REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION

LUZON EXTRA HIGH VOLTAGE TRANSMISSION SYSTEM DEVELOPMENT PROJECT

FEASIBILITY REPORT

AUGUST 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request of the Government of the Republic of the Philippines, the Japanese Government decided to conduct a survey on the Luzon Extra High Voltage Transmission Line System Development Project and entrusted the survey to the Japan International Cooperation Agency (J.I.C.A.). The J.I.C.A. sent to the Philippines a survey team headed by Mr. Yoshiro Sekimura from August 17, 1980 to June 11, 1981.

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

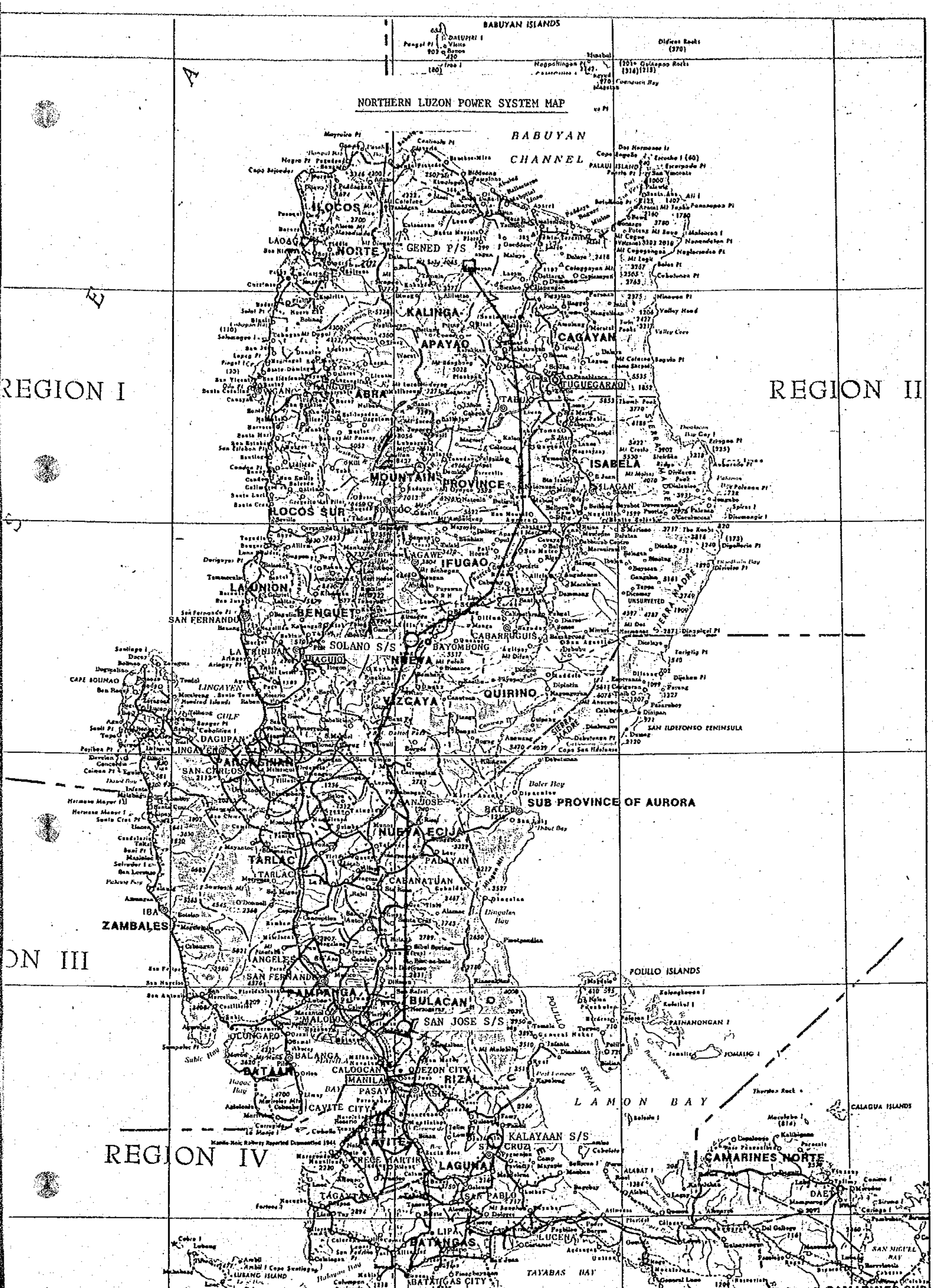
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

August, 1981

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency


NORTHERN LUZON POWER SYSTEM MAP
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1. INTRODUCTION

1.1. Background

To substantiate the current Government thrust to lessen heavy dependency on imported oil and maintain self-reliance on alternative indigenous sources of energy to meet the country's demands from its growing economic activities, the National Power Corporation (NAPOCOR) has been executing massive program to harness water and geothermal resources to the maximum possible extent.

Such main energy sources which are in contemplation by NAPOCOR in Luzon are potential hydroelectric power sites in the Northern area, geothermal power sites in the Southern part of the island and nuclear plants to be constructed near Metro Manila which presently consume two-thirds of the total energy production in Luzon. The capacities of these planned plants will be made large-sized so as to meet the increasing power load with higher economic efficiency.

Southern Luzon is favored particularly with abundant geothermal potentials, most of which lies at the southern tip of the area such as Tiwi and Manito. In coming eight (8) years up to 1988, the accelerated development of geothermal generation will be implemented and further to the above expansion, power import is planned from Tongonan in Leyte over an inter-island transmission line, a portion of which has to be submarine cable connection.

Besides, the power plant sites in the Northern Luzon are located 300 km to 400 km distant from Manila. If the power generated by these power stations is transmitted on existing 230 kV class transmission lines, they will be short in transmitting capacity and many additional transmission line routes will be required for construction. So, this large block of power to be transmitted for long distances necessitates introduction of higher voltage or EHV level transmission system.

On the other hand, the incoming of such large power from the north and south to Metro Manila as well as from the vicinity plants will require appropriate improvement on the existing system and also introduction of higher voltage connections around the center grid in Luzon.

Consequently, the situations stated above call for a feasibility study on the introduction of the EHV transmission system to the Luzon Grid.

1.2. Objective of the Study

The broad objective of the feasibility study is to deliberate and establish the optimum plan of EHV transmission system in the Luzon Grid until the year 1995 by reviewing the previous related studies, to prepare a basic design of EHV facilities and to study the feasibility from the engineering and economic points of view.

1.3. Scope of the Study

A feasibility study of the Project to be carried out by JICA experts is to work out the load forecast and the system engineering of the Luzon Grid, and to prepare a revised power development and a basic design of main power facilities which can meet the system requirements until 1995.

The scope of the study is summarized as follows:

(1) Review of load forecast

(2) Recognition and study of the latest status of the Luzon System

(3) Evaluation of system stability and reliability

(4) Determination of optimum transmission system

(5) Basic design of EHV facilities

(6) Detailed estimate of cost and quantity of the Project

(7) Economic and financial analyses of the Project

(8) Construction schedule and program of the Project

1.4. History of EHV Transmission System Plan

In January 1980, the JICA mission of EHV transmission system plan was dispatched to the Philippines to discuss with NAPOCOR and collect necessary data for the EHV plan. At the meeting with NAPOCOR it was confirmed that the establishment of EHV transmission system is necessary for large-scale hydro power plants at the Northern Luzon. In addition, as the result of the meeting, the Implementing Arrangement was signed between NAPOCOR and JICA on January 28, 1980, and in the Implementing Arrangement, the scope of work of this feasibility study was agreed between both parties.

JICA, in compliance with above-mentioned agreement, sent to the Philippines a team leader and one (1) expert for conducting a system engineering study for the duration of twenty (20) days from August 17, 1980 and one (1) economist for the duration of ten (10) days from August 24, 1980, and subsequently carried out the review and analyses based on the data and information gathered. After study of power system, a team leader, one (1) transmission engineer and one (1) substation engineers were sent to the Philippines for conducting a basic design study of EHV facilities and reconnaissance of proposed line routes and substation sites for the duration of fifty (50) days from November 5, 1980 and discussed the investigation results and design criteria of EHV facilities.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1. Conclusions and Recommendations

2.1.1. Conclusions

The system study was based mainly on power flow calculations and transient stability analyses for the system that is expanded as its generating sources are developed. The basic designs regarding the transmission and substation facilities were required for the optimum development plan determined taking into account the design criteria on the existing 230 kV facilities as well as the geographic and topographic conditions and other technical factors.

The conclusions derived from the study are enumerated below:

(1) 500 kilovolts (kV) is deemed adequate as a transmission line voltage for carrying large blocks of power for long distances.

(2) The development of Northern Luzon EHV Transmission Line Project considering the timing and sequence of the Southern Luzon EHV Project, will be technically and financially feasible:

(a) Completion by the end of 1987, of a 423 km 500 kV double circuit line from Gened to Solano to San Jose. This line will be operated at 500 kV from the beginning for Gened Hydro Plant completion. At the same time, the lines between San Jose - Kalayaan - Naga in the Southern Luzon Project will be boosted up to 500 kV line voltage.

(b) At the same time, two (2) units of 500 kV/230 kV 300 MVA transformers and a shunt reactor of 700 MVAR will be installed at Solano,

(c) For the Southern Luzon EHV Project, one unit each of 500 kV/230 kV 300 MVA power transformer will be additionally installed respectively at San Jose and Kalayaan plus one unit of 500 kV/115 kV 300 MVA power transformer at San Jose, and one of shunt reactor of 180 MVAR capacity is needed at San Jose.

(3) The Project will serve to transmit stably and economically to the consumers in the Luzon Grid, particularly in Greater Manila, the power generated by the hydro power plants which will be developed in the Northern Luzon area and connected to the Luzon Grid in accordance with the latest Generation Expansion Plan of NAPOCOR, thus providing adequate power supply to the load of the Luzon Grid.

(4) 500 kV transmission lines are designed for the double-circuits using 4 x 795 MCM ACSR on the self-supporting square based galvanized steel towers with concrete foundation.

