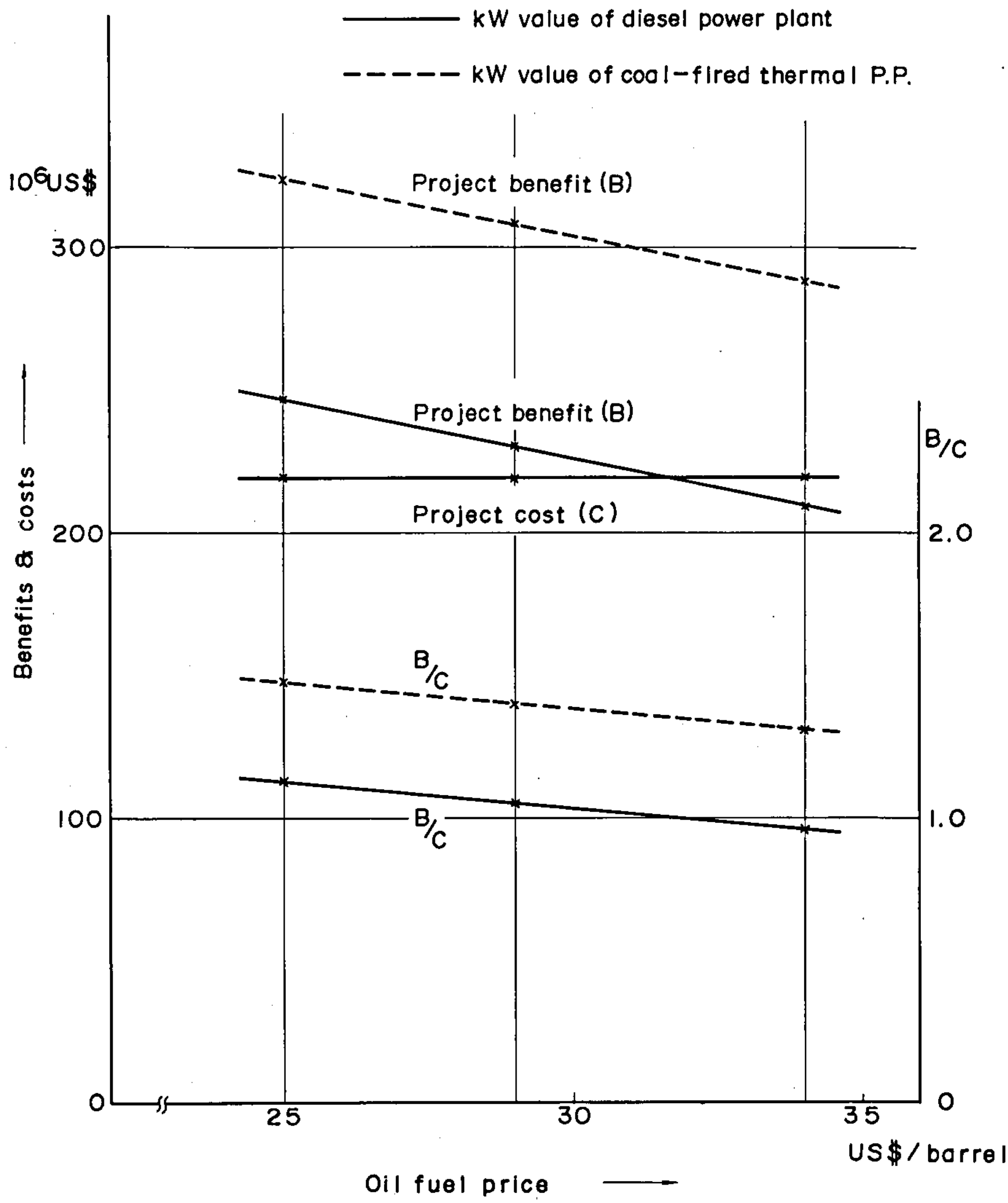


Table 9-1-(1) Economic Evaluation for Leyte - Mindanao Power Transmission Project (Independent)

n	Year	Tongonan geothermal power plants					Bislig No.3 & No.4 coal-fired thermal P.P					Luzon oil-fired thermal P.P				Remarks
		Avail. energy (GWh)	Power demand (GWh)	Surplus energy (GWh)	To Mindanao (GWh)	To Luzon (GWh)	Con. cost (10^3US$)	O & M cost (10^3US$)	Gen. energy (GWh)	Fuel cost (10^3US$)	Total (10^3US$)	Gen. energy (GWh)	Fuel cost (10^3US$)	O & M cost (10^3US$)	Total (10^3US$)	
-3	1988	2,440	938	1,502	0	1,502	—	—	—	—	0	0	0	0	0	
-2	1989	4,028	1,020	3,008	0	3,008	25,327	—	—	—	25,327	0	0	0	0	
-1	1990	4,028	1,101	2,927	0	2,927	75,981	—	—	—	75,981	0	0	0	0	
0	1991	5,616	1,145	4,471	0	4,471	25,327	—	—	—	25,327	0	0	0	0	
1	1992	7,204	1,196	6,008	613	5,395	0	3,165	595	17,076	20,241	613	29,301	1,700	31,001	
2	1993	7,998	1,232	6,766	613	6,153	0	3,165	595	17,076	20,241	613	29,301	1,700	31,001	
3	1994	7,998	1,269	6,729	613	6,116	25,327	3,165	595	17,076	45,568	613	29,301	1,700	31,001	Fuel cost for oil fired thermal 47.8 US mills per kWh
4	1995	7,998	1,307	6,691	613	6,078	75,981	3,165	595	17,076	96,222	613	29,301	1,700	31,001	
5	1996	7,998	1,346	6,652	613	6,039	25,327	3,165	595	17,076	45,568	613	29,301	1,700	31,001	
6	1997	7,998	1,386	6,612	1,226	5,386		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
7	1998	7,998	1,428	6,570	1,226	5,344		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
8	1999	7,998	1,471	6,527	1,226	5,301		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
9	2000	7,998	1,527	6,471	1,226	5,245		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
10	2001	7,998	1,557	6,441	1,226	5,215		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
11	2002	7,998	1,588	6,410	1,226	5,184		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
12	2003	7,998	1,620	6,378	1,226	5,152		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
13	2004	7,998	1,652	6,346	1,226	5,120		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
14	2005	7,998	1,685	6,313	1,226	5,087		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
15	2006	7,998	1,719	6,279	1,226	5,053		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
16	2007	7,998	1,754	6,244	1,226	5,018		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
17	2008	7,998	1,789	6,209	1,226	4,983		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
18	2009	7,998	1,824	6,174	1,226	4,948		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
19	2010	7,998	1,861	6,137	1,226	4,911		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
20	2011	7,998	1,898	6,100	1,226	4,874		6,331	1,190	34,153	40,484	1,226	58,602	3,400	62,002	
21	2012	0	1,917	0	0	0		0	0	0	0	0	0	0	0	
22	2013	0	1,936	0	0	0		0	0	0	0	0	0	0	0	
23	2014	0	1,956	0	0	0		0	0	0	0	0	0	0	0	
24	2015	0	1,975	0	0	0		0	0	0	0	0	0	0	0	
25	2016	0	1,995	0	0	0		0	0	0	0	0	0	0	0	
26	2017	0	2,015	0	0	0		0	0	0	0	0	0	0	0	
27	2018	0	2,035	0	0	0		0	0	0	0	0	0	0	0	
28	2019	0	2,055	0	0	0		0	0	0	0	0	0	0	0	
29	2020	0	2,076	0	0	0		0	0	0	0	0	0	0	0	
30	2021	0	2,097	0	0	0		0	0	0	0	0	0	0	0	
Total		175,278	55,370	139,965	21,455	118,510	253,270	110,790	20,825	597,675	961,735	21,455	1,025,535	59,500	1,085,035	

Table 9-1-(2) Economic Evaluation for Leyte - Mindanao Power Transmission Project (Independent)

n	Year	Discounted rate	Cost flow (C)				Benefit flow (B)									
			Cons. cost	O &M cost	Total	Present value	R.P. saving	*R.P.S benefit	Surplus energy	Loss improve	L.I benefit	Economic energy interchange			Total	Present value
		(i=14%)	(10³US$)	(10³US$)	(10³US$)	(10³US$)	(MW)	(10³US$)	(GWh)	(GWh)	(10³US$)	(10³US$)	(10³US$)	(10³US$)	(10³US$)	(10³US$)
-3	1988	1.481	2,150		2,150	3,184	0		1,502	0	0	0	0	0	0	0
-2	1989	1.299	20,435		20,435	26,545	0		3,008	0	0	25,327	0	25,327	25,327	32,899
-1	1990	1.140	98,158		98,158	111,900	0		2,927	0	0	75,981	0	75,981	75,981	86,618
0	1991	1.000	35,392		35,392	35,392	0		4,471	0	0	25,327	0	25,327	25,327	25,327
1	1992	0.877		2,342	2,342	2,053	100	8,910	5,395	67	3,202	20,241	31,001	-10,760	1,352	1,185
2	1993	0.769		2,342	2,342	1,800	100	8,910	6,153	77	3,680	20,241	31,001	-10,760	1,830	1,407
3	1994	0.674	4,402	2,342	6,744	4,545	100	8,910	6,116	76	3,632	45,568	31,001	14,567	27,109	18,271
4	1995	0.592	30,489	2,342	32,831	19,435	100	8,910	6,078	75	3,585	96,222	31,001	65,221	77,716	46,007
5	1996	0.519	5,422	2,342	7,764	4,029	100	8,910	6,039	75	3,585	45,568	31,001	14,567	27,062	14,045
6	1997	0.455		2,946	2,946	1,340	200	17,820	5,386	67	3,202	40,484	62,002	-21,518	-496	-225
7	1998	0.399		2,946	2,946	1,175	200	17,820	5,344	66	3,154	40,484	62,002	-21,518	-544	-217
8	1999	0.350		2,946	2,946	1,031	200	17,820	5,301	66	3,154	40,484	62,002	-21,518	-544	-190
9	2000	0.307		2,946	2,946	904	200	17,820	5,245	65	3,107	40,484	62,002	-21,518	-591	-181
10	2001	0.269		2,946	2,946	792	200	17,820	5,215	65	3,107	40,484	62,002	-21,518	-591	-158
11	2002	0.236		2,946	2,946	695	200	17,820	5,184	64	3,059	40,484	62,002	-21,518	-639	-150
12	2003	0.207		2,946	2,946	609	200	17,820	5,152	64	3,059	40,484	62,002	-21,518	-639	-132
13	2004	0.182		2,946	2,946	536	200	17,820	5,120	64	3,059	40,484	62,002	-21,518	-639	-116
14	2005	0.159		2,946	2,946	468	200	17,820	5,087	63	3,011	40,484	62,002	-21,518	-687	-109
15	2006	0.140		2,946	2,946	412	200	17,820	5,053	63	3,011	40,484	62,002	-21,518	-687	-96
16	2007	0.122		2,946	2,946	359	200	17,820	5,018	62	2,963	40,484	62,002	-21,518	-735	-89
17	2008	0.107		2,946	2,946	315	200	17,820	4,983	62	2,963	40,484	62,002	-21,518	-735	-78
18	2009	0.094		2,946	2,946	276	200	17,820	4,948	61	2,915	40,484	62,002	-21,518	-783	-73
19	2010	0.082		2,946	2,946	241	200	17,820	4,911	61	2,915	40,484	62,002	-21,518	-783	-64
20	2011	0.072		2,946	2,946	212	200	17,820	4,874	60	2,868	40,484	62,002	-21,518	-830	-59
21	2012	0.063		2,946	2,946	185	200	17,820	0	0	0	0	0	0	17,820	1,122
22	2013	0.055		2,946	2,946	162	200	17,820	0	0	0	0	0	0	17,820	980
23	2014	0.049		2,946	2,946	144	200	17,820	0	0	0	0	0	0	17,820	873
24	2015	0.043		2,946	2,946	126	200	17,820	0	0	0	0	0	0	17,820	766
25	2016	0.037		2,946	2,946	109	200	17,820	0	0	0	0	0	0	17,820	659
26	2017	0.033		2,946	2,946	97	200	17,820	0	0	0	0	0	0	17,820	588
27	2018	0.029		2,946	2,946	85	200	17,820	0	0	0	0	0	0	17,820	516
28	2019	0.025		2,946	2,946	73	200	17,820	0	0	0	0	0	0	17,820	445
29	2020	0.022		2,946	2,946	64	200	17,820	0	0	0	0	0	0	17,820	392
30	2021	0.019		2,946	2,946	55	200	17,820	0	0	0	0	0	0	17,820	338
Total		—	196,448	85,360	281,808	219,348	—	490,050	118,510	1,323	63,231	961,735	1,085,035	-123,300	429,981	230,501
															EIRR = 21.3%	

Note: R.P. saving: Reserve power saving, L.I. benefit: Loss improvement benefit, *89.1US$/kW in diesel plant

