REPUBLIC OF THE PHILIPPINES

REPORT ON FEASIBILITY STUDY ON LEYTE POWER TRANSMISSION PROJECT

(MAIN REPORT)

VOLUME I

FEBRUARY 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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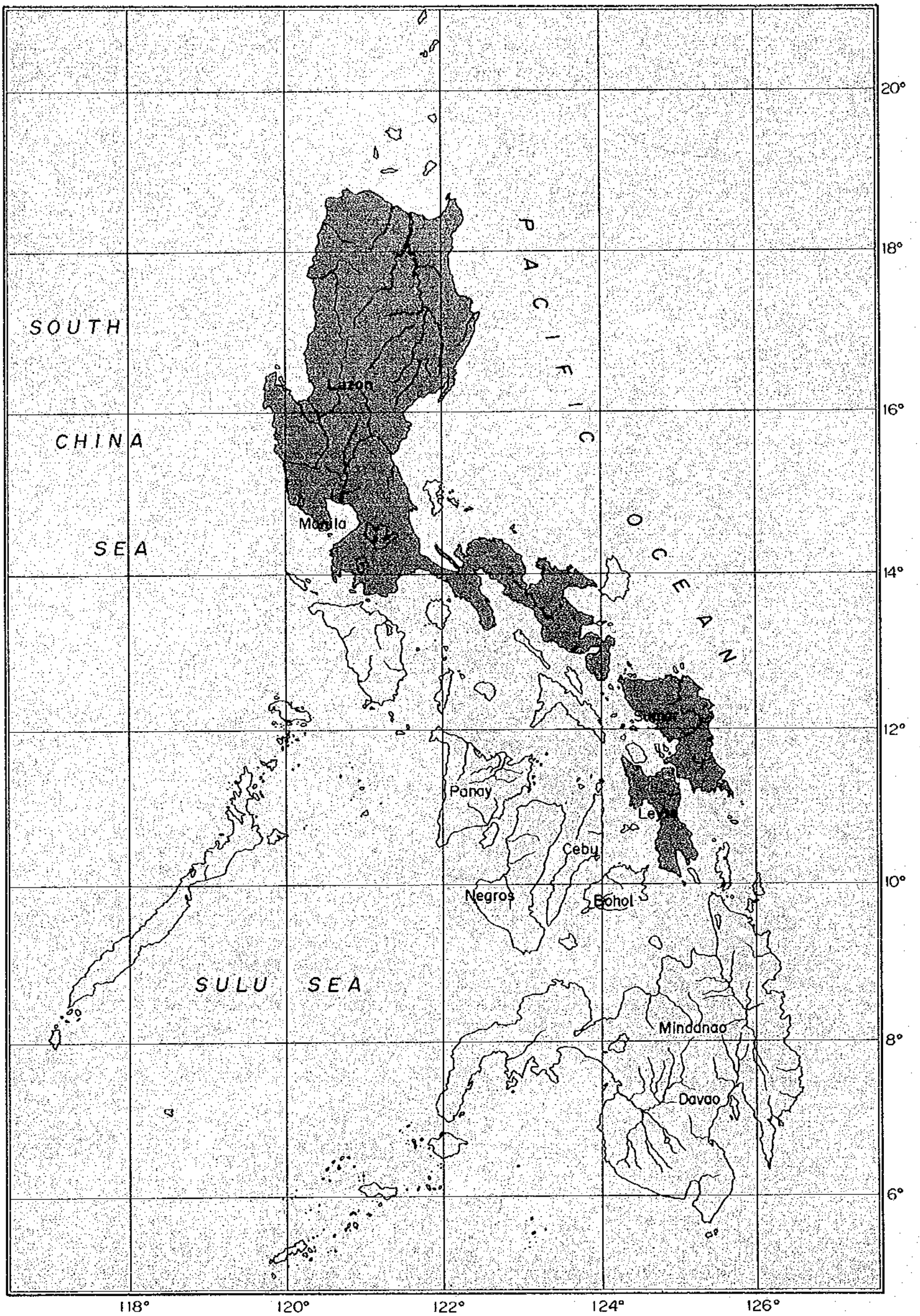
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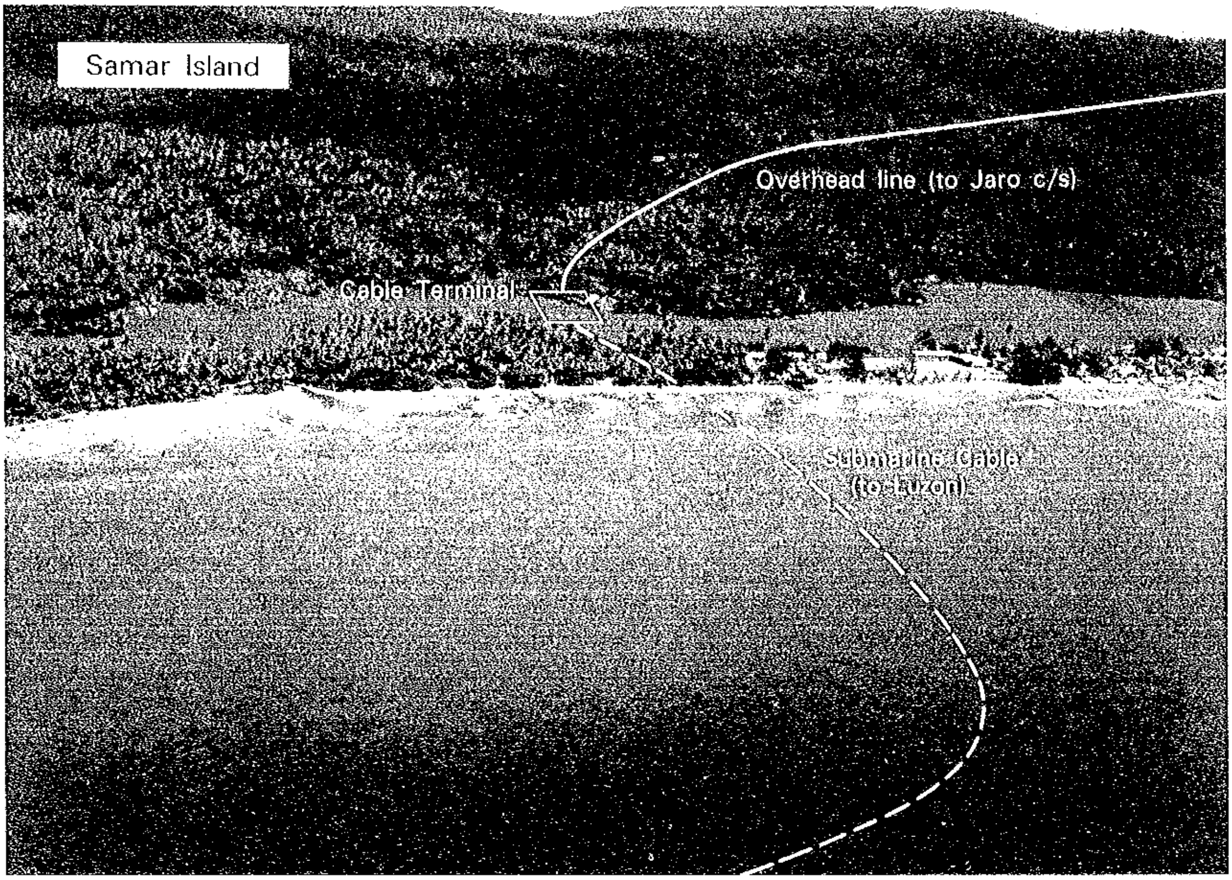
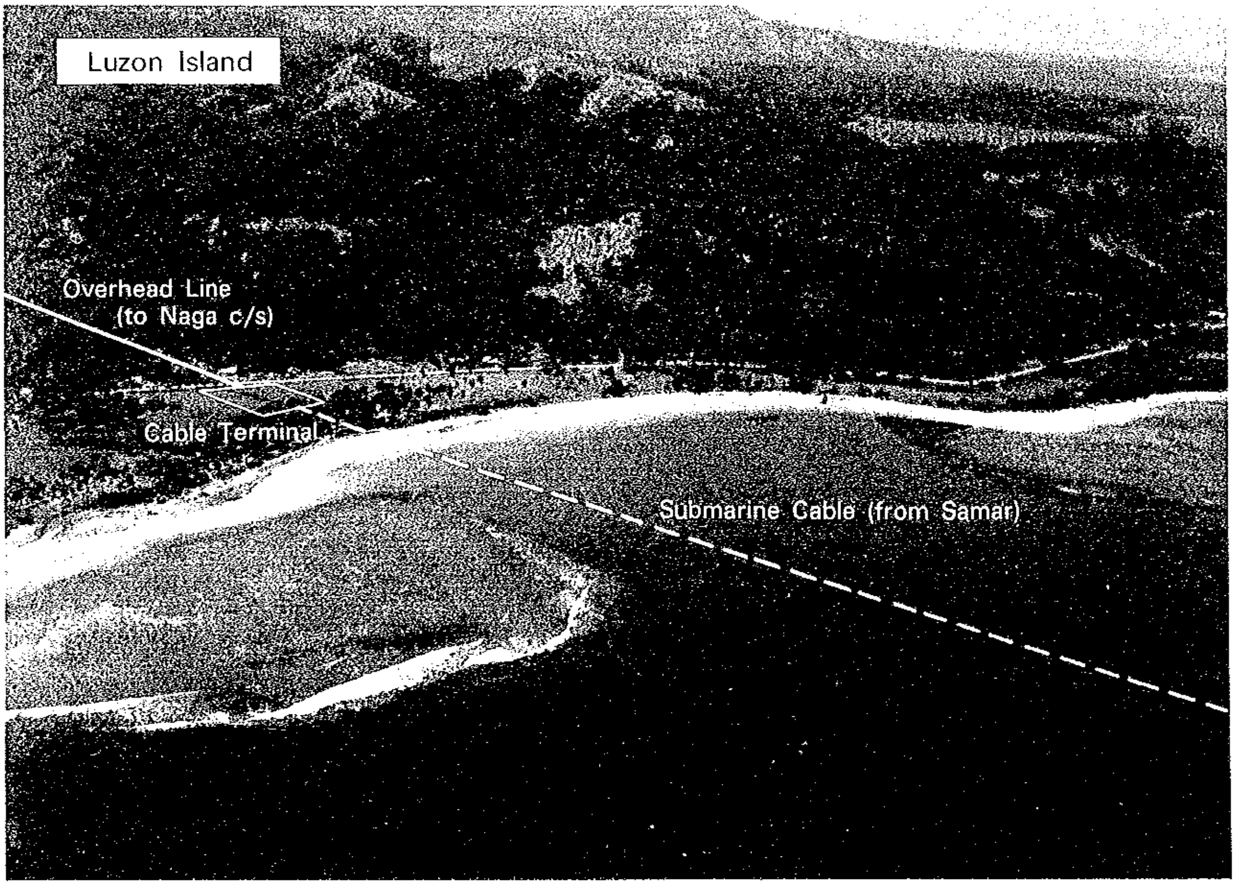
Proposed Cable Landing Sites (San Bernardino Strait)





Overhead Transmission Line (San Juanico Strait)

PREFACE

In response to the request of the Government of the Republic of the Philippines, the Government of Japan decided to conduct a survey on Leyte Power Transmission Project and entrusted the survey to the Japan International Cooperation Agency (JICA). The JICA sent to the Philippines a survey team headed by Mr. Hitoshi Kitazawa from March 2 to March 31, from July 5 to July 25 and from October 7 to October 21, 1981.