500 kV substations are designed to accommodate 300 MVA power transformers to lower voltages of 230 kV or 115 kV at 1550 kV BIL.

(5) The milestone schedule of development of the Project in accordance with the development program proposed in (2) above is shown as follows.

	Transmission Line	Substation
Contract Design	Mar. 1982 - Oct. 1982	Mar.1982 - Oct.1982
Tendering	Mar. 1983 - Oct. 1983	Jul.1984 - Feb.1985
Manufacturing	Jun. 1984 - Dec. 1986	Jul.1985 - Apr.1987
Construction	Feb. 1985 - Dec. 1987	Sep.1985 - Dec.1987

(6) The estimated construction cost of the Project excluding the interest during construction is PESOS 5,716,820,000 (US$ 762,243,000), the particulars of which are broken down as follows:

Item	Foreign Currency Cost	Local Currency Cost	Total
	(US$)	(Pesos)	(Pesos Equivalent)
Transmission Line	227,174,000	2,861,016,000	4,564,821,000
Substation	85,543,000	510,426,000	1,151,999,000
Total	312,717,000	3,371,442,000	5,716,820,000

6) The economic analysis of the Project indicates that the Project will produce an economic rate of return of 13.46%. The power rate that will be able to pay for the financial cost required for the foreign loan and the OM cost, keeping a financial rate of return of 8%, is estimated to be 108.338 centavos per KWH.

2.1.2. Recommendations

In order to develop the Project in accordance with the proposed development schedule, it is recommended that the following action be taken immediately.

(1) Engineering Work

The following should immediately be accomplished by NAPOCOR surveying groups and qualified consulting engineers:

(a) to complete field investigations including topographic surveys and soil test by August of 1982 and

(b) to complete contract design and preparation of tender documents for the Project by the end of 1982.

(2) Financial Arrangement

Following normal procedure of finances by international financing institutions, the loan agreement on the finance of foreign exchange cost required for the Project should be signed before the announcement of tender for the Project. According to the milestone of the Project development, the prequalification questionnaires are scheduled to be issued in January 1983 for transmission lines and in May 1984 for substations. Considering a time set aside for the loan procedure before the signing of the loan agreement, a commitment of the finance of foreign exchange cost for the construction of the Project should be secured from an international financing institution in due time. It is, therefore, recommended that a timely action be taken to secure the required financial commitment.

2.2. Project Characteristics

The Project will connect the Gened Hydroelectric Power Plant to Metro Manila and other power load centers in Northern Luzon and will involve the following

(a) a total of 423 km 500 kV double-circuit transmission line

(b) installation of four (4) 500 kV/230 kV 300 MVA power transformers, one (1) 500 kV/115 kV 300 MVA power transformer and two (2) shunt reactors

The location of substations and route of the transmission lines are identified in Fig. 2-1 (Luzon Grid Power System Map).

The Project has the following characteristics:

(1) The Project together with the Southern Luzon EHV Project will be the first EHV transmission line to be introduced to the power system in the Philippines.

(2) In association with completion of the Southern Luzon EHV Project, it will form backbone trunk line of the Luzon Grid traversing the Luzon Island from the Gened Hydroelectric Power Station in Northern Luzon to Legaspi in Southern Luzon in 1988 when the Manito additional 110 MW (No.5 and No.6) is scheduled to be placed in service.

(3) The alternative equivalent transmission line in Northern Luzon is the erection of:

Gened - Solano	2 routes of 230 kV double-circuit transmission line (4 x 795 MCM) completed by 1988
Solano-San Jose	3 routes of 230 kV double - circuit transmission line (4 x 795 MCM) completed by 1988

(4) The alternative equivalent power sources and the associated transmission line in Northern Luzon are the erection of:

Two units of Coal Fired Plant 300 MW and one route of 230 kV double-circuit transmission line (2 x 795 MCM)

Completed by 1988

One unit of Coal Fired Plant 300 MW and one route of 230 kV double-circuit transmission line (2 x 795 MCM)

Completed by 1993

One unit of Coal Fired Plant 360 MW and one route of 230 kV double-circuit transmission line (1 x 795 MCM)

Completed by 1994

One unit of Coal Fired Plant 350 MW and one route of 230 kV double-circuit transmission line (1 x 795 MCM)

Completed by 1995

2.3. Overall Project Implementation Schedule

The construction work of the Project will be carried out according to Fig. 2-2 (Overall Project Implementation Schedule), assuming that the necessary steps in planning, design, tendering, manufacturing and execution of construction are taken within the specified times.

Fig. 2-1 LUZON GRID POWER SYSTEM MAP (FY-1980)

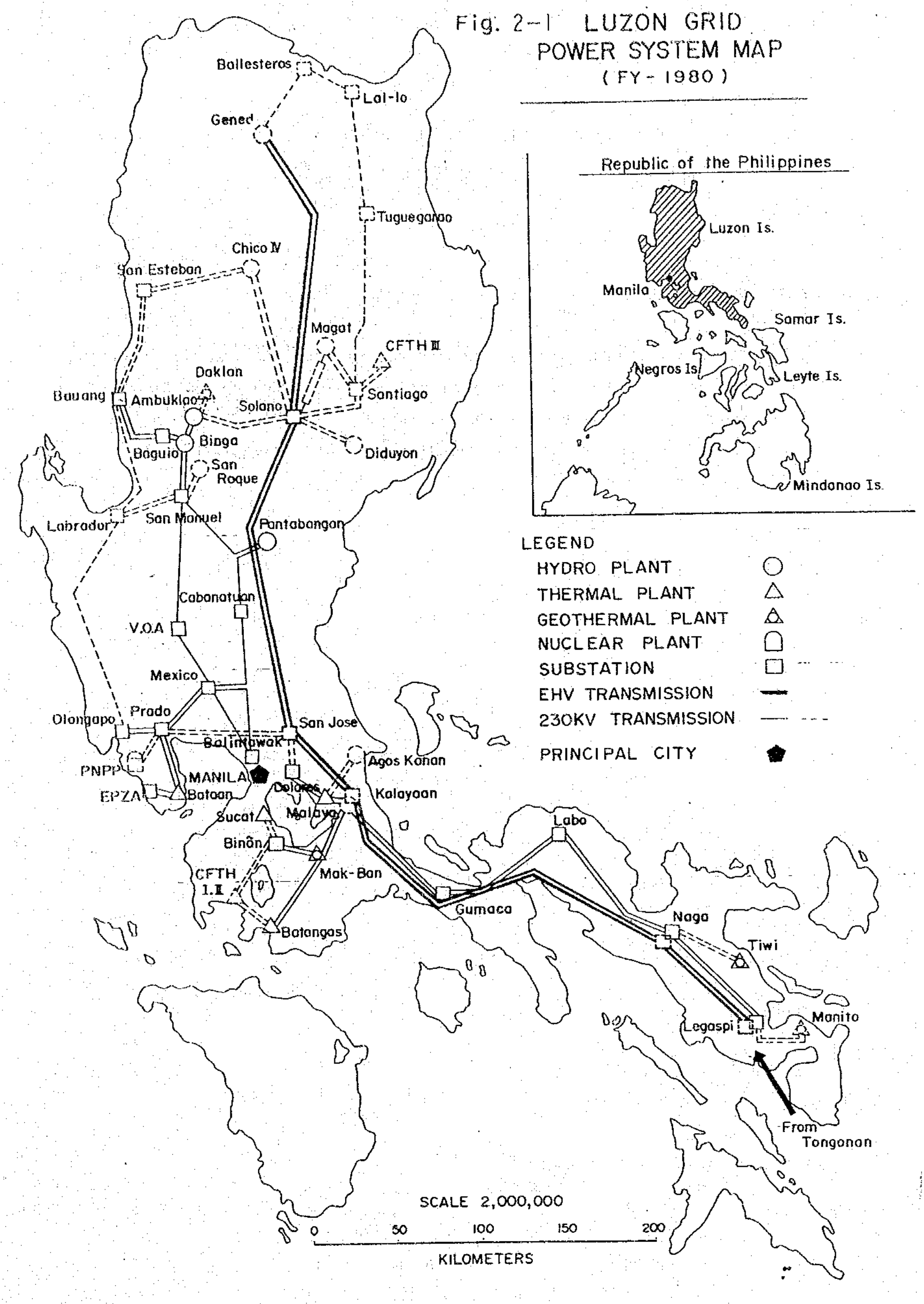
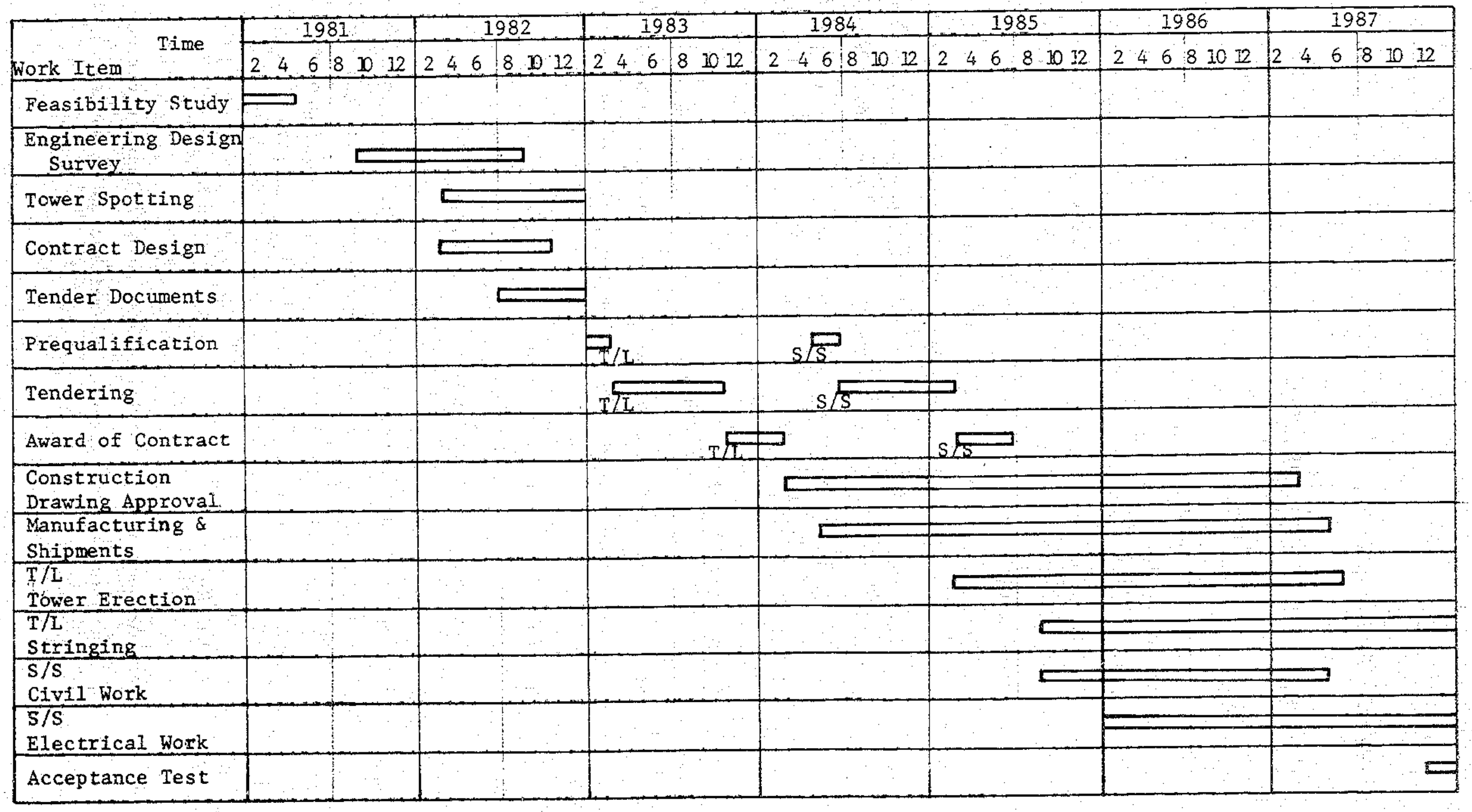