Table 9-2-(1) Economic Evaluation for Luzon - Leyte - Mindanao Power Transmission Project (Integrated)

n	Year	HVDC Power Transmission System					Tongonan Geothermal Power Plants								(C)	
		Luzon - Leyte		Leyte - Mindanao		Total	Power flow			Additional installed cap.	Construction cost	O & M cost	Purchased steam cost	Total	Total cost	
		Cons. cost	O & M cost	Cons. cost	O & M cost		Surplus energy	To Mindanao	To Luzon							
		(10^3US$)	(10^3US$)	(10^3US$)	(10^3US$)	(10^3US$)	(GWh)	(GWh)	(GWh)	(MW)	(10^3US$)	(10^3US$)	(10^3US$)	(10^3US$)	(10^3US$)	
-3	1984	2,252				2,252									2,252	
-2	1985	31,876				31,876					16,390			16,390	48,266	
-1	1986	159,990				159,990					81,950			81,950	241,940	
0	1987	42,379				42,379					114,730			114,730	157,109	
1	1988	9,239	3,547	2,150		14,936	1,502	0	1,502	110	65,560	2,048	22,980	90,588	105,524	
2	1989	73,680	3,547	20,435		97,662	3,008	0	3,008	220	131,120	6,146	46,022	183,288	280,950	
3	1990	19,863	3,547	98,158		121,568	2,927	0	2,927		147,510	6,146	44,783	198,439	320,007	
4	1991		5,089	35,392		40,481	4,471	0	4,471	220	81,950	10,243	68,406	160,599	201,080	Economic steam cost: 15.3 US mills per kWh (0.147 peso per kWh in Mar. 1983)
5	1992		5,089		2,342	7,431	6,008	613	5,395	220	16,390	14,341	91,922	122,653	130,084	
6	1993		5,089		2,342	7,431	6,766	613	6,153	110		16,390	103,519	119,909	127,340	
7	1994		5,089	4,402	2,342	11,833	6,729	613	6,116			16,390	102,953	119,343	131,176	
8	1995		5,089	30,489	2,342	37,920	6,691	613	6,078			16,390	102,372	118,762	156,682	
9	1996		5,089	5,422	2,342	12,853	6,652	613	6,039			16,390	101,775	118,165	131,018	
10	1997		5,089		2,946	8,035	6,612	1,226	5,386			16,390	101,163	117,553	125,588	
11	1998		5,089		2,946	8,035	6,570	1,226	5,344			16,390	100,521	116,911	124,946	
12	1999		5,089		2,946	8,035	6,527	1,226	5,301			16,390	99,863	116,253	124,288	
13	2000		5,089		2,946	8,035	6,471	1,226	5,245			16,390	99,006	115,396	123,431	
14	2001		5,089		2,946	8,035	6,441	1,226	5,215			16,390	98,547	114,937	122,972	
15	2002		5,089		2,946	8,035	6,410	1,226	5,184			16,390	98,073	114,463	122,498	
16	2003		5,089		2,946	8,035	6,378	1,226	5,152			16,390	97,583	113,973	122,008	
17	2004		5,089		2,946	8,035	6,346	1,226	5,120			16,390	97,093	113,483	121,518	
18	2005		5,089		2,946	8,035	6,313	1,226	5,087			16,390	96,588	112,978	121,013	
19	2006		5,089		2,946	8,035	6,279	1,226	5,053			16,390	96,068	112,458	120,493	
20	2007		5,089		2,946	8,035	6,244	1,226	5,018			16,390	95,533	111,923	119,958	
21	2008		5,089		2,946	8,035	6,209	1,226	4,983			16,390	94,997	111,387	119,422	
22	2009		5,089		2,946	8,035	6,174	1,226	4,948			16,390	94,462	110,852	118,887	
23	2010		5,089		2,946	8,035	6,137	1,226	4,911			16,390	93,896	110,286	118,321	
24	2011		5,089		2,946	8,035	6,100	1,226	4,874			16,390	93,330	109,720	117,755	
25	2012		5,089		2,946	8,035	0	0				0	0	0	8,035	
26	2013		5,089		2,946	8,035	0	0				0	0	0	8,035	
27	2014		5,089		2,946	8,035	0	0				0	0	0	8,035	
28	2015		5,089		2,946	8,035	0	0				0	0	0	8,035	
29	2016		5,089		2,946	8,035	0	0				0	0	0	8,035	
30	2017		5,089		2,946	8,035	0	0				0	0	0	8,035	
Total		339,279	148,044	196,448	73,576	757,347	139,965	21,455	118,510	880	655,600	350,334	2,141,455	3,147,389	3,904,736	

Table 9-2-(2) Economic Evaluation for Luzon - Leyte - Mindanao Power Transmission Project (Integrated)

n	Year	Energy saving in Luzon Grid				Bislig No.3 & No.4 coal-fired thermal P.P					(B)	(B) - (C)	Economic internal rate of return	
		Energy saving (GWh)	Saving oil fuel (10^3US$)	Saving O&M cost (10^3US$)	Total (10^3US$)	Generating energy (GWh)	Construction cost (10^3US$)	Fuel cost (10^3US$)	O & M cost (10^3US$)	Total (10^3US$)	Total benefit (10^3US$)	(10^3US$)	(i=14.4%)	
-3	1984										0	-2,252	-3,368	
-2	1985										0	-48,266	-63,123	
-1	1986										0	-241,940	-276,683	
0	1987										0	-157,109	-157,109	
1	1988	1,435	68,593	2,382	70,975						70,975	-34,549	-30,211	Transmission line loss from Tongonan to San Jose, Luzon: 4.4%
2	1989	2,875	137,425	4,772	142,197		25,327			25,327	167,524	-113,426	-86,729	
3	1990	2,798	133,744	4,644	138,388		75,981			75,981	214,369	-105,638	-70,631	
4	1991	4,274	204,297	7,094	211,391		25,327			25,327	236,718	35,638	20,836	
5	1992	5,157	246,504	8,560	255,064	595	0	17,076	3,165	20,241	275,305	145,221	74,244	
6	1993	5,882	281,159	9,764	290,923	595	0	17,076	3,165	20,241	311,164	183,824	82,178	
7	1994	5,846	279,438	9,704	289,142	595	25,327	17,076	3,165	45,568	334,710	203,534	79,564	Fuel cost for oil fired thermal: 47.8 US mills per kWh
8	1995	5,810	277,718	9,644	287,362	595	75,981	17,076	3,165	96,222	383,584	226,902	77,561	
9	1996	5,773	275,949	9,583	285,532	595	25,327	17,076	3,165	45,568	331,100	200,082	59,805	
10	1997	5,149	246,122	8,547	254,669	1,190		34,153	6,331	40,484	295,153	169,565	44,319	
11	1998	5,108	244,162	8,479	252,641	1,190		34,153	6,331	40,484	293,125	168,179	38,438	
12	1999	5,067	242,202	8,411	250,613	1,190		34,153	6,331	40,484	291,097	166,809	33,337	
13	2000	5,014	239,669	8,323	247,992	1,190		34,153	6,331	40,484	288,476	165,045	28,843	
14	2001	4,985	238,283	8,275	246,558	1,190		34,153	6,331	40,484	287,042	164,070	25,072	
15	2002	4,955	236,849	8,225	245,074	1,190		34,153	6,331	40,484	285,558	163,060	21,789	
16	2003	4,925	235,415	8,175	243,590	1,190		34,153	6,331	40,484	284,074	162,066	18,937	
17	2004	4,894	233,933	8,124	242,057	1,190		34,153	6,331	40,484	282,541	161,023	16,452	
18	2005	4,863	232,451	8,072	240,523	1,190		34,153	6,331	40,484	281,007	159,994	14,295	
19	2006	4,830	230,874	8,017	238,891	1,190		34,153	6,331	40,484	279,375	158,882	12,413	
20	2007	4,792	229,057	7,954	237,011	1,190		34,153	6,331	40,484	277,495	157,537	10,762	
21	2008	4,763	227,671	7,906	235,577	1,190		34,153	6,331	40,484	276,061	156,639	9,357	
22	2009	4,730	226,094	7,851	233,945	1,190		34,153	6,331	40,484	274,429	155,542	8,125	
23	2010	4,694	224,373	7,792	232,165	1,190		34,153	6,331	40,484	272,649	154,328	7,049	
24	2011	4,659	222,700	7,733	230,433	1,190		34,153	6,331	40,484	270,917	153,162	6,117	
25	2012	0	0	0	0	0		0	0	0	0	-8,035	-281	
26	2013	0	0	0	0	0		0	0	0	0	-8,035	-245	
27	2014	0	0	0	0	0		0	0	0	0	-8,035	-215	
28	2015	0	0	0	0	0		0	0	0	0	-8,035	-188	
29	2016	0	0	0	0	0		0	0	0	0	-8,035	-164	
30	2017	0	0	0	0	0		0	0	0	0	-8,035	-143	
Total		113,278	5,414,682	188,031	5,602,713	20,825	253,270	597,675	110,790	961,735	6,564,448	2,659,712	403	

Table 9-3 kW Value for Reserve Power Saving due to Power System Interconnection

(1) In case of diesel power plant

a) Unit construction cost: 550 US$/kW

b) Useful project life: 15 years

c) Discounted rate: 14% per year

kW value: 550 US$ × 0.162 = 89.1 US$/kW

(2) In case of coal-fired thermal power plant

a) Unit construction cost: 1,087 US$/kW

b) Useful project life: 20 years

c) Discounted rate: 14% per year

kW value: 1,087 US$ × 0.150 = 163.1 US$/kW

Table 9-4 Alternative Coal-fired Thermal Power Plants

(1) Unit construction cost: 1,087 US$/kW based on the completed cost of the Naga Thermal I

(2) Coal fuel cost: 28.7 US mills per kWh based on 60% of fuel oil cost assumed at 29 US$ per barrel

(3) Installed capacity: 100 MW × 2 unit × 1.165 = 233 MW

(4) Useful project life: 20 years

(5) Disbursement of construction investment

Unit: 10^3US$

Year	No.1 Unit	No.2 Unit	Total
1988	25,327	—	25,327
1989	75,981	—	75,981
1990	25,327	—	25,327
1991	0	—	0
1992	0	—	0
1993	0	—	0
1994	0	25,327	25,327
1995	0	75,981	75,981
1996	0	25,327	25,327
	126,635	126,635	253,270

(6) Operation and maintenance cost: 6,331 × 10^3US$/year

9.2 Financial Analysis

9.2.1 Basic considerations for financial analysis

In this section, financial analysis of the Project was carried out through computation of financial internal rate of return (FIRR) and through preparations of income statement and cash flow statement.

In computing the FIRR, not only the independent analysis for the Leyte-Mindanao transmission project but also the integrated analysis comprising both the Leyte-Mindanao and the Luzon-Leyte transmission projects was conducted as was made in the preceeding economic evaluation.

(1) Financial Internal Rate of Return (FIRR)

a) Basic assumptions for FIRR computation

(i) The value of capital cost to be used in financial analysis does not include the interest during construction.

(ii) All the cost and the benefit were first estimated on the basis of price level in March, 1983. As financial cost, the local currency cost included transfer cost such as taxes which were assumed to be 20%.

(iii) All the cost and the benefit were inflated based on the assumed escalation rate shown below.

	1983	1984	1985	1986	1987-96
Local currency	14% p.a.	24	18	12	8
Foreign currency	4% p.a.	3.75	3.5	3.0	3.0

(iv) The financial analysis was made for the period of 30 years following the same period as applied in the economic evaluation. In computing FIRR, however, since the geothermal power will be dried up in 2012, the evaluation period of independent analysis was shortened to 25 years from 1988 to 2012 and that of integrated analysis to 29 years from 1984 to 2012.

(v) The cost of steam which NAPOCOR purchases from PNOC was assumed at US mill 25.1/kWh (= ₱0.241/kWh). The unit construction cost of Tongonan geothermal power station was assumed at US$745/kW. These cost estimates were based on the information obtained from the Study on Tongonan Geothermal Development Phase II prepared by NAPOCOR.

(vi) The operation and maintenance (O & M) costs of transmission line and Tongonan geothermal power station were estimated at 1.5% and 2.5% of the construction cost respectively.

(vii) Transmission loss was estimated at the same value as in the economic evaluation: 2.9% in Mindanao transmission and 4.4% in Luzon transmission.

(viii) Energy sales that were considered as the sole financial revenue accrued from the Project were computed by applying the power rate of US mill 46.3/kWh which was determined by inflating 42.99 centavo/kWh of the average rate throughout the Philippines in 1982.

(ix) The same exchange rate as in the economic evaluation was adopted: US$1 = 9.6 Pesos

b) FIRR computation

(i) Independent analysis

In the independent analysis, the FIRR was computed by taking up the Leyte-Mindanao transmission line project alone. The project cost consisted of steam cost, construction costs and O & M costs of the Tongonan geothermal power station and the Leyte-Mindanao power transmission for the capacity of 200 MW at its maximum. The project benefit was computed by the energy sales brought by the generation capacity of 200 MW at its maximum.

(ii) Integrated analysis

In the integrated analysis, the FIRR was computed combining the Leyte-Mindanao and the Luzon-Leyte power transmission projects. The project cost consisted of steam cost, construction cost and O & M cost of 880 MW generation capacity of No. 7 through No. 22 units in Tongonan geothermal power station, and construction costs and O & M costs of the Leyte-Mindanao and the Luzon-Leyte power transmission. The project benefit was computed by the energy sales brought by 880 MW generation capacity. Allocation of power between Mindanao and Luzon grids was made so that transmission to Mindanao grid might be given priority to that of Luzon grid with the consideration of reserve power interchange (200 MW maximum).

c) Computed value of FIRR

Computation procedures are shown in Tables 9-5 and 9-6 for independent and integrated analyses respectively and the computed FIRRs were shown below.

FIRR of Independent Analysis: 7.8 %

FIRR of Integrated Analysis: 12.5 %

Sensitivity analysis was made by applying the assumed power rates of 10 % lower (= US mill 41.67/kWh) and 10 % higher (= US mill 50.93/kWh) than the assumed normal rate of US mill 46.3/kWh. The result of sensitivity analysis is shown in Fig. 9-3.

(2) Financial statements

a) Basic assumptions for preparation of financial statements

In preparing financial statements including income statement and cash flow statement, basic assumptions were made as mentioned below. The financial statements were prepared for independent analysis only.

(i) Terms of foreign loan were assumed as:

Interest Rate	:	3 % per annum
Repayment Period:		30 years including grace period of 10 years

Considering the characteristics of the Project that it is not a private investment but a public one and that its gestation period of investment is so long, the foreign currency portion of the construction cost was assumed to be financed by such a soft loan as shown above, which may be financed only through a government basis assistant fund.

(ii) The local currency portion was assumed to be provided by government's equity. The local currency portion to be required for the second stage construction was assumed to be provided from the internal cash generation accrued from the Project.

(iii) Sensitivity analysis was carried out to test the change in debt service coverage according to the varied interest rates of foreign loan of 5 % and 7 % in addition to the normal interest rate of 3 % (Table 9-11).

b) Projected income statement

Projected income statement is prepared based on the assumptions mentioned above and is shown in Table 9-9. As shown in the table, when the operating revenue is compared with the operating expenditure, surplus is projected in the period after the commissioning. Rate of return of plant in service shows that it will exceed the NAPOCOR standard rate of 8 % after the 6th year from the commissioning. The income statement was prepared up to the year of 2012 when the geothermal resources are anticipated to be dried up.

c) Projected cash flow statement

In the cash flow statement, the repayability of the foreign loan required for the Project was examined (Table 9-10). The cash flow statement was prepared for 30 years during which all the foreign loan is scheduled to be repaid. The operating income attributed to the Project i.e. Leyte-Mindanao Power Transmission Project was computed by the operating income accrued from the whole process of geothermal power generation and power transmission multiplied by the ratio of the Project cost to the whole investment cost comprising both the power generation cost and the transmission cost. As shown in Table 9-10, deficit is projected in the construction period due to interest payment and also in the second stage construction period due to local currency portion financing.

In accumulation, however, surplus is projected even after paying interest and principal every year after commissioning.

Debt service coverage that is defined as the sum of operating income and depreciation both of which are to be internally reserved divided by annual debt service exceeds 2.0 throughout the lifetime of 20 years excluding 5 years after 2013 when geothermal energy is anticipated to be exhausted. This ensures a firm repayability of the loan.

9.2.2 Conclusion of financial analysis

Based on the foregoing analyses, no peculiar problems were found in FIRR nor in financial statements. It is noted, however, that a foreign loan with low interest rate and with long repayment period, and a power rate set reasonably after considering real cost and appropriate return constituted the influential assumptions of this financial analysis.