The team exchanged views with the officials concerned of the Government of the Philippines and conducted a field survey in Luzon, Leyte and Samar areas. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation extended to the team.

February, 1982

Keisuke Arita

Keisuke Arita, President
Japan International Cooperation
Agency

LETTER OF TRANSMITTAL

Mr. Keisuke Arita, President
Japan International Cooperation Agency

Dear Sir:

Herewith submitted is a feasibility study report on the Leyte Power Transmission Project, the Republic of the Philippines.

The objectives of the study were to investigate and examine, in accordance with the commission given by Japan International Cooperation Agency, the technical and economical feasibilities for realization of power transmission project of geothermal power in Leyte to Luzon grid.

In order to achieve the objectives, a ten-member survey team headed by Mr. Hitoshi Kitazawa, of Electric Power Development Co., Ltd. was organized and sent, making a joint venture by Electric Power Development Co., Ltd. and Nippon Koei Co., Ltd., and field investigation was conducted during a 30 day period from March 2 to March 31, 1981, on topographical survey of submarine cable route, converter stations, sea electrodes, overhead transmission line route and radio repeating stations, various investigation for demand forecasting and basic data collection on meteorology etc. The survey team examined and analyzed the results of the field investigation and provided a basic plan of Leyte power transmission for the study of the fundamental features of the project and additional field investigation for modification of the project requested by NAPOCOR were done respectively in July and October 1981 for complete planning and data collection. Depending on the result of the field investigation, the survey team carried out load forecasts in Leyte-Samar and Luzon, planning and preliminary design of the transmission project, power system analysis, cost estimation, construction schedule, economic evaluation, financial analysis, and prepared the feasibility report.

Leyte power transmission project is an actual method to realize the important policy of deducing oil dependence by the Government of the Philippines and early completion of the project is strongly desired by the Philippine Government for oil conservation and it is sure that the project will greately contribute to the development of the Philippines.

Finally, the team expresses its sincerest and deepest gratitude to all those persons concerned of National Power Corporation and other related agencies of the Government of the Philippines for their kind cooperation in carrying out the study, as well as those persons concerned of the Ministry of Foreign Affairs, the Ministry of International Trade and Industry of Japan, the Embassy of Japan in the Philippines and the Japan International Cooperation Agency for their hearty assistance.

February, 1982

H. Kitazawa

Hitoshi Kitazawa, Team Leader
Survey Team for Feasibility
Study on the Leyte Power
Transmission

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CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background

The Government of the Republic of the Philippines announced in September of 1977 approving and adopting the five-year Philippine Development plan for 1978 to 1982 as well as ten-year development plan for 1978 to 1987 and a long-term development plan up to the year 2000.

Planned reduction of dependence of energy consumption in the Philippines on oil was indicated as a large target in these programs. It was planned to reduce it to seventy (70) per cent in 1987 and further to fifty (50) per cent by the year 2000 from the current level of ninety five (95) per cent. It was planned to make efforts in the development of indigenous energy sources such as hydraulic, coal and geothermal energy for this purpose.

Development of geothermal energy sources was commenced in Leyte Island since the beginning of 1970's. A test plant of 3,000 KW commenced its operation in the middle of 1977 in Tongonan, and a plant of 37.5 MW × 3 is under construction for supplying electric power to Leyte and Samar areas including Isabel Industrial Complex in Leyte in 1983. In addition to the above, development of geothermal energy sources for the electric power of 440 MW has been confirmed in Tongonan area. It has been planned by NAPOCOR to construct the power plants for utilization of these geothermal energy by 1985 and to develop further geothermal energy of 550 MW by the year 1993.

It is planned to transmit the electric power generated at these power plants to Metro-Manila and its vicinity for making a major contribution to reduction of consumption of oil.

For transmission of electric power from Tongonan in Leyte to Metro-Manila, long distance transmission lines of as long as about 900 KM should be constructed including crossing of San Bernardino Straight by means of submarine cables, and construction of a viable project requires thorough examination.

With the matters described above as the background, NAPOCOR requested Nippon Koei to execute a preliminary feasibility study, and the report on this preliminary feasibility study was submitted by Nippon Koei to NAPOCOR in April, 1980.

In addition to the above, the Government of the Republic of the Philippines requested the Government of Japan to implement a feasibility study on the Leyte Power Transmission Project. Accordingly, it was decided that the Japan International Cooperation Agency (JICA) will implement said feasibility study as requested by the Government of Japan, and the survey team was dispatched from JICA to the Philippines.

Prior to dispatch of the survey team, a preliminary survey was implemented by the Japan International Cooperation Agency in December, 1980, and discussion was made regarding the scope of study to be executed by the survey team and other matters, and an implementing arrangement was provided.

This implementing arrangement was partially amended in October, 1981 based on the request from the Government of the Republic of the Philippines through NAPOCOR.

1.2 Purpose and Scope of the Study

The purpose of this study is to examine technically and economically based the viability of the Leyte Power Transmission Project depending on the implementing arrangement concluded by the Pre-feasibility study team in accordance with the "Report on Pre-feasibility Study on Leyte Power Transmission Project" and "Leyte Power Transmission Project Preliminary Feasibility Study" by Nippon Koei Co., Ltd.

Field surveys were conducted on the following activities.

(1) Survey for submarine cables

Submarine topography, conditions of bottom surfaces, tidal current velocity, number of sailing ships and so forth were investigated at the San Bernardino Strait between Luzon Island and Samar Island, based on which drawings and a report were made.

(2) Survey of converter station sites

Places for converter stations were investigated in Jaro area in Leyte and also in Legaspi and Naga areas in Luzon.

(3) Survey of electrodes and electrode lines

Survey of proposed sites of grounding electrodes and of electrode line routes for connection of electrodes sites with converter stations was carried out by vehicles, boats and helicopters.

(4) Survey of transmission line routes

The route of transmission lines from Tongonan to Naga was surveyed by using helicopters and motor vehicles.

(5) Survey of location of radio repeating stations

Places which were mainly selected on the map were roughly surveyed by using helicopters and motor vehicles.

(6) Collection of various materials

Materials and data for assumption of demand, existing facilities and equipment, expansion programs and design were collected in as much volume as possible.

Materials and data related to number of ships crossing the straight, possibility of anchoring, situations of fishing and so forth in the San Bernardino Strait were obtained through inquiries with concerned offices agencies for the submarine cables to be laied.

1.3 Formation of Survey Team

(1) Composition of joint venture

Sufficient and effective surveys and investigations should be carried out within a limited period of time for implementation of the feasibility study. Therefore, it was decided that this feasibility study be jointly implemented by Nippon Koei Co., Ltd. which submitted preliminary Feasibility Report on the Leyte Power Transmission Project, in April 1980 to the NAPOCOR and by Electric Power Development Co., Ltd. who has the largest experience in Japan on DC power transmission technology. A study on the demand and supply of electric power and surveys for laying of submarine cables were assigned to Nippon Koei Co., Ltd. and other fields mainly including DC power transmission technology were assigned to Electric Power Development Co., Ltd.

(2) Formation of survey team

The study team was composed of the following members from Electric Power Development Co., Ltd., Nippon Koei Co., Ltd. and Japan International Cooperation Agency. The duties assigned to members and their participation in studies are as follows. (① ② ③ represent first study visit, second study visit and third study, respectively.)

Hitoshi Kitazawa (Team Leader)	Electric Power Development Co., Ltd.		
		General Affairs	① ② ③
Kazuo Kamikawaji	"	Telecommunication, Dispatching	①
Mitsuru Sakai	"	Converter station	① ②
Yoshikazu Inoue	"	System Analysis	①
Tadao Iso	"	Transmission Line	② ③
Minoru Sato	"	"	①
Akira Tanaka	"	Development Planning	③
Kimihiko Yanagisawa	Nippon Koei Co., Ltd.	Economic Analysis	①
Yuzo Yamaguchi	"	Submarine Survey	①
Yoshito Watanabe	"	"	①
Teruo Omura	"	"	①
Keiji Shimo	"	"	①
Katsuhiko Ozawa	Japan International Cooperation Agency	Coordinator	③

1.4 Time Schedule of Field Survey

It was scheduled to implement the field survey two times, that is, to make total survey at the first time and supplementary study for confirmation at the second time. However, it was decided to change the location of the converter station in Luzon from Legaspi to Naga in accordance with a request by NAPOCOR. Accordingly, the third study was made mainly for the survey of Naga converter station as an additional survey.

First survey :	March 2, 1981 through March 31, 1981; 30 days
Second survey:	10 members including team leader
Third survey :	July 5, 1981 through July 25, 1981; 21 days
	3 members including team leader
	October 7, 1981 through October 21, 1981; 15 days
	4 members including team leader

These studies were implemented in good order under full cooperation of NAPOCOR. Prior to return of the survey team to Japan, the results of the field investigation were reported, and minutes of meeting were submitted to NAPOCOR.

1.5 Fundamental Considerations in Preparation of Report

In accordance with the matters determined upon agreement between NAPOCOR and the survey team based on various materials and data collected through field survey and with reference made to existing materials and data, the following fundamental considerations were established for examining the technical and economic viability for the construction of the Leyte power transmission facilities and for preparation of report. These were confirmed with mutual arrangements made between NAPOCOR and the survey team.

1.5.1 Power Demand Forecast

The power demand forecast was made in this study for the period of 1981-2000 for both the Luzon power grid and the Leyte-Samar sub-grid.

For the Luzon power grid, the demand was projected based on the historical trend of power consumption through applying the estimated GDP elasticity of power consumption. After obtaining the projected demand, it was examined by comparing with the demand projection prepared by NPC.

For the Leyte-Samar sub-grid, since the rapid development of industrialization is planned and being implemented partly, the power demand projection was not made based on the historical trend, but made mainly based on the industrialization plan and on the Government's regional development plan for the Leyte-Samar region.

1.5.2 Stable Operation and Analysis of AC-DC Interconnection System

The AC power system constitutes power generation plants, transmission line and load. This means that the power system has such inertia characteristics since the rotary machines are connected through power transmission lines and distribution. Transmitting capacity for the power system of this pattern can be determined primarily from the phase angle between the systems.

On the other hand, the DC system has no such inertia characteristics as the rotary machines but has its own characteristic which is the ability to control transmitted power quickly and artificially.

Therefore, in the event that the two systems of such different electrical characteristic as mentioned above will be interconnected, well-coordinated operation between the two systems will be required. In drafting the well-coordinated interconnecting plan, consideration of stable operation must be fully assured beforehand.

Because of this requirement, simulation test will be executed by use of the model circuits simulating both AC and DC circuits to the possible realistic extent. These model circuits will be processed as input into the computer or the analog simulator in order to make sure that the planned AC-DC interconnection system can be operated with stability against any crucial conditions of failure which would probably occur on the actual system.

1.5.3 Preliminary Design and Construction Cost

This power transmission project involves long distance bulk power transmission of as long as about 455 km from Tongonan Geothermal Power Plants to Naga Substation including submarine cables of about 23 km for transmission of as much as 900 MW in the final stage.

Because of the fact that the power transmitted through the facilities to be constructed in accordance with power transmission project will have a considerable share in the total electric energy to be consumed on the Luzon Island, it is necessary to pay sufficient consideration to the reliability of supply for executing preliminary design of this transmission project.

Besides conventional AC power transmission, DC power transmission (HVDC), which is a new technology, should also be considered as the object of examination for satisfying the requirements given to this project stated earlier.

A comparative examination will be made between AC power transmission and DC power transmission from technical and economical aspects for selecting optimum power transmission system for this project. Then, preliminary design will be made for overhead transmission lines, submarine cables, converter stations (substations) and telecommunication facility for the selected system, and construction cost will be calculated based on this preliminary design.