Fig. 2-2 Overall Project Implementation Schedule

T/L = Transmission Line
S/S = Substation



3. POWER MARKET AND POWER SYSTEM ANALYSIS IN LUZON

3.1. Description of Present System

3.1.1. Generation

As of the end of 1979, the total capacity of the generating plants in the Luzon Grid is 2,991 MW excluding small capacity generators supplying local loads. This total installed capacity is made up of hydro 541 MW (18%), geothermal 220 MW (7%) and oil-fired thermal 2,230 MW (75%). Most of the hydro power stations are located in the north of Manila, geothermal power stations in the south and oil-fired power stations in and around Manila. The main technical data of the existing power stations in the Luzon Grid is presented on Table 3-1 (Existing Power Stations in the Luzon Grid), and their locations are shown in Fig. 2-1 (Luzon Grid Power System Map).

3.1.2. Transmission Lines

As of the end of 1979, NAPOCOR operates in the Luzon Grid the following transmission lines with the indicated voltages:

230 kV	route length	1,118.6 km
115 kV	route length	444.8 km
69 kV	route length	1,637.8 km

The line routes of the existing 230 kV transmission lines are shown in Fig. 2-1 (Luzon Grid Power System Map), and the 230 kV system configuration is presented in Fig. 3-1 (Luzon Grid 230 kV System Single Line Diagram as of the End of 1979).

3.1.3. Substations

NAPOCOR operates in the Luzon Grid substations of various voltages with the following aggregate capacities as of the end of 1979:

230 kV	2,283.0 MVA
115 kV	460.0 MVA
69 kV	549.0 MVA

The locations of the 230 kV substations are identified in Fig. 2-1 (Luzon Grid Power System Map), and their configurations are presented in Fig. 3-1 (Luzon Grid 230 kV System Single Line Diagram as of the End of 1979).

3.2. Historical Power Load and Load Forecast

3.2.1. Historical Power Load

3.2.1.1. System of Power Supply in Luzon

Electric power utilities in the Luzon Grid are: NAPOCOR which is solely responsible for the construction, operation and maintenance of generating plants, bulk transmission and transformation facilities not only in Luzon but also in other areas of the country as a whole; Manila Electric Company (MECO), a privately owned utility distributing electricity to the Metro Manila area; and the local electric cooperatives (COOPS) under the administration of National Electrification Administration (NEA). Most of the COOPS purchase power from NAPOCOR and distribute it to their consumers on a local franchise basis, but some of them generate parts of their power requirements with their own small-capacity generators.

The power system of NAPOCOR is composed mostly of 230 kV lines and supplies load through 230 kV/69 kV transformer banks, while MECO's trunk system is composed mainly of 115 kV lines and supplies load through 115 kV/34.5 kV transformer banks.

The service area of MECO is about 2,600 km^2 embracing the Metro Manila area which corresponds to approximately 2.5%

of the total land area of Luzon (104,000 km^2). However, the service area has the heaviest load density which consumes nearly two-thirds (2/3) of the total load in Luzon in 1978. On the other hand, NAPOCOR's service area involves non-electrified districts. NEA statistics as of the end of 1978 show that 71% of cities and villages in Luzon are electrified with 47% of the households enjoying the benefits of electricity. According to the present rural electrification program, all provinces in the Luzon Island will be connected to the power network in 1981 when the on-going Cagayan Valley Electrification Project will be completed, and the residential electrification level will reach 100% by 1990.

As for generating facilities, before government purchase of MECO plants, NAPOCOR and MECO operated their own generating plants separately. However, starting November 1, 1978, the majority of MECO's oil-fired thermal plants with a total installed capacity of 1,150 MW were turned over to NAPOCOR. At present, NAPOCOR absorbed all generating plants owned by MECO. There are eight (8) electric cooperatives who are generating power by their own generators, with a total installed capacity of 18,422 kW and peak output of 10,533 kW, which is too small to give any impact on demand and supply balance on the whole.

3.2.1.2. Historical Load Increase

Load increases in the Luzon Grid during the past ten years of 1969 to 1978 are tabulated on Table 3-2. As seen on the table, the peak load and annual energy requirement in 1969 were 1,020 MW and 6,087 x 10^6 kWH. These reached 1,780 MW and 11,223 x 10^6 kWH in 1978 which is nearly twice as much as those in 1969. The average growth rate in this duration was 7% both in peak load and annual energy requirement. However, the peak load in 1973 and the annual energy requirement in 1974 showed particularly low growth rates of only 0.3% from the previous year. This was due to the first oil crisis which prevailed in these years. Except for 1973 and 1974, other years show normal rate increases.

Although there are some variations by years, the load factor ranges from 65% to 72% which showed a higher figure in recent years.

The power loss rate in the past is also shown on Table 3-2.

The breakdown of power load into the categories of household use, industrial use and other uses is presented on Table 3-3.

Figs. 3-2 and 3-3 represent daily load curves in each month of 1979. They indicate that no remarkable difference is found in each other though the loads in January to March are slightly lower.

Fig. 3-4 shows a montly peak load curve for three years of December 1976 to December 1979. As seen from the curve, there is no acute seasonal change observed but a gradual increase in the load.

The above trend in the power load is common characteristics to the countries in the tropical zone. The power load is projected to move in the similar trend in the future, too.

3.2.2. Power Load Forecast by Categories of Consumers

NAPOCOR made a load forecast up to the year 2000 in June 1980, which is shown on Table 3-2. This load forecast indicates that the growth rates of peak demand and energy requirement in 1979 are estimated at 10% and 5.5% respectively and the load will increase annually at the rate of 7% from 1980 to 1990.

The estimated breakdown of power loads in the categories of residential use, industrial use and other uses is presented on Table 3-4.

The method of the load forecast used by NAPOCOR is outlined below:

(1) Historical load was classified into the categories of residential, industrial and other use.

(2) The residential load was forecasted by an analysis of trend of historical load growth.

(3) Future industrial load was forecasted by classifying the load into certain load, load which will become firm subject to connection upon the completion of supplying facilities, and uncertain load.

(4) Other demands considered include loads from military bases, construction activities and street lighting.

(5) The load increase resulting from rural electrification was forecasted based on a correlation between the population and power demand in electrified areas, taking account of load growth rates after electrification.

(6) As data for population which is one basic parameter for the load forecast, the lower value of population increase projection by NEDA in 1975 was used.

On the basis of the power loads by regions estimated in the above method, the annual total energy requirement in the Luzon Grid was estimated, assuming that the diversity factor of load within the jurisdiction of NAPOCOR is 1.1 and that between NAPOCOR and MECO is 1.03. The loss rates in the power system of NAPOCOR and in the distribution system of MECO are 10% and 4.8% respectively. The annual peak load forecast was based on the annual total energy requirement thus forecasted, assuming that the load factor is 70%. The method outlined above is conventional and no objectionable factor is seen in the estimate.

Fig. 3-5 gives a statistical relation between energy consumption and Gross Domestic Product (GDP) in 1974 in various countries in the world. This figure indicates that the Philippines is situated on the average expressed with a bold line.

In view of recent worldwide energy conservation efforts, the Philippine's national policy of oil import cut-down, use of non-oil energy for new industrial development and diversification of industry to the areas other than Luzon, a sharp load increase inside the Luzon Island would not be expected for the decade. In forecasting the power load for the coming 10 years, it is a normal practice that a growth rate of the load in the latter years is made a little bit lower. The projected growth rate of 7% per annum from 1979 to 1990 is, however, considered reasonable at the present, considering that the electrification program in Luzon is scheduled to be completed in 1990, energy use in recent years is suppressed due to conservation of oil-consumed energy and development of indigenous energy resources is being accelerated.

In view of the above, it was decided to adopt the NAPOCOR load forecast for this study. After 1991, the annual growth rate of 6.5% is projected for the years up to 1995 and 6.0% from 1996 to the year 2000 as the load after completion of the rural electrification in 1991 is forecast to grow at somewhat lower rate.

3.2.3. Power Load Forecast by Bulk Substations

It is necessary to forecast load distribution by major bulk substations in the Luzon Grid, which will provide a base for the system planning and analysis.