Table 9-5 FIRR Computation (Independent)

Unit: US$ 10³

No.	Year	Benefit: Energy Sales /1 (GWh)	Benefit: Power Rate (US mil/kWh)	Benefit: Benefit	Cost: Geothermal P/S Capital /5	Cost: Geothermal P/S O&M /2	Cost: Leyte-Mindanao T/L Capital	Cost: Leyte-Mindanao T/L O&M /3	Cost: Steam /4	Cost: Total	Benefit-Cost
1	1988	-	-	-	-	-	2,774	-	-	2,774	-2,774
2	1989	-	-	-	27,447	-	33,446	-	-	60,893	-60,893
3	1990	-	-	-	101,571	-	165,656	-	-	267,227	-267,227
4	1991	-	-	-	122,804	-	64,604	-	-	187,408	-187,408
5	1992	595	137.3	81,701	48,745	3,943	0	4,317	45,607	102,612	-20,911
6	1993	595	148.2	88,238	-	4,258	0	4,662	49,256	58,176	30,062
7	1994	595	160.1	95,297	-	4,599	8,575	5,035	53,196	71,405	23,892
8	1995	595	172.9	102,920	-	4,967	62,851	5,438	57,452	130,708	-27,788
9	1996	595	186.7	111,154	-	5,364	13,577	5,873	62,048	86,862	24,292
10	1997	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
11	1998	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
12	1999	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
13	2000	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
14	2001	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
15	2002	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
16	2003	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
17	2004	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
18	2005	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
19	2006	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
20	2007	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
21	2008	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
22	2009	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
23	2010	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
24	2011	1,190	201.7	240,092	-	11,470	-	7,720	134,024	153,214	86,878
25	2012	655	201.7	132,188	-	6,244	-	7,720	73,713	84,377	47,811

FIRR = 7.8%

Note: /1 Transmission loss of 2.9% was deducted.

/2 O&M cost was assumed at 2.5% of the total capital cost.

/3 O&M cost was assumed at 1.5% of the total capital cost.

/4 Steam cost was derived by unit cost (financial) of US mil 25.10/kWh (= 0.241 Peso/kWh) multiplied by generation volume at Tongonan power station.

/5 Generation capacity of 100 MW was assumed from No. 17 through No. 20 plants (with total capacity of 220 MW) and another 100 MW from No. 21 and No. 22 (with total capacity of 110 MW). Unit cost of US$745/kW was adopted from the study of Tongonan II Project prepared by NAPOCOR.

Table 9-6 FIRR Computation (Integrated)

Unit: US$$10^3$

No.	Year	Benefit					Cost								Benefit-Cost
		Energy Sales (GWh) /1			Power Rate (US mil/kWh)	Benefit	Geothermal P/S		Leyte-Mindanao T/L		Leyte-Luzon T/L		Steam	Total	
		Luzon	Mindanao	Total			Capital /2	O & M	Capital /3	O & M	Capital /3	O & M			
1	1984	–	–	–	–	–	–	–	–	–	2,499	–	–	2,499	-2,499
2	1985	–	–	–	–	–	23,859	–	–	–	44,567	–	–	68,426	-68,426
3	1986	–	–	–	–	–	115,323	–	–	–	226,752	–	–	342,075	-342,075
4	1987	–	–	–	–	–	175,832	–	–	–	68,463	–	–	244,295	-244,295
5	1988	645	–	645	100.9	65,105	142,851	3,470	2,774	–	12,557	5,545	36,919	204,116	-139,011
6	1989	1,936	–	1,936	109.0	210,941	211,339	11,097	33,446	–	112,549	5,989	119,618	494,038	-283,097
7	1990	1,936	–	1,936	117.7	227,817	287,301	11,985	165,656	–	38,480	6,468	129,187	639,077	-411,260
8	1991	3,227	–	3,227	127.1	410,070	185,741	21,148	64,604	–	–	9,635	232,537	513,665	-103,595
9	1992	3,931	595	4,526	137.3	621,288	53,620	31,515	0	4,317	–	10,406	351,597	451,455	169,833
10	1993	4,576	595	5,171	148.2	766,653	–	38,626	0	4,662	–	11,238	433,971	488,497	278,156
11	1994	4,576	595	5,171	160.1	827,985	–	41,716	8,575	5,035	–	12,137	468,688	536,151	291,834
12	1995	4,576	595	5,171	172.9	894,223	–	45,052	62,851	5,438	–	13,108	506,183	632,632	261,591
13	1996	4,576	595	5,171	186.7	965,761	–	48,658	13,577	5,873	–	14,157	546,678	628,943	336,818
14	1997	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
15	1998	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
16	1999	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
17	2000	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
18	2001	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
19	2002	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
20	2003	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
21	2004	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
22	2005	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
23	2006	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
24	2007	3,990	1,190	5,180	201.7	1,044,876	–	52,550	–	7,720	–	15,290	590,412	665,972	378,904
25	2008	3,341	1,190	4,531	201.7	913,959	–	45,614	–	7,720	–	15,290	516,611	585,235	328,724
26	2009	2,050	1,190	3,240	201.7	653,860	–	32,010	–	7,720	–	15,290	369,008	424,028	229,832
27	2010	2,050	1,190	3,240	201.7	653,860	–	32,010	–	7,720	–	15,290	369,008	424,028	229,832
28	2011	762	1,190	1,952	201.7	393,761	–	18,991	–	7,720	–	15,290	221,405	263,406	130,355
29	2012	0	655	655	201.7	132,188	–	6,244	–	7,720	–	15,290	73,802	103,056	29,132

FIRR = 12.5%

Notes: /1 Transmission loss was deducted by 2.9% for Mindanao and 4.4% for Luzon grids power transmission.

/2 The capital cost corresponds to the construction of No.7 through No.22 plants of Tongonan geothermal power station, the breakdown of which is presented in Table 9-5.

/3 The breakdown into foreign currency and local currency is presented in Table 9-6.

Table 9-7 Construction Schedule and Capital Cost of Tongonan Geothermal P/S

Unit: US$ 10^3

Year	Accumulated Generation Capacity (Plant No.)	(MW)	Capital Cost #7, 8 (110 MW)	#9 - 12 (220 MW)	#13 - 16 (220 MW)	#17 - 20 (220 MW)	#21, 22 (110 MW)	Total
1985			23,859					23,859
1986			64,068	51,255				115,323
1987			40,576	135,256				175,832
1988	#7 - #8	110		85,710	57,141			142,851
1989	#7 - #12	330			150,956	60,383		211,339
1990	#7 - #12	330			95,767	159,611	31,923	287,301
1991	#7 - #16	550				101,313	84,428	185,741
1992	#7 - #20	770					53,620	53,620
1993	#7 - #22	880						

Table 9-8 Capital Cost of Transmission Line Projects

Unit: US$ 10^3

Year	Leyte-Luzon Transmission Line F.C.	L.C.	Total		Leyte-Mindanao Transmission Line F.C.	L.C.	Total	
1984	2,322	177	2,499	1st Stage				
1985	25,255	19,312	44,567					
1986	142,563	84,189	226,752					
1987	34,039	34,424	68,463					
1988	10,234	2,323	12,557	2nd Stage	2,502	272	2,774	1st Stage
1989	77,736	34,813	112,549		19,896	13,550	33,446	
1990	16,936	21,544	38,480		100,548	65,108	165,656	
1991					36,128	28,476	64,604	
1992					0	0	0	
1993					0	0	0	
1994					5,316	3,259	8,575	2nd Stage
1995					37,661	25,190	62,851	
1996					6,085	7,492	13,577	

Table 9-9 Projected Income Statement

Unit: US$$10^3$

No.	Year	Power Sales (GWh)	Power Rate (US mil/kWh)	Operating Revenue	Transmission Lines Operation O&M Cost	Transmission Lines Operation Depreciation	Steam Cost	Generation Expense O&M Cost	Generation Expense Depreciation	Total Operating Expense	Operating Income	Plant in Service	Return on P.I.S. (%)
1	1992	595	137.3	81,701	4,317	5,330	45,607	3,943	7,302	66,499	15,202	412,529	3.7
2	1993	595	148.2	88,238	4,662	5,330	49,256	4,258	7,302	70,808	17,430	392,171	4.4
3	1994	595	160.1	95,297	5,035	5,330	53,196	4,599	7,302	95,297	19,835	371,813	5.3
4	1995	595	172.9	102,920	5,438	5,330	57,452	4,967	7,302	80,489	22,431	351,455	6.4
5	1996	595	186.7	111,154	5,873	5,330	62,048	5,364	7,302	85,917	25,237	331,097	7.6
6	1997	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	160,522	64,820	557,987	11.6
7	1998	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	535,929	12.1
8	1999	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	513,871	12.6
9	2000	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	491,813	13.2
10	2001	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	469,755	13.8
11	2002	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,228	175,272	64,820	447,697	14.5
12	2003	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	425,639	15.2
13	2004	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	403,581	16.1
14	2005	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	381,523	17.0
15	2006	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	359,465	18.0
16	2007	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	337,407	19.2
17	2008	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	315,349	20.6
18	2009	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	293,291	22.1
19	2010	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	271,233	23.9
20	2011	1,190	201.7	240,092	7,720	7,030	134,024	11,470	15,028	175,272	64,820	249,175	26.0
21	2012	655	201.7	132,188	7,720	7,030	73,713	6,244	7,726	102,433	29,755	234,419	12.7

Table 9-10 Projected Cash Flow Statement

Unit: US$$10^3$

	Year	Income before Interest	Income from T/L	Depreciation	Foreign Loan	Government Equity	Total Source	Capital Cost F.C.	Capital Cost L.C.	Debt Service Interest	Debt Service Principal	Total Appication	Increase in Cash	Cash at End	Debt Service Coverage
1	1988				2,502	272	2,774	2,502	272			2,774	0	0	
2	1989				19,896	13,550	33,446	19,896	13,550	75		33,521	-75	-75	
3	1990				100,548	65,108	165,656	100,548	65,108	672		166,328	-672	-747	
4	1991				36,128	28,476	64,604	36,128	28,476	3,688		68,292	-3,688	-4,435	
5	1992	15,202	8,194	5,330	0		13,524	0	0	4,772		4,772	8,752	4,017	2.8
6	1993	17,430	9,395	5,330	0		14,725	0	0	4,772		4,772	9,953	13,970	3.1
7	1994	19,835	10,691	5,330	5,316		21,337	5,316	3,259	4,772		13,347	7,990	21,960	3.4
8	1995	22,431	12,090	5,330	37,661		55,081	37,661	25,190	4,932		67,783	-12,702	9,258	3.5
9	1996	25,237	13,603	5,330	6,085		25,018	6,085	7,492	6,062		19,639	5,379	14,637	3.1
10	1997	64,820	34,938	7,030			41,968			6,244		6,244	35,724	50,361	6.7
11	1998	64,820	34,938	7,030			41,968			6,244	7,746	13,990	27,978	78,339	3.0
12	1999	64,820	34,938	7,030			41,968			6,012	7,978	13,990	27,978	106,318	3.0
13	2000	64,820	34,938	7,030			41,968			5,772	8,218	13,990	27,978	134,296	3.0
14	2001	64,820	34,938	7,030			41,968			5,526	8,464	13,990	27,978	162,274	3.0
15	2002	64,820	34,938	7,030			41,968			5,272	8,718	13,990	27,978	190,252	3.0
16	2003	64,820	34,938	7,030			41,968			5,010	8,980	13,990	27,978	218,230	3.0
17	2004	64,820	34,938	7,030			41,968			4,741	9,249	13,990	27,978	246,208	3.0
18	2005	64,820	34,938	7,030			41,968			4,464	9,527	13,990	27,978	274,186	3.0
19	2006	64,820	34,938	7,030			41,968			4,178	9,812	13,990	27,978	302,164	3.0
20	2007	64,820	34,938	7,030			41,968			3,883	10,107	13,990	27,978	330,142	3.0
21	2008	64,820	34,938	7,030			41,968			3,580	10,410	13,990	27,978	358,120	3.0
22	2009	64,820	34,938	7,030			41,968			3,268	10,722	13,990	27,978	386,098	3.0
23	2010	64,820	34,938	7,030			41,968			2,946	11,044	13,990	27,978	414,076	3.0
24	2011	64,820	34,938	7,030			41,968			2,615	11,375	13,990	27,978	442,054	3.0
25	2012	29,755	20,669	7,030			27,699			2,274	11,716	13,990	13,709	470,032	2.0
26	2013	0	0	7,030			7,030			1,922	12,068	13,990	-6,960	463,072	0.5
27	2014	0	0	7,030			7,030			1,560	12,430	13,990	-6,960	456,112	0.5
28	2015	0	0	7,030			7,030			1,187	12,803	13,990	-6,960	449,152	0.5
29	2016	0	0	7,030			7,030			803	13,187	13,990	-6,960	442,192	0.5
30	2017	0	0	7,030			7,030			407	13,583	13,990	-6,960	435,232	0.5

Table 9-11 Sensitivity of Debt Service Coverage by Interest Rate

Interest Rate(%) / Year	3%	5%	7%
1992	2.8	1.7	1.2
1993	3.1	1.9	1.3
1994	3.4	2.0	1.4
1995	3.5	2.1	1.5
1996	3.1	1.9	1.3
1997	6.7	4.0	2.9
1998	3.0	2.5	2.1
1999	3.0	2.5	2.1
2000	3.0	2.5	2.1
2001	3.0	2.5	2.1
2002	3.0	2.5	2.1
2003	3.0	2.5	2.1
2004	3.0	2.5	2.1
2005	3.0	2.5	2.1
2006	3.0	2.5	2.1
2007	3.0	2.5	2.1
2008	3.0	2.5	2.1
2009	3.0	2.5	2.1
2010	3.0	2.5	2.1
2011	3.0	2.5	2.1
2012	2.0	1.7	1.4
2013	0.5	0.4	0.4
2014	0.5	0.4	0.4
2015	0.5	0.4	0.4
2016	0.5	0.4	0.4
2017	0.5	0.4	0.4