Detailed design will have to be made after completion of the feasibility study. Nevertheless, it is required that calculation of construction cost to be estimated in the feasibility study (F/S) should be of as high accuracy as possible because it exerts major influence over the fund program and economic evaluation of the project. Consequently, efforts will have to be made during the feasibility study stage to make technical calculation and to prepare drawings to as high accuracy as possible to be used as basis for the calculation of construction costs.

1.5.4 Construction Schedules

It is desired that construction of the Tongonan Geothermal Power Plant should be completed as early as possible in view of urgent need to minimize dependence on oil consumption and to maximize utilization of the alternative indigenous energy resources.
In order to carry out construction of transmission line and substation facilities consistent with economic advantage, the time length of reasonable limit should be allowed for in the total construction schedule.

In reference to the Leyte power transmission project,NAPOCOR sets up the target in 1986 for initial start-up of Units No. 4 through No. 11 of Tongonan Geothermal Power Plant. It follows then, that the lead time until commencement of operation will only be 45 months including time for detailed design, tender and contract and construction work all together. How to carry out survey, design, manufacture, construction and test in a rationalized and economical way is certainly a matter of vital importance to the whole project.

Moreover, considerable length of time for survey is required on submarine cable and transmission line routes and radio repeating station sites, etc. In particular, survey for the straits crossing section should be given as sufficient time as available.

All those conditions taken into account, the best suitable time schedule will be arranged to ensure achievement of the objective aimed at by this Project.

1.5.5 Economic Evaluation

Economic evaluation on this Project will be made by comparative study between the estimated costs for the alternative transmission system construction and for the transmission construction proposed under the Project. In this instance, the alternative plan to be considered would be to construct the AC high voltage transmission line with sufficient capability to transmit, both technically and economically, power generated at Tongonan Geothermal Power Plant to San Jose Substation near Metro Manila as the large consuming center in Luzon.

Meanwhile, NAPOCOR is now proceeding with its construction plan of the AC 500 kV transmission line from San Jose Substation to Naga Substation situated in the southern Luzon. Accordingly, the scope of economic evaluation under this Project will cover basically the section between Naga Substation and Tongonan Switchyard within the area of Tongonan geothermal power sources. The alternative system for comparative study would be AC 500 kV and AC 230 kV transmission lines for the corresponding section.

In as much as the transmission line under this Project will be constructed as the exclusive transmission line connected with Tongonan geothermal power sources, unlike the usual pattern of the line in and between the power system, it has no such additional advantages as improvement of service reliability, reduction of reserve capacity and coordinated operation over wide area. Therefore, those economic factors will not be taken into account in the process of economic evaluation.

1.5.6 Fund Arrangement and Financial Analysis

The financing plan will refer to the annual fund requirements of construction costs and the terms and conditions of financing arrangements for implementation of the Project.

By nature of the Project, it is difficult to evaluate only this Project alone for financial analysis. Therefore, the two proposed projects including the Tongonan geothermal power development plan will be taken up for this purpose to evaluate finance from both revenue from tariffs and expenditure to compensate costs.

Incidentally, NAPOCOR makes it the basic principle of its power development program to reduce to the minimum the operation of existing oil fired power plants by replacing them with geothermal power generation. In this case, the depreciation expense for the oil fired power plant should be compensated by the benefits from the geothermal power development. This balance will be taken up for evaluation.

CHAPTER 2

CONCLUSION AND RECOMMENDATION

CHAPTER 2 CONCLUSION AND RECOMMENDATION

The following are the conclusions and recommendations on the results of the Leyte Power Transmission Project.

2.1 Conclusion

(1) The ultimate capacity of transmission is planned at 900 MW

In view of the geothermal power development plan and the surplus power available in Leyte, total transmissible power to Metro Manila is estimated at 400 MW in 1986, 600 MW in 1991, 800 MW in 1992 and 900 MW in 1993. Required capacity of transmission facilities will then be 450 MW in 1986 and 900 MW in 1991.

According to the power development program on the Luzon grid planned by NAPOCOR (Table 2-1), it is proposed that the development in the Togonan area of Leyte Island (where the pilot plant of 3 MW is now in operation) aims at operation of 37.5 MW x 3 units by 1983 to meet the regional demand in the Leyte-Samar area, followed by the subsequent stage of development for 55 MW x 8 units towards the end of the year 1985. Since the power to be generated from the latter eight (8) units will be transmitted to Metro Manila, the total transmission capacity required to meet such requirement is estimated to exceed 400 MW by early 1986.

Table 2-1 Luzon Grid Generation Expansion Program On-Going, Firm and Probable Projects

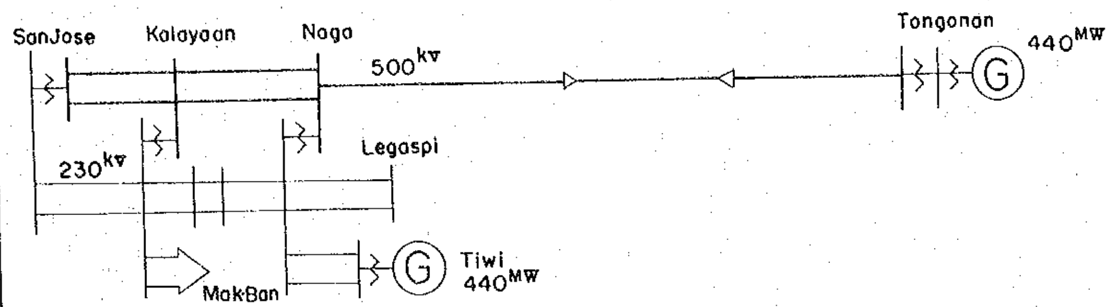
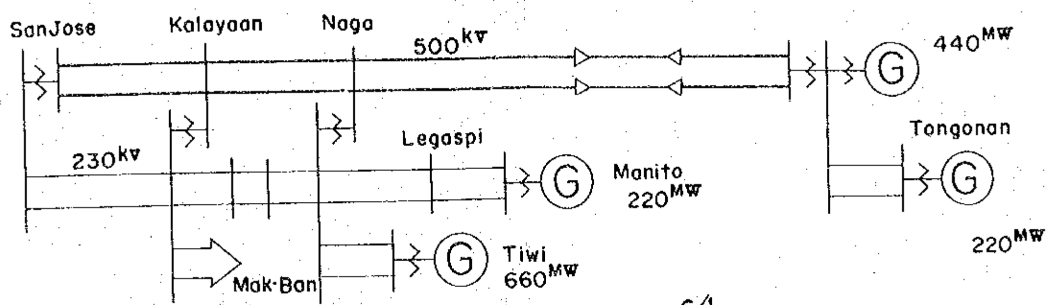
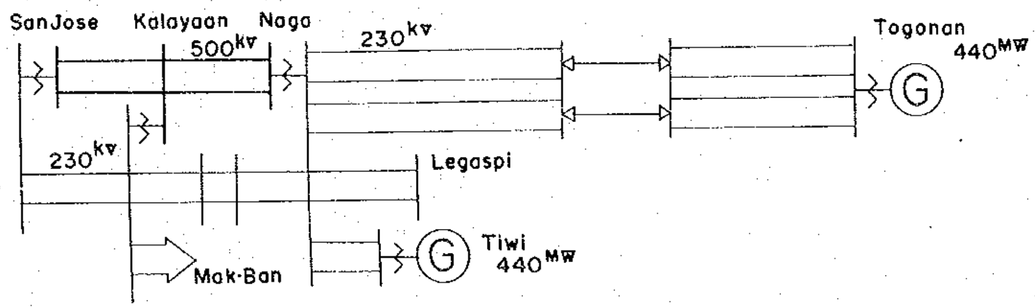
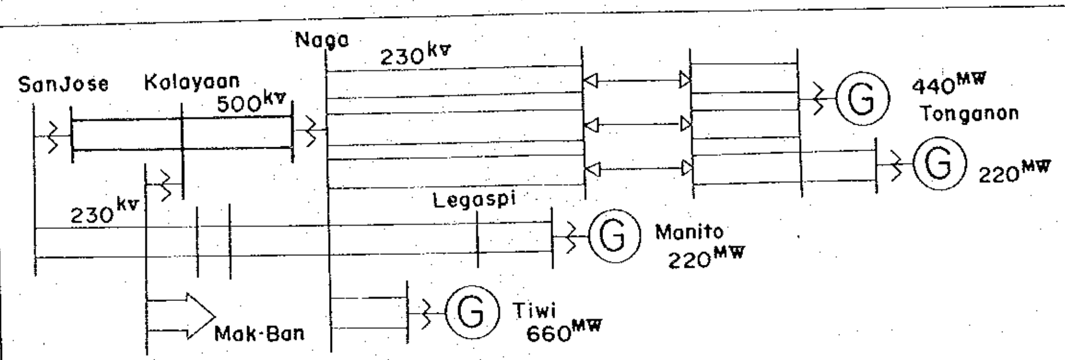
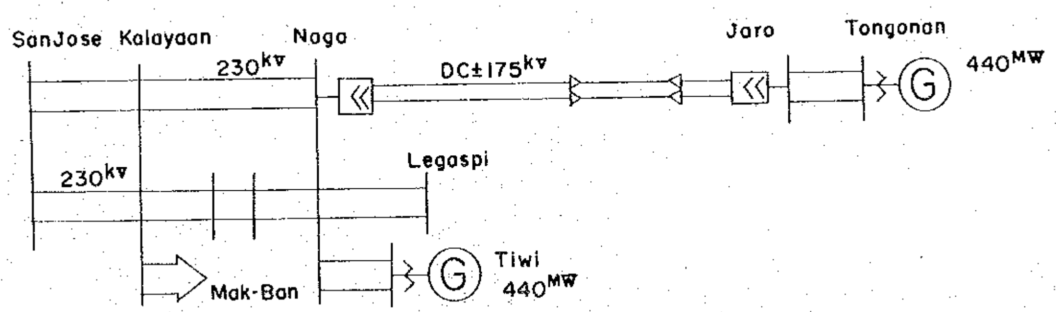
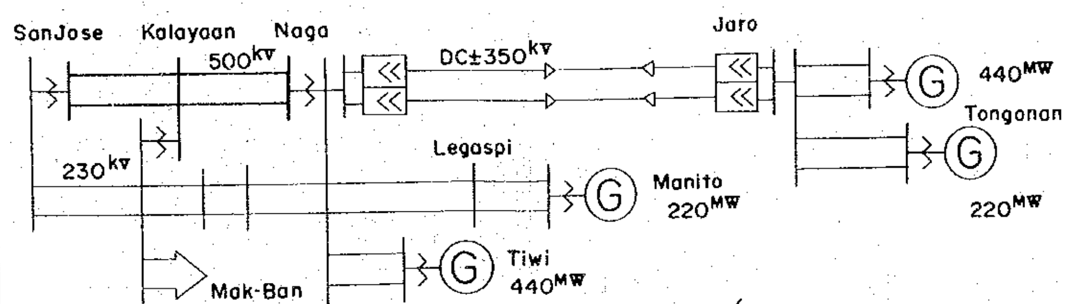
Year of Comm.	Plant Addition	Installed Capacity (MW)						Dep. Cap.	Peak Demand	Res. Cap.	Res.	Available Energy (GWh)	Energy Capability and Requirement (GWh)							
													System Capability						Generation Level	Surplus (Dep.)
		Hydro	Geo.	Coal Ther.	Nuc.	Oil Ther.	Total						Hydro	Geo.	Coal Ther.	Nuc.	Oil Ther.	Total		
1980	Existing	542	440			2,230	3,212	2,880	2,070	470	23	19,097	2,050	2,283			13,871	18,204	13,113	5,091
1981	Masiway (1 x 12)	554	440			2,105	3,099	2,816	2,240	235	11	48	2,098	3,176			13,297	18,571	13,750	4,821
1982/7	Tiwi Geo 5-6 (110)	854	550			1,925	3,329	3,066	2,400	325	14	794	2,248	3,672			13,510	19,430	15,080	4,350
1982/5	Kalayaan 1 (150)											150								
1982/8	Kalayaan 2 (150)											150								
1983/9	Magat 1-4 (360)	1,214	605			1,925	3,744	3,387	2,565	482	19	1,103	3,042	4,036			13,510	20,588	16,140	4,448
1983/11	Mak-Ban Geo 5 (55)											397								
1984/2	Mak-Ban Geo 6 (55)	1,214	660	300		1,925	4,099	3,707	2,745	622	23	397	3,501	4,731	830		13,510	22,572	17,240	5,332
1984/8	Coal Ther. I (300)											1,989								
1985	PNPP 1 (620)	1,214	770	300	620	1,925	4,829	4,157	2,940	1,067	36	3,910	3,501	5,558	1,989	1,684	13,510	26,242	18,420	7,822
	Tiwi Geo 7-8 (110)											794								
1986	Coal Ther. II (300)	1,214	1,265	600	620	1,925	5,624	4,927	3,145	1,382	44	1,989	3,501	9,131	3,978	3,367	13,510	33,487	19,680	13,807
	Tongonan 4-11 (440)											3,176								
	Daklan 1 (55)											397								
1987	Manito Geo 1-2 (110)	1,214	1,375	600	620	1,925	5,734	5,127	3,365	1,262	38	794	3,501	9,925	3,978	3,639	13,510	34,553	21,030	13,323
1988	Tiwi Geo 9-10 (110)	1,214	1,540	600	620	1,925	5,899	5,327	3,600	1,177	33	794	3,501	11,116	3,978	3,356	13,510	35,961	22,475	13,486
	Daklan 2 (55)											397								
1989	San Rogue (390)	1,604	1,650	600	620	1,925	6,399	5,755	3,850	1,315	34	1,153	4,654	11,910	3,978	3,910	13,510	37,962	24,020	13,942
	Tiwi Geo 11-12 (110)											794								
1990	Manito 3 & 4 (110)	1,604	1,870	600	620	1,925	6,619	5,955	4,120	1,245	30	794	4,654	13,498	3,978	3,910	13,510	39,550	25,675	13,875
	Mak-Ban 7 & 8 (110)											794								
1991	Tongonan 12-15 (220)	1,647	2,090	600	620	1,925	6,882	6,177	4,390	1,175	27	1,588	4,853	15,086	3,978	3,910	13,510	41,337	27,320	14,017
	Bonga (43)											199								
1992	Tongonan 16-19 (220)	1,646	2,310	600	620	1,925	7,101	6,377	4,670	1,117	24	1,588	4,853	16,674	3,978	3,910	13,510	42,925	29,070	13,855
1993	Mak-Ban 9-10 (110)	1,756	2,530	600	620	1,925	7,431	6,654	4,975	1,089	22	794	5,373	18,262	3,978	3,910	13,510	45,033	30,930	14,103
	Tongonan 20-21 (110)											794								
	Tabu (110)											520								
1994	Magat 5-6 (180)	2,251	2,530	900	620	1,925	8,226	7,419	5,300	1,529	29	-	6,330	18,262	5,967	3,910	13,510	47,979	32,915	15,064
	Diduyon (345)											957								
	Luzon Coal III (300)											1,989								
1995	Abra III-B (300)	2,551	2,530	900	620	1,925	8,526	7,516	5,645	1,281	23	825	7,155	18,262	5,967	3,910	13,510	48,804	35,030	13,774
1996	Gened (600)	3,711	2,530	900	620	1,925	9,686	8,434	5,985	1,859	31	1,153	9,642	18,262	5,967	3,910	13,510	51,291	37,105	14,186
	Abra II (200)											530								
	Chico IV (360)											804								
1997	Chico II (250)	3,961	2,640	900	620	1,925	10,046	8,731	6,340	1,801	28	1,050	10,692	19,056	5,967	3,910	13,510	53,135	39,310	13,825
	Batangas Geo 1-2 (110)											794								
1998	Luzon Coal IV (300)	3,961	2,750	1,200	620	1,925	10,456	9,101	6,725	1,786	26	1,989	10,692	19,850	7,956	3,910	13,510	55,918	41,645	14,273
	Zamcales Geo 1-2 (110)											794								
1999	Cagayan Geo 1-2 (110)	4,641	2,860	1,200	620	1,925	11,246	9,731	7,125	2,016	28	794	12,242	20,644	7,956	3,910	13,510	58,262	44,120	14,142
	Agos Kanan (280)											875								
	Agbulu (400)											675								
2000	(300)	4,641	2,860	1,500	620	1,925	11,546	10,001	7,555	1,856	25	1,989	12,242	20,644	9,945	3,910	13,510	60,251	46,740	13,511