As discussed in the preceding section, the NAPOCOR load forecast was prepared on the basis of integration of projected regional loads. For the projection of loads by regions, power load at the respective substations on the NAPOCOR power network was estimated by NAPOCOR for each year from 1980 to 1990. Likewise, bulk substation loads within the MECO service area for the years 1980 to 1989 were projected by MECO. The values in this MECO projection are, however, rather higher as compared with the overall load forecast as forecast in the preceding section 3.2.2. Besides, there is available load forecast data at substations within the MECO service area in the year 1984 only which were prepared by NAPOCOR. Total of the substation loads on the NAPOCOR power network and the substation loads at the substations within the MECO service area, both in 1984, which were forecast by NAPOCOR quite agrees with the overall load forecast in 1984. After having conferred with NAPOCOR regarding the treatment of different values of the substation loads within the MECO service area, following procedures were taken to arrive at final figures:

(1) Bulk substation loads forecast by NAPOCOR were adopted as they are.

(2) To obtain the total load in the MECO service area in each year the sum of NAPOCOR bulk substation loads was subtracted from the overall NAPOCOR-MECO integrated load.

(3) MECO bulk substation loads in each year of 1980 to 1989 which were forecasted by MECO were divided in proportion to agree to the total load in the MECO service area in the corresponding year obtained under the above item (2).

(4) MECO bulk substation loads in 1990 were projected by extending those in 1989 with annual growth rate of 7%.

(5) During the period 1991 - 1995, both NAPOCOR and MECO bulk substation loads were computed at the average annual growth rate of 6.5%.

(6) MECO substation loads, except the load at Tayabas, were grouped into four (4): Sucat, San Jose, Dolores and Malaya, because the MECO 115 kV system consists of many transmission lines in the form of a mesh which will make it possible to transfer loads among the groups and to deal with overloading or abnormal voltage drop of a transmission line.

The forecasted loads by substations which were estimated in the above method are presented in Tables 3-5 and 3-6.

3.3. Generation Expansion Plan

3.3.1. NAPOCOR's Principal Policy for Future Generation Expansion

NAPOCOR is implementing power development program in line with the following basic policy:

(1) Accelerated development of country's indigenous energy resources such as hydro and geothermal.

(2) Development of nuclear power.

(3) Promotion of domestic coal-fired thermal power development, and no more addition of oil-fired thermal plants.

(4) Suppression of operation of existing oil-fired thermal plants to the maximum extent and their gradual retire-

ment in the order of lower efficiency plants as new power sources are placed in service.

This basic policy is considered reasonable in view of recent global energy situation, especially from the viewpoint of conservation of oil energy. The holding of existing oil-fired thermal plants as standby plants in the Generation Expansion Plan will give more flexibility in providing for more load increase than forecasted or change in the Generation Expansion Plan.

3.3.2. Generation Expansion Plan

Based on the load forecast up to the year 1990 and in line with the above-mentioned basic policy for generation expansion, NAPOCOR worked out its generation expansion program in October, 1980, which is designed to increase the total installed capacity of the Luzon Grid to 7,043 MW in 1990, composed of hydro 1,993 MW (28%), geothermal 1,675 MW (24%), nuclear 620 MW (9%), coal-fired thermal 600 MW (8%) and oil-fired thermal 2,155 MW (31%). This latest Generation Expansion Plan is presented on Table 3-7. A main difference from the former plan based on the system engineering report for generation expansion program in June 1980, is that the development of geothermal power sources such as Manito is accelerated. The acceleration of Manito will be scheduled as 110 MW of No.3 and No.4 in 1986, 110 MW of No.5 and No.6 in 1988 and 110 MW of No.7 and No.8 in 1990, thus the total installed capacity of 1,345 MW will be increased to 1,675 MW in 1990. The acceleration of geothermal development is designed to decrease oil-based energy generation as early as possible. Moreover, the construction period of a geothermal power plant is shorter than other alternatives. Except for the retirement of an oil-fired thermal plant made in early 1980 due to its deterioration, no other oil-fired thermal retirement is considered in the generation expansion program.

The Tiwi Geothermal Power Station units Nos. 5 and 6 (each 55 MW) are under construction with the target date of completion in 1982. A feasibility study of additional units Nos. 7 to 10 (each 55 MW) is being carried out by NAPOCOR. The investigation of availability of geothermal steam for the feasibility study is under way by the Philippine Geothermal, Inc., a subsidiary of Union Oil in U.S.A.

The construction of the Tongonan Geothermal Power Station Units 1 to 3 (each 37.5 MW) is in progress, and scheduled for completion early in 1983. A feasibility study of the Tongonan geothermal units 4 to 9 development is being carried out by Kingston Reynolds Thom and Allcardice, Ltd., New Zealand under a New Zealand-Philippine technical assistance program. The pre-feasibility report issued by the same company in November 1979 describes that the Tongonan site has geothermal potentials to enable the development of 750 MW to 1,000 MW. As far as the interconnection line between Tongonan and Legaspi in Southern Luzon including submarine cable, NAPOCOR has recently signed an agreement with JICA to undertake the feasibility studies of the project on grant basis. It is expected that the detailed engineering phase will follow to complete the contract design until February, 1982, so that the interconnection may be operational by the end of 1985.

In the meantime, a feasibility study of the Mak-Ban geothermal power station units Nos.5 & 6 is also being carried out by NAPOCOR. The investigation of availability of geothermal steam for the feasibility study is under progress by the Philippine Geothermal, Inc.

A feasibility study of the Manito Geothermal Power station units Nos. 1 & 2 is being carried out by NAPOCOR. The investigation of availability of geothermal steam for the feasibility study is now being carried out by the PNOC-Energy Development Corp.

As the sources of the Northern Luzon, Magat Hydro Plant of No.1 to No.4 will be completed in 1983 and No.5 and No.6 added and connected to 230 kV system in 1985. 600 MW of Gened Hydro Plant conducted by NEWJEC engineering service will be operated in 1988. The more additional generation expansion will be planned at San Roque for 390 MW in 1992, Coal Thermal III for 300 MW in 1993, Chico IV for 360 MW in 1994, and Agos Kanan for 280 MW and Diduyon for 350 MW respectively in 1995.

3.4. Load and Supply Balance

Using the load forecast and generation expansion plan which were discussed in the preceding sections, the load and supply balance in the Luzon Grid was analyzed. In the analysis, the following approach was used:

(1) This study covers a period up to the year 1995. However, the demand and supply balance was analyzed until the year 2000 because the transmission line voltage and power conductor size should be selected so as to cater to the system requirements for a long term.

(2) Generation expansion plan for the decade of 1991 to 2000 was programmed with the generation projects which have proven viable or feasible as the result of previous studies.

(3) A maximum power output of the system is considered as the sum of dependable capacities of power plants in the system.

(4) The reserve capability of the system is considered as reserved capability at the outage of the second largest generating unit in the system while the largest unit undergoes a periodical inspection.

As the power load in the Philippines does not vary much seasonablly, the maintenance of plants should be averaged throughout a year, and a case of out-of-operation of the largest plus the second largest units would be unavoidable in any combination of various types of power stations.

The largest plus the second largest units are two units of the Malaya thermal power station (total dependable capacity 630 MW) before the nuclear power plant is commissioned. After the nuclear power plant is placed in operation, there will be a single unit of the nuclear power plant and unit No.2 of the Malaya thermal power station with a total dependable capacity of 930 MW. The system reserve capacity is defined as the difference of (total dependable capacity) - (peak load + dependable capacities of the two above-mentioned largest units in the system).

The load and supply balance in the Luzon Grid computed in the above approach is presented on Tables 3-7 to 3-9. The dependable capacities of thermal and hydro power plants used for the computation are presented on Tables 3-10 and 3-11.

Tables 3-7 and 3-8 indicate that the power balance (kW) showed a deficiency of 44 MW in 1981, but in 1981 no addition of a new plant could be expected to cover this up. The deficiency in power is equivalent to approximately 2% only and such shortage can be overcome by reducing the voltage without restriction on power supply, unless shutdown of any power plant occurs.

After 1982, the system will augment gradually its reserve capacity which will reach 1,666 MW in 1985. This reserve capacity is still less than the total installed capacity of oil-fired thermal plants, i.e., 2,155 MW or 2,015 MW in terms of dependable capacity, in which case the operation of all oil-fired thermal plants can not be suspended over the year.

On the other hand, Tables 3-7 and 3-9 show that the energy balance (kWH) would not pose any problem, for it has some surplus against the requirement. If this surplus energy is offset by limiting the operation of oil-fired thermal plants, the years when oil thermal energy will not be required completely are only the years of 1985 to 1988 in figures. However, these years will need the power (kW) generated by oil-fired thermal plants, which accompany some energy generation, hence complete suspension of oil-fired plant operation can not be expected.

As a result, any apprehension is not foreseen on the load and supply balance over the projected period, except the year 1981. At a glance, it gives an impression that the system will have rather large reserve capacity, but from the viewpoint of oil conservation, the generation expansion program is not considered ambitious but it is desirable to implement more power source development as far as the situation permits.

3.5. Introduction of EHV Transmission System for the Expanding Luzon Grid

Generally, projected power sources in Luzon will be hydro located in the north and geothermal in the south, whereas the heaviest load center is Metro Manila and its vicinity. Therefore, the trunk transmission lines should be extended from both north and south ends of Luzon toward Metro Manila.

The load forecast and corresponding generation expansion plan for Luzon give a quantity of differential power to be transmitted to Metro Manila as follows:

(Unit: MW)

	1990	1995	2000
Power Output in Northern Luzon	1,370	2,770	4,100
Power Load in Northern Luzon	448	613	820
(Difference)	922	2,157	3,280
Power Output in Southern Luzon	1,290	1,400	2,110
Power Load in Southern Luzon	108	149	199
(Difference)	1,182	1,251	1,911

The power output in Northern Luzon means power generated by power sources located farther north of the Binga hydroelectric power station while the power load therein represents the total forecasted load in the area north of Baguio and Solano. Almost all of the power sources in Northern Luzon will be hydro power plants with a few exceptions of coal-fired thermal and geothermal units. The power output and power load in Southern Luzon are defined as those available south of Gumaca. The majority of the Southern Luzon power sources are geothermal generating units and 600 MW of coal-fired thermal station.