Fig. 9-3 Sensitivity Analysis of FIRR

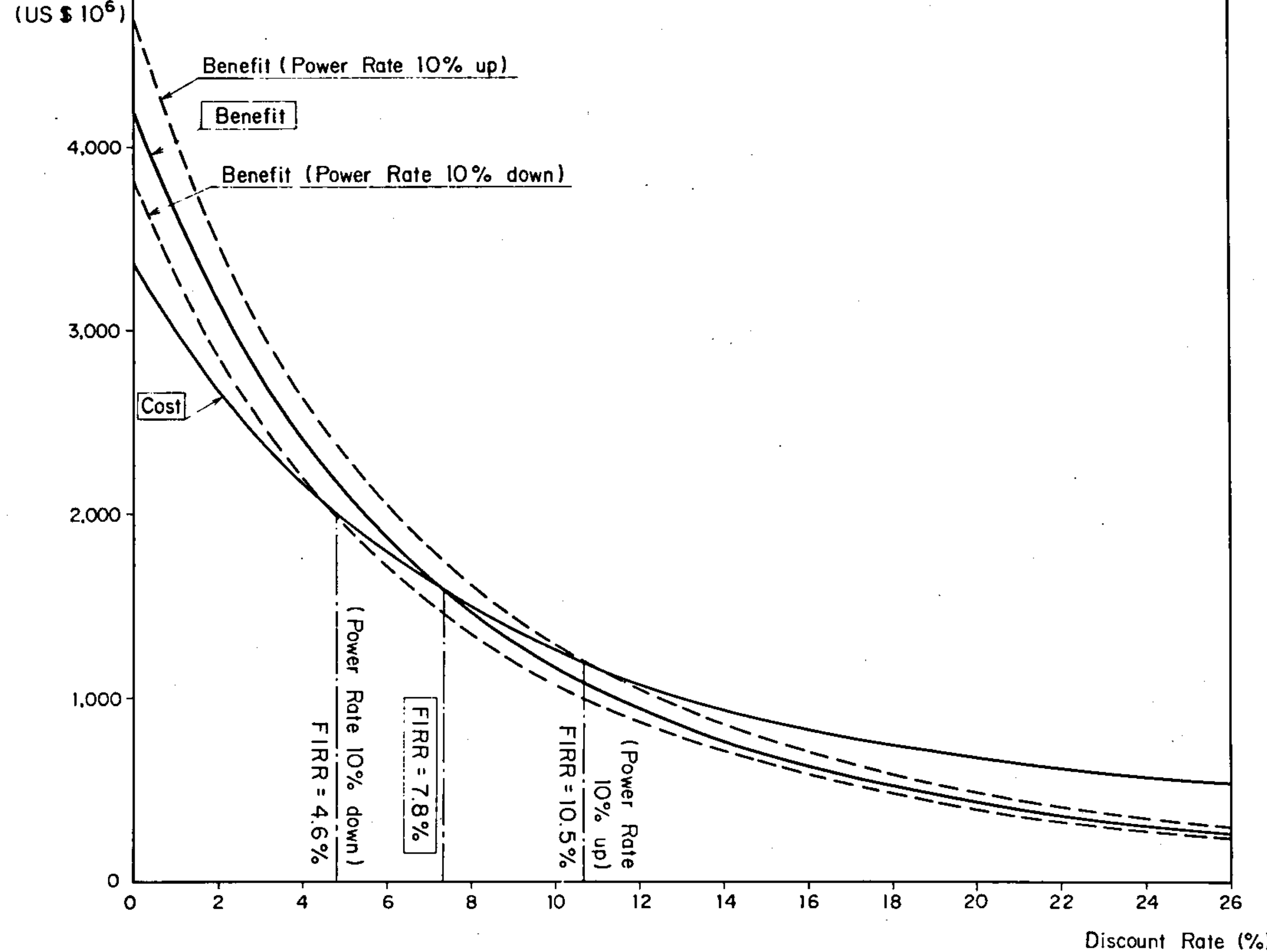
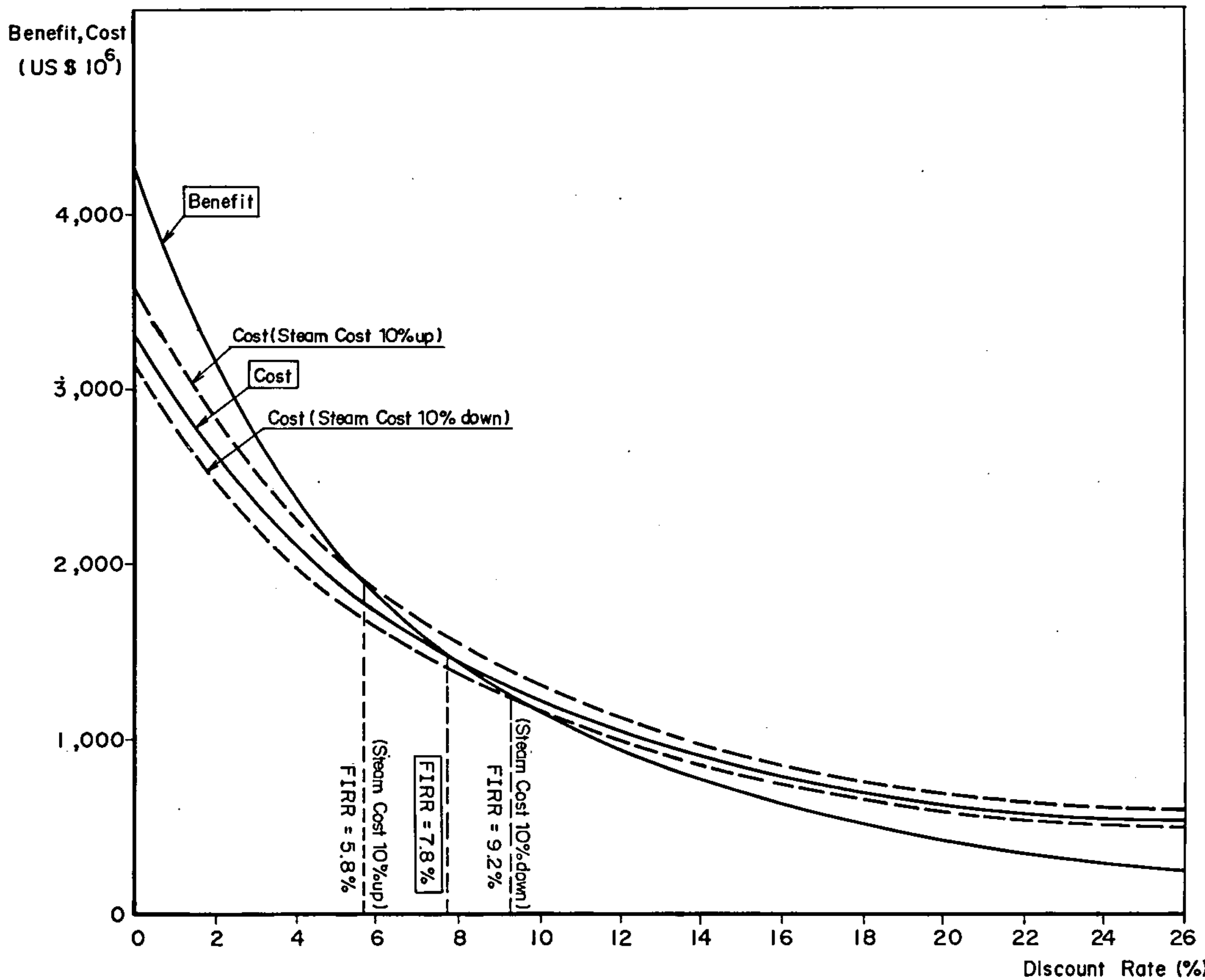


Fig. 9-4 Sensitivity Analysis of FIRR due to Steam Cost of PNOC



APPENDIX

A-1 WEATHER CONDITIONS IN THE PROJECT AREA AND WIND VELOCITY FOR DESIGNING

A-1 WEATHER CONDITIONS IN THE PROJECT AREA AND WIND VELOCITY FOR DESIGNING

(1) Weather Conditions of the Philippines

Philippine Islands are composed of over 7,000 islands located in the span of about 5°N.L. to 21°N.L., and these islands are roughly divided into Luzon area, Visayas area and Mindanao area.

Because of the fact that the Philippines is located in a low altitude area, characters of tropical climate are observed in this country except for high mountains, and accordingly, changes in temperature are small all the year round and humidity is high. The rainfall is large in general, and its distribution is affected by monsoon.

The factors which govern the climate of the Philippines can be mainly divided into the following four types.

a) Southwest monsoon

The southwest monsoon is caused by the Indian Ocean trade wind originated by high atmospheric pressure in Indian Ocean generated in winter of the southern hemisphere. In the area around the Philippines it becomes southwest air stream. This wind starts blowing at the beginning of June, becomes the strongest in August and continues up to the end of September. There are cases at occasions that it continues up to the end of October. It brings heavy rain to the entire west coast of the Philippines in June through September. Therefore, this period is so-called rainy season.

In this period of June through September, the wind mainly blows in southwest direction on the Leyte Island, Dinagat Island and on the north side of the Mindanao Island. The wind direction varies between south-southwest and west, and the wind velocity is around 4 to 6 kt in general.

b) Northwest monsoon

This is the cold air current caused by Asian winter high pressure, and it becomes northeast wind in the Philippines. It starts blowing toward the end of October, becomes the strongest in January and usually continues up to the end of April. Relative cold climate is continued because of influence of this air current, and heavy rain is observed along the east coast (Pacific Ocean side) in December, January and February.

In the areas on the Leyte Island, Dinagat and the north side of the Mindanao Island, the wind direction is northeast in general and the wind velocity is around 4 to 6 kt in general.

c) The North Pacific Trades

This is the air current from North Pacific high pressure. Wind direction is north or east in general in the Philippines. It becomes predominant in April, May and October, and it suppresses the air mass of northwest monsoon in the east area. It is most characteristic that it is the warmest air current that exerts influence over the Philippines. It brings fine weather, and thunder storms are occasionally produced out of a cumulus.

d) South Pacific Trades

This is the air current from South Pacific high atmospheric pressure produced in the southern hemisphere. The wind direction is southwest in June in the Philippines. This is a warm air current. Although its low layer is of high humidity, its upper layer is relatively dry, and its characteristic is similar to that of the southwest monsoon described earlier.

What characterize the climate of the Philippines besides four air currents described above are South Sea typhoons. In addition, the Philippines is also affected by fronts and the equatorial calm. It is also largely affected by sea currents as it is surrounded by seas.

(2) Weather Conditions in Project Area

The weather data collected at weather observation stations in the project area, that is, Tacloban (Leyte Island), Surigao, Cagayan de Oro and Davao (Mindanao Island) are shown in Table A-1-1. The weather conditions in these areas can be summarized as follows from these data.

a) Temperature

The mean annual temperature is about 27.3°C. The maximum temperature is 37.2°C at Surigao and minimum temperature is 17.8°C at Tacloban, but when regional difference, altitude difference and so forth are considered, it can be considered that the temperatures are around maximum 40°C and minimum 10°C in the project area.

b) Rainfall

The average annual rainfall in the project area is estimated 2,300 mm. There is no distinction in particular between dry season and rainy season. A lot of rain is brought in winter by northeast monsoon. The maximum annual value amounts to 3,600 mm in Surigao.

c) The number of days of thunderstorm is 70 days in Tacloban and 83 days in Surigao. The average for the two is 80 days. Both of these towns belong to a thunderstorm area.

(3) Typhoon

The Philippines is the country that is most directly hit by typhoons. The middle part and the north part of the Philippine Islands in particular tend to be attacked by typhoons, but very minor at Leyte and Mindanao. Typhoons are usually generated on the east side of the Philippines and they advance toward the Philippine Islands and Indo-China. Occurrence of typhoons is frequent in June through December. The average course of these typhoons is toward the north in February through August, and it is usual that they go down south after August up to January.

Table A-1-1 Climatic Data in the Project Area

Item		Station	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Observation period
Temperature (C)	Average	Tacloban	25.8	26.1	26.7	27.6	28.0	27.9	27.9	28.0	27.9	27.8	27.2	26.4	27.3	17
		Sunigao	25.7	25.7	26.2	27.1	28.1	28.1	28.0	28.1	28.1	27.1	26.8	26.2	27.1	13
		Butuan	26.0	26.2	27.2	28.0	28.7	28.1	28.2	27.9	28.3	27.7	26.9	26.4	27.4	16
		Cagayan de oro	25.8	26.0	26.6	27.3	28.1	27.7	27.3	27.3	27.4	27.1	26.8	26.4	27.1	8
		Davao	26.3	26.7	27.5	28.3	28.1	27.6	27.3	27.4	27.6	27.4	27.4	26.8	27.4	8
	Highest	Tacloban	33.0	34.4	34.4	36.1	36.1	36.1	35.6	35.6	36.1	35.6	34.4	33.3	36.1	16
		Surigao	31.1	32.2	32.2	33.3	35.0	36.1	34.4	35.5	37.2	34.4	33.3	32.8	37.2	15
	Average of daily max	Tacloban	28.9	29.1	30.0	31.1	31.3	31.2	31.1	31.5	31.4	31.1	30.4	29.4	30.5	17
		Sunigao	28.5	28.9	29.8	31.1	32.4	32.5	31.9	32.3	32.2	31.0	30.1	29.4	30.8	13
		Butuan	30.0	31.3	32.2	33.2	34.1	33.3	33.2	32.9	33.7	32.5	31.6	30.7	32.4	16
		Cagayan de oro	30.5	30.6	31.5	32.5	33.0	32.5	32.2	32.4	32.3	31.7	31.4	30.8	31.7	8
		Davao	30.8	31.4	32.6	33.6	32.9	32.1	31.8	32.0	32.5	32.2	32.3	31.4	32.1	8
	Average of darly min	Tacloban	22.6	22.8	23.1	24.2	24.6	24.6	24.5	24.6	24.6	24.3	23.9	23.5	23.9	17
		Surigao	22.7	22.3	22.5	23.1	23.6	23.7	23.7	23.9	24.1	23.3	23.0	23.0	23.3	13
		Butuan	22.0	22.0	22.2	22.7	23.3	23.0	23.0	22.9	22.9	23.0	22.4	22.2	22.6	16
		Cagayan de oro	21.0	21.3	21.7	22.4	23.2	22.8	22.8	22.3	22.4	22.5	22.2	21.9	22.4	8
		Davao	21.8	22.0	22.4	22.9	23.3	23.1	23.1	22.7	22.7	22.6	22.4	22.0	22.6	8
	Lowest	Tacloban	18.9	17.8	17.8	20.0	22.2	22.2	22.2	21.7	21.7	21.7	20.0	17.8	17.8	16
		Surigao	19.4	20.0	20.0	20.5	21.1	21.1	21.1	22.2	22.2	21.1	21.1	18.9	18.9	15
Sea level pressure (nib)		Tacloban	1,011	1,012	1,012	1,010	1,009	1,009	1,008	1,008	1,009	1,009	1,009	1,011	1,010	15
		Surigao	1,101	1,011	1,011	1,010	1,010	1,009	1,009	1,009	1,009	1,009	1,009	1,010	1,010	10
		Cagayan de oro	1,011	1,011	1,010	1,010	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009	8
		Davao	1,011	1,011	1,011	1,010	1,010	1,010	1,010	1,010	1,009	1,010	1,010	1,010	1,010	8
Relative humidity (%)		Tacloban	83	83	80	81	81	82	81	79	81	83	85	86	82	15
		Surigao	87	87	85	84	83	82	81	80	80	83	86	88	84	10
		Cagayan de oro	81	81	77	74	77	81	80	80	79	81	81	83	80	8
		Davao	82	80	78	77	81	82	82	81	80	81	81	81	81	8
Rain fall (mm)		Tacloban	251	206	147	133	142	189	179	131	135	189	322	329	2,310	18
		Surigao	597	488	351	235	129	144	163	130	137	275	432	560	3,641	14
		Cagayan de oro	53	82	38	21	73	221	213	266	208	204	152	91	1,622	8
		Davao	143	81	59	125	257	155	155	169	189	134	151	90	1,725	8
Thunder storm (days)		Tacloban	1	1	2	5	10	11	10	8	9	8	3	2	70	10
		Surigao	0	0	1	3	8	12	12	10	14	14	7	2	83	20

20 typhoons at average per year enter the area that affects the Philippines and 42 % pass through the Philippine Island. An average of 4.8 typhoons per year cause damage to somewhere in the Philippines, and only 0.3 of them cause loss of man power and economy in the project area. (Table A-1-2)

Figures of maximum wind velocity, lowest atmospheric pressure and maximum rainfall in 24-hour period in the northern part of Leyte, and northern part of Mindanao summarized from the data related to typhoons are shown in Table A-1-3.