The ultimate size of the development project in the Leyte area will terminate, according to the NAPOCOR's plan, with completion of Unit No. 21, which will amount to 990 MW in total installed capacity covering Units No. 4 up to 21. Considering station service power requirement, the net dependable power will be 900 MW, which will be transmitted to Luzon as surplus power in the Leyte-Samar area. As far as additional installation of converter stations is concerned, the plan is to double the capacity from 450 MW at the first stage to 900 MW at the second stage, this scheme being the most economical.

(2) HVDC transmission is most economical

On the basis of ultimate 900 MW total capacity, comparative study has been made (as shown in Table 2-2) between AC 500 kV, AC 230 kV and DC ±350 kV systems as the means of power transmission over a distance of 455 km from Tongonan Switchyard to Naga Converter Station. Total construction costs for both first and second stages considering schedule and cost for stepping-up of voltage to 500 kV amount to the sums as indicated in the following Table at the 1986 price level.

TABLE 2-2 AC·DC ECONOMICAL COMPARISON (DIRECT COST)

PLAN	1ST STAGE (1986)	2ND STAGE (1991)	Total Construction Cost ⚠1
AC 500kV	 Construction Cost US $ 419×10^6 ∘ Tongonan~Naga 500kV T/L 1/2cct (including submarine cable) ∘ SanJose, Kalayaan, Naga, 230kV→ 500kV step up cost	 Construction Cost US $ 133×10^6 ⚠ ∘ Tongonan~Naga 500kV T/L 1/2cct (including submarine cable) ∘ Tongonan 138kV T/L 2cct 80km	US $ 552 ×10^6
AC 230kV	 Construction Cost US$ 307×10^6 ∘ Tongonan~Naga 230kV T/L 2cct×2route (including submarine cable) ∘ SanJose, Kalayaan, Naga 230kV→500kV step up cost	 Construction Cost US $ 103×10^6 ⚠ ∘ Tongonan~Naga 230kV T/L 2cct (including submarine cable) ∘ Tongonan 230kV T/L 2cct 80km	US $ 410 ×10^6
HVDC ±350kV	 Construction Cost US$ 213×10^6 ∘ Jaro~Naga HVDC ±175kV bipolar system (including submarine cable) ∘ Tongonan Jaro 138kV T/L 2cct 26km	 Construction Cost US $ 107×10^6 ⚠ ∘ Jaro~Naga HVDC System DC Voltage ±175kV→ ±350kV • Tongonan 138kV T/L 2cct 80km • SanJose, Kalayyaan, Naga 230kV→500kV step up cost	US $ 320 ×10^6

Note ⚠1 Price in year 1986, Discount rate 10%/year, NO Price escalation.

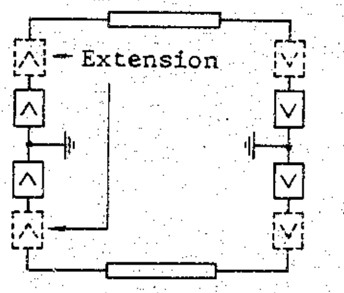
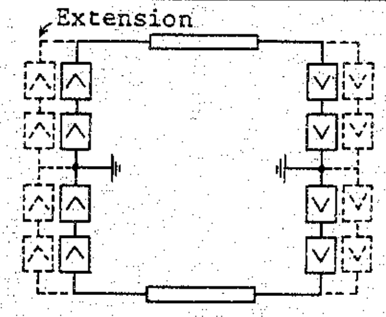
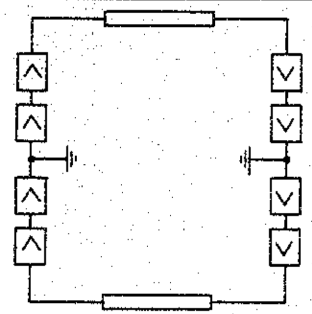
AC 500 kV	US$ 552 x 10^6	100%
AC 230 kV	US$ 410 x 10^6	74.3%
DC ±350 kV	US$ 320 x 10^6	58.0%

In the evaluation over 30 years ahead in the future (Chapter 9), the ratio of total costs, even considering transmission loss and operation and maintenance expenses for the corresponding period, for the AC 230 kV system as against the HVDC system is computed at 1.106. From this result of comparison it can be concluded that the HVDC system is most advantageous.

(3) Optimum design for HVDC is of bipolar composition with series addition

The HVDC system is designed for bipolar composition (as shown in Table 2-3) so as to ensure continuous operation at half its rated capacity through the earth return circuit, in case of any fault on one pole of the DC circuit, considering to the project scale and time schedule for completion of 450 MW by 1986 at the first stage and 900 MW by 1991 at the second stage and the important role which the Leyte transmission project will play in the whole Luzon grid. As to the method of expansion for doubling of the capacity, there are two alternatives; doubling the voltage rating with additional installation of the thyrister valve in series and doubling the current rating with parallel addition.

Table 2 - 3　Comparison of HVDC Patterns

Pattern	HVDC Schemes	Technical Items	Total Construction Cost /1 (%)
1		∘ This extension is common method in the world. ∘ Operates in 6-pulse during the other pole's failure.	100
2		∘ Parallel extension means new technology of multi-terminal HVDC System, and can be adopted for this project.	115
3		∘ No additional work	110

Note: /1　Price in year 1986.　Discount rate 10%.　No price escalation.

After comparison by economic merit or demerit and easiness or hardness of expansion work, the method of series addition has been adopted.

(4) Outline of Leyte Power Transmission Project

The project aiming ultimately at transmission capacity of 900 MW is, as shown in Table 2-4, Figs. 2-1 and 2-2, to construct and operate the HVDC transmission line of about 430 km in length (including submarine cable of 23 km length) at the rating of ±350 kV, 1,290 A, at each end of which the AC-DC converter station of 900 MW capacity will be installed with microwave communication system to connect both ends.

(5) Selection of voltage rating and conductor size

In view of the fact that both voltage rating and conductor size are the influencial factors to the economy of the whole power transmission project, a careful comparative study selection has been made to use voltage and conductor size which will make it possible to minimize overall expenses including power loss and annual construction cost (Fig. 2-3). Finally, voltage rating has been determined at 350 kV with ACSR 810 mm^2 each of two (2) conductors.