These power sources in both south and north areas are about 300 to 400 km distant from the load center, Metro Manila. A bulk power transmitting capacity for such long distance is limited by the stability of the system. At present, the NAPOCOR standard 230 kV transmission system is 1 x 795 MCM double circuit, of which power carrying limit is approximately 300 to 350 MW.

(1) Northern Luzon

The generation expansion plan adopted in this study will require the construction of 6 to 8 transmission circuits in Northern Luzon in 1995, if the line voltage is maintained at 230 kV. The locational concentration of power sources in the north of Baguio and around Solano will restrict an increase in the utilization rates of the transmission lines by interchange of power among them. There is a possibility that many more circuits of transmission lines may be required. Besides, more than 1,000 MW is planned for development until the year 2000. If the transmission lines are expanded at 230 kV level, every power plant construction will require the construction of a transmission line of more than 300 km, in the extreme case. This is quite unrealistic nor practicable. In view of the topographic conditions in Northern Luzon and the locations of power sources, the transmission system in Northern Luzon should adequately be planned to be less than two routes or four circuits. The introduction of an EHV transmission line is imperative to carry such large power with minimum number of line routes or circuits.

(2) Southern Luzon

The generating capacity in Southern Luzon will be in the order of 1,200 MW in 1990 and it will be doubled to 2,000 MW in the year 2000. The Southern Luzon power system is at present a 230 kV double circuit line only, but, as the power sources, existing and planned, are concentrated around its southern end, new transmission lines will be required to transmit the increasing power.

Southern Luzon is topographically very narrow and most of its land area, even the mountain ridges, have been developed for extensive coconut plantations. Therefore, the environmental constraints are deemed more severe. If the transmission voltage is maintained at 230 kV, two (San Jose - Kalayaan), one (Naga - Legaspi) and three (Kalayaan - Naga) additional routes of 230 kV, double-circuit transmission lines will be required for construction to maintain the equivalent carrying capacity of a 500 kV transmission line. The right-of-way with a total area of 37.68 km^2 will be needed by NAPOCOR for the construction of the additional 230 kV lines, while the construction of an alternative equivalent 500 kV double-circuit line requires the right-of-way area of 25.35 km^2.

It is believed that the addition of one route of transmission line in Southern Luzon will have to be the limit because of the topographic and geographic restriction, hence the introduction of an EHV transmission line into the power system in Southern Luzon becomes necessary.

If EHV is adopted to both the systems in Northern Luzon and Southern Luzon, hourly variations in power flow will become large because of different characteristics in the main power sources in both areas (mainly geothermal in Southern Luzon and hydroelectric in Northern Luzon). The interconnection of both systems at 230 kV will bring an increase in the capacity of tie transformers and make difficult interchange between both north and south systems. Accordingly, the interconnecting line between both systems should be an EHV line to initiate savings in tie transformer capacity.

For the above reasons, it is recommended that next transmission lines be constructed at a higher line voltage and operated initially at 230 kV as long as possible and then boosted to a designed higher line voltage at the appropriate time.

3.6. Optimization of EHV Transmission Voltage

Table 312 shows transmission voltage levels in the countries where extra high voltage transmission systems are in operation. Generally, a higher transmission voltage has been selected to be more than twice as much as the previous highest voltage level.

The carrying capacity of a transmission line considering its stability is determined in the following power equation:

$$P = \frac{E_s E_r}{X} \sin \theta$$

Where, P = carrying capacity
E_s = voltage at the sending end
E_r = voltage at the receiving end
X = Reactance
θ = Phase angle

As clearly known from this equation, the carrying capacity will increase in proportion to the square of a voltage; if the voltage is doubled, the carrying capacity will become four times. This is the major reason why higher voltage has been normally determined at a level more than twice as much as the previous highest voltage.

The present highest transmission voltage in the Luzon Grid is 230 kV. So the next higher should be selected at 400 kV or 500 kV.

The reasons why 500 kV was recommended as the optimum transmission voltage to the Luzon Grid are enumerated as follows:

(1) The European countries raised their highest voltage in power systems from 220 kV to 400 kV. This voltage increase was made

in the latter half of 1950 to 1960. In those days, design criteria of 500 kV transmission lines were not established yet. However, nowadays design criteria for 500 kV systems have been thoroughly developed and 500 kV lines are operated successfully.

(2) In Europe, excluding Sweden, the transmission lines are relatively short in distance. As the systems are interconnected among the countries, the power systems in the different countries were required to be coordinated by the first adopted voltage level. In Sweden, series condensers are used for compensation of shortage in the transmission capacity.

(3) The frequency of power in Europe is 50Hz, while in the Philippines it is 60Hz. The transmission capacity of a transmission line at certain voltage in the 60Hz power system is reduced to 80% of the transmitting capacity of a transmission line rated at the same voltage in the 50Hz system. It is, therefore, justified to have a higher voltage in the 60Hz system in order to cover this disadvantage.

(4) To compare the construction cost of 500 kV with that of 400 kV having an equivalent transmission capacity (allowable current), the cost is higher by 10% for substation but lower by 3% in transmission line. This results in that, for a long distance transmission line, 500 kV system becomes more economical as a whole.

(5) Considering the extensive generation expansion in the Luzon Grid after 1995 and difficulties in acquiring the right-of-way, the transmitting capacity of next transmission lines should desirably be maximized to a possible extent by adoption of 500 kV voltage level. From the stability point of view, a transmission capacity of 500 kV can be expected 140% more than 400 kV.

3.7. System Analysis

3.7.1. Basic Data for System Planning

3.7.1.1. Outline of Present Major Transmission System

The present major power systems in the Luzon Island are composed of NAPOCOR 230 kV system extending to the north and south of the island and MECO 115 kV network serving Metro Manila and its vicinity. These two systems are integrated with each other, and is called the Luzon Grid. Fig. 3-6 shows the outline of said system, Metro Manila area has a number of MECO 115 kV lines in the form of a mesh. Both north and south 230 kV system of NAPOCOR are interconnected to the MECO 115 kV systems through 230 kV/115 kV transformer banks. The transformer bank capacities at major interconnections are Balintawak 420 MVA connecting with the north 230 kV lines and 200 MVA at Binan and 75 MVA at Malaya, both connecting with the south 230 kV system.

3.7.1.2. Luzon Grid Expansion Plan

The Luzon Grid Expansion Plan until 1995 is shown in Fig. 3-7.

The main characteristics of this expansion plan are enumerated as follows:

(1) Establishment of 500 kV transmission system.

(2) Interconnection between the two systems in the south and the north by a 500 kV tie line.

(3) Reinforcement of the 230 kV system around Metro Manila keeping pace with the staged retirement of oil-fired thermal plants in or near Manila.

(4) Extension and reinforcement of the 230 kV system to cope with load increase in Northern Luzon.

3.7.1.3. NAPOCOR's Criteria for Present System Planning

The criteria for system planning currently being applied by NAPOCOR are given below:

(1) The system shall withstand against at least single fault. This means that the power system should be planned so as to function without disturbance against one circuit trip out or one transformer failure.

(2) The standard size of line conductors shall be 795 MCM.

(3) The maximum current rating of 1 x 795 MCM transmission line shall be 900 A.

(4) In case one circuit of double circuit transmission lines falls down, a short period allowable current limit for the lines carrying power from hydro plants shall be maintained within 140 % of the rated maximum current and within 110% for the other lines.

(5) In case of failure of one transformer, the overloading of other remaining transformer units in a short period shall be kept within 110% of their rated capacities.

(6) The bus bar system shall be in principle the 1.5 circuit breakers system, or the ring bus system. The grounding system shall be direct grounding.

(7) The target value of voltage control shall be $\pm 5\%$ of the rated voltage.

(8) The system stability is measured by a difference in the phase angles between the two generating units obtained by power flow calculation. The stability criterion is $\angle \delta \leq 30°$, within which the system is said to be "stable".

(9) Where the system frequency is abnormally lowered due to a generator accident or line fault, the system shall be maintained by temporary load shutdown with frequency values of relays necessary for load shutdown in case a nuclear unit trips out of operation.

3.7.1.4. New Criteria Proposed for System Planning Including 500 kV System

(1) The stability of the 500 kV system is most important in this study. A combined method of power flow calculation and transient stability analysis was applied to produce more accurate analysis of the system stability.

For this analysis, following conditions were assumed:

- ° Fault condition - One circuit three phase to ground fault (3LG)
- ° Fault clearance time - 0.1 second (6 cycles)
- ° High speed reclosing - Not applied

The system is considered "stable" if no generating units will step out in the calculation under the above conditions, and it is considered "unstable" should any generating unit step out.

(2) The allowable sending end voltage of the 500 kV system is limited to 1.1 P.U., to reduce the capacity of shunt reactors which would be required to compensate for the charging current rise of the 500 kV system.

If it results in voltage rise of more than 5% in the 230 kV system, such voltage rise will be suppressed by means of tap changing of 500 kV transformers.

(3) The standard conductor of 500 kV lines shall be 4 x 795 MCM, and the tower structure shall be designed for two circuits.

(4) The unit capacity of 500 kV/230 kV or 500 kV/115 kV transformers shall be standardized at 300 MVA, and tertiary side transformers are rated at a unit capacity of 100 MVA. Also, the voltage at the tertiary winding is generally set at 69 kV, except for San Jose where 34.5 kV is selected.

(5) In working out the system plan, due consideration was given to the maximum effective utilization of the system facilities, existing and under construction. On the other hand, the 500 kV system was designed to be a simple system as much as possible, in order to minimize unexpected disturbances; the different voltage loop operation of 230 kV one circuit line and 500 kV line in Northern Luzon was avoided.

3.7.1.5. Basic Input Data for System Analysis

The system analysis was performed by means of power flow calculation, transient stability study and short circuit current limit.

Those basic technical data on various system components used for the calculations are presented as follows:

(1) Generating capacities, substation capacities, and size and distance of transmission lines.