The extreme values observed in this area are as follows.

Max. wind velocity : 195 kph (54 m/sec) (Tacloban, 1966)

Min. atmospheric pressure : 956 mb (Surigao, 1968)

Max. rainfall in 24-hour period : 565 mm (Surigao, 1968)

The southern part of Leyte Island and the northern part of Mindanao Island are not busy courses of typhoons as described earlier.

(4) Estimation of Wind Velocity for Designing

A overhead transmission line should be kept on running with high reliability over a long period of time, and large loads should be assumed for this purpose. However, the construction expenses increase and the economy is lost if excessively large loads are assumed. Accordingly, the wind velocity level used for the design is a very important factor.

For determining the design wind velocity, the method to use the maximum wind velocity recorded in the past in the subject area and the method to estimate the wind velocity value through analysis of probability of occurrence of strong winds are available. The former has such a defect of being affected by the difference in the number of years of records in the subject area. The latter method is adopted generally in these days, and there are many cases where a return period is determined depending on the reliability of transmission lines, and the estimated wind velocity in this period is adopted as the design wind velocity.

It has been confirmed through analysis of weather data that the distribution of maximum wind velocity in every year confirms to I type of Gumbel. According to Gumbel, probability P (V) of excess of wind velocity beyond a certain wind velocity level V is expressed by the following equation.

$$P(V) = 1 - \exp\left[-\exp\left\{-\frac{\pi}{6\sigma_V}(V - \bar{V} + 0.45\sigma_V)\right\}\right]$$

where; P (V) : Probability of excess of wind velocity beyond V ($= \frac{1}{T}$; T : return period)

$\bar{V}$: Mean value of annual maximum wind velocity

σ_V : Standard deviation of annual maximum wind velocity

Table A-1-2 Number of Tropical Cyclone

Month	Cyclones which affected the Philippines	Disastrous cyclone	
		Philippines	Project area
Jan.	17	3	2
Feb.	9	1	0
Mar.	8	0	0
Apr.	12	2	1
May	25	5	2
June	48	10	0
July	100	14	0
Aug.	108	19	0
Sept.	97	17	0
Oct.	77	21	0
Nov.	74	35	3
Dec.	41	17	1
Total	616	144	9
Mean	20	4.8	0.3
Period	1948 - 1978	1948 - 1978	

Reference: Tropical cyclone summaries from 1948 to 1978
PAGASA (Dec. 1978)

Table A-1-3 Tropical Cyclone in Project Area (1948 - 1978)

Station	Max. Wind Speed (KPH)	Min Pressure (mb)	Max. 24 Hours Rainfall (mm)	Reference
Tacloban	195	967	287	1,966/May
(Leyte)	160	987	69	1,971/Apr.
	104	993	187	1,972/Jan.
	93	996	198	1,962/May
	85	1,003	—	1,971/Mar.
	41	1,006	65	1,965/Mar.
Surigao	167	956	565	1,968/Nov.
(Mindanao)	121	1,000	355	1,950/Nov.
	120	1,001	94	1,967/Mar.
	112	1,003	356	1,954/May
	111	1,001	170	1,969/Apr.
	65	1,002	173	1,960/Apr.
	45	1,005	55	1,971/Nov.
Hinatuan	93	1,002	240	1,955/Jan.
	84	986	215	1,954/Dec.
	39	1,008	177	1,954/Mar.
	88	1,004	391	1,949/Nov.

Table A-1-4 Ranks of Annual Max. Wind Speed

(in Knots)

Rank \ Station	Surigao	Davao	Cagayan de Oro	Tacloban
1	19	22	9	25
2	21	24	9	26
3	22	25	10	30
4	24	25	10	30
5	26	25	10	32
6	28	26	10	34
7	32	26	10	36
8	32	26	10	36
9	34	27	10	37
10	35	28	10	37
11	38	28	10	38
12	40	28	11	38
13	48	28	12	40
14	52	30	13	42
15	52	30	14	43
16	56	35	15	44
17	58	60	18	47
18	60		20	50
19	90		20	52
20			20	52
21			20	55
22			22	56
23			22	56
24			22	61
25			22	72
26			25	84
27			26	90
28			26	102
29				105

The relationship between return period (RP) and wind velocity (V) was obtained based on the annual maximum wind velocity data (1 minute evaluation) at observation stations located in the project area shown in Table A-1-4 in accordance with the above equation. The result is shown in Fig. A-1-1.

It is usual that the return period of 50 years is adopted and steel towers are designed with the wind velocity (extreme value) in this period for overhead transmission lines requiring high reliability.

The extreme wind velocity value at observation station in Tacloban, Surigao and Davao are estimated respectively at 105 knots, 86 knots and 51 knots as shown in Fig. A-1-1.

Meanwhile, a statistical analysis has been made of the return period of the annual maximum wind speed (1-minute evaluation) at major observation stations throughout the Philippines by Dr. Roman L. Kintanar of the Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). From this report, ("Climatology and Wind Related Problems in the Philippines") the wind speed map for a return period of 50 years is indicated in Fig. A-1-2.

In the project area, practically the entire region is included in a zone with about 90 knots wind speed.

The design wind velocity is a factor that exerts direct influence over the economy and reliability of transmission lines. Therefore, the value of 100 knots (185 kph) is adopted as the design wind velocity for DC overhead transmission line according to the estimation based on the value measured at Tacloban and design existing transmission line in the Philippines.

Fig. A-1-1 Wind and Return Period

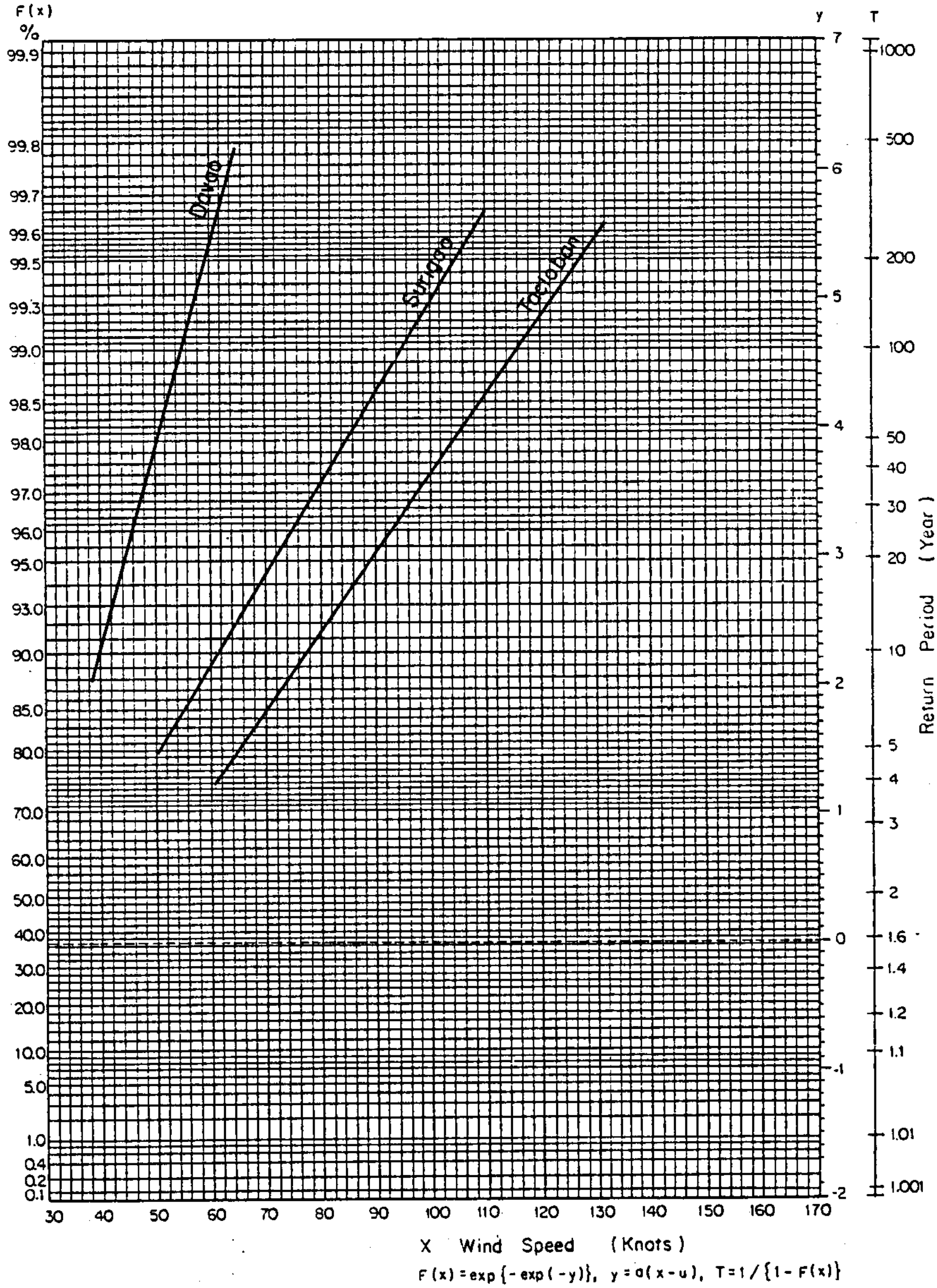
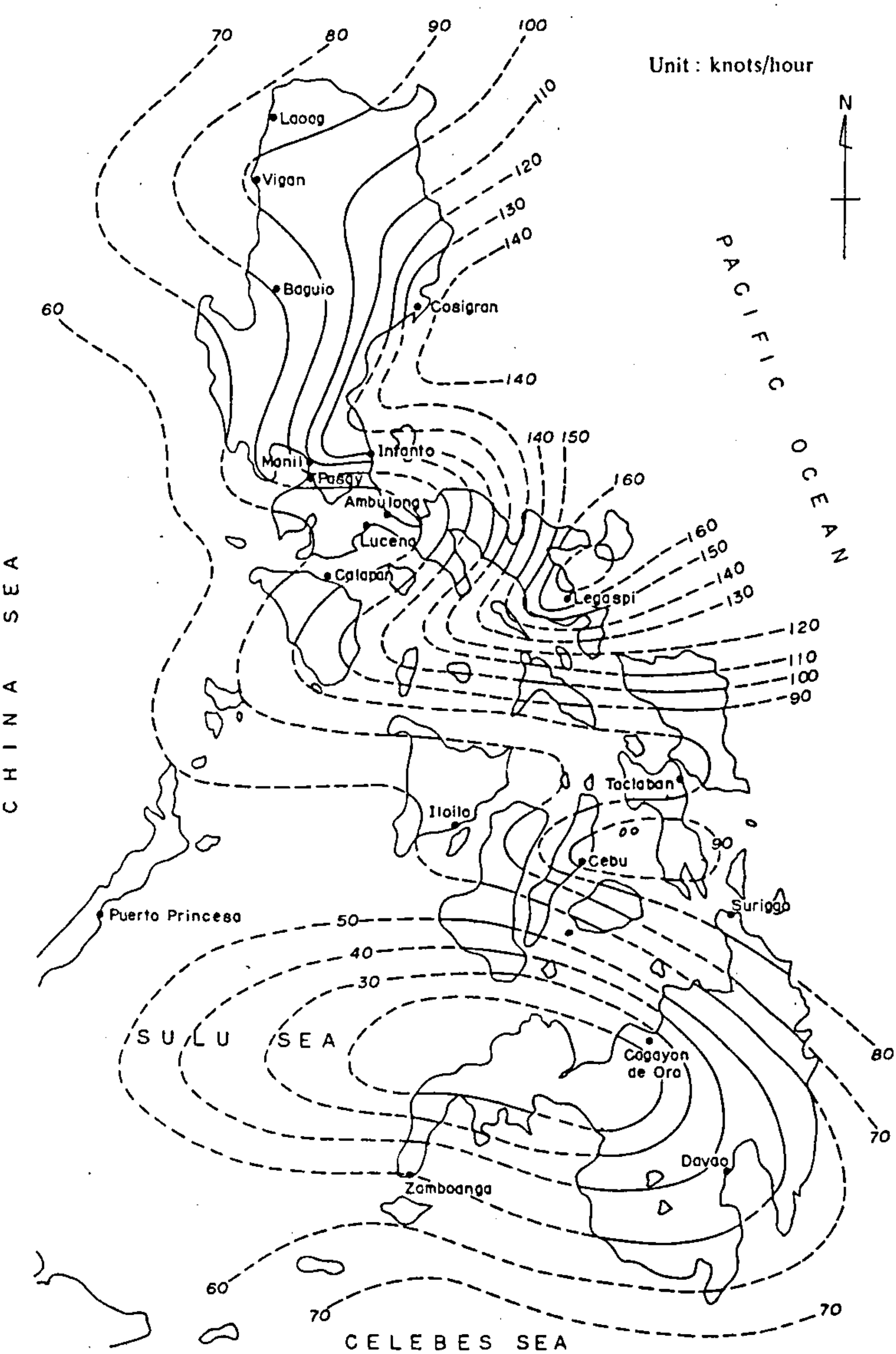


Fig. A-1-2 Annual Max-Wind Speed at 50 years Return Period by Dr. R.L. Kintanar PAGASA



A—2 SUPPLEMENTAL SEABED SURVEY

A-2 SUPPLEMENTAL SEABED SURVEY

(1) Background

Seabed survey of the submarine cable routes of the Leyte-Mindanao Transmission Line had been conducted between the middle of June to the middle of August 1983.

As for the wide Surigao Strait between Leyte and Dinagat, it was confirmed that there was wide rocky seabed of considerable width at the center of the strait with nearly 200 m in depth. The seabed is rather rugged, which may damage the laid cables during the long time usage. However, due to lack of the survey period and limitation of survey equipment, an echo sounder which are usually used for a feasibility study, details of the seabed conditions of the strait could not be well known and technical feasibility of the route could not be confirmed.