Table 2-4 Outline of Facilities for the Project

i) Converter station	
Location	Jaro in Leyte and Naga in Luzon
Rated voltage and capacity	First stage: DC ±175 kV, 450 MW Final stage: DC ±350 kV, 900 MW
ii) Transmission line	
- AC transmission line	Tongonan S/Y - Jaro C/S, 138 kV, 2 cct
Length	26 km
Conductor	ACSR 610 mm^2 x 2
- DC transmission line	Jaro C/S - Naga C/S, DC ±350 kV, bipolar
Length	429 km (incl. 23 km of submarine cable)
Conductor	ACSR 810 mm^2 x 2, AACSR 520 mm^2 x 2 for only crossing on the strait
Submarine cable	OF, 1,000 mm^2, 2 cables
iii) Electrode	
Location	Managasnas (Carigara bay) Pasacao (Ragay bay)
Electrode line	Jaro C/S - Managasnas electrode: 28 km Naga C/S - Pasacao electrode : 32 km ACSR 410 mm^2 x 2
iv) Telecommunication	Micro wave radio link between Tongonan S/Y - Naga C/S

Fig. 2-1 LENGTH OF TRANSMISSION LINE AND ELECTRODE LINE (PRELIMINARY)

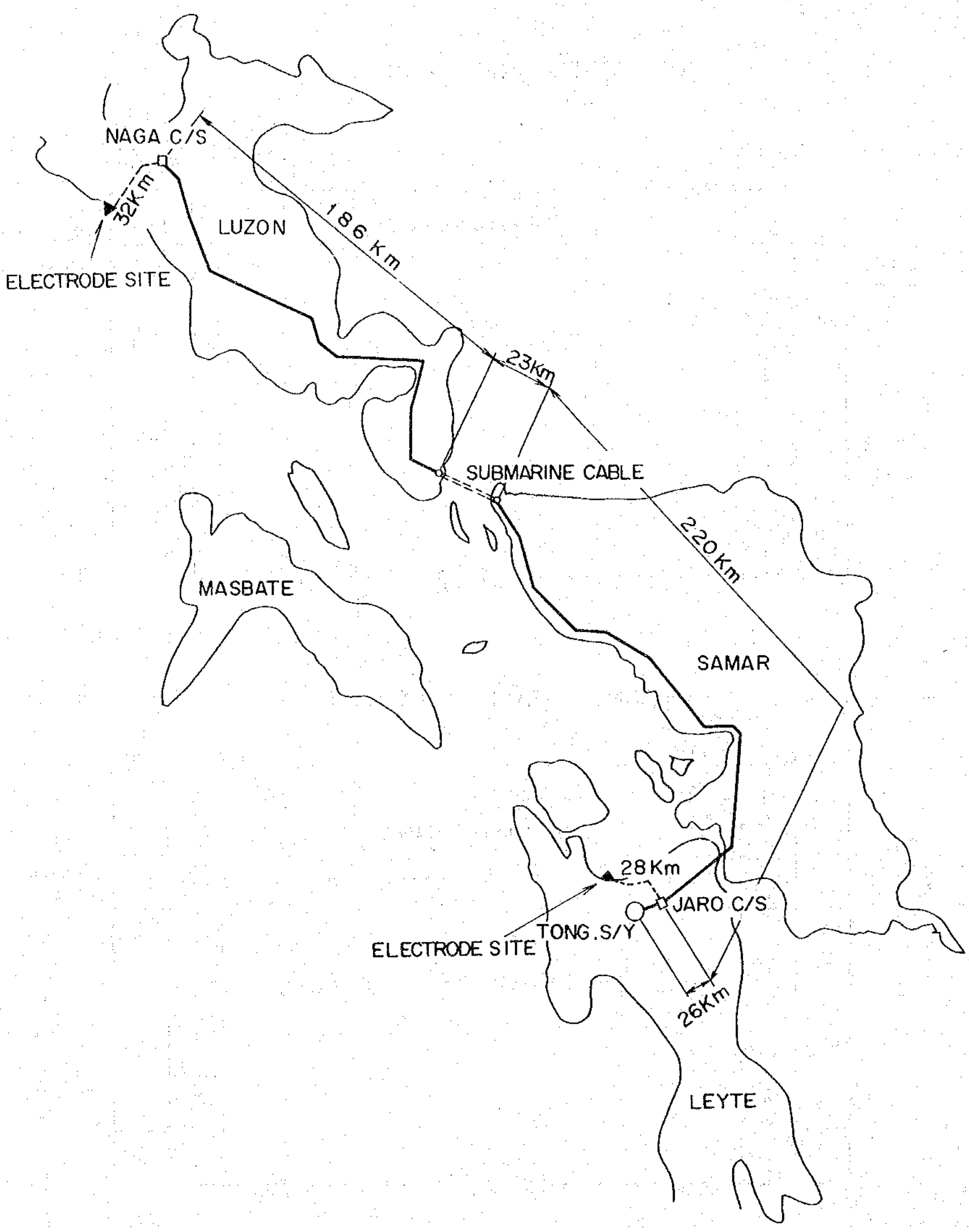
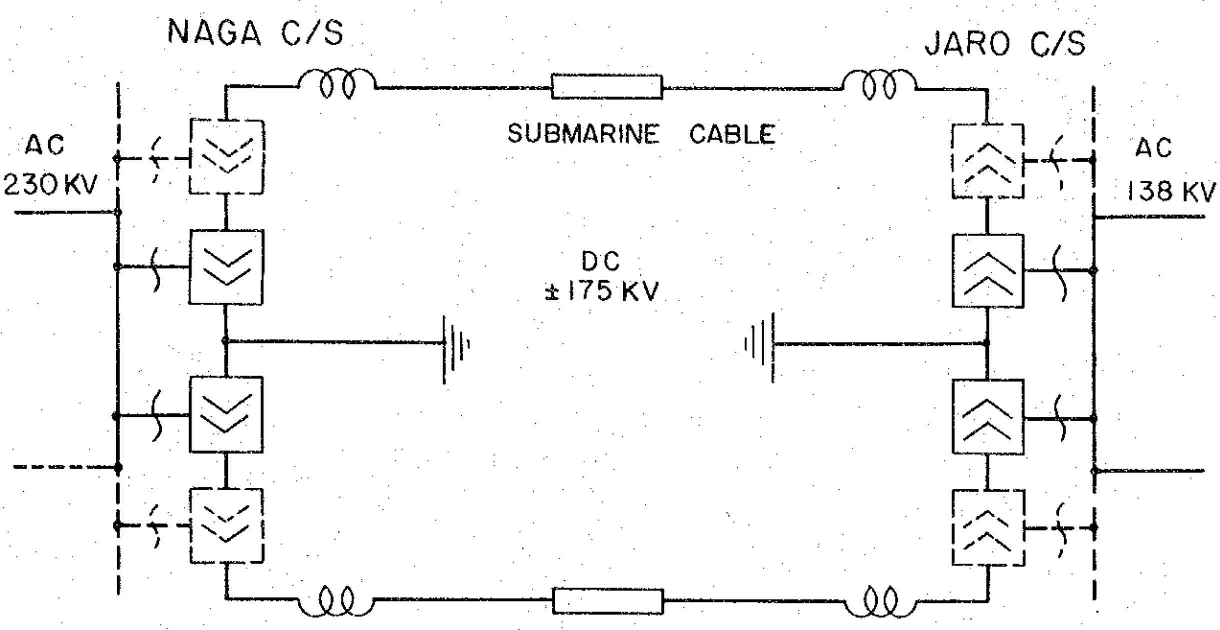


Fig. 2-2 MAIN CIRCUIT DIAGRAM (PRELIMINARY)

(a) FIRST STAGE (450MW)



(b) FINAL STAGE (900MW)

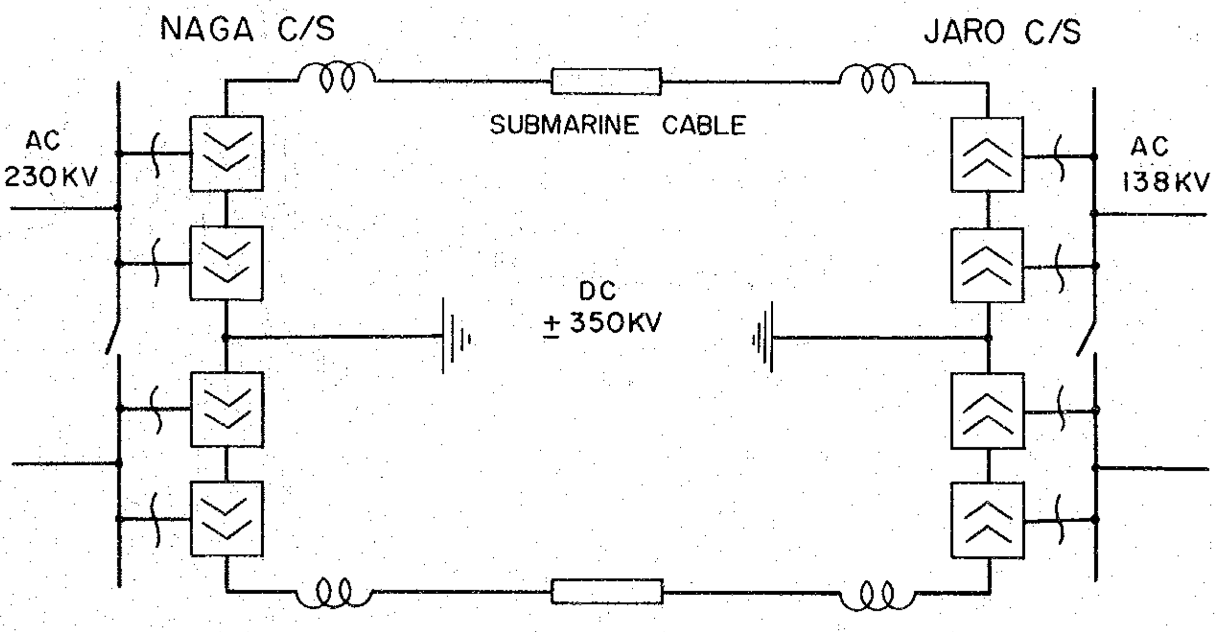
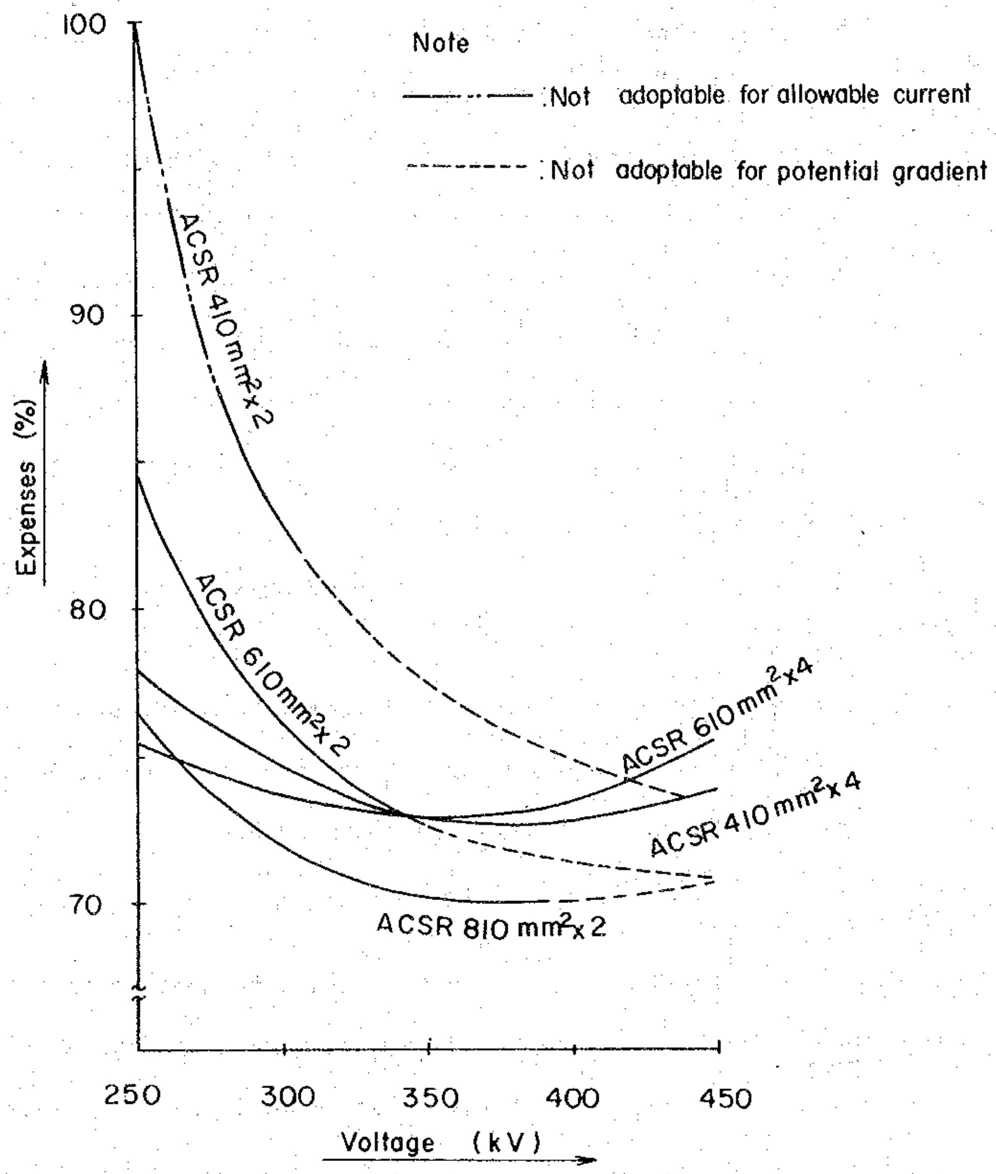