See Fig. 3-8. The circled figures on the diagram means node numbers given for the purpose of computer run.

(2) Substation loads

The substation loads shown on Tables 3-5 and 3-6 were used for the load by substations. These substations are assumed to be charged with about 50% of their peak loads at light load time.

The following NAPOCOR's target power factors were used as the power factors:

Peak load time	-	NAPOCOR 90%,	MECO 95%
Light load time	-	NAPOCOR 95%,	MECO 99.5%

(3) Characteristics of transmission lines

The main characteristics of 795 MCM by voltages and number of circuits are shown on Table 3-13.

(4) Characteristics of generators and transformers

The main characteristics of generators and transformers, existing and planned, are shown on Table 3-14 to 3-16.

Based on the figures shown on Fig. 3-8 and Tables 3-13 to 3-16, the impedance map of the Luzon Grid was developed as shown in Fig. 3-9.

3.7.2. Results of System Analysis

3.7.2.1. Power Flow and Transient Stability Analyses

Power flow and transient stability calculations were carried out with electronic computer based on the system expansion plan shown in Fig. 3-7 for the system configuration in key years.

The calculations were made for peak load time assuming that hydro plants are being operated at their rated outputs and geothermal, nuclear and coal-fired thermal plants are operated at dependable capacities. For oil conservation, surplus supplying capacity over the load was offset by primarily stopping the operation of oil-fired thermal plants around Metro Manila, and further surplus, if any, was cut down by stoppage or suppressed operation of the pumped storage station, hydro or coal-fired plants around Metro Manila which have less influence on the north and south power systems. Detailed adjustments such as the system losses were made using the output of the Malaya plant. The results of analyses are shown on Tables 3-17 to 3-24 and Fig. 3-10 to 3-17.

The results of analyses under the above conditions and of modified studies for the accelerated power expansion plan are summarized on the following.

(1) 1982 Power System

The connection of a transmission line from the Tiwi geothermal plant to one circuit of the Nega-Legaspi line, and the transmission capacity of the present Kalayaan-Malaya line were main problems to be studied.

The transient stability calculation of the connection of the transmission line from Tiwi indicates the system to be "unstable". Therefore, a new transmission line is required for construction between Tiwi and Naga.

Regarding the second problem, power flow between Kalayaan and Malaya will reach 158% of the rated current capacity of one circuit. This section will, therefore, need reinforcement.

(2) 1985 Power System

As the 550 MW output of Tiwi is scheduled to be put in the system in 1985, the current capacity and stability in the Naga-Kalayaan section pose a problem from the beginning of this study. Therefore, the calculations were made on the assumption that a 500 kV designed transmission line has been constructed in this section. The result show that the system in 1985 under the above condition will not cause any problem.

On the other hand, Magat extension and Daklan are scheduled to be operational in the north system in 1985. Studies were conducted for overloading and stability on the Ambuklao - Binga line and the system analyses show that the power flow in the above section would reach 164% of the rated current of one circuit, but no transient stability problem would be posed.

An interim result of the analysis indicates that if the operation of all oil-fired thermal plants except Malaya were stopped, the voltage within the MECO service area dropped below 95% of the rating, with some portions lower than 90%. Therefore, calculations were made at the power factor raised to 99.5%.

As the voltage of load-end system in the north of Baguio also dropped to about 90%, the transmission line of Baguio - Bauang - San Esteban - Batang Buhay was assumed to be double circuit line.

(3) 1986 Power System

The power 300 MW from Tongonan in Leyte will be transmitted on D.C. line to Legaspi in Luzon System in 1986.

The system analyses show that the Legaspi-Naga line will carry current equivalent to 101% or less of the rated current of one circuit at peak load time, while at off-peak time when the load at Legaspi is assumed to be totally lost, the power flow will reach nearly 110% which is almost marginal. The system will be stable without stepping-up to 500 kV operating voltage in the section between Naga and Kalayaan. This may probably be due to the fact that the power from Tongonan will be transmitted on the DC transmission line which has no problem in stability.

Manito in Southern Luzon will be equipped with additional 110 MW installation in 1986, and a new transmission line will definitely be needed for the section between Legaspi and Naga. This line shall be of 500 kV design because one coal-fired thermal station with a capacity of 600 MW is contemplated for construction around Legaspi.

To carry 1,070 MW consisting of Tiwi 550 MW, Manito 220 MW and Tongonan 300 MW, the necessity of stepping-up the Kalayaan-Naga line to 500 kV was examined by analysis of the transient stability. The result of examination indicates that 500 kV operation will not be required yet.

(4) 1988 Power System

The total output of power sources in Southern Luzon will reach 1,180 MW on completion of 330 MW at Manito. The analysis indicates that the step-up to 500 kV will be required between Naga-Kalayaan.

In this year, Gened hydro with 600 MW is expected to come in to the Northern System. It is considered impossible to transmit this power through 230kV line, since the distance to San Jose is more than 400 km. However, for confirmation, computer runs were conducted to examine the posibility. The result show that the system will become "unstable" if a line fault occurs in the Gened-Solano section. It, in turn, implies that this transmission line should be operated at 500 kV from the beginning. The transient stability will be secured at 500 kV operation.

(4) 1995 Power System

The 500 kV system connection from Gened - Solano - San Jose - Kalayaan - Naga and the 500 kV designed Naga - Legaspi line operated 230 kV will be still stable, even with additional units of Manito and new plants composed of CFTH III, Chico IV and Diduyon are introduced into the system.

3.7.2.2. Shunt Reactors

The charging current of the 500 kV system is quite large, about 7 times as much as that of a 230 kV 1 x 795 MCM transmission line. Accordingly, a considerable capacity of shunt reactors would be required, and the capacity of shunt reactors was calculated for the 1995 power system at both peak load and midnight time by means of power flow. The charging current was planned to be reduced by leaving one circuit of the Gened - Solano line out of operation on the assumption that all hydro plants will be out of operation in a draught period. The result of calculation indicates that the required capacity of shunt reactors will be as follows:

(Unit: MVAR)

	Peak	Midnight
Solano	327	726
San Jose	0	179
Kalayaan	130	565

The power flow diagram corresponding to the above result is as given in Figs. 3-17 and 3-18.

3.7.2.3. Short Circuit Current Capacity

In order to estimate approximate values of breaking capacity of power circuit breakers and unit capacity of shunt reactors, short circuit current was computed with respect to the power system as of 1995. For this calculation, all generators are assumed to be in parallel operation. Therefore, the value obtained could be considered as the estimate of the maximum short circuit current.

The calculation results were given on Fig. 3-19. As shown in the calculation, the largest short circuit current is still below 10,000 MVA. With reference to the current manufacturing technology of power circuit breakers, this would not pose any serious problem.

3.8. Time Sequence of Luzon System Expansion

The time sequences of the system expansions in Luzon Grids have been ascertained by considering the results of the system analysis and the study results of the accelerated generation expansion program.

3.8.1. EHV Power System Expansion in Southern Luzon

(1) By 1985: A 238 km 500 kV designed 4 x 795 MCM double circuit line will be completed between Naga and Kalayaan. This will be energized initially at 230 kV with Tiwi at 550 MW, Manito at 110 MW and Tongonan at 300 MW.

(2) By 1986: 76 km of Legaspi-Naga will be connected by a 500 kV designed 4 x 795 MCM double circuit line to be operated initially at 230 kV for additional Manito outputs of 110 MW, and the 76 km long 4 x 795 MCM 500 kV design double circuit line will be constructed between Kalayaan and San Jose and will be operated initially at 230 kV for utilizing effectively transport of southern power to Metro Manila,

(3) By 1988: The Naga-Kalayaan transmission line will be boosted up to 500 kV operation in order to match the additional Manito outputs of 110 MW. Accordingly, one unit of 500 kV/230 kV 300 MVA transformer and a 550 MVAR shunt reactor will be installed at Kalayaan Substation and three units of 500 kV/230 kV transformers will be installed at Naga Substation.

The Kalayaan-San Jose transmission line will be boosted up to 500 kV operation for utilizing effectively transformers at Kalayaan and San Jose at the time when either the Southern or Northern Luzon Power System will be operated at 500 kV. At San Jose two units of 500 kV/230 kV and one unit of 500 kV/115 kV 300 MVA transformers will be installed.

(4) By 1990: In connection with the additional units of 110 MW at Manito, Naga will have installation of one unit of 500 kV/230 kV transformer with 300 MVA capacity.

3.8.2. Power System Expansion in Northern Luzon

(1) 180 MW additional units of Magat will be completed by 1985. However, the additional units will be put in operation only during probable years of spilling water discharge or just as the reserve capacity when other plants are on outage, and will not produce any energy, so that new transmission line will not be required for Magat additional units. Only a 17 km long 230 kV 1 x 795 MCM one circuit line will be constructed for connection of Daklan geothermal plant to Ambuklao.

(2) By 1988: 500 kV transmission lines will be constructed for 219 km distance between Gened and Solano, and also for 204 km between Solano and San Jose, which will be operated at 500 kV. At this time, two (2) 300 MVA units of 500 kV/230 kV transformers and 700 MVAR shunt reactor will be constructed at Solano for the Northern Luzon power system, and one 300 MVA unit of 500 kV/230 kV transformer, one 300 MVA 500 kV/115 kV transformer, and 180 MVAR shunt reactor at San Jose, and one 300 MVA unit of 500 kV/230 kV transformer at Kalayaan for the Southern Luzon power system.

(3) By 1992: A 9km 230 kV 1 x 795 MCM double circuit line will be constructed between San Roque plant and San Manuel substation,

(4) By 1993: A 230 kV transmission line will be completed for 36 km distance between CFTH-III and Santiago. The coal-fired plant is planned to have a total installed capacity of 600 MW (CFTH-IV), so that the line will be of 2 x 795 MCM double circuit. No addition of transformers will be necessary in consideration of load increase at Baguio side.