An additional survey was concluded to supplement the previous survey by using some additional equipment and to confirm technical feasibility for the submarine cable laying by selecting an appropriate route. Confirmation of the seabed conditions of the presumed rocky surface at the middle of the selected route between Nonoc and Lipata was also included in the additional survey.

(2) Procedures for Survey

a) Applied equipment

In addition to an echo sounder for measuring sea depth and an audistor for identifying location of the survey ship the following two apparatuses were used.

a. Side scan soner for visual inspection of the seabed.

b. Aanderaa current meter combined with an accoustic releasing device for measuring tide current speed and its direction on the seabed.

b) Survey of Surigao Strait

In addition to 6 km width, 3 km each on both sides of the proposed route, which was surveyed previously, echo sounding was conducted covering wide areas to the south and north. Survey by the side scan soner was conducted for some selected routes.

Measurement of the tide current on the seabed and collection of seabed materials were also conducted.

Survey items were as given below:

a. Echo sounding .... 1,050 km (Excluding 405 km during the previous survey)

b. Side scanning .... 393 km

c. Measurement of seabed current

4 points for 3 days

1 point for 15 days (Equipment were set at two locations but one equipment was lost)

d. Seabed material sampling ... 8 points

c) Survey of Hinatuan Passage

Echo sounding and side scanning were conducted on and in parallel with the selected route and in the cross direction around the presumed rocky area at the middle of the route.

Measurement of tide current on the seabed was carried out for 2 days at the mouth of the narrow strait between Hikdop and Hanigad, where the current is fastest.

(3) Findings of Survey

a) Survey of Surigao Strait

It is revealed that the rock surface is exposed in the deep sea covering wide areas at the middle of the strait. The seabed is generally rough and not suitable for cable laying except for the very limited area. It is supposed that sand on the rocky surface moves towards the deep sea of the Surigao Strait to the south and not to the reverse direction. The measured data of seabed current are showin in Fig. A-2-1 to A-2-5, Fig. A-2-1 to A-2-4 are 3 days' data including the high tide time and Fig. A-2-5 is 15 days data at the southern side of the strait. The maximum current speed during the high tide time is slightly exceeding 1 m/sec and even the maximum speed along the selected route is expected to be within 1.5 m/sec, which is the minimum current speed to move the laid cables with the tide force. From Fig. A-2-5 it is known that time temperature is rather high when the current is flowing from north to south and when the current is flowing from south, cold water in the deep sea seems to come up and temperature goes down remarkably. Difference between the highest temperature (26°C) and the lowest temperature (12°C) was 14 degrees.

The most recommendable route to cross the strait is running the southern side of the initially selected route, from the south of Hinundayan to Libjo bay to the south of Balete Cove with five turning points as shown on the attached drawing. Out of total route length of 32.5 km, about 13 km runs on the rocky surface. However, undulation is rather gentle and the recorded maximum inclination of the route is about 16 degrees, which is within the allowable range.

The selected landing point on Leyte is more than 4 km south of the previously selected site, just south of Sagbuk. The terminal site is in a coconut plantation about 200 m from the seaside. The suitable landing point on Dinagat is at the same location as that selected during the preliminary survey in

1979. The terminal site is on a hill about 300 m from the seashore. It is protected from northern to north-eastern strong wind by a ridge running northern side of the site.

An alternative route runs to the north, from Hinunangan in Leyte to the south of Hibuson and to Tubajon in Dinagat along Tubajon bay. The seabed condition is better than the southern route mentioned above but, the submarine cable route is more than 10 km longer than the selected route, the overhead transmission line route also becomes several kilometers longer and tide current between Hibuson and Dinagat is very fast, assumed to be 6 knots during high tide time which is exceeding the measuring range of the current meter. Moving of the laid cables on the bottom rocky surface is inevitable. Therefore this route is not recommendable.

Thus, it is considered that there is no other way to select the recommended southern route.

b) Survey of Hinatuan Passage

It was revealed that the presumed rocky surface at the middle of the route is the rocky bed covered with sand with some exposed rocks. Therefore, there is no problem for laying submarine cables.

The cable route selected during the previous survey was confirmed as the best one in the area.

The measured tide current data are as shown in Fig. A-2-6. The measured maximum current speed for two days, which was two days earlier than the highest tide, was 0.9 m/sec, and the maximum current in the area is supposed to be within 1.5 m/sec.

Fig. A-2-1

SURIGAO STRAIT
MEASURING POINT A

B+5.0M

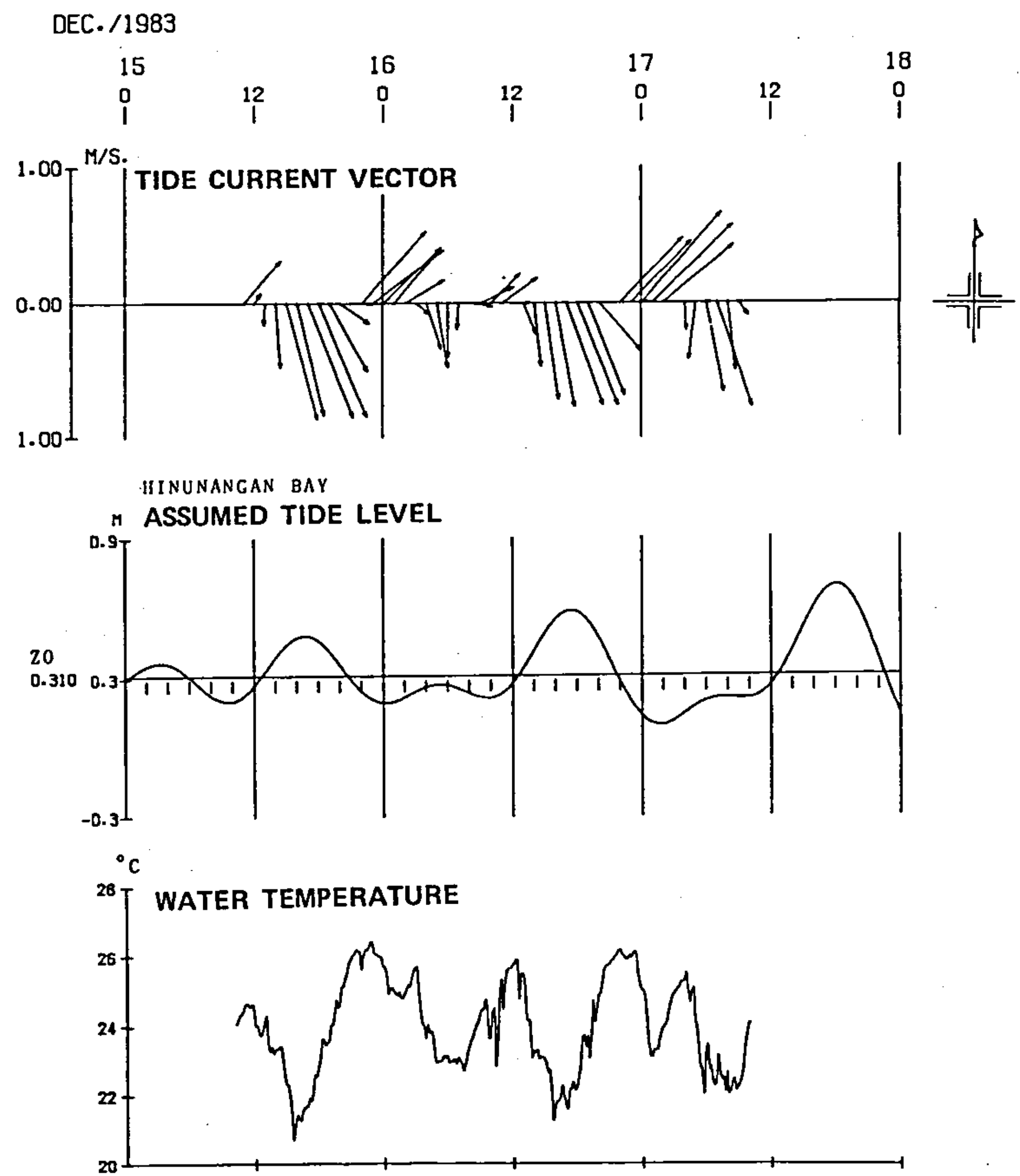


Fig. A-2-2

SURIGAO STRAIT

MEASURING POINT B

B+5.0M

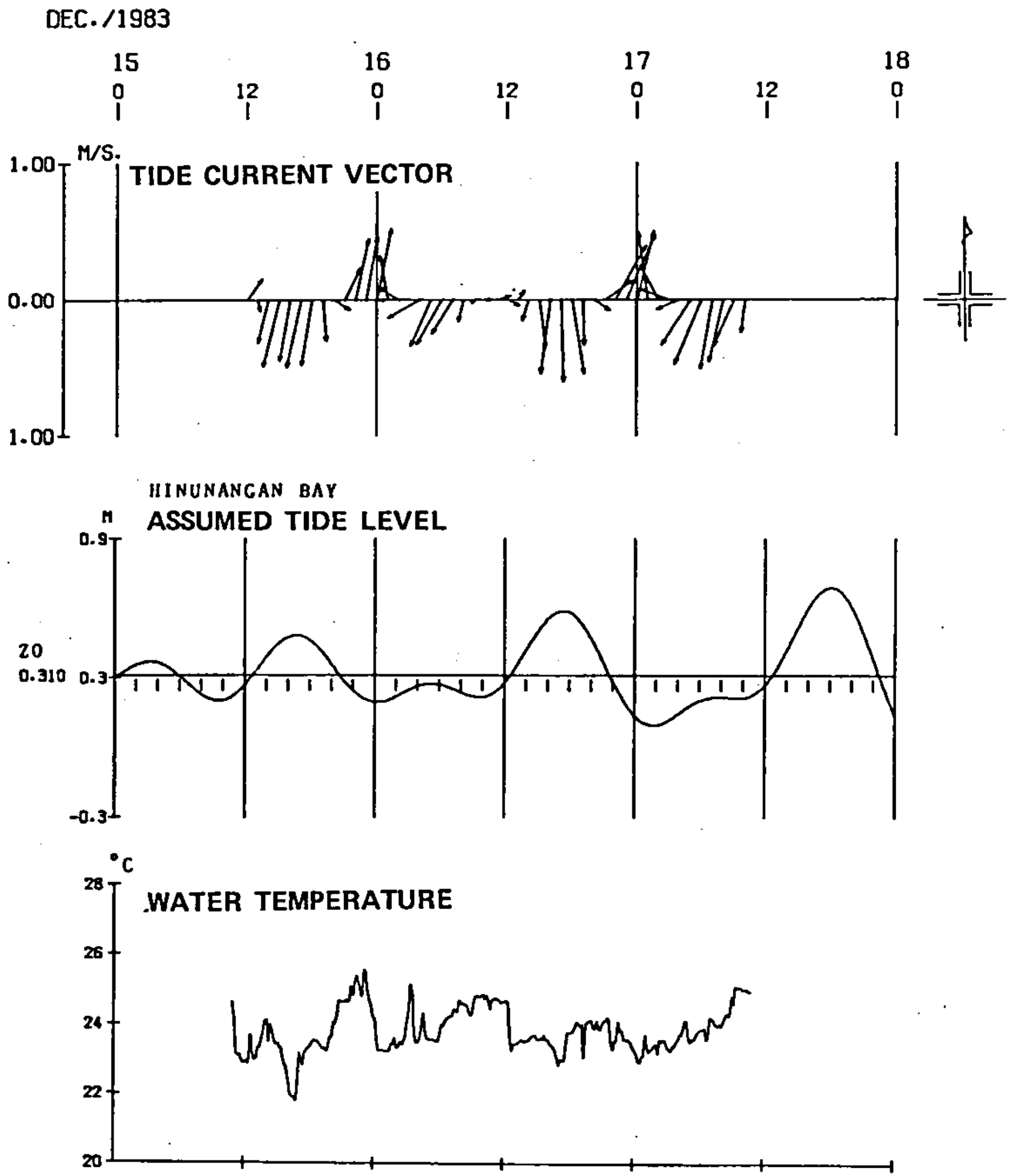


Fig. A-2-3

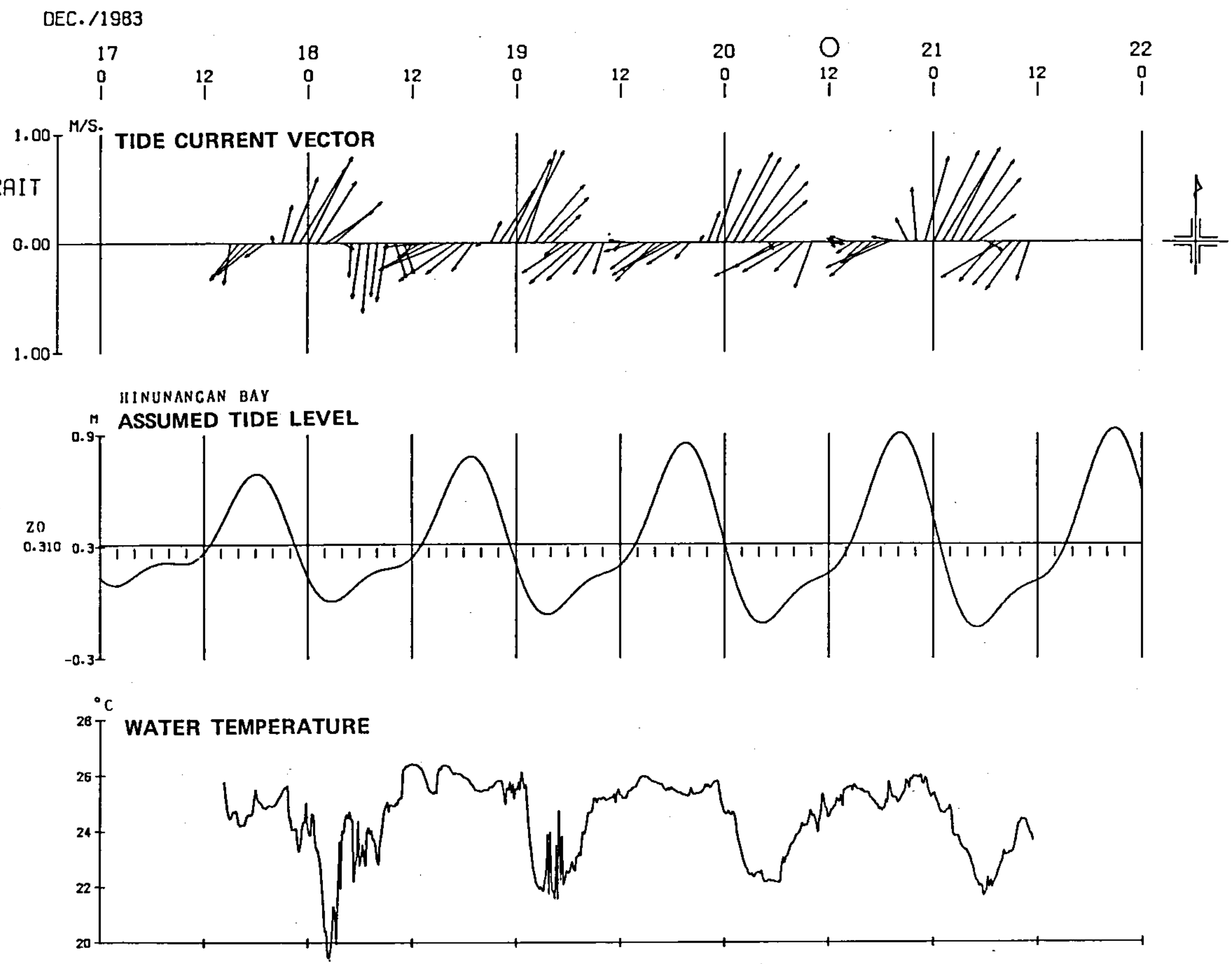

DEC./1983
17
18
19
20
21
22
0
12
SURIGAO STRAIT
MEASURING POINT C
B+5.0M
M/S.
1.00
0.00
1.00
TIDE CURRENT VECTOR
HINUNANGAN BAY
ASSUMED TIDE LEVEL
M
0.9
ZO
0.310
0.3
-0.3
°C
WATER TEMPERATURE
28
26
24
22
20