Fig. 2-3 Comparison of Expenses on Voltages and Conductors



(6) Selection of submarine cable

The submarine cable for crossing the San Bernardino Strait will be installed on the 23 km route selected from the result of latest survey, starting from the coast of Santa Magdalena in Luzon and, by way of the straits with maximum depth of 160 m, ending at Lipata in Samar. Cable terminals will be constructed at both villages (Fig. 2-4). The OF cable will be used for this purpose because of its excellence in technical reliability. Although the sea bottom geology still remains unknown in its details, the cable size has been selected at 1000 mm^2 for rated current of 1,290 A as estimated from the thermal conductivity of seabed soil (Fig. 2-5).

With regard to the oil supply system, the stationary type will be used in view of the planned scale of submarine cable and for the sake of simplified maintenance.

(7) Thyristor valve

The thyristor valve as the main component of the AC-DC converter is designed so as to withstand against high voltage by series connection of thyristor as semiconductor element to a required quantity. This Project makes use of the thyristor valve, which will be designed at 175 kV/arm 1,290 A of air insulation and cooling, 2-arms laminated type with forced air/water cooling system (Fig. 2-6).

Fig. 2-4 PLAN AND PROFILE OF SUBMARINE CABLE ROUTE IN THE SAN BERNARDINO STRAIT (LUZON - SAMAR)

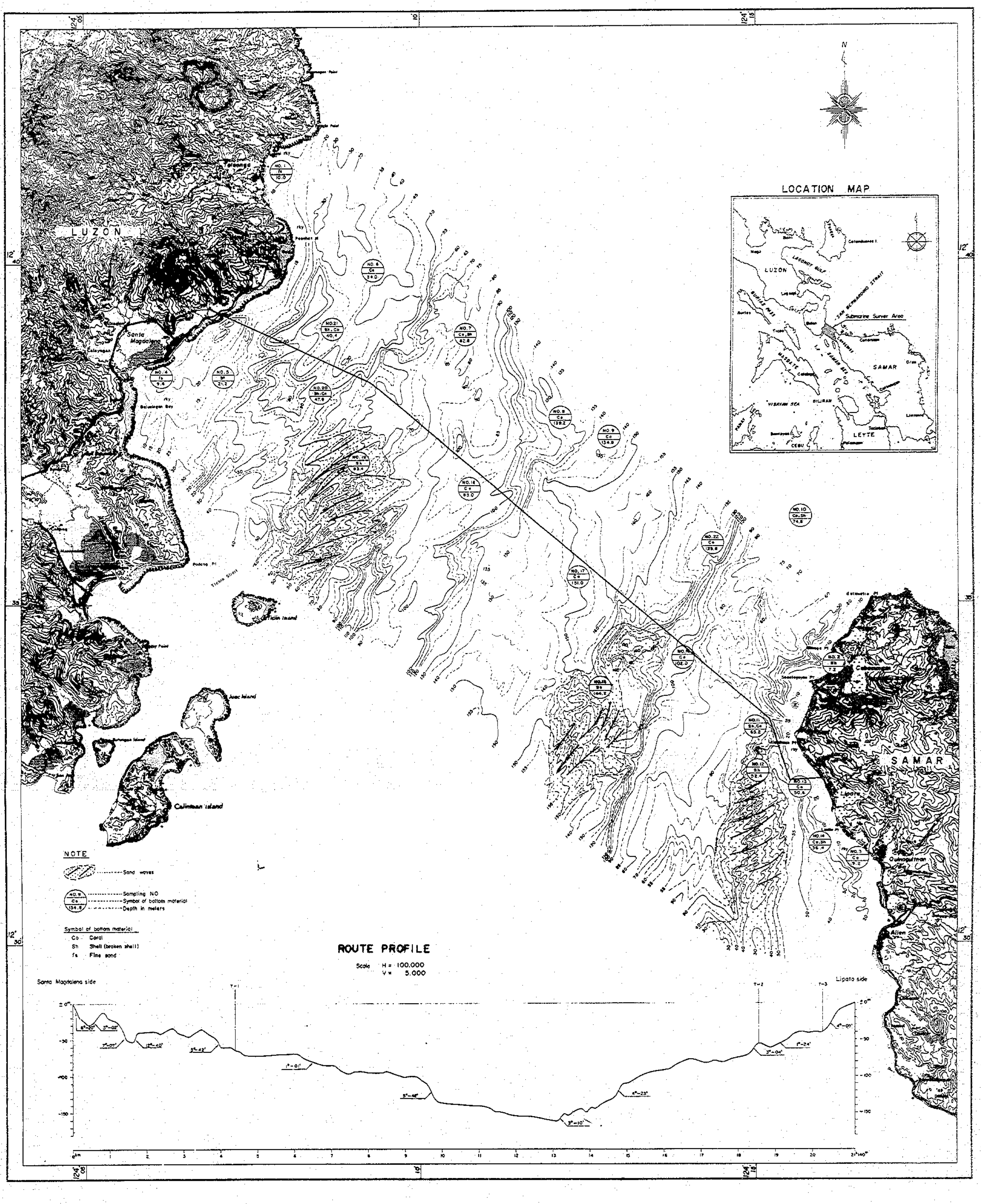


Fig.2-5 Cross Section of Submarine Cable

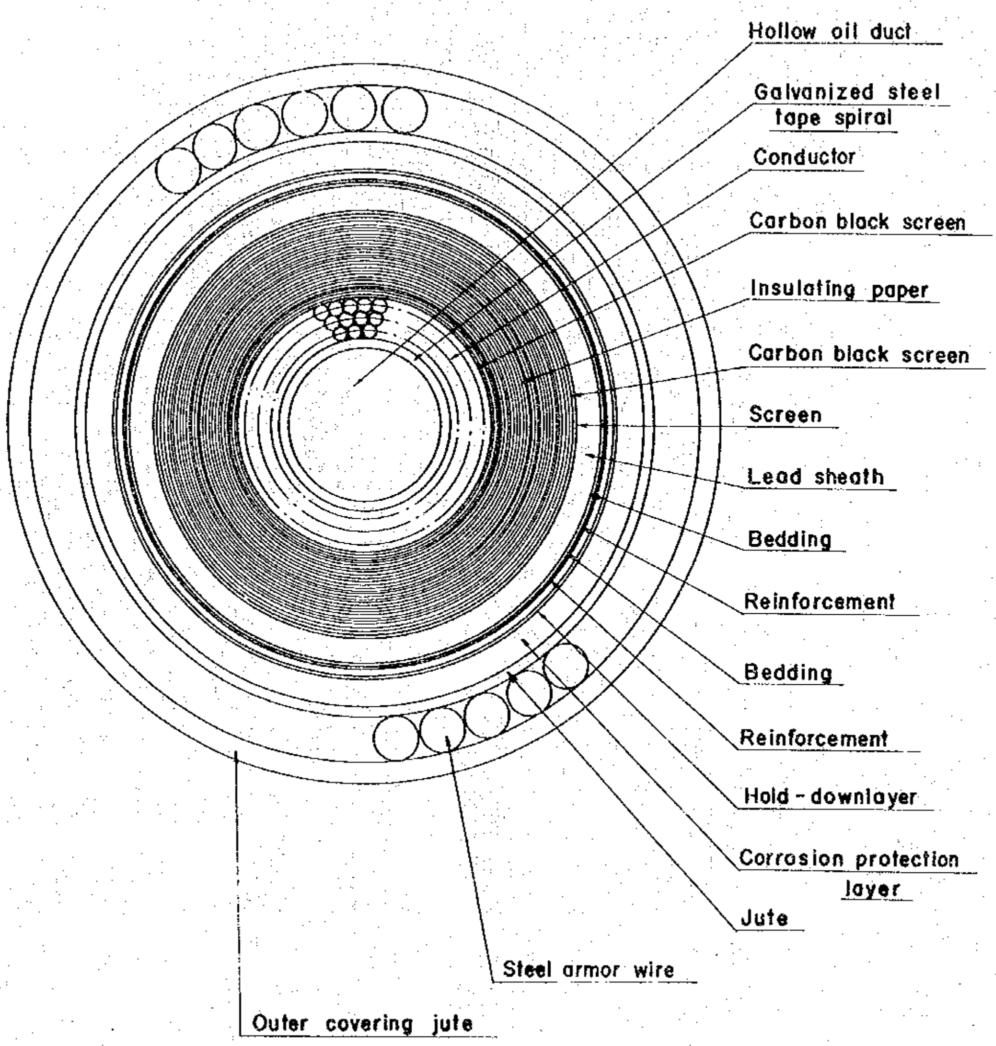
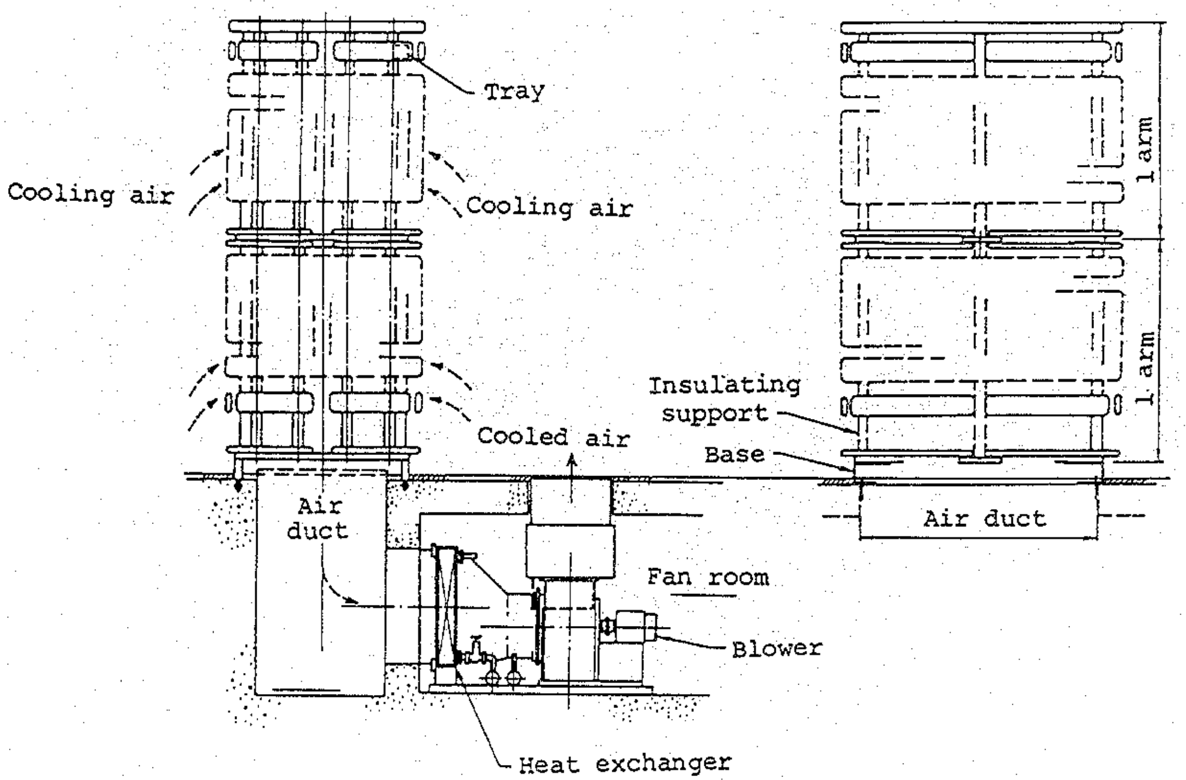