(5) By 1994: Chico IV will be connected to Solano by constructing a 107 km 230 kV line. Previously, Chico IV is proposed to be linked through the 500 kV Gened-Solano line which was planned to pass nearby the site. However, said 500 kV line route was changed and Chico IV will be tied to the system through Solano. 230 kV lines will be necessary to meet the increasing demand in the north areas of Baguio and the Chico IV-Solano line would serve for this purpose. Since the area includes various hydro potential sites, the line considered will be 2 x 795 MCM double circuit. At this time, Solano and San Jose will be provided with additional one 300 MVA unit each of 500 kV/230 kV transformer and 500 kV/115 kV transformer respectively.

(6) By 1995: A 230 kV transmission line will be constructed for 45 km distance between Diduyon and Solano with 1 x 795 MCM double circuit. At the same time, one unit of 500 KV/ 230 kV transformer of 300 MVA will be additionally installed at Solano.

3.9. Summary of Luzon System Expansion Program

The Luzon System expansion program described in 3.7.2. and 3.8. above is summarized in Table 3-25 and Fig. 3-20. This table shows the system expansion program based on the new developing power plants. In the table, any circuit breakers necessary for the operation of shunt reactors are not included. The location of installation and voltage of shunt reactors will change, depending on the conditions of substations, in which the shunt reactors will be installed. Accordingly, the necessary shunt reactors shall be designed and added to the quantities of installation during the detailed design stage.

3.10. Scope of the Northern Luzon EHV Transmission Line Project

The Northern Luzon EHV Transmission Line Project involves the construction of 500 kV transmission lines and substations, and the additional substation facilities in relation with the Southern Luzon EHV Transmission Line Project.

The scope of the Project are specified below;

(1) Completion by the end of 1987 of a 423 km long Gened-Solano San Jose 500 kV double circuit lines which will be operated initially at 500 kV.

(2) Completion by the end of 1987 of Solano substation which will have two units of 500 kV/230 kV 300 MVA transformers, additional units of 500 kV/230 kV and 500 kV/115 kV 300 MVA transformers at San Jose, and additional unit of 500 kV/230 kV 300 MVA at Kalayaan.

3.11. Recommendations for Further Study

(1) The system analysis shall be reviewed, if the load forecast and generation expansion plan will be altered. If the development of Gened is accelerated by the change in the timing and sequence of geothermal power plants in Southern Luzon, it will have a large effect on the reliability of the system.

(2) It is a general tendency that the manufacturing costs of equipment are reduced by the economic use of materials as

the design technique progresses. But the cost-reduced equipment will, once they are used in the system, affect badly the stability of the system. As the Luzon Grid has no restriction in the short circuit capacity, the specification of equipment to be used therefore, shall be determined, giving importance to the stability.

(3) The present system analysis which was made on the assumption that all oil-fired thermal power plants other than Malaya will be placed out of operation indicates that the analytical calculation of the initially assumed load factor is difficult because of the voltage drop and the assumed load factor was compelled to be changed. This fact suggests that the retirement of oil-fired steam power plants will be very difficult, if the power system in and around Metro Manila remains as it is. The improvement of load factor in the MECO system, reinforcement of the system, and rotary condenser operation of generators of retired oil-fired thermal power stations are considered as the countermeasure. Which means will be adopted shall be studied very carefully.

Table 3-1 Existing Power Stations in the Luzon Grid
(as of the end of 1979)

Name of Plant	Installed Capacity (MW)			Dependable Capacity (MW)	Energy Capability (GWH)
	Hydro	Geothermal	Oil-fired thermal		
HYDRO					
Ambuklao	75			50.9	459
Biñga	100			85.1	610
Angat	218			150	505
Pantabañgan	100			67	224
Caliraya	32			32	192
Botocan	16			15	60
Sub-total	541			400	2,050
THERMAL					
Bataan 1			75	72	473
Bataan 2			150	143	940
Malaya 1			300	290	1905
Snyder 1			200	190	1248
Snyder 2			300	290	1905
Gardner 1			150	140	920
Gardner 2			200	180	1182
Tegen 1			100	190 (Tegen 1 & 2)	624
Tegen 2			100		624
Rockwell (1-5)			125	75	574
Rockwell (6-8)			180	150	985
Malaya 2			350	340	2491
Sub-total			2,230	2,060	13,871
GEOTHERMAL					
Tiwi 1 & 2		100		100	959 (Tiwi & Mak-Ban)
Mak-Ban 1 & 2		100		100	
Sub-total		220		200	959
TOTAL	541	220	2,230	2,660	16,880

Table 3-2 Historical and Projected Energy Generation and Peak Load Luzon Grid

CALENDAR YEAR	TOTAL GRID ENERGY REQ'T.[1/] GWH	PEAK LOAD MW	LOAD FACTOR %	Loss Rate %
ACTUAL				
1969	6087	1020	68.1	14.4
1970	6386	1111	65.6	12.8
1971	7048	1205	66.8	13.1
1972	7555	1331	64.8	13.0
1973	8212	1335	70.2	12.4
1974	8240	1379	68.2	12.0
1975	9014	1513	68.0	11.1
1976	9626	1659	66.2	11.1
1977	10357	1709	69.2	12.4
1978	11223	1780	71.9	12.1
1970-1978[2/]	7.0%	7.0%		
FORECAST				
1979	12010	1960	70.0	10.6
1980	12850	2100	70.0	7.2
1981	13750	2240	70.0	7.2
1982	14710	2400	70.0	7.2
1983	15740	2565	70.0	7.2
1979-1983[2/]	7.0%	7.6%		
1984	16840	2745	70.0	7.2
1985	18020	2940	70.0	7.2
1986	19280	3145	70.0	7.2
1987	20630	3365	70.0	7.2
1988	22075	3600	70.0	7.2
1989	23620	3850	70.0	7.2
1990	25275	4120	70.0	7.2
1984-1990[2/]	7.0%	7.0%		
1979-1990[2/]	7.0%	7.2%		

Table 3-2

1991	26920	4390	70.0
1992	28670	4670	70.0
1993	30530	4975	70.0
1994	32515	5300	70.0
1995	34630	5645	70.0
1991-1995 2/	6.5%	6.5%	
1979-1995 2/	6.8%	6.8%	
1996	36705	5985	70.0
1997	38910	6340	70.0
1998	41245	6725	70.0
1999	43720	7125	70.0
2000	46340	7555	70.0
1996-2000 2/	6.0%	6.0%	
1979-2000 2/	6.6%	6.6%	

Note:

1/ - Excludes pumping requirements for the Kalayaan pump-storage hydroelectric project.

2/ - Average annual compound growth.

Table 3-3 Breakdown of Power Load in the Luzon Grid into the Categories of Residential Use, Industrial Use and Other Uses.

Year	Gross Generation (GWH)	Sales Energy (GWH)						Loss
		Residential	Commercial	Utilities	Industries	Others	Total	(%)
1973	8212	1447	1649	620	2871	608	7195	12.4
1974	8240	1302	1629	637	3029	657	7254	12.0
1975	9014	1418	1812	783	3261	737	8011	11.1
1976	9626	1486	1958	797	3527	793	8561	11.1
1977	10357	1623	2177	889	3665	722	9076	12.4
1978	11223	1818	2365	1092	3895	693	9863	12.1

Table 3-4 Estimated Breakdown of Power Loads in the Categories of Residential Use, Industrial Use and Other Uses

Year	Gross Generation (GWH)	Sales Energy (GWH) Residential	Commercial	Utilities	Industries	Total	Loss (%)
1979	12010	2014	2508	1270	4941	10733	10.6
1980	12850	2064	2752	1670	5439	11925	7.2
1981	13750	2207	2950	1787	5816	12760	7.2
1982	14710	2352	3160	1911	6227	13650	7.2
1983	15740	2508	3381	2045	6672	14606	7.2
1984	16840	2656	3614	2188	7172	15630	7.2
1985	18020	2815	3860	2342	7708	16725	7.2
1986	19280	2975	4119	2506	8300	17900	7.2
1987	20630	3139	4390	2681	8935	19145	7.2
1988	22075	3306	4667	2868	9644	20485	7.2
1989	23620	3481	4961	3069	10409	21920	7.2
1990	25275	3655	5273	3285	11245	23458	7.2

Table 3-5 Bulk Substations Forecasted Load (NPC Area)

Substations	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Ballesteros										9.5	10	10.5	11	12	13	14	14
Narvacan	-	-	30	37	43	49	56	64	72	82	93	96	102	109	116	123	132
Bauang		43	22	24	25	27	29	41	44	52	66	81	86	92	98	104	111
Baguio		65	70	77	78	83	91	98	102	108	110	111	117	124	132	141	150
Ambuklao*(Beckel)		30	30														
Mankayan	-	-	-	41	48	50	53	53	54	56	58	58	62	66	70	75	80
Batang-Buhay	-	-	9	9	9	9	10	12	15	20	25	37	40	42	45	48	51
Tuguegarao, Lal-Lo	-	-	9	13	17	19	23	28	30	21	22	20	21	23	24	26	27
Santiago	-	-	13	17	17	19	20	18	19	21	22	24	26	27	29	31	33
Solano	-	-	1	2	3	3	3	3	6	8	9	11	12	12	13	14	15
San Manuel		48	51	35	36	39	42	43	42	44	46	49	52	56	59	63	67
Labrador		-		22	25	27	30	33	36	40	44	49	52	56	59	63	67
Botolan		-	9	10	12	14	15	16	17	18	18	19	20	22	23	24	26
Olongapo		93	91	93	94	95	101	102	104	105	106	108	115	122	131	139	148
Prado		24	24	25	26	28	29	31	33	34	36	38	41	43	46	49	52
BTPP		32	33	34	35	36	37	39	40	41	43	44	47	50	53	57	60
EPZA		20	23	27	31	34	36	38	40	41	44	45	48	51	55	58	62
Mexico		83	88	92	94	100	104	111	116	123	131	139	148	158	168	179	191