Fig. A-2-4

SURIGAO STRAIT

MEASURING POINT D

B+5.0M

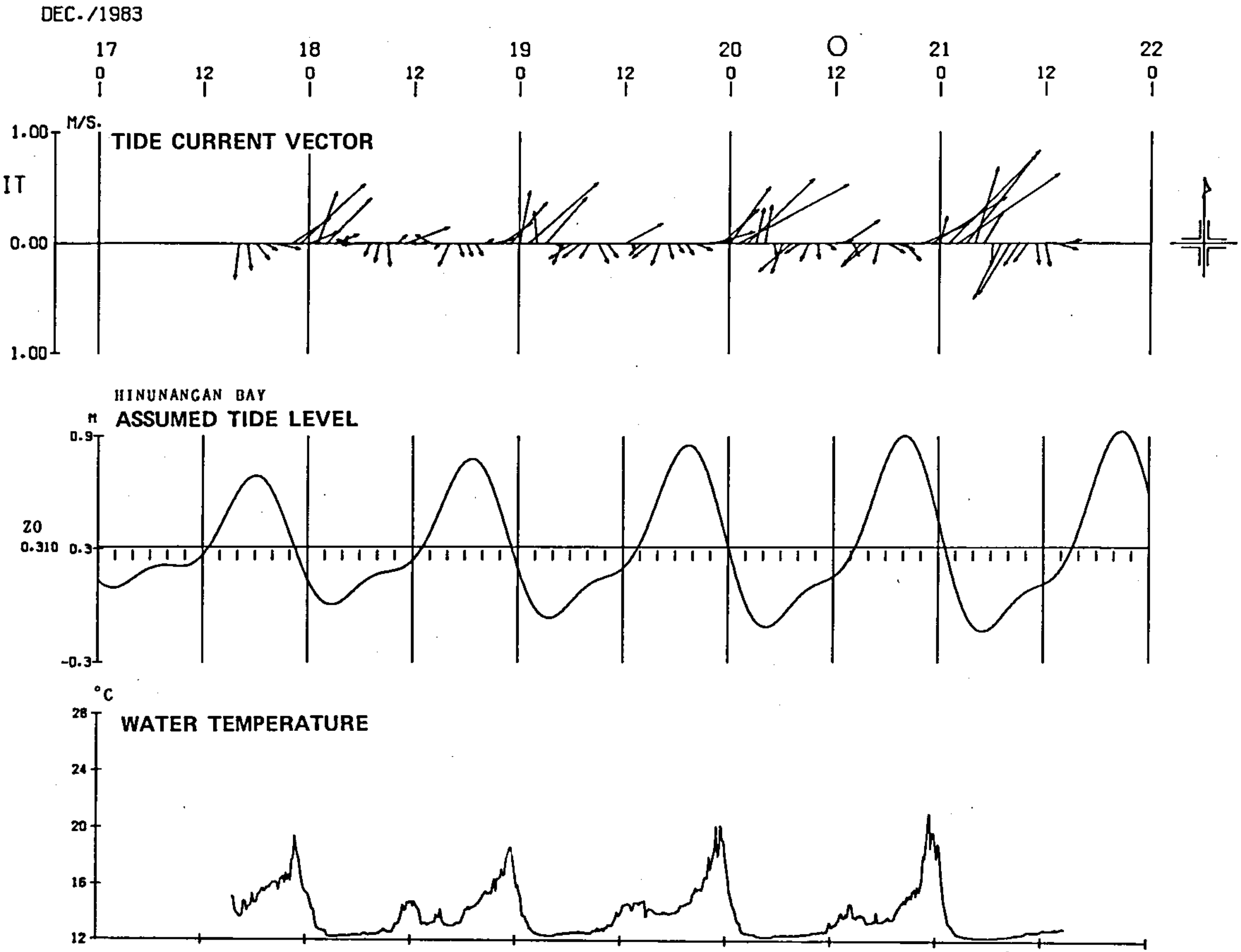


Fig. A-2-5

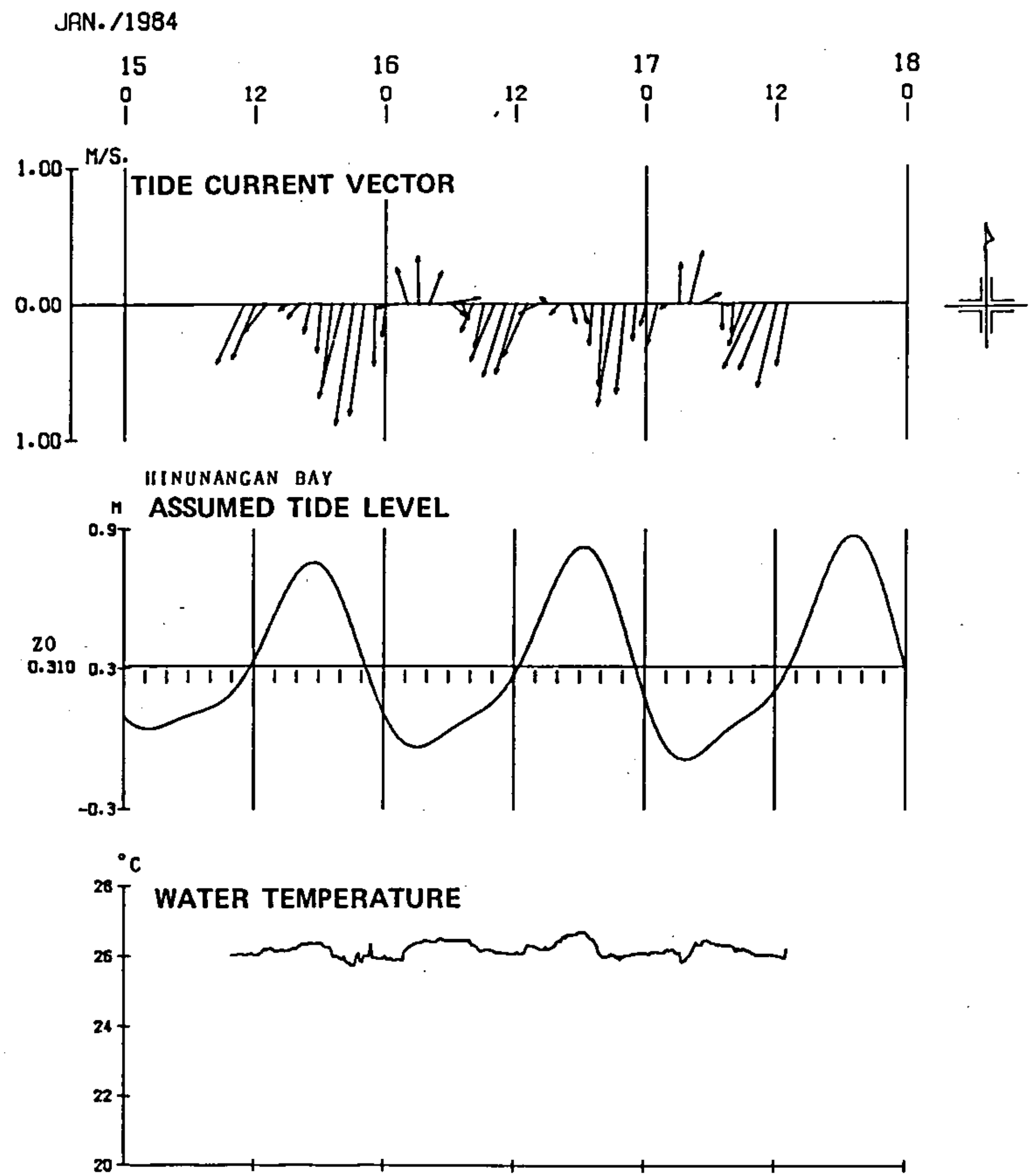

DEC./1983
JAN./1984
22
23
24
25
26
27
28
29
30
31
1
2
3
4
5
6
7
8
0
12
M/S.
TIDE CURRENT VECTOR
1.00
0.00
SURIGAO STRAIT
MEASURING POINT F
B+5.0M
HINUNANGAN BAY
M
ASSUMED TIDE LEVEL
0.9
ZO
0.310
0.3
-0.3
°C
WATER TEMPERATURE
28
24
20
16
12

Fig. A-2-6

HINATUAN PASSA.

MEASURING POINT G

B+5.0M



A– 3 FIRR COMPUTATION

(The case of NAPOCOR proposed escalation rate)

A-3 FIRR COMPUTATION (The case of NAPOCOR-proposed escalation rate)

In Chapter 8, as one of the factors for cost estimation, escalation rates of construction cost were estimated for domestic and foreign currency portions.

NAPOCOR-proposed escalation rate was adopted for domestic portion and half of NAPOCOR rate was applied for foreign currency, considering the worldwide price conditions, in Chapter 9.

Here in appendix, for reference, FIRR computation was made, applying NAPOCOR escalation rate for both domestic and foreign currency portions. (Table A-3-1 & A-3-2)

Escalation Rate (NAPOCOR-proposed)

Unit: %p.a.

	1983	1984	1985	1986	1987-96
Local Currency	14.0	24.0	18.0	12.0	8.0
Foreign Currency	8.0	7.5	7.0	6.0	6.0

FIRR

	With NAPOCOR-proposed escalation rate	(JICA evaluation)
Independent Case	6.0%	7.8%
Integrated Case	10.6%	12.5%

Table A-3-1 FIRR Computation (Independent) Based on NPC proposed Escalation Rate (Foreign)

Unit: US$$10^3$

No.	Year	Benefit			Cost						Benefit-Cost
		Energy Sales /1 (GWh)	Power Rate (US mil/kWh)	Benefit	Geothermal P/S		Leyte-Mindanao T/L		Steam /4	Total	
					Capital /5	O & M /2	Capital	O & M /3			
1	1988	—	—	—	—	—	3,305	—	—	—	-3,305
2	1989	—	—	—	30,530	—	38,375	—	—	68,905	-68,905
3	1990	—	—	—	114,316	—	194,221	—	—	308,537	-308,537
4	1991	—	—	—	133,619	—	76.219	—	—	209,838	-209,838
5	1992	595	137.3	81,701	56,087	4,278	0	5,056	5,056	111,028	-29,327
6	1993	595	148.2	88,238	—	4,620	0	5,461	49,256	59,337	28,901
7	1994	595	160.1	95,297	—	4,990	10,915	5,898	5,898	74,999	20,298
8	1995	595	172.9	102,920	—		5,389	81,015	6,370	150,226	-47,306
9	1996	595	186.7	111,154	—	5,820	16,774	6,879	62,048	91,521	19,633
10	1997	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
11	1998	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
12	1999	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
13	2000	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
14	2001	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
15	2002	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
16	2003	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
17	2004	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
18	2005	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
19	2006	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
20	2007	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
21	2008	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
22	2009	1,190	201,7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
23	2010	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
24	2011	1,190	201.7	240,092	—	12,755	—	9,190	134,024	155,969	84,123
25	2012	655	201.7	132,188	—	6,469	—	9,190	73,713	89,372	42,816

FIRR = 6.0%

Note:
/1 Transmission loss of 2.9% was deduced.
/2 O & M cost was assumed at 2.5% of the total capital cost.
/3 O & M cost was assumed at 1.5% of the total capital cost.
/4 Steam cost was derived by unit cost (financial) of US mil 25.10/kWh (=0.241 Peso/kWh) multiplied by generation volume at Tongonan power station.
/5 Generation capacity of 100 MW was assumed from No. 17 through No. 20 plants (with total capacity of 220 MW) and another 100 MW from No. 21 and No. 22 (with total capacity of 110 MW). Unit cost of US$745/kW was adopted from the study of Tongonan II Project prepared by NAPOCOR.

Table A-3-2 FIRR Computation (Integrated) Based on NPC proposed Escalation Rate (Foreign)

Unit: US$$10^3$

No.	Year	Benefit: Energy Sales (GWh) /1: Luzon	Mindanao	Total	Power Rate (US mil/kWh)	Benefit	Cost: Geothermal P/S: Capital /2	O & M	Leyte-Mindanao T/L: Capital /3	O & M	Leyte-Luzon T/L: Capital /3	O & M	Steam	Total	Benefit-Cost
1	1984	—	—	—	—	—	—	—	—	—	2,792	—	—	2,792	-2,792
2	1985	—	—	—	—	—	25,225	—	—	—	47,405	—	—	72,630	-72,630
3	1986	—	—	—	—	—	123,484	—	—	—	247,393	—	—	370,877	-370,877
4	1987	—	—	—	—	—	190,771	—	—	—	74,526	—	—	265,297	-265,297
5	1988	645	—	645	100.9	65,105	205,303	3,722	3,305	—	14,731	6,028	36,919	270,008	-204,903
6	1989	1,936	—	1,936	109.0	210,941	235,077	13,312	38,375	—	131,808	6,511	119,618	544,701	-333,760
7	1990	1,936	—	1,936	117.7	227,817	323,349	14,377	194,221	—	43,292	7,031	129,187	711,457	-483,640
8	1991	3,227	—	3,227	127.1	410,070	197,862	23,516	70,219	—	—	10,669	232,537	540,803	-130,733
9	1992	3,931	595	4,526	137.3	621,288	61,696	34,808	0	5,056	—	11,523	351,597	464,680	156,608
10	1993	4,576	595	5,171	148.2	766,653	—	42,823	0	5,461	—	12,445	433,971	494,700	271,953
11	1994	4,576	595	5,171	160.1	827,985	—	46,249	10,915	5,898	—	13,440	468,688	545,190	282,795
12	1995	4,576	595	5,171	172.9	894,223	—	49,949	81,015	6,370	—	14,515	506,183	658,032	236,191
13	1996	4,576	595	5,171	186.7	965,761	—	53,945	16,774	6,879	—	15,676	546,678	639,952	325,809
14	1997	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
15	1998	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
16	1999	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
17	2000	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
18	2001	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
19	2002	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
20	2003	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
21	2004	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
22	2005	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
23	2006	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
24	2007	3,990	1,190	5,180	201.7	1,044,876	—	58,260	—	9,190	—	16,931	590,412	674,793	370,083
25	2008	3,341	1,190	4,531	201.7	913,959	—	51,371	—	9,190	—	16,931	516,611	594,103	319,856
26	2009	2,050	1,190	3,240	201.7	653,860	—	34,172	—	9,190	—	16,931	369,008	429,301	224,559
27	2010	2,050	1,190	3,240	201.7	653,860	—	34,172	—	9,190	—	16,931	369,008	429,301	224,559
28	2011	762	1,190	1,952	201.7	393,761	—	20,744	—	9,190	—	16,931	221,405	268,270	125,491
29	2012	0	655	655	201.7	132,188	—	7,116	—	9,190	—	16,931	73,802	107,039	25,149

FIRR = 10.6%

Notes:
/1 Transmission loss was deducted by 2.9% for Mindanao and 4.4% for Luzon grids power transmission.
/2 The capital cost corresponds to the construction of No. 7 through No. 22 plants of Tongonan geothermal power station, the breakdown of which is presented in Table 9-3.
/3 The breakdown into foreign currency and local currency is presented in Table 9-4.