Fig.2-6 Thyristor Valve



(8) Application of microwave communication line

The DC transmission system requires high-speed signal transmission, for control and protection of the system, between both ends. In this case, the required level of reliability for the communication line should be higher than HVDC system. To satisfy those requirements and to provide for possible future expansion, the preliminary design includes use of the 7 GHz microwave system for communication with especial consideration given to topographic and climatic conditions all the way along the proposed route. The experience on 7 GHz radio communication system has shown that its operation is relatively economical and very efficient.

(9) System analysis

Study has been made as to power flow and voltage at normal operation of the Leyte HVDC project, and stability of the transmission line at ground fault.
The result of study assures that because of power transmission by HVDC system would essentially present no stability problem in the synchronous operation between Leyte and Luzon. However, since the power to be transmitted from Leyte will have to be transmitted over about 300 km up to San Jose after mixing the power from Tiwi and Manito at Naga, the transmissible power through the HVDC system will be determined by stability of the power systems of Tiwi and Manito in the southern Luzon.

The analized result in this respect predicts that by taking necessary measures to improve stability at Tiwi and Manito, power can be transmitted through the HVDC system at 400 MW in 1986, 600 MW in 1991 and 900 MW in 1993.

(10) Construction cost and time schedule

The total construction costs are estimated as tabulated below at 1981 price level on the following target for completion:

- 1st stage construction, to be completed by end of 1985 at total capacity of 450 MW
- 2nd stage construction, to be completed by end of 1990 at ultimate capacity of 900 MW

(Unit : x 10^3 US$)

	Foreign Currency	Local Currenty	Total
1st stage	185,365	67,502	252,867
2nd stage	86,923	21,795	108,718
Total	272,288	89,297	361,585

On the basis of scheduled completion by end of 1985, the first-stage work allows a total time length of 45 months to complete from detailed design, tender document preparation, tendering, bid evaluation, contract negotiation and award, fabrication design, manufacturing, erection, construction and testing until scheduled initial operation in January 1981.

Fig. 2-7 Schedule Leyte Power Transmission Project (First Stage)

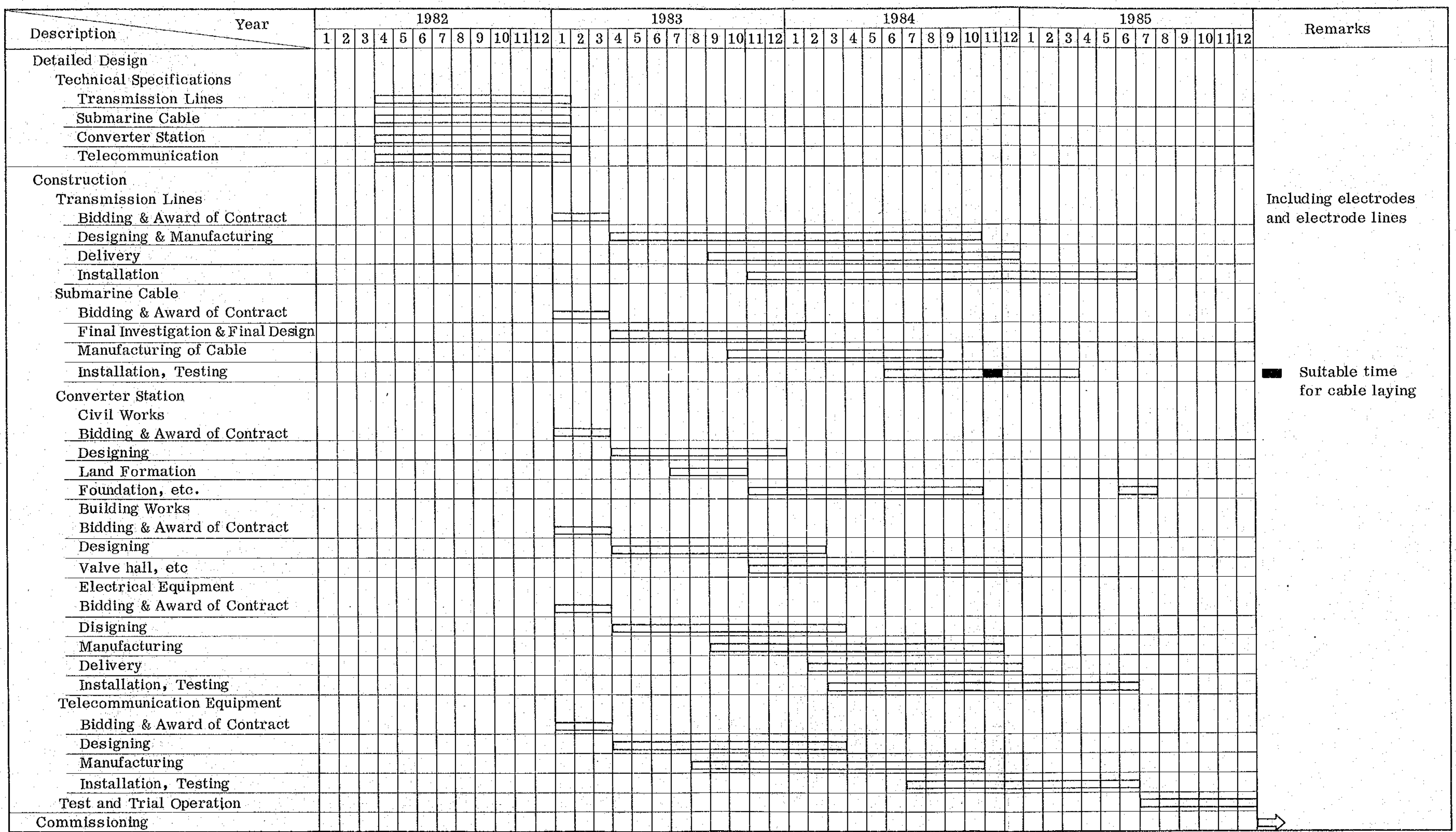
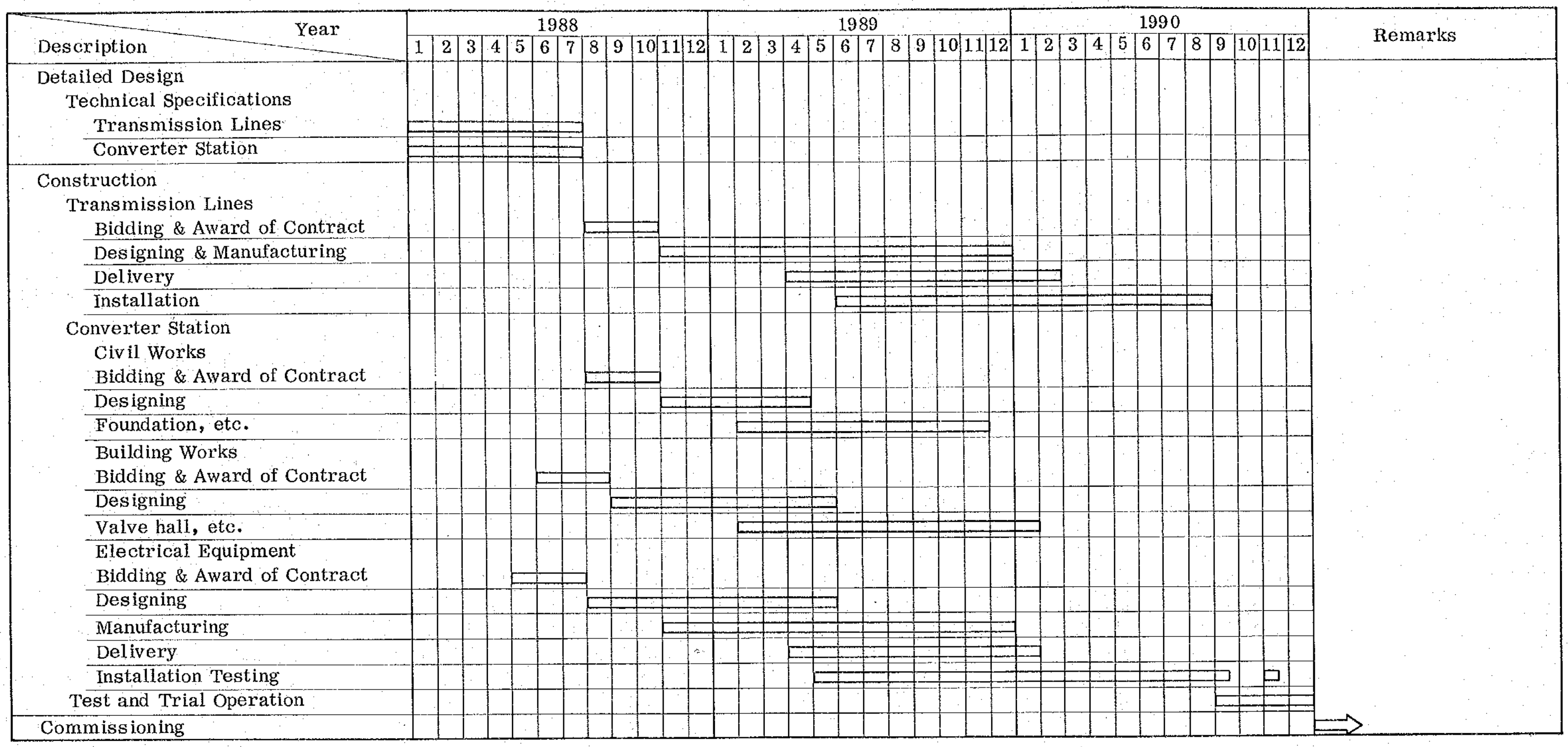


Fig. 2-8 Schedule Leyte Power Transmission Project (Second Stage)



(11) Economic evaluation and financial analysis

The following is the result of cost comparison, between HVDC construction plan and AC 230 kV plan as its alternative, on the basis of the 10-percent discounted cash flow projected over 30 years including construction cost, operating and maintenance expenses and power loss.

$$B/C = \frac{\text{AC 230 kV cost}}{\text{HVDC cost}} = 1.106$$

According to NAPOCOR's plan, the electricity tariff would be increased at an annual rate of 8.6 percent up to 1987 and the financial internal rate of return is 6.6 percent from both power sales revenues for consecutive 30 years at San Jose Substation to be earned from power generation at Tongonan and expenditures covering power generation and transmission costs and allocated cost between Naga and San Jose.