Table 3-5

Substations	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Tarlac		28	29	30	31	33	34	36	38	40	42	44	47	50	53	57	60
Cabanatuan		36	41	46	50	57	66	76	89	105	123	146	155	166	177	188	200
Angat (34.5 kW)		(36)	-	-	-												
San Jose (34.5 kV)		40	42	43	45	47	49	50	52	54	56	58	62	66	70	75	80
Kalayaan		-	-	15	16	17	19	20	22	23	25	27	29	31	33	35	37
Caliraya		7	10	-	-	-											
Mak-Ban		18	19	20	21	23	24	25	27	30	32	35	37	40	42	45	48
Dasmarinas		20	23	25	28	30	32	36	39	43	45	50	53	56	60	64	69
Batangas		42	45	49	50	54	58	61	66	72	81	90	96	102	109	116	123
Gumaca		6	7	8	9	9	10	11	12	13	15	15	16	17	18	19	21
Labo		4	4	7	9	9	10	10	11	11	12	12	13	14	15	15	17
Naga		17	18	20	21	23	26	29	31	34	36	40	43	45	48	51	55
Lagaspi		20	22	24	26	24	27	29	32	34	37	41	44	46	50	53	56
NPC Total		676	763	845	899	958	1034	1113	1189	1282.5	1387	1497.5	1595	1698	1809	1926	2052

Table 3-6 Bulk Substations Forecasted Load (MECO Area)

Substation \ Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total Load	2100	2240	2400	2565	2745	2940	3145	3365	3600	3850	4120	4390	4670	4975	5300	5645
N P C Load	676	763	845	899	958	1034	1113	1189	1282.5	1387	1497.5	1595	1698	1809	1926	2052
MECO Load	1424	1477	1555	1666	1787	1906	2032	2176	2317.5	2463	2622.5	2795	2972	3166	3374	3593
Sucat group Balibago, Calauan Gardner, Malibay Rockwell, Taguig	513	529	551	591	631	669	713	760	808	861	921	981	1045	1118	1185	1262
San Jose group Balintawak, Bocaue Malinta, N-Port Novaliches, Sta Mesa Tegen	640	672	709	762	819	875	934	1006	1070.5	1136	1202.5	1283	1362	1446	1548	1648
Dolores group Dolores, Marikina Rosario, St. Antony Teresa	239	244	257	272	293	313	331	350	373	396	424	451	480	512	545	580
Malaya group Malaya, Botocan	32	32	33	36	38	43	47	53	58	62	66	71	75	80	85	91
Toyabas	–	–	5	5	6	6	7	7	8	8	9	9	10	10	11	12

Table 3-7

Luzon Grid Generation Expansion Program
Revised Accelerated
with Tongonan Interconnection
(1980 - 2000)

YEAR OF COMM.	PLANT ADDITION	INSTALLED CAPACITY (MW) HYDRO	GEO	COAL THER.	NUCL.	OIL THER.	TOTAL	DEPEND CAP.	PEAK DEMAND	RES. CAP.	% RES.	AVAILABLE ENERGY (GWH)	ENERGY CAPABILITY AND REQUIREMENT (GWH) SYSTEM CAPABILITY HYDRO	GEO	COAL THER.	NUCL.	OIL THER.	TOTAL	GENERATION LEVEL	SURPLUS (DEF.)
1979	Existing Plant	541	220			2230	2991	2660	1960	70	4	2491	2050	959			13871	16880	12010	4870
79/1	Tiwi (1 x 55)											397								
79/3	Tiwi 2 (1 x 55)											397								
79/8	Mak-Ban 1 (1 x 55)											397								
79/11	Mak-Ban 2 (1x55)											397								
80/3	Tiwi 3 (1 x 55)	541	440			2155	3136	2815	2100	85	4	397	2050	2283			13571	17904	12850	5054
80/5	Tiwi 4 (1 x 55)											397								
80/10	Mak-Ban 3 (1 x 55)											397								
80/12	Mak-Ban 4 (1 x 55)											397								
1981	Masiway (1 x 12)	553	440			2155	3148	2826	2240	(44)	-	48	2098	3176			13571	18845	13750	5095
1982	Kalayaan #1 (1x150)	853	550			2155	3558	3226	2400	196	8	150	2373	3671			14769	20813	15080	5733
82/3	Kalayaan #2 (1x150)											150								
82/4	Tiwi 5 (1 x 55)											397								
82/7	Tiwi 6 (1 x 55)											397								
1983	Magat 1-4 (4 x 90)	1213	550			2155	3918	3496	2565	301	12	1103	3501	3970			14769	22240	16140	6100
1984	Coal Thermal I (300)	1213	550	300		2155	4218	3766	2745	391	14	1989	3501	3970	1989		14769	24229	17240	6989
1985	Coal Thermal II (300)	1393	1345	600	620	2155	6113	5536	2940	1666	57	1989	3501	9748	3978	1684	14769	33680	18420	15260
	Magat 5 & 6 (180)											-								
	PNPP 1 (620)											3910								
	Manito 1-2 (110)											794								
	Tiwi 7-10 (220)											1588								
	Mak-Ban 5-6 (110)											794								
	Daklan Geo. (55)											397								
	Tongonan (300)											2205								
1986	Manito 3-4 (110)	1393	1455	600	620	2155	6223	5636	3145	1561	50	794	3501	10542	3978	3367	14769	36157	19680	16477
1987	-	1393	1455	600	620	2155	6223	5636	3365	1341	40		3501	10542	3978	3639	14769	36439	21030	15399
1988	Gened 1-6 (600)	1993	1565	600	620	2155	6933	6198	3600	1668	46	1153	4654	11336	3978	3856	14769	38593	22475	16118
	Manito 5-6 (110)																			
1989		1993	1565	600	620	2155	6933	6198	3850	1418	37	794	4654	11336	3978	3910	14769	38647	24020	14627
1990	Manito 7-8 (110)	1993	1675	600	620	2155	7043	6298	4120	1248	30	794	4654	12130	3978	3910	14769	39441	25675	13766

Table 3-7

YEAR OF COMM.	PLANT ADDITION	INSTALLED CAPACITY (MW) HYDRO	GEO	COAL THER.	NUCL	OIL THER.	TOTAL	DEPEND CAP.	PEAK DEMAND	RES. CAP.	% RES.	AVAILABLE ENERGY (GWH)	ENERGY CAPABILITY AND REQUIREMENT (GWH) SYSTEM CAPABILITY HYDRO	GEO	COAL THER.	NUCL.	OIL THER.	TOTAL	GENERATION LEVEL	SURPLUS (DEF.)
1991		1993	1675	600	620	2155	7043	6298	4390	978	22		4654	12130	3978	3910	14769	39441	27320	12121
1992	San Roque (390)	2383	1785	600	620	2155	7543	6720	4670	1120	24	1157	5811	12924	3978	3910	14769	41392	29070	12322
	Tiwi 11-12 (110)											794								
1993	Coal Ther III (300)	2383	1785	900	620	2155	7843	6990	4975	1085	22	1989	5811	12924	5967	3910	14769	43381	30930	12451
1994	Chico IV (360)	2743	1895	900	620	2155	8313	7381	5300	1151	22	804	6615	13718	5967	3910	14769	44979	32915	12064
	Mak-Ban 7-8 (110)											794								
1995	Agos Kanan (280)	3373	1895	900	620	2155	8943	7823	5645	1248	22	815	8402	13718	5967	3910	14769	46766	35030	11736
	Diduyon (350)											972								
1996	Chico II (250)	3623	2005	900	620	2155	9303	8120	5985	1205	20	1050	9452	14512	5967	3910	14769	48610	37105	11505
	Daklan 2-3 (110)											794								
1997	Coal Ther IV (300)	3763	2005	1200	620	2155	9743	8503	6340	1233	19	1989	9979	14512	7956	3910	14769	51126	39310	11816
	Cabingatan (140)											527								
1998	Chico III (120)	3983	2115	1200	620	2155	10073	8758	6725	1103	16	266	10937	15306	7956	3910	14769	52878	41645	11233
	Amburayan (100)											692								
	Tongonan (110)											794								
1999	Coal Ther V (600)	4103	2115	1800	620	2155	10793	9398	7125	1343	19	3978	11352	15306	11934	3910	14769	57271	44120	13151
	Dakgan (120)											415								
2000	Abuan (100)	4563	2115	1800	620	2155	11253	9761	7555	1276	17	362	12735	15306	11934	3910	14769	58654	46740	11914
	Gadeng (150)											418								
	Ilagan (210)											603								

Table 3-8 Luzon Grid KW Balance (1979-2000)

Unit: MW

INSTALLED CAPACITY \ CY	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HYDRO	541	541	553	553	913	913	1093	1093	1093	1693	1693	1693	1693	2083	2083	2443	3073	3323	3463	3683	3803	4263
PUMP HYDRO				300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
GEOTHERMAL	220	440	440	550	550	550	1345	1455	1455	1565	1565	1675	1675	1785	1785	1895	1895	2005	2005	2115	2115	2115
COAL FIRED THERMAL						300	600	600	600	600	600	600	600	900	900	900	900	900	1200	1200	1800	1800
NUCLEAR							620	620	620	620	620	620	620	620	620	620	620	620	620	620	620	620
OIL FIRED THERMAL	2230	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155
TOTAL	2991	3136	3148	3558	3918	4218	6113	6223	6223	6933	6933	7043	7043	7543	7843	8313	8943	9303	9743	10073	10793	11253
DEPENDABLE CAPACITY	2660	2815	2826	3226	3496	3766	5536	5636	5636	6198	6198	6298	6298	6720	6990	7381	7823	8120	8503	8758	9398	9761
PEAK DEMAND	1960	2100	2240	2400	2565	2745	2940	3145	3365	3600	3850	4120	4390	4670	4975	5300	5645	5985	6340	6725	7125	7555
RESERVE (1)	700	715	586	826	931	1021	2596	2491	2271	2598	2348	2178	1908	2050	2015	2081	2178	2135	2163	2033	2273	2206
RESERVE (2)	360	375	246	486	591	681	2006	1901	1681	2008	1758	1588	1318	1460	1425	1491	1588	1545	1573	1443	1683	1616
RESERVE (3)	70	85	(44)	196	301	391	1666	1561	1341	1668	1418	1248	978	1120	1085	1151	1248	1205	1233	1103	1343	1276

Reserve (1) = Dependable capacity (minus) Peak Demand.

Reserve (2) = Reserve 1 (minus) largest unit under maintenance.

Reserve (3) = Reserve 2 (minus) largest unit on line being outage.