A－4 AN OBSERVATION OF THE ECONOMIC EVALUATION OF THE PROJECT

A-4 An Observation of the Economic Evaluation of the Project

In the economic evaluation of the Project, the effect of the reserve power saving benefit was computed based on the kW value of diesel power plant. On the other hand, NAPOCOR suggested in the meeting for the draft report that the kW value should be evaluated by the investment cost of the diesel power plant.

As a result of the study, the cost of the Project is higher than the benefit at the discounted rate of zero as shown on Fig. A-4-1. It means that the expected return of the alternative project (diesel power plants) is lower than 6.154%, on the contrary the return of the Project is more than 6.154%. Therefore, it can be said that the Project is economically feasible.

Table A-4-1 kW Value for Reserve Power Saving due to Power System Interconnection

a) Unit construction cost: 550 US$/kW (Diesel power plant)

b) Useful project life: 15 years

c) kW compensation factor: 16.5%

d) Total investment cost:
550 US$/kW × 100 MW × 2 × 1.165 = 128,150 × 10^3US$

Fig. A-4-1 Relation between the Cost and the Benefit

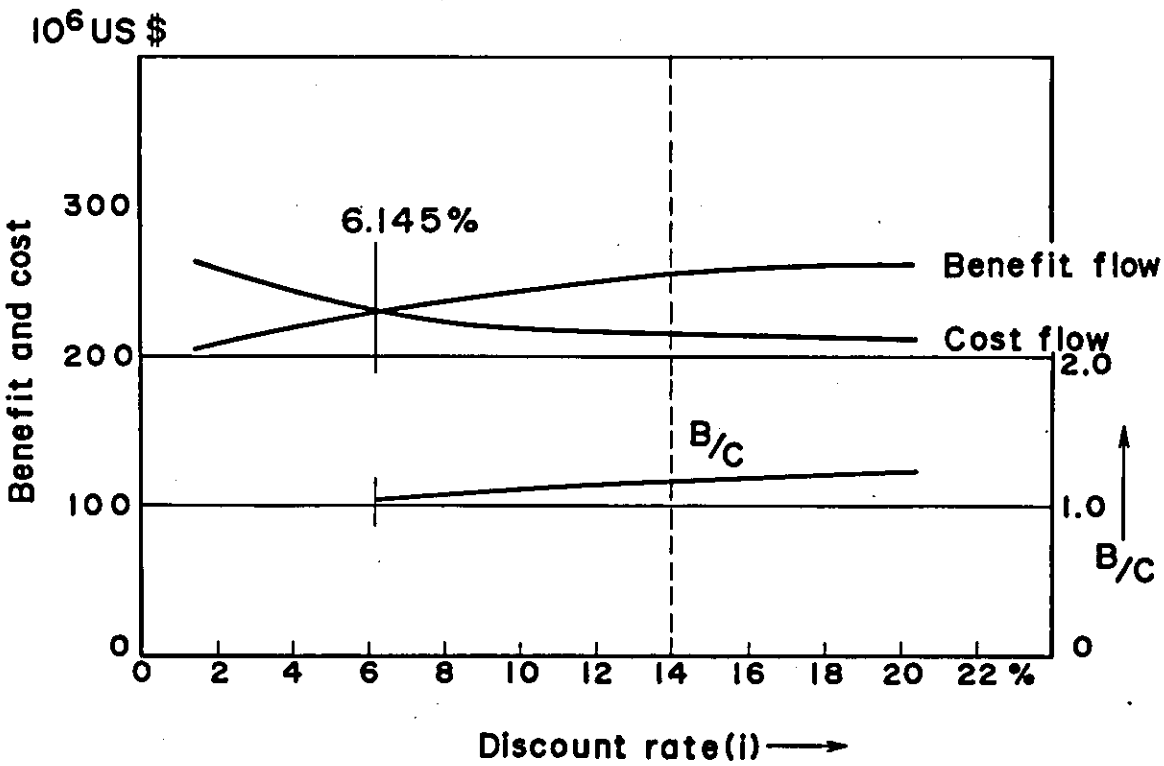


Table A-4-2 Economic Evaluation for Leyte - Mindanao Power Transmission Project (Independent)

n	Year	Discounted rate	Cost flow (C)				Benefit flow (B)									
			Cons. cost	O & M cost	Total	Present value	R.P. saving	*R.P.S benefit	Surplus energy	Loss improve	L.I benefit	Economic energy interchange			Total	Present value
		(i = 14%)	(10³US$)	(10³US$)	(10³US$)	(10³US$)	(MW)	(10³US$)	(GWh)	(GWh)	(10³US$)	(10³US$)	(10³US$)	(10³US$)	(10³US$)	(10³US$)
-3	1988	1.481	2,150		2,150	3,184	0		1,502	0	0	0	0	0	0	0
-2	1989	1.299	20,435		20,435	26,545	0		3,008	0	0	25,327	0	25,327	25,327	32,900
-1	1990	1.140	98,158		98,158	111,900	0	32,037	2,927	0	0	75,981	0	75,981	108,018	123,141
0	1991	1.000	35,392		35,392	35,392	0	32,038	4,471	0	0	25,327	0	25,327	57,365	57,365
1	1992	0.877		2,342	2,342	2,053	100		5,395	67	3,202	20,241	31,001	-10,760	-7,558	-6,628
2	1993	0.769		2,342	2,342	1,800	100		6,153	77	3,680	20,241	31,001	-10,760	-7,080	-5,445
3	1994	0.674	4,402	2,342	6,744	4,545	100		6,116	76	3,632	45,568	31,001	14,567	18,199	12,266
4	1995	0.592	30,489	2,342	32,831	19,435	100	32,037	6,078	75	3,585	96,222	31,001	65,221	100,843	59,699
5	1996	0.519	5,422	2,342	7,764	4,029	100	32,038	6,039	75	3,585	45,568	31,001	14,567	50,190	26,049
6	1997	0.455		2,946	2,946	1,340	200		5,386	67	3,202	40,484	62,002	-21,518	-18,316	-8,334
7	1998	0.399		2,946	2,946	1,175	200		5,344	66	3,154	40,484	62,002	-21,518	-18,364	-7,327
8	1999	0.350		2,946	2,946	1,031	200		5,301	66	3,154	40,484	62,002	-21,518	-18,364	-6,427
9	2000	0.307		2,946	2,946	904	200		5,245	65	3,107	40,484	62,002	-21,518	-18,411	-5,652
10	2001	0.269		2,946	2,946	792	200		5,215	65	3,107	40,484	62,002	-21,518	-18,411	-4,953
11	2002	0.236		2,946	2,946	695	200		5,184	64	3,059	40,484	62,002	-21,518	-18,459	-4,356
12	2003	0.207		2,946	2,946	609	200		5,152	64	3,059	40,484	62,002	-21,518	-18,459	-3,821
13	2004	0.182		2,946	2,946	536	200		5,120	64	3,059	40,484	62,002	-21,518	-18,459	-3,360
14	2005	0.159		2,946	2,946	468	200	32,037	5,087	63	3,011	40,484	62,002	-21,518	13,530	2,151
15	2006	0.140		2,946	2,946	412	200	32,038	5,053	63	3,011	40,484	62,002	-21,518	13,531	1,894
16	2007	0.122		2,946	2,946	359	200		5,018	62	2,963	40,484	62,002	-21,518	-18,555	-2,264
17	2008	0.107		2,946	2,946	315	200		4,983	62	2,963	40,484	62,002	-21,518	-18,555	-1,985
18	2009	0.094		2,946	2,946	276	200		4,948	61	2,915	40,484	62,002	-21,518	-18,603	-1,749
19	2010	0.082		2,946	2,946	241	200	32,037	4,911	61	2,915	40,484	62,002	-21,518	13,434	1,102
20	2011	0.072		2,946	2,946	212	200	32,038	4,874	60	2,868	40,484	62,002	-21,518	13,388	964
21	2012	0.063		2,946	2,946	185	200		0	0	0	0	0	0	0	0
22	2013	0.055		2,946	2,946	162	200		0	0	0	0	0	0	0	0
23	2014	0.049		2,946	2,946	144	200		0	0	0	0	0	0	0	0
24	2015	0.043		2,946	2,946	126	200		0	0	0	0	0	0	0	0
25	2016	0.037		2,946	2,946	109	200		0	0	0	0	0	0	0	0
26	2017	0.033		2,946	2,946	97	200		0	0	0	0	0	0	0	0
27	2018	0.029		2,946	2,946	85	200		0	0	0	0	0	0	0	0
28	2019	0.025		2,946	2,946	73	200		0	0	0	0	0	0	0	0
29	2020	0.022		2,946	2,946	64	200		0	0	0	0	0	0	0	0
30	2021	0.019		2,946	2,946	55	200		0	0	0	0	0	0	0	0
Total		—	196,448	85,360	281,808	219,348	—	256,300	118,510	1,323	63,231	961,735	1,085,035	-123,300	196,231	255,230

Note: R.P. saving: Reserve power saving, L.I. benefit: Loss improvement benefit, R.P.S benefit: Investment cost of diesel power plants

Table A-4-3 Computation Sheet

Discounted Cash Flow Method

Discount rate = 14.0000 (%)
B/C =1.163000786
B-C =35767.29685

Year	Serial Number	Cost Flow	Discounted Cost Flow	Benefit Flow	Discounted Benefit Flow
1988	-3	2150	3185.32	0	0.00
1989	-2	20435	26557.33	25327	32914.97
1990	-1	98158	111900.12	108018	123140.52
1991	0	35392	35392.00	57365	57365.00
1992	1	2342	2054.39	-7558	-6629.82
1993	2	2342	1802.09	-7080	-5447.83
1994	3	6744	4552.01	18199	12283.81
1995	4	32831	19438.59	100843	59707.15
1996	5	7764	4032.38	50190	26067.11
1997	6	2946	1342.16	-18316	-8344.52
1998	7	2946	1177.33	-18364	-7338.94
1999	8	2946	1032.75	-18364	-6437.67
2000	9	2946	905.92	-18411	-5661.53
2001	10	2946	794.67	-18411	-4966.25
2002	11	2946	697.07	-18459	-4367.72
2003	12	2946	611.47	-18459	-3831.33
2004	13	2946	536.38	-18459	-3360.82
2005	14	2946	470.51	13530	2160.88
2006	15	2946	412.72	13531	1895.65
2007	16	2946	362.04	-18555	-2280.25
2008	17	2946	317.58	-18555	-2000.22
2009	18	2946	278.58	-18603	-1759.12
2010	19	2946	244.37	13434	1114.33
2011	20	2946	214.36	13388	974.13
2012	21	2946	188.03	0	0.00
2013	22	2946	164.94	0	0.00
2014	23	2946	144.68	0	0.00
2015	24	2946	126.92	0	0.00
2016	25	2946	111.33	0	0.00
2017	26	2946	97.66	0	0.00
2018	27	2946	85.66	0	0.00
2019	28	2946	75.14	0	0.00
2020	29	2946	65.92	0	0.00
2021	30	2946	57.82	0	0.00
2022	31		0.00		0.00
2023	32		0.00		0.00
2024	33		0.00		0.00
2025	34		0.00		0.00
2026	35		0.00		0.00
2027	36		0.00		0.00
2028	37		0.00		0.00
2029	38		0.00		0.00
2030	39		0.00		0.00
2031	40		0.00		0.00
2032	41		0.00		0.00
2033	42		0.00		0.00
2034	43		0.00		0.00
2035	44		0.00		0.00
2036	45		0.00		0.00
2037	46		0.00		0.00
2038	47		0.00		0.00
2039	48		0.00		0.00
2040	49		0.00		0.00
2041	50		0.00		0.00
2042	51		0.00		0.00
2043	52		0.00		0.00
2044	53		0.00		0.00
	Total	281808	219430.21	196231	255197.51

Table A-4-4 Computation Sheet

```
Discount rate  =      2.0000  (%)
         B/C =0.817582736  B=212092.7826
         B-C =-47321.6756  C=259414.4583

Discount rate  =      4.0000  (%)
         B/C =0.916641172  B=224286.2175
         B-C =-20396.4613  C=244682.6787

Discount rate  =      6.0000  (%)
         B/C =0.995071878  B=233708.1903
         B-C =-1157.44654  C=234865.6368

Discount rate  =      8.0000  (%)
         B/C =1.055850141  B=241045.4499
         B-C =12750.31545  C=228295.1345

Discount rate  =     10.0000  (%)
         B/C =1.102208991  B=246822.2614
         B-C =22888.08617  C=223934.1752

Discount rate  =     12.0000  (%)
         B/C =1.137098244  B=251438.1907
         B-C = 30315.5286  C=221122.6621

Discount rate  =     14.0000  (%)
         B/C =1.163000786  B=255197.5071
         B-C =35767.29685  C=219430.2103

Discount rate  =     16.0000  (%)
         B/C =1.181921413  B=258331.8055
         B-C =39762.44652  C=218569.3589

Discount rate  =     18.0000  (%)
         B/C =1.195443738  B=261017.2959
         B-C =42673.85776  C=218343.4381

Discount rate  =     20.0000  (%)
         B/C =1.204804671  B=263387.9698
         B-C =44773.30463  C=218614.6651

Discount rate  =      6.1450  (%)
         B/C =1.000032588  B=234303.0925
         B-C = 7.63044135  C=234295.4621
```