2.2 Recommendation

The followings are the recommend actions based on the 'Conclusion' stated in the foregoing Section 2.1.

(1) Detailed design

In order to achieve the completion of construction at the first stage by end of 1985, detailed design and preparation of tender documents including technical specifications must be completed at the least by the end of 1982, so that bidders can be invited to the tender of the Project at the beginning of 1983. To meet such time requirement, it is recommended that detailed design should proceed as early as possible within the year 1982.

(2) Financing arrangements for construction fund

For financing arrangements for necessary construction fund of the Project vigorous effort should be made to secure the financing source for implementation of the Project by early negotiation with the concerned agencies.

(3) Future site survey

It is recommended that effort should be made by NAPOCOR to conduct the following surveys at the earliest possible opportunity:

i) Proposed route for submarine cable

Because the time in this Project is relatively limited, it would be difficult to expect any detailed survey by the cable installation contractor. Therefore, survey must be made to the fullest extent by NAPOCOR prior to the tendering of the cable work, with due reference to the survey result by the survey team in March 1981 (Appendix A-3).

ii) With regard to the overhead transmission line across San Juanico Straits, prompt action must be taken for topographic and geological survey on the proposed site.

iii) Survey for grounding electrodes

Detailed survey must be conducted for selection of the suitable site and detailed design for grounding electrodes for both Jaro and Naga Converter Stations.

iv) Salt contamination survey

Since salt contamination is of great importance to the HVDC system, it is recommended that prompt action should be taken to measure salt adhesion over the whole project area, so that the survey result can be incorporated into the detailed design (Appendix A-2).

(4) Acquisition of land

Prompt steps should be taken to acquire land required for construction of converter stations, transmission lines and microwave radio stations in advance so as to avoid any possible delay in the work progress.

(5) Microwave communication line

It is essentially of importance to this Project to install the 7 GHz microwave communication line. Therefore

NAPOCOR should enter into negotiation, with the authorities concerned as early as possible to prevent and delay in placing order for equipment. Moreover, the definite prospect for availability should be projected as early as possible for selection of each location of repeating stations.

(6) Term of equipment delivery

Equipment should be delivered on a turnkey contract basis, in view of the fact that most of the Project-related equipment is of particular design and manufacture and it is therefore important to secure time for completion as scheduled, to define the division of responsibility and to control the quality.

(7) Spare cable line

Preliminary design specifies laying of two submarine cables from the beginning and no spare cable in particular. Later, however, if the importance of the Leyte transmission line with its role in the Luzon grid receives enhanced evaluation and desired higher reliability, it would probably become possible to have the spare cable laid additionally. If such is the case in future, an extra increase of cost should be added to the construction costs estimated herein.

(8) Establishment of operation and maintenance service-system and HVDC training

Needless to mention, high and sophisticated technology will be required for operation and maintenance of the HVDC transmission system. Therefore, to meet the time requirement of scheduled start-up operation by 1986 all operating and maintenance workforce must be fully trained and a considerable number of engineers must get well familiar with new technology involved in the HVDC system. Since this will, in turn, help in the improvement of the present technical level, full effort should be exerted to provide such training program for as many personnel as available.

(9) Coordinated operation with Tongonan Geothermal Power Plant

The operation of the HVDC transmission system requires closest coordination with the operation of Tongonan Geothermal Power Plant. Therefore, any additional units of the geothermal power plant for future operation should fully reflect specific design for coordinated plant operation to meet this need.

(10) Installation of power system stabilizer

The result of system analysis suggests that the power system stabilizer should be installed at the existing power plant as well as the newly constructed plant. It is certain that this equipment is necessary for establishment of stable plant operation (Appendix A-5).

(11) Schedule for EHV stepping up

From the system analysis result it is recommended that the EHV transmission line between Naga and San Jose should be stepped up to 500 kV in 1990, the year of scheduled completion of the 2nd stage HVDC construction work.

(12) Study on HVDC reverse operation

The Leyte transmission line is planned at present only to serve as the power source line to transmit power from the Leyte geothermal power plants to the Metro Manila. If the future circumstance demand power transmission of reversed direction, study must be made at that time including study on short-circuit capacity required.

CHAPTER 3

POWER INDUSTRY OF THE PHILIPPINES

CHAPTER 3 POWER INDUSTRY OF THE PHILIPPINES

3.1 Market for Power

3.1.1 Organization

The power sector in the Philippines is comprehensively administered by the Ministry of Energy (MOE). The two major Government agencies which share the responsibilities for stable electric power supply are: (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 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 92 electric cooperatives. 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 and 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 in the whole Philippines amounted to 4,075 MW in 1979. The NAPOCOR is the major owner occupying 86% of the total capacity, followed by private utilities (9%) and cooperatives (5%) (Table 3-1). The installed capacity is composed of 56% thermal power plant, 23% hydro power plant, 16% diesel power plant and 5% geothermal power plant (Table 3-2). In terms of geographical location, over four-fifth of the total system capacity provides for Luzon's power requirements with the remaining one-fifth shared by Visayas and Mindanao (Table 3-3). Over the past eight years of 1971 to 1979, system capacity increased at an annual rate of 9.7%.

Energy generation in the period from 1971 to 1979 grew at the rate of 7.5% per annum. Of the 15,033 GWh generation in 1979, 77% was produced by oil-fired power plant, 19% by hydroelectric power plant and 4% by geothermal power plant (Table 3-4). In terms of type of ownership, NAPOCOR supplied 92% of the total energy in 1979, followed by other private utilities (6%) and cooperatives (2%) (Table 3-5). According to the data of MECO, energy sales for industrial use in 1979 amounted to 42% of the total energy sales, for commercial use 31% and for residential use 25%. The industrial and commercial power uses increased at an annual rate of 7.2% in six years from 1973 to 1979 and the residential power use at 5.7% (Table 3-6).

In 1979, about 35% of the total population of the Philippines was served by electric utilities. Geographically, about 49% of the total population was served by electric power in Luzon, 18% in Visayas and 17% in Mindanao (Table 3-7). The population served by electric power increased at the rate of 5.8% per annum in the period from 1972 to 1979.

In 1979, the average power rates of NAPOCOR were 22.77 centavos/kWh in Luzon, 30.60 centavos/kWh in Visayas and 13.80 centavos/kWh in Mindanao (Table 3-8). In the period from 1973 to 1979, the average power rates of NAPOCOR increased at the annual rate of about 26% in Luzon and Visayas and at about 36% in Mindanao.

Table 3-1 Installed Capacity of Electric Utilities in the Philippines by Type of Ownership

Unit: MW

Ownerships	1967	1971	1972	1977	1978	1979	(%)
MECO	554	1,104	1,404	1,672	522	-	-
NAPOCOR	381	578	654	1,006	2,193	3,517	(86)
Other Private Utilities	145	251	249	326	346	376	(9)
Municipal Gov't	16	16	16	10	-	-	-
Cooperatives	-	-	-	49	138	182	(5)
Total	1,096	1,949	2,323	3,063	3,199	4,075	(100)

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-2 Installed Capacity of Electric Utilities in the Philippines by Plant Type

Unit: MW

Plant Type	1967	1971	1972	1977	1978	1979	(%)
Hydro	400	600	600	749	749	929	(23)
Thermal	586	1,136	1,473	1,912	1,912	2,262	(56)
Diesel	110	213	250	399	535	661	(16)
Geothermal	-	-	-	3	3	223	(5)
Total	1,096	1,949	2,323	3,063	3,199	4,075	(100)

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-3 Installed Capacity of Electric Utilities in the Philippines by Geographical Location

Unit: %

Region	Hydro	Thermal	Diesel	Geothermal	Total (MW)	
	1972					
Luzon	22	74	4	-	1,975	
Visayas	4	9	87	-	113	
Mindanao	66	0	34	-	235	
Philippines	26	63	11	-	2,323	
	1977					
Region	Hydro	Thermal	Diesel	Geothermal	Total (MW)	(%)
Luzon	22	76	2	-	2,490	(81)
Visayas	1	4	95	0	223	(7)
Mindanao	59	6	35	-	350	(12)
Philippines	24	62	13	1	3,063	(100)

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-4 Energy Generation of Electric Utilities in the Philippines by Power Source

Unit: GWh

Power Source	1971	1972	1977	1978	1979	(%)
Hydro	2,550	2,542	2,278	2,796	2,869	(19)
Oil-Fired	5,885	6,109	10,156	10,887	11,507	(77)
Geothermal	-	-	-	3	657	(4)
Total	8,435	8,651	12,434	13,686	15,033	(100)

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-5 Energy Generation of Electric Utilities in the Philippines by Type of Ownership

Unit: GWh

Ownership	1971	1972	1977	1978	1979	(%)
NAPOCOR	2,420	2,665	3,397	4,172	13,892	(92)
MECO	5,289	5,281	8,047	8,324	-	(-)
Other Private Utilities	726	705	815	823	830	(6)
Cooperatives	-	-	175	361	311	(2)
Total	8,435	8,651	12,434	13,686	15,033	(100)

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-6 MECO
Energy Sales by Customers

Unit: GWh

Customers	1973 (%)	1974	1975	1976	1977	1978	1979 (%)	Growth '73/'79 (% p.a.)
Residential	1,447 (26)	1,302	1,418	1,486	1,623	1,786	2,015 (25)	5.7
Commercial	1,649 (30)	1,629	1,812	1,958	2,177	2,323	2,508 (31)	7.2
Industrial	2,202 (40)	2,248	2,386	2,571	2,764	2,990	3,349 (42)	7.2
Street Lights	44 (0)	43	45	47	49	51	52 (1)	2.8
Resale	225 (4)	216	228	255	281	187	63 (1)	-19.1
Total	5,567(100)	5,438	5,889	6,317	6,894	6,337	7,987(100)	6.2

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-7 Ratio of Population Served by Electric Utilities

Region	1972 With Electricity (%)	1972 Total Population /1 (10^3)	1979 With Electricity (%)	1979 Total Population /1 (10^3)
Luzon	34.7	21,535	49.0	25,358
Visayas	20.3	9,565	17.9	11,040
Mindanao	18.2	7,717	16.9	10,182
Total Philippines	27.9	38,817	34.6	46,580

Remarks: /1 Total population with and without electricity.

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980

Table 3-8 NAPOCOR
Average Power Rates by Region

Unit: centavo/kWh

Region	1973	1974	1975	1976	1977	1978	1979
Luzon	5.56	7.08	12.65	14.03	18.10	18.16	22.77
Visayas	7.57	7.07	13.48	14.20	29.21	29.45	30.60
Mindanao	2.20	2.34	2.98	2.98	4.26	11.00	13.80

Source: 1979 Statistical Yearbook on the Philippine Electric Power Industry, NAPOCOR Corporate Planning, July 